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Visual Feedback In Voice Therapy for Individuals with Parkinson's Disease

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VISUAL FEEDBACK IN VOICE THERAPY FOR INDIVIDUALS WITH PARKINSON’S DISEASE

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DEDICATION

This work is dedicated to my grandmother, Sandra Seligman. You will always be a part of me. I am ever grateful for your blue pencil.
ACKNOWLEDGMENTS

I would like to thank Dr. Derek Isetti, Dr. Ward-Lonergan, and Dr. Susca for their dedication to this project. The time they have spent assisting me through this process, reviewing my project ideas and editing documents is greatly appreciated. Their support has been unwavering, and for that I am grateful.

My gratitude goes out to my participant and his family. His participation in this project was made possible by his wife. Their dedication to ensuring he attended each of the sixteen session and completed the assigned homework assignments cannot be overlooked. Their motivation to complete the program was evident from the beginning, I am thankful for their constant participation and support.

Finally, I would like to thank my family, many aspects of this project would not have been possible without them. Thank you to my father and brother for assisting the design and development of my visual feedback scale. And thank you to my mother, for you constant support and encouragement through this process. I am ever grateful that you shared your passion for Speech-Language Pathology with me.
VISUAL FEEDBACK IN VOICE THERAPY FOR INDIVIDUALS WITH PARKINSON’S DISEASE

Abstract

By Rachel Convey

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2019

Parkinson’s disease (PD) is a progressive neurological disorder that affects one’s movement. As the disease develops, individuals begin to present with symptoms that include but are not limited to bradykinesia, rigidity, tremors, and hypokinetic dysarthria. These symptoms affect a person’s entire body, including his/her voice. The Lee Silverman Voice Treatment (LSVT) program for treating individuals with PD is supported by over twenty-five years of research. It is considered a safe, non-invasive method to improve vocal loudness and speech clarity in individuals with PD. However, simply because LSVT is effective in its current state, it does not mean that the protocol is the most efficient or effective it can be. One potential shortcoming of LSVT is that it does not provide patients with much, if any, visual feedback. We hypothesized that visual feedback would enable the client to more easily produce a voice characterized by increased loudness and vocal quality. The results of the study do not fully support this hypothesis. There was less variability in the client’s performance within each session during the experimental weeks the patients performance over the course of the week improved, this pattern was not observed during the non-experimental weeks. Additionally, the participant expressed preference for treatment
days when the visual feedback was used, finding it helpful in more effectively regulating the volume of his voice.
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CHAPTER 1: INTRODUCTION

Parkinson’s disease (PD) is a progressive neurological disorder that affects one’s movement. As the disease develops, individuals begin to present with symptoms that include but are not limited to bradykinesia, rigidity, tremors, and hypokinetic dysarthria (Kempler & Lancker, 2002). These symptoms affect a person’s entire body, including his/her voice. Patients with PD often experience a gradual loss of vocal volume and slurred speech, which together in combination affect the ability to communicate and be understood (Manes et al., 2018).

Although there are several speech and voice intervention programs designed to improve the communication of individuals with PD, the efficacy of the Lee Silverman Voice Treatment (LSVT) program for treating individuals with PD is supported by over twenty-five years of research (Fox et al., 2006). LSVT has undergone multiple studies including randomized controlled trials funded by the National Institutes of Health. It is considered a safe, non-invasive method to improve vocal loudness and speech clarity in individuals with PD (Ramig, Halpern, Spielman, Fox, & Freeman, 2018).

However, simply because LSVT is effective in its current state, it does not mean that the protocol is the most efficient or effective it can be. One potential shortcoming of LSVT is that it does not provide patients with much, if any, visual feedback. During treatment sessions, individuals with PD must rely on the clinician to verbally inform them that the desired level of vocal loudness has been reached.
CHAPTER 2: LITERATURE REVIEW

PD is a progressive neurodegenerative disease that is projected to affect more than one million people in the United States by the year 2030 (Ramig, Halpern, Spielman, Fox, & Freeman, 2018). PD is typically characterized by several motoric and voice traits including: bradykinesia, rigidity, and hypokinetic dysarthria. The voice of individuals in both early and late stages of PD is perceptually described as having “limited pitch and loudness variability, breathiness, harshness and reduced loudness” (Holmes, Oates & Debbi, 2000). Although these characteristics have been observed in all stages of the disease, the quality of one’s voice does continuously decrease as the disease progresses. The specific voice characteristics observed to deteriorate with the disease include breathiness, monopitch, monoloudness, low loudness, and reduced maximum phonation frequency (Holmes, Oates & Debbi, 2000). These qualities impact an individual’s ability to effectively and efficiently communicate.

Physiology and Etiology of Parkinson’s Disease

Changes in specific neurological circuits and neurotransmitters have been correlated with the specific physiology of PD. The neurotransmitter most closely associated with PD is dopamine. In PD, the loss of dopaminergic innervation disrupts circuitry in the striatum, a portion of the basal ganglia that controls goal directed habits and actions, which results in the hypokinetic characteristics of the disease (Zhai, Tanimura, Graves, Shen & Surmeier, 2018).

More specifically, PD can be classified as an extrapyramidal motor system disorder (Norden, 2016). The pyramidal and extrapyramidal systems are subsystems within our motor system and aid in the control of voluntary and involuntary movements respectively (Norden, 2016). The pyramidal system forms part of the cortex and axons within this system project to connect to lower motor neurons (LMN) as both
the corticobulbar tracts and corticospinal tracts (Duffy, 2005). It is responsible for the control and initiation of volitional motor movements (Von Berg & Elandary, 2019). Like the pyramidal system, the extrapyramidal system also forms part of the UMN system. The neurons of the extrapyramidal system originate in the brainstem (or subcortical structures), but unlike those of the pyramidal system, these neurons synapse through the basal ganglia and the brainstem and spinal cord (Duffy, 2005). This indirect activation is involved in acts that include regulating reflexes, maintaining posture, and, to a certain extent, regulating involuntary or reactive movements (Duffy, 2005; Von Berg & Elandary, 2019). Degeneration of the neurons of the substantia nigra, a nuclei of the extrapyramidal motor system located in the midbrain below the basal ganglia, contributes to the classification and diagnosis of PD (Norden, 2016). This degeneration occurs as a result of decreased levels of dopamine, for these specific neurons utilize the neurotransmitter to modulate activity of the extrapyramidal system (Norden, 2016).

Outside of function, one distinguishing feature of the pyramidal and extrapyramidal system is that the extrapyramidal system is dopamine dependent (Von Berg & Elandary, 2019). PD occurs as a result of a dopamine deficiency. Therefore, to increase the ability of an individual with PD to perform the involuntary functions regulated by the extrapyramidal system, they must now invoke the pyramidal system by volitionally completing the action (Von Berg & Elandary, 2019). For example, walking in a straight line on an even surface comes second nature to many healthy individuals. Yet individuals with PD often present with bradykinesia, or decreased movements, resulting in a reduced gait that presents as a shuffle. However, when markers are placed on the ground regulating their stride, or when told to walk with confidence, individuals with PD employ their pyramidal system. This modification in prompting results in an increased gait and speed of walk. The same modification can
be applied to speech. By taking what is typically an involuntary task and utilizing specific prompts to make it a voluntary task, an individual with PD is able to produce speech with increased quality and loudness (Von Berg & Elandary, 2019).

**Sensory Deficits in Individual’s with Parkinson’s Disease**

Accompanying the visible symptoms of PD (e.g., bradykinesia, rigidity, tremors, reduced gait) is an underlying physiological change that impacts the sensorimotor and somatosensory feedback in individuals affected by the disease. These changes are not isolated to a specific region or system of the body. Instead they are globally impactful, and, therefore, affect not only an individual’s ability to accurately produce gross motor movements but also fine motor movements. Reduced vocal loudness is a known characteristic in individuals with PD. This characteristic is the result of a decline in respiratory and laryngeal control. Full laryngeal closure is an essential movement in the series of gestures required to produce a strong, audible voice (Hammer & Barlow, 2010). The primary target of LSVT LOUD, a voice treatment program designed for individuals with PD, is to increase vocal loudness. The simplicity of this target greatly benefits individuals with PD, for it not only reduces the cognitive load placed on them during therapy, but it also addresses the issues of laryngeal closure, a motor movement that is essential to producing loud, audible speech (Narayana et al., 2009).

As stated by Hammer and Barlow in the introduction of their 2010 study, “individuals with PD often report that they feel as though they are shouting or they feel as if they are exerting great physical effort when asked to speak at a more normal audible loudness level. This clinical observation suggests that speech and voice impairment in PD may be related to impaired somatosensory function.” A measure taken in this study was a laryngeal mechanosensory detection threshold (LMDT). The investigators defined LMDT as the “level of stimulus pressure at which the subject
responded 50% of the time.” The stimulus presented was calibrated bursts of air to the laryngeal mucosa, and participants clicked a switch to indicate that they detected the stimulus. Individuals with PD had greater LMDTs, meaning that it took a significantly greater amount of air pressure to elicit a response compared to the healthy control group (Hammer & Barlow, 2010). Individuals with PD required a greater amount of sensory stimulation to elicit the same response as the healthy control group. This finding helps explain why patients with PD often feel as though they are speaking with excessive volume when they are, in fact, producing speech at a volume that falls within normal limits.

**Voice Therapy for Individuals with Parkinson’s Disease**

The concept of utilizing intent to turn a habitual, automatic task such as speech into an intentional task was initially implemented in voice therapy for individuals with PD by Dr. Daniel Boone (Hammer & Barlow, 2010). SPEAK OUT! is a Parkinson’s voice therapy treatment program supported by the Parkinson’s Voice Project. It was developed by Samantha Elandary, M.A., CCC-SLP. The primary prompt given in this program is “Speak with Intent”. This prompt was designed to “improve verbal communication holistically,” without giving explicit instructions to increase one’s vocal intensity, vocal clarity, and amplitude of one’s speech movements, while still making the task of speech effortful and volitional (Levitt & Walker-Batson, 2018).

Similar to the Speak Out! Program, the Lee Silverman Voice Treatment (LSVT) program reduces the cognitive load placed on clients through a simplified prompt, “Speak LOUD” (Spielman et al., 2011). This prompt engages the individual’s intact pyramidal motor system by limiting the automaticity of speaking and, as a result, turning it into a volitional task. LSVT is an intensively regimented program consisting of sixteen one hour treatment sessions, four sessions per week for four weeks. All
sessions share the same structure, and only a few components of the material presented differs. The first thirty minutes of the session is reserved for exercises that include: sustained ‘ah’ phonation, pitch glides, and the production of functional phrases. The second half of the session is reserved for more naturalistic speech tasks. The program will be further discussed with increased specificity in the methods section.

**Research Supporting the Efficacy of Lee Silverman Voice Treatment**

The efficacy of LSVT in improving the vocal quality of individuals with PD has been heavily researched, including the long-term effectiveness of the program. Ramig, et al. published a study in 2001 that examined the impact of LSVT two years post treatment compared to an alternative treatment that emphasized high respiratory effort alone (RET). Twenty-one participants received LSVT, and 12 participants received RET. Both groups received four, one hour sessions for four weeks. Three speech tasks were analyzed: sustained ‘ah,’ reading of the “Rainbow Passage,” and a monologue. These tasks were completed by the participants, in both groups, three times during the study: before treatment, immediately after treatment and 24 months post treatment. Two characteristics of participants’ voices were analyzed: voice loudness (measured as sound pressure level, SPL) and inflection in voice fundamental frequency (measured in terms of semitone standard deviation, STSD). The results of the study revealed the lasting effects of LSVT compared to that of RET. The RET showed no significant improvement in either SPL or STSD when comparing pre-treatment to the 24 month post-treatment levels in all but one speech task analyzed. Since both treatments were administered in equal doses for an equal duration, the gains made as a result of LSVT were treatment specific (Ramig, 2001).

Ramig et al. went on to conduct a randomized control trial in 2018 analyzing the effectiveness of different speech treatments for individuals with PD. The treatment
methods tested were: LSVT LOUD (voice), LSVT ARTIC (articulation), and an untreated or control group. All therapies were administered for one month. Several aspects of participants’ voice and communication abilities were measured, including sound pressure level (SPL) in reading and spontaneous speech. Participants also completed the Modified Communication Effectiveness Index (CETI-M), this measure has “demonstrated significant correlation with intelligibility and voice handicap, with established reliability for PD” (Ramig, Halpern, Spielman, Fox, & Freeman, 2018). The results of this study showed greater improvements in SPL as a result of the LSVT LOUD treatment program when compared to that of the LSVT ARTIC group and the control group. With regards to the CETI-M, participants who underwent both the LSVT LOUD and LSVT ARTIC treatments showed improved scores at one month post-treatment, but only the LSVT LOUD group showed sustained improvement seven months post-treatment.

The research conducted by Ramig and Fox support the efficacy of LSVT LOUD in improving the vocal loudness and overall voice quality in individuals with PD. By implementing a simple direct target, the program addresses several biological systems, including but not limited to aspects of the reparatory and muscle systems, that contribute to the production of speech without being cognitively overwhelming.

**Statement of the Problem**

One potential shortcoming of the LSVT program, however, is that it does not provide the patient with visual feedback that is adequate enough to overcome the sensory deprivation caused by Parkinson’s Disease. Therefore, the aim of this current research proposal is to modify the existing LSVT protocol by introducing low-tech visual feedback in the form of a color coded paper scale with a sliding bar (see Appendix A). In this modification, feedback is provided during the typical exercises
that are part of the LSVT program: vowel prolongation exercises (e.g., produce “ahh” for as long as you can), pitch glides, and during functional phrases that the person might use daily. More specifically, the objectives for the current study are to ascertain if the introduction of visual feedback for individuals with PD may:

1) Increase the mean sound pressure level of vocal production (the level of loudness during speech tasks).

2) Increase the length of time that vowels can be sustained after a deep breath.

3) Increase patient satisfaction of the LSVT program as compared to sessions where visual feedback is not utilized.

The specific research questions to be addressed are as follows:

1) Does the introduction of visual feedback decrease the calibration period of patient’s achieving their maximum sound pressure level on sustained vowels?

2) Does visual feedback increase patient satisfaction with the LSVT program?
Training and Certification

The principal investigator (PI) completed the online Lee Silverman Voice Treatment LOUD (LSVT LOUD) Student training. Training consisted of online modules that discussed the following topics: origins of LSVT LOUD, research done to support the efficacy of LSVT LOUD, how to administer therapy, including specific modules for each of the exercises completed during the sessions (e.g., sustained phonation, pitch glides, functional phrases, speech hierarchy drills, spontaneous speaking tasks), and LSVT Global resources available to certified clinicians. The training completed for the student certification is the same as that completed by licensed speech-language pathologists.

After completing the training, the PI had access to speech and language therapy resources provided by LSVT. Several of the provided resources were used in therapy to maintain continuity and to ensure that all required exercises were completed during each session. The resources utilized during research were the LSVT LOUD Treatment Packet, which included both the treatment data record forms and client homework forms, the loud/soft illustration, the Perceived LOUDNESS Effort Scale, and the LSVT LOUD Assessment Packet.

Participant

Following Institutional Review Board approval, recruitment took place via an in-person announcement and flyer at a local PD support group meeting. Inclusion criteria for participation were: adults aged 30-90 who have been diagnosed with PD by a physician, and consent to have their vocal folds examined to ensure they were healthy (free from any kind of lesion). Exclusion criteria were: a formal diagnosis of dementia, documented moderate-severe hearing loss, and any lesion found on the vocal folds that
might require surgery rather than voice therapy. After the flyer distribution, the wife of an individual with PD contacted the PI and expressed interest in the study.

The participant (SB) was a 61 year old male who was diagnosed with PD between the years 2002 and 2003. Initial PD symptoms for SB included: tremor, small hand writing, decreased gait, and masked expression. At the time of the research, SB’s symptoms included visible tremors in his extremities, masked expression, bradykinesia (e.g., shortened gait, shuffle like walk), and hypokinetic dysarthria characterized by slurred speech and decreased speech loudness. Medications taken by SB for PD included: Carbidopa-Levodopa, Azilect, and anti-depression medication. Additional medication included an Exelon patch. No diagnosis of dementia had been made, but SB’s wife reported some cognitive deficits including decreased short-term memory and difficulty with sentence formulation. Several years after his diagnosis, SB received deep brain stimulation to decrease his tremors. As reported by SB he received speech therapy at St. Joseph’s Medical Center in Stockton, California over ten years ago, but he was unable to recall any specific information regarding the therapy. During the initial interview, his wife stated she was unaware that he received this treatment.

Materials

Several pieces of equipment were utilized to provide the client feedback and take measurements. A LuckyStone, XL-013 stopwatch was utilized to record the duration of the client’s sustained vowels. The application, G-Strings, was utilized to measure the client’s pitch. This application was chosen because it displayed dynamic pitch in real time without a permanent record. Additionally, it presented the pitch being perceived as both a hertz value and musical note. An SPL meter (Radio Shack 03-99) was utilized to record the client’s vocal amplitude level (dB). A 30cm string was utilized to ensure
consistency in the distance between the SPL meter and the client’s mouth. A small camera tripod was utilized to elevate the SPL meter off of the table.

The visual feedback scale (the experimental variable) was designed and constructed by the PI and Jason Convey. Images of the scale are included in Appendix A. The scale consists of three main parts: the base, a vertical support piece with a laminated five-point paper scale, and a sliding metal bar. The base of the scale is 19.50cm x 13.50cm x 4.30cm (length x width x height). The visible portion of the vertical piece is 1.90cm x 5.30cm x 53cm. Both the base and vertical piece are made out of cedar wood. The vertical piece inserts into the base and is further stabilized by a screw that connects the bottom of the vertical piece to an L-bracket. The L-bracket is mounted on the base. The five-point paper scale consists of two pieces that mirror each other in shape and size. Each piece is 7.10cm x 47.8 cm (width x height). The scale is divided into five sections, and each section is 7.10 cm x 9.56cm. As one moves up the scale, each section gets gradually darker; the bottom section near the base is nearly white and the top section is dark blue. The sliding metal bar that extends across the scale is 20.20 cm in length. The bar is able to be manipulated and adjusted by loosening the handle on the back of the scale. As the participant reached a certain dB level on the SPL meter, the PI would move the sliding scale up to the colored section that corresponded to the participant’s current loudness level. In this manner, the participant received visual feedback during phonation. Adjustments could be made in real time during the participant’s sustained vowels.

Assessment / Interview

Questions and information from the LSVT Assessment Packet guided the initial assessment and interview process. SB’s medical history, date of diagnosis, and the social and emotional impact PD has had on him and his family were discussed. After
the interview, only a partial view of the vocal folds was able to be obtained via rigid endoscopy. It was recommended to SB and his wife that he make an appointment with an otolaryngologist to rule out any possible pathology of his vocal folds. It is unknown if this recommendation was followed. A hearing screening was conducted and SB presented with a mild hearing loss in his left ear. The results of the screening are below:

<table>
<thead>
<tr>
<th></th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left Ear</strong></td>
<td>25 dB</td>
<td>30 dB</td>
<td>30 dB</td>
</tr>
<tr>
<td><strong>Right Ear</strong></td>
<td>15 dB</td>
<td>10 dB</td>
<td>0 dB</td>
</tr>
</tbody>
</table>

During the initial meeting, SB’s wife primarily spoke. When questions were directed at SB he was observed to glance at his wife, attempt to start speaking, and then his wife would take over answering the question. When he did speak, his voice was observed to be effortful and characterized by low intensity. Several trials of the Daily Task 1 and Daily Task 2 were completed to gain SB baseline status, and the results are summarized below:
Procedure

Each therapy session consisted of the following activities: Daily Task 1 (prolonged vowel), Daily Task 2, (pitch glides), Daily Task 3 (functional phrases), Hierarchical Speech Loudness Drills, and Spontaneous Speaking Tasks. The format and content of the three daily tasks did not change over the course of the treatment period. Daily Task 1 required the patient to prolong the vowel /a/ for as long as he was able to at his habitual pitch. Daily Task 2 was divided into two sections, high pitch glides and low pitch glides. During high pitch glides, the patient was required to vocalize at his fundamental frequency (producing the vowel /a/) and increase his pitch to the highest frequency he was able to achieve. During low pitch glides, the patient was required to vocalize at his fundamental frequency (producing the vowel /a/) and decrease his pitch to the lowest frequency he was able to achieve. Daily Task 3 required the patient
to read through the list of his ten functional phrases, five times. The content spoken in
the next two exercises changed each session. The Hierarchical Speech Loudness Drill
increased in complexity over the treatment period (i.e., week one: single word/phrases,
week two: sentences, week three: paragraph reading, week four: conversation). For this
exercise, the patient was presented with reading material and was prompted to read the
content in a loud voice. The final exercise, Spontaneous Speaking Task or Spontaneous
Conversation, also increased in complexity over the treatment period. During this task,
the patient was required to produce loud speech in response to information received
 auditorily (e.g., complete a phrase with a single word, answer a simple question,
produce a short list, and respond to a prompt).

**Experimental Design**

This four week single subject experimental counter-balanced treatment design study was constructed with an ABAB design, with one week representing each phase of the design. The dependent variables were the participant’s sound pressure level on Daily Task 1 (sustained vowels) as well as the participant’s satisfaction level under the experimental and nonexperimental conditions. The independent variable for this study was the introduction of visual feedback compared to traditional LSVT therapy. Using this model, traditional LSVT therapy was administered during the first and third week of the study, with the addition of the experimental visual feedback incorporated during weeks two and four. Baseline data was collected during the first week of therapy. All sessions lasted one hour, four times per week (Monday through Thursday) for the duration of the four week study. All therapy sessions were held in a private therapy room at the Pacific Speech, Hearing and Language Center on the Stockton Campus.

**Weeks 1 and 3.** Traditional LSVT therapy was administered, and all LSVT guidelines were followed. Each session started with the completion of the three daily tasks. Daily task 1 consisted of maximum duration of a sustained vowel, /a/, phonation. Across all
four weeks, SB required initial clinician modeling and clinician prompting throughout this activity. Prompting did decrease as SB became more familiar with the task, but it was still required for him to exert maximum effort continuously throughout the exercise. The clinician modeled the exercise for SB. This model was preceded with the verbal prompt, “Do what I do.” SB completed 15 trials of this exercise per session. The following data was obtained during each trial of daily task 1: duration of phonation (seconds), and loudness achieved throughout each trial (dB). Throughout the trials, the clinician supported SB by modeling the correct body posture (sitting up in chair, feet on floor, hands away from mouth, and mouth pointed toward the SPL meter), holding her mouth in the desired open position and prompting SB to copy her posture by pointing to her mouth, verbally prompting him to be louder, and providing feedback after some trials. The feedback consisted of discussing SB’s perceived level of effort, how he felt during the trial, and growth the clinician saw during the trial.

Daily task 2 consisted of pitch glides, both high and low. Across all four weeks, SB required initial clinician modeling and clinician prompting throughout this activity. The clinician modeled both high and low pitch glides for SB. This model was preceded with the verbal prompt “Do what I do.” SB completed 15 trials of both high and low pitch glides. For high pitch glides, SB was prompted to begin each trial at his fundamental, or habitual, frequency and increase his pitch as high as he could. He sustained the vowel at his highest frequency for 3-5 seconds. For low pitch glides, SB was prompted to begin each trial at his fundamental, or habitual, frequency and decrease his pitch as low as he could. He sustained the vowel at his lowest frequency for 3-5 seconds. If SB was unable to begin at his fundamental frequency, he was prompted to sustain the vowel /a/ again. This aided in helping him produce a vowel at his fundamental frequency. The data obtained during high pitch glides included the
highest pitch achieved during each trial. The data taken during low pitch glides included the lowest pitch achieved during each trial.

Daily task 3 consisted of maximum loudness achieved during the reading of functional phrases. Ten functional phrases were determined by SB and his wife after the initial assessment and finalized before the first therapy session. These phrases were used during each therapy session for this exercise and did not change over the course of the treatment period. The clinician transferred SB’s functional phrases to the Daily Exercise 3: Functional Phrases Course Practice worksheet, a material provided by LSVT Global. The method utilized to display the functional phrases changed over the treatment period. Initially, the clinician placed the worksheet on the table in front of SB. This resulted in SB lowering his head to read the phrases during the exercise, in this posture he did not project his voice toward the SPL meter. To improve SB’s posture, the clinician placed the worksheet on a clipboard and held the clipboard in front of SB at a comfortable level. The clinician also had a copy of the phrases on the table in front of her. SB read the set of 10 phrases, five times for this exercise. The data obtained during this exercise was the maximum level of loudness (dB) achieved for each functional phrase, every time it was read.

Following the completion of the three daily task exercises, the remaining time was focused on completing the hierarchical speech loudness drills and spontaneous speaking tasks. The hierarchical speech loudness drill consisted of SB reading salient texts that increased in length over the course of the four weeks (week 1: single words/phrases, week 2: sentences, week 3: paragraphs, week 4: conversation). SB’s salient topics were determined during the initial assessment. SB and his wife shared that he enjoyed comics, skiing, and movies. These topics were incorporated into the hierarchical speech drill each treatment session. Due to the cognitive difficulties SB faced with reading, the clinician often had to read the material for SB before he was able
to verbally produce the text. SB was prompted to produce ‘loud’ speech during this exercise. Data collected consisted of loudness (dB) readings which were obtained continuously during the periods when SB was producing speech.

**Weeks 2 and 4.** Experimental modifications to LSVT therapy were made during the second and fourth weeks of therapy. However, all modifications were made during Daily Task 1. The remaining exercises completed during each session (Daily Task 2, Daily Task 3, speech hierarchy, and spontaneous speech) were not modified.

During Daily Task 1, SB was instructed to sustain /a/ with a loud, clear quality voice, and 15 trials of this exercise were completed. The materials utilized included the SPL meter, the visual feedback scale, and a stopwatch. Modification to traditional LSVT therapy came in the form of biofeedback for this experiment. While SB was sustaining the vowel, the PI was observing the SPL meter and adjusting the visual scale accordingly by moving the bar on the scale to represent SB’s current dB output. Each section on the scale was given a 10dB range, and the ranges represented on the scale, from lowest to highest, were as follows: 50-60 dB, 60-70 dB, 70-80 dB, 80-90 dB, and 90+ dB. The target range for SB, as directed by LSVT, is the 80-90 dB with a specific target around 85 dB. A star was placed in this section of the scale to provide additional visual support to SB.

As SB was completing each trial, the role of the PI was to manipulate the scale, record SB’s loudness throughout the trial on the data sheet, and prompt SB when appropriate. Thesis advisor Dr. Derek Isetti, was seated behind the one-way mirror for all therapy sessions. His role, during Daily Task 1 of the experimental sessions, was to record the length of each trial (in seconds). Dr. Isetti could clearly see and hear the session given the technology of the clinic room.

At the beginning of the first therapy session of week two, the first experimental week, the PI discussed the scale with SB. She reviewed the dB range each section
represented and showed SB where on the scale his target level of loudness was in colloquial terms. To further ensure that SB was aware of the difference in loudness represented by each section, the PI modeled a prolonged vowel at each range of loudness, and she additionally demonstrated what SB’s target level of loudness sounded like. This additional modeling was required to ensure that SB understood what the scale represented. The manipulation of a single variable, biofeedback, allowed for the impact of that variable to be studied and its effects on the client to be analyzed.

**Homework**

SB and his wife were instructed on how to complete the homework exercises and fill out the LSVT homework sheet. SB’s wife played an integral role in the homework, for she often assisted SB in completing the tasks. Both SB and his wife were motivated to complete the homework. The importance of homework and its aid in the generalization of skills being taught were also discussed.

The LSVT LOUD Homework Recording Form was utilized. Homework consisted of three components: Daily Task 1, Daily Task 2 and Daily Task three. The trials that needed to be completed for each daily task differed. For Daily Task 1, six trials needed to be completed. For Daily Task 2, six trials of ‘high’ pitch glides and six trials of ‘low’ pitch glides needed to be completed. For Daily Task 3, the ten functional phrases needed be read through one time.

The number of sets of homework exercises that were required to be completed each day differed. A set of homework exercises consisted of the above stated trials for each of the three daily tasks. On therapy days (four days a week), one set of exercises needed to be completed. On non-therapy days (three days a week), two sets of exercises needed to be completed at different times of the day. SB was instructed to complete the first set in the morning and the second set later in the afternoon.
CHAPTER 4: RESULTS

The results pertaining to each objective will be addressed independently below. The data obtained was consistent across all therapy sessions and included the following:

- **Daily Task 1**: Duration of vowel prolongation in seconds, and changes in loudness (dB) level across each trial.

- **Final Paper Questionnaire**: Questions about the participant’s preferences regarding the use of visual feedback.

It is customary that visual examination of the data in single-subject design is an acceptable form of analysis (Engel & Schutt, 2014). As stated by Engle and Schutt, visual analysis “is the process of looking at a graph of the data points to determine whether the intervention has altered the subject’s preintervention pattern of scores.”

**Results: Daily Task 1**

Experimental visual feedback was solely implemented during Daily Task 1, vowel (/a/) prolongation, during alternate weeks. Fifteen trials of this exercise were completed each session. The table below illustrates SB’s mean loudness level on this exercise per therapy session and the mean loudness level per week (across four therapy sessions). The shaded sections represent when visual feedback was utilized.
Table 3
*Daily Task 1, Mean dB values*

<table>
<thead>
<tr>
<th>Week Number</th>
<th>Session Number</th>
<th>Mean dB per session</th>
<th>Mean dB per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>82.88</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>79.61</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>81.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>81.18</td>
<td>81.37</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>79.11</td>
<td>79.44</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>83.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>77.68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>77.82</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>75.36</td>
<td>75.38</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>75.03</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>74.66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>76.44</td>
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<tr>
<td>4</td>
<td>13</td>
<td>76.03</td>
<td>77.66</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>80.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>73.68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>80.94</td>
<td></td>
</tr>
</tbody>
</table>

SB’s mean loudness level per session remained fairly consistent across all therapy sessions within a week. During the first week of therapy, Treatment A (LSVT Treatment), session 1 – session 4, there was a 3.27 dB range of averages. During the
second week of therapy, Treatment B (LSVT with Visual Feedback), session 5 – session 8, there was a 5.46 dB range of averages. During the third week of therapy Treatment A (LSVT Treatment), session 9 – session 12, there was a 1.78 dB range of averages. And, finally during the fourth week of therapy Treatment B (LSVT with Visual Feedback), session 13 – session 16, there was a 7.26 dB range of averages. Greater variability in SB’s performance was seen during weeks two and four, the experimental weeks. The highest dB level in a session was recorded during one of the experimental weeks (Week 2) at 83.14 dB.

![Figure 1. Mean Session Loudness, Daily Task 1](image)

Variability was also seen across the mean levels of loudness per each week (four sessions) of therapy. The first two weekly averages were fairly consistent, 81.368 dB and 79.436 dB respectively. When analyzing the data from the third week, one should note a more obvious decrease in SB’s weekly mean level of loudness for it decreases to 75.375 but, as stated in the above paragraph, the session mean values within that week
were the most consistent (lowest range of average values). The weekly average for the fourth week increased slightly, but not to the level it was at in the first or second week. This information is more clearly illustrated in Figure 1, Mean Session Loudness, Daily Task 1.

Additionally, this figure reveals trends in loudness levels. These levels were observed to decrease at the start of each new week. For example, the mean dB of session 4 was 81.182 dB. After the three day period of no therapy, the mean dB of the next week’s session was 79.112 dB. The most significant decrease occurred between the second and third week, the difference between session 8 and 9 was 2.451 dB. Since LSVT is administered formally four times per week, this particular participant seemed to have difficulty maintaining his prior week’s loudness level after a three day period of not working with the clinician.

A second trend that can be observed through these graphs is the change in the duration of each trial across the four weeks. Duration of the trials gradually increased over the course of treatment with the longest trial occurring during session 8 (27.8 seconds). In addition to the increase in duration of each trial, SB’s performance also became more consistent, with the range of duration gradually decreasing. The range of duration over week one was 18 seconds (3 – 21 seconds), over week two the duration was 18.6 seconds (9.2 - 27.8 seconds), over week three the duration was 12.3 seconds (12.7 - 25.1 seconds) and over week four, the duration was 11.5 seconds (11.1 – 22.9 seconds).
Figure 2. Week 1: Average Trial Values for Daily Task 1 (Vowel Prolongation)

Figure 3. Week 2: Average Trial Values for Daily Task 1 (Vowel Prolongation)
Figure 4. Week 3: Average Trial Values for Daily Task 1 (Vowel Prolongation)

Figure 5. Week 4: Average Trial Values for Daily Task 1 (Vowel Prolongation)
Results: Daily Task 2

In every session, during a separate pitch range task, the participant was asked to glide to both his highest and lowest pitch levels. It is important to note that visual feedback was not ever provided during this range task. However, this range data is collected as part of the general LSVT protocol. The investigator has included this data below in Figure 5 to show that pitch range seemed to be unaffected during Weeks 2 and 4, even when visual feedback was provided on the other sustained vowel task.
*It should be noted that the minimum frequency measured during session 7 (55 Hz) is not believed to be an accurate representation of SB’s abilities, but rather a malfunction in the application utilized to obtain these measurements.*
Figure 5 above illustrates SB’s performance on both high and low pitch glides across all 4 weeks of the LSVT protocol. The orange line is representative of SB’s performance on high pitch glides, each point representing the highest frequency (Hz) achieved during that therapy session. The blue line is representative of SB’s performance on low pitch glides, each point representing the lowest frequency (Hz) achieved during that therapy session. The aim of this exercise is to increase SB’s pitch range. This range is represented graphically by the distance between the orange and blue lines.

The greatest increase in SB’s pitch range was seen over the course of the first week. SB’s pitch range increased from 109 Hz to 172 Hz. Similar to the trend observed in SB’s slight regression at the beginning of each week on Daily Task 1, SB also demonstrated a slight decrease in his pitch range at the start of week two and four of therapy. Between therapy sessions four (end of week one) and five (start of week two), SB’s pitch decreased from a range of 172 Hz to a range of 122 Hz. Between therapy sessions eight (end of week two) and nine (start of week three), SB’s pitch range was seen to increase from a range of 159 Hz to a range of 165 Hz. Between therapy sessions twelve (end of week three) and thirteen (start of week four), SB’s pitch range again decreased from a range of 148 Hz to a range of 110 Hz.

Overall, SB’s range remained fairly consistent across all four weeks. Ranges did not seem to fluctuate or benefit from positive carryover effects during sessions 5-8 or 13-16 when the visual feedback was given on the sustained vowel task.

**Results: Final Paper Questionnaire**

SB required assistance to complete the questionnaire (see Appendix B for questionnaire), which was done after the last session. His wife assisted him by reading
he questions to him, repeating the information to ensure that he understood what was being asked, and filling out his answers on the questionnaire.

Each response fell on a scale of 1 to 5 (1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree). Question 2 on the form is not applicable to the study, for a timer was not utilized as a form of visual feedback. This questionnaire allowed for analysis of SB’s perception of the impact of the visual feedback scale on the therapy, outside of the data documenting his performance. Overall, SB felt that visual feedback in the form of a sliding scale/chart was beneficial and assisted him in both improving his voice and keeping his voice at a certain loudness level during the exercises in which it was implemented. He circled that he “strongly agreed,” 5, with the following statements: “Overall, the timer and color chart helped me improve my voice,” and “The timer helped me keep my voice going for a longer period of time (question 2),” and “I am better able to regulate the volume of my voice because of the color chart,” and “I preferred the weeks when I used the chart and timer to those when I did not,” and “My voice is stronger now.” He circled that he “agreed,” 4, with the following statement: “The color chart helped me keep my voice at a loud volume level.”

When asked to provide any additional thoughts or suggestions about the use of the chart/scale, he stated that he felt that the visual feedback should have been implemented earlier into the therapy. Due to the design of the study, the visual feedback was not introduced until the second week of therapy. SB also shared that the feedback helped him to “focus longer during ‘ah’s.’”
CHAPTER 5: DISCUSSION

This research study examined the effects of visual feedback in voice therapy for an individual with PD, specifically analyzing the changes in the loudness level during vowel prolongations and generalization of this skill to other structured and unstructured exercises. No gross improvements in SB’s performance were seen over the course of treatment as a result of the implementation of visual feedback. Additionally, SB’s performance remained inconsistent and unpredictable over the course of treatment, however, several patterns have emerged from the data following analysis.

Discussion: Daily Task 1

Visual feedback, presented in the form of a colored paper scale with a sliding metal bar, was provided during Daily Task 1 of the second and fourth weeks of therapy. The greatest variability in SB’s performance on this task took place in the experimental weeks, for SB’s highest level of loudness occurred in week two, and his lowest level of loudness achieved occurred in the final week of therapy. SB’s performance on this task gradually decreased across the first three weeks of the treatment period. Over the fourth week of therapy, his performance varied greatly. He achieved an average of 80 dB during session 14, 73.68 dB during session 15, and 80.94 during session 16. This pattern could possibly be attributed to the fatigue SB was experiencing as a result of the intensity of the therapy program, given the general trend observed and the relative lack of variability of results within each week.

Further patterns can be deduced when examining SB’s performance on this task within each session. Fifteen trials of Daily Task 1 were completed each session. During week one, for each of the four sessions that week, there are notable differences between SB’s loudest and softest trials. For example, across the fifteen trials completed in session two of SB’s loudness levels, data ranged from 84.29 - 71.75 dB (12.54 dB). A
similar pattern can be observed during the first two sessions of week two, the first experimental week, with the greatest range occurring during session 6. Data ranged from 87 - 78.82 dB (8.18 dB). However, as the week progressed, his performance range narrowed slightly. During the final session of that week, his loudness range on this task was 81.33 – 74.33 dB (7 dB). Patterns observed during the sessions of week 3 parallel very closely with those observed in the first week of treatment. Given the variability of SB’s performance across week four, no distinct patterns were observed.

Discussion: Daily Task 2

Through visual inspection of the data, one can observe that SB’s performance on Daily Task 2 remained consistent over the course of the treatment period. The greatest increase in SB’s frequency range occurred during the first week of therapy. The frequency ranges he achieved in the third and fourth sessions are predictive of his performance for the remaining weeks of treatment. The implementation of visual feedback in Daily Task 1 did not appear to impact SB’s performance on Daily Task 2. The application used to record his frequency was inconsistent, and when observed by the PI during the trial, it did not consistently reflect changes in SB’s frequency as his frequency was perceived to be changing.

Results Obtained

SB’s observed cognitive deficits, in part, contributed to him being unable to fully access the visual feedback. The cognitive deficits exhibited were characterized by an inability to decode graphemes, track text while reading out loud, decreased ability to attend to therapy task and decreased initiation during the session.

Throughout trials of Daily Task 1, he required consistent prompting to look at the visual feedback chart. When sitting at the table, he had a forward leaning posture, and he was often looking down. Before each set of trials, he was prompted to sit back in the chair, bettering his posture, and look at the scale. The workings of the scale were
also reviewed with him at this time. He was told what his target section was on the scale. The section was marked with a star. The level of prompting SB required was inconsistent and fluctuated from session to session, depending on his level of alertness and ability to attend.

Additionally SB was observed to have difficulty attending during Daily Task 3. Though the ten functional phrases did not change throughout the treatment period, SB was consistently unable to read the phrases presented to him. The phrases were presented on the worksheet titled Daily Exercise 3: Functional Phrases Course Practice, provided by LSVT. The phrases were printed in thirty point Times New Roman font. The phrases were evenly spaced on the page and each phrase was numbered. It was determined that he was able to see the words clearly on the sheet, but he was unable to code the graphemes he saw into words without assistance. SB stated that he required glasses to read, but his performance on this task did not change with the added visual support. To aid SB, the PI read each phrase on the first trial, and all ten phrases were read once per trial. For the remaining four trials, the clinician would model the phrase if SB was unable to produce it or lost track of the phrase he was on.

SB’s overall performance was negatively impacted if he was fatigued or tired during the session. He would require additional prompting and modeling to complete each task. His posture and physical PD symptoms (e.g. tremors) were also observed to be much worse during these sessions. SB’s ability to remain alert and attend to the entire session also decreased. This contributed to the variability in his performance and the ability to complete each task to the best of his ability. SB’s wife reported that during the third week of therapy, his medications were altered. No changes were observed in SB or his performance as a result of this.
Discussion: Final Paper Questionnaire

It became evident through SB’s answers on this questionnaire that his perceived experience and performance differed from that which was observed. When SB completed the questionnaire with the assistance of his wife, the PI and advisor Dr. Isetti left the clinic room to ensure their presence would not influence the answers given. SB required significant prompting to attend to the visual feedback, yet it is evident through the responses on his survey that he felt he benefited from its use. SB reported that benefits of the color chart included: allowing him to better regulate and adjust his voice with PI input, keeping his voice at a loud volume level, and improving his voice overall. SB also expressed that he preferred the weeks when the color chart was used, and he independently expressed that he wished the chart was used sooner in the therapy program.

The questionnaire results do not directly allow for the deduction of concrete reasons to explain why the visual feedback was perceived to be beneficial by SB, yet did not strongly influence his performance throughout the therapy program. One reason is speculated to be related to the changes in sensorimotor and somatosensory feedback experienced by SB as a result of PD. Independently, he was unable to achieve full laryngeal closure, and because of this, he was unable to produce a loud voice. When the feedback was introduced, he now had an external means through which he could regulate the loudness of his voice. He was able to visually perceive his loudness and as a result modify his effort level to achieve the desired level of loudness.

Second, the color chart might have served as a source of external support for SB. When he engaged with the chart and utilized it, he was able to visualize his performance. The prompts given to SB consisted only of qualitative phrases. He was prompted to “speak LOUD” and to “do as I do,” but he was never told exactly how
loud he was being. The chart allowed for him to correlate effort level and loudness, providing him with concrete, quantitative feedback.

**Limitations to Visual Feedback**

One intentional aspect of the LSVT program design was to decrease the cognitive load placed on clients (Spielman et al., 2011). This reduced cognitive load would in turn allow for clients to focus solely on their productions and effort required to achieve a louder voice. The addition of a visual feedback chart increased the cognitive load that was placed on SB, compared to traditional LSVT. During sessions when the visual feedback was implemented, he was required to focus on his productions and effort level in addition to attending to the chart.

At times, SB did not attend to the visual feedback. It was difficult to determine if this was because the expectations placed on him (e.g., to produce a loud voice, maintain good posture, look at the visual feedback) were too great for his level of ability, or if the cognitive load was too high. The visual feedback only had the potential to be effective if SB was looking at it and understood where his target level of loudness was on the chart. If any of the above mentioned reasons impeded SB from accessing the visual feedback, then it would not be effective.

**Future Research**

There is a great amount of future research that could be conducted to further analyze the impact that visual feedback has on voice therapy for individuals with PD. SB had been diagnosed with PD for approximately twenty years at the time of the study. Given how progressed his disease was and the cognitive deficits he was experiencing as a result of this, future studies may examine the impact of the color chart on less severe populations. Individuals who have been diagnosed with PD for less than five years often display less physical symptoms and cognitive deficits. These factors have the possibility to enable the client to more fully access and understand the color
chart, and as a result achieve his/her maximum phonation goal in a shorter period of time within the program. Future research may also include comparing the effectiveness of the color chart and other forms of biofeedback compared to the LSVT Companion.
CHAPTER 6: CONCLUSION

The purpose of this study was to analyze the influence of visual feedback on voice therapy (LSVT) for individuals with Parkinson’s disease. It was hypothesized that visual feedback would enable the client to more easily produce a voice characterized by increased loudness and vocal quality. The results of the study do not fully support this hypothesis.

Results from Daily Task 1 reveal most clearly the influence of the visual feedback color chart. During the experimental weeks, the patient’s performance over the course of the week improved, this pattern was not observed during the non-experimental weeks. Additionally, as illustrated in the series of charts titled “Average Trial Values for Daily Task 1 (Vowel Prolongation),” there was less variability in the client’s performance within each session during the experimental weeks, but not better overall performance.

Significant improvements in the client’s performance were not observed over the course of treatment and he required continuous, maximum prompting. However, in the final paper questionnaire, the client expressed preference for treatment days when the visual feedback was used, finding it helpful in more effectively regulating the volume of his voice.
REFERENCES


internal globus pallidus is related to speech impairment in Parkinson’s disease.

*Brain and Behavior, 8*(9), e01073. https://doi.org/10.1002/brb3.1073


APPENDIX A: VISUAL FEEDBACK DEVICE IMAGES
Final Paper Questionnaire

1. Overall, the timer and color chart helped me improve my voice.
   1 Strongly Disagree  2 Disagree  3 Undecided  4 Agree  5 Strongly Agree

2. The timer helped me keep my voice going for a longer period of time.
   1 Strongly Disagree  2 Disagree  3 Undecided  4 Agree  5 Strongly Agree

3. I am better able to regulate the volume of my voice because of the color chart.
   1 Strongly Disagree  2 Disagree  3 Undecided  4 Agree  5 Strongly Agree

4. The color chart helped me keep my voice at a loud volume level.
   1 Strongly Disagree  2 Disagree  3 Undecided  4 Agree  5 Strongly Agree

5. I preferred the weeks when I used the chart and timer to those when I did not.
   1 Strongly Disagree  2 Disagree  3 Undecided  4 Agree  5 Strongly Agree

6. My voice is stronger now.
   1 Strongly Disagree  2 Disagree  3 Undecided  4 Agree  5 Strongly Agree

Please list any other thoughts or suggestions you might have about the use of the timer and chart during therapy: