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AN INTENSIVE TOTAL SPEECH TREATMENT USING PRINCIPLES OF MOTOR LEARNING IN AN INDIVIDUAL WITH DYSARTHRIA

BY

OCTAVIA C. MILLER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTERS OF SCIENCE

IN

INTERDISCIPLINARY NEUROSCIENCE

UNIVERSITY OF RHODE ISLAND

2014

MASTER OF SCIENCE THESIS

OF

OCTAVIA C. MILLER

APPROVED:

Thesis Committee:

Major Professor Leslie Mahler

Dana Kovarsky

W. Grant Willis

Nasser H. Zawia
DEAN OF THE GRADUATE SCHOOL

UNIVERSITY OF RHODE ISLAND
2014

ABSTRACT

Objective: Dysarthria is a motor speech disorder that is characterized by weak, slow, and imprecise movements. Previous research has shown that behavioral treatment can improve speech characteristics and have a positive impact on the intelligibility of people with dysarthria; however, data about the impact of specific treatment approaches is lacking. The purpose of this study is to examine the feasibility of a novel behavioral speech treatment that incorporates principles of motor learning and its impact on communication characteristics of an individual with spastic dysarthria secondary to a traumatic brain injury (TBI).

Method: This study used a single subject pre-post treatment design to investigate the impact of an intensive behavioral treatment on communication and pragmatic behaviors. The treatment consisted of 24 one-hour sessions administered four times a week for six weeks.

Results: The results showed that speech intelligibility scores improved for sentences. Analysis of discourse showed small increases in humor, assertive routines, narrative, and questions. Perceptual measures of voice and speech showed that listeners preferred the participant's treated speech to his non-treated speech at the sentence level. Articulation measures for the F2 of corner vowels increased following treatment. Statistically significant increases in dB SPL were found for single words and sentence repetition ($p<0.01$). dB SPL also increased for reading paragraph reading, and picture description, but these were not statistically significant. Responses to the Visual Analog Scale showed that there were large increases in both the participant's and his wife's perception of the participant's speech characteristics,

including an increase in loudness of his speech, participation in conversations, and speaking so that others can understand.

Conclusions: These data suggest that people with dysarthria secondary to traumatic brain injury can respond positively to an intensive speech treatment implementing principles of motor learning. They also suggest that positive changes in behaviors that are associated with speech may result in improved communication.

ACKNOWLEDGMENTS

I would like to thank my major professor, Dr. Leslie Mahler. You have helped me to transform from an undergraduate student to a graduate student. I know that it has not been an easy process, so I thank you for your patience and guidance, and for the countless hours of work required to get me to this point. Your dedication to ensuring that I succeed has been amazing and greatly appreciated. I truly admire your passion for research and it has been a pleasure working with you.

I would also like to thank each of my committee members, Dr. Nasser Zawia, Dr. W. Grant Willis, Dr. Dana Kovarsky, and Dr. Leslie Mahler, for your support throughout this process. I really appreciate the time that you have committed to ensure that I would be successful. Your time and commitment is truly appreciated.

In addition, I would like to thank the participant and his wife for completing this study. Thank you for your enthusiasm during the sessions and for your commitment to this study. I hope that this study has made a difference in your life.

I would also like to acknowledge my colleagues, Victoria Seites-Rundlett and Lauren Ferrara. Thank you for all of your help with data collection and analyses. I would also like to thank you for listening to me ramble when I am stressed and for your encouragement through tough times.

Last, but not least, I would like to thank my friends and family. Thank you for your encouraging words and for continuously motivating me to push forward. Your endless love and support has been beyond incredible. I would not have made it this far without each of you in my corner cheering me on.

TABLE OF CONTENTS

ABSTRACT ii

ACKNOWLEDGMENTS iv

TABLE OF CONTENTS v

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER 1 INTRODUCTION 1

Dysarthria 1

Traumatic Brain Injury 2

The Impact of TBI 3

Purpose of This Study 4

CHAPTER 2 REVIEW OF LITERATURE 5

Treatments for Dysarthria 5

Motor Learning 7

CHAPTER 3 METHODOLOGY 11

Research Design 11

Characteristics of the Study Population 11

Data Collection Schedule 12

Equipment Used 13

Evaluation Tasks 13

Data Analysis 17

CHAPTER 4 RESULTS 26

CHAPTER 5 DISCUSSION 39

CHAPTER 6 CONCLUSIONS **44**

APPENDICES **47**

Components of Speech **47**

Data Collection Schedule **49**

Dependent Variables Assessed **50**

Total Speech Treatment Tasks and Principles of Motor Learning Used **52**

Behaviors Analyzed Using the RHLB **54**

BIBLIOGRAPHY **62**

LIST OF TABLES

TABLE PAGE

Table 1. Speech Intelligibility. 26

Table 2. Discourse Ratings Using the RHLB 28

Table 3. Perceptual Measures of Voice and Speech: Listener Preference 31

Table 4. Articulation Measures of the F1 Corner Vowels 31

Table 5. Articulation Measures of the F2 Corner Vowels 32

Table 6. Quantitative Changes in Vocal dB SPL Measured at 40cm 32

Table 7. Quantitative Changes in MDVP Values During the Sustained Vowel Phonation Task 34

Table 8. Quantitative Changes in Lip and Tongue Pressures (kPa) 35

Table 9. Quantitative Changes for Maximum Inspiratory and Expiratory Pressures (cmH20) 36

Table 10. Visual Analog Scale Results 37

Table 11. Quantitative Changes for Grip Strength (lbs) 38

LIST OF FIGURES

FIGURE PAGE

Figure 1. Humor, Variety, Formality and Completeness Ratings Using the RHLB... 29

Figure 2. Questions and Turn-Taking Ratings Using the RHLB..... 30

Figure 3. Assertive Routines and Narrative Ratings Using the RHLB Ratings Using the RHLB 30

Figure 4. Changes in Vocal dB SPL Measured at 40cm..... 33

Figure 5. Changes in Vocal dB SPL for Sustained Ah Measured at 40cm..... 34

Figure 6. Changes in Lip and Tongue Pressures (kPa) 35

Figure 7. Participant Visual Analog Scale Results 37

Figure 8. Participant's Spouse Visual Analog Scale Results..... 38

CHAPTER 1

INTRODUCTION

This study reports the results of an intensive behavioral treatment on communication characteristics of an adult with spastic dysarthria secondary to a traumatic brain injury. Outcome measures were based on three pre-treatment evaluations administered immediately before treatment and three post-treatment evaluations administered immediately following treatment as well as 5 probes administered during treatment.

1.1 Dysarthria

Dysarthria is a term that refers to a group of motor speech disorders that result from disturbances in muscular control over speech (Yorkston, 1996). It is caused by a neurological impairment to the central or peripheral nervous system (American Speech- Language and Hearing Association (ASHA), 2013; Yorkston, 1996), and is characterized by slow, weak, and uncoordinated movements (Sellars, Hughes, & Langhorne, 2002; Yorkston, 1996). Dysarthria affects approximately 46.3% of people affected by neurogenic communication disorders (Palmer & Enderby, 2007).

There are many different types of dysarthria associated with damage to specific areas of the nervous system. Spastic dysarthria is caused by bilateral damage to the pyramidal and extrapyramidal tracts of the central nervous system (Roy, Leeper, & Blomgren, 2001). Spastic dysarthria results in muscle weakness, fatigue, and a loss of skilled motor movements. Deficits in these areas lead to slow, weak, and reduced

movements, increased muscle tone (also referred to as hypertonia or spasticity), incoordination of movement, and abnormal muscle reflexes (Duffy, 2005).

Spastic dysarthria can result in impaired motor control of the mandible, velum, pharynx, tongue, and the upper and lower portions of the face. Motor impairment may result in the inability to effectively move the jaw for speech, weakness or paralysis of the muscles of the face, weakness and/or atrophy of the tongue, and limited lip, jaw, and tongue movement (Duffy, 2005; McNeil, 1997). Deficits in these areas could lead to a reduction in the rate of speech, drooping of the mouth, a diminished ability to produce resonance and phonation during speech, hypernasality, and weak, distorted consonants (McNeil, 1997). This could cause the production of speech to be limited and non-effective.

Multiple components of speech production must be working effectively for speech to be understood. These include respiration, phonation, resonance, and articulation (Roy, et al., 2001). In spastic dysarthria, many of these speech production systems are non-effective due to the damage to the nerves innervating the muscles required for speech.

1.2. Traumatic Brain Injury

Traumatic brain injury (TBI) is an acquired brain injury that is defined as "an alteration in brain function, or other evidence of brain pathology caused by an external force" (Menon, Schwab, Wright, & Maas, 2010, p.1637). It is one of the leading causes of permanent disability or death in the United States (Center for Disease Control (CDC), 2012; NLM, 2013) and is a major public health issue since it can create life-long disabling conditions. According to the CDC, there are at least 1.7

million TBI's each year and approximately 52,000 result in an injury related death (CDC, 2012; National Institute of Health (NIH), 1999). Individuals who survive TBI's are often disabled and have to depend on others for care. Direct and indirect medical costs of TBI are estimated to be as high as $76.5 billion in the U.S. (CDC, 2012).

1.3. The Impact of TBI

Previous studies have reported that approximately one third of individuals with TBI develop dysarthria (McAuliffe et al, 2010; Yorkston, 1996). TBI may have a negative impact on communication in a variety of ways. Individuals diagnosed with moderate to severe TBI's often experience changes that affect cognition, sensation, emotions, and language including the inability to reason, maintain attention, remember, and make good judgments (CDC, 2012). In addition, individuals with TBI may have a difficult time learning new information, concentrating, and understanding their deficits as a result of their cognitive impairment.

1.3.1. Social & Behavioral Changes Caused by Dysarthria and TBI

Social and behavioral aspects of communication can be affected by dysarthria (Brookshire, 2007). Pragmatics play a major role in communication. Pragmatics refers to rules for socially and culturally appropriate communication interactions (ASHA, 2014). This includes rules for using language, rules for changing language, and rules to follow during conversations according to the context of the situation (ASHA, 2014). Following rules during conversations includes taking turns during the conversation, staying on topic, introducing new topics, appropriate eye contact, using facial expressions, and how close to stand to someone during speech (ASHA, 2014). Social

awkwardness or inappropriateness may occur when pragmatic rules are not followed during conversations.

1.4. Purpose of This Study

The purpose of this study was to examine the impact of a novel behavioral speech treatment that incorporates principles of motor learning on speech characteristics of an individual with spastic dysarthria secondary to a traumatic brain injury (TBI). It is hypothesized that this individual will improve speech characteristics, which will have a positive impact on intelligibility of speech and pragmatics during conversation following treatment. It is further hypothesized that pragmatic behaviors during communication interactions will improve. The specific aims of this study are to:

Aim 1: Assess whether this treatment will have a functional impact on the intelligibility of the participant's speech.

Aim 2: Assess the impact of treatment on pragmatic behaviors during communication interactions with the participant's wife.

Aim 3: Assess the feasibility of a novel comprehensive speech treatment using principles of motor learning for an individual with dysarthria secondary to a traumatic brain injury.

Aim 4: Assess the impact of treatment on acoustic parameters of speech.

CHAPTER 2

REVIEW OF LITERATURE

2.1. Treatments for Dysarthria

Research studies examining the impact of specific treatments for individuals with dysarthria are needed. Although there are many types of treatments currently available, there is a lack of scientific evidence supporting the efficacy and long-term effectiveness of these treatments (Sellars, Hughes, & Langhorne, 2002). The lack of evidence in the literature may be due to the fact that dysarthria among individuals with neurological disorders is heterogeneous and not all treatment approaches work equally well for all individuals with dysarthria. Therefore, treatment studies to examine the outcomes of well-defined speech interventions are needed to maximize the quality of life and social participation in individuals with dysarthria.

2.1.1. Speech Treatments

Treatment approaches for dysarthria may focus on breathing techniques to increase subglottic air pressure through the vocal folds, articulation techniques to increase the strength of the articulators needed for speech production (Tamplin, 2008), increasing coordination of respiration and phonation by increasing loudness of the individual's speech (Ramig, Sapir, Countryman, Pawlas, O'Brien, Hoehn, & Thompson, 2001) and/or decreasing the rate of speech to improve intelligibility (Yorkston, Hammen, Beukelman, & Traynor, 1990). Studies of stimulated clear speech in healthy adults have identified acoustic correlates of clear speech compared with habitual speaking such as reduced rate, increased fundamental frequency, increased pause frequency and duration, increased loudness, and expansion of vowel

space area (Beukelman, Burke, Ball, & Horn, 2002; Goberman & Elmer, 2005; Tjaden & Wilding, 2004). Palmer & Enderby (2007) conducted a review of treatment techniques currently used for the treatment of stable dysarthria. This study showed that many of current treatments for dysarthria focus on improving resonance, oromotor skills, articulation, prosody, and slowing the rate of speech (Palmer & Enderby, 2007). These studies collectively showed that physiological characteristics of speech could be increased through speech treatment.

Some studies have investigated the impact of speech treatment on physical characteristics of speech. Studies investigating clear speech in healthy adults and people with hearing loss show that people can increase intelligibility by 17-26% with the cue to speak more clearly (Payton, Uchanski, & Braida, 1994; Picheny, Durlack & Braida, 1986). It can be concluded from these previous studies that speech treatments should focus on maximizing the effectiveness, efficiency, and naturalness of communication.

Other studies used LSVT LOUD^{TM} to examine the outcomes of treatment targeting voice in adults with dysarthria secondary to stroke, Down syndrome, and Parkinson disease (Mahler & Jones, 2012; Mahler & Ramig, 2012; Mahler, Ramig & Fox, 2009; Ramig et al., 2001; Wenke, Theodoros & Cornwell, 2008). This treatment has been proven to be effective in individuals with Parkinson's disease; however, the effectiveness of this treatment for other types of dysarthrias is still being established. LSVT LOUD incorporates principles of motor learning that have been identified to drive changes in neuroplasticity and create long-term changes in speech motor

behaviors (Ludlow, Hoit, Ramig, Shrivastav, Strand, Yorkston, & Sapienza, 2008; Maas, Robin, Hula, Freedman, Wulf, Ballard, & Schmidt, 2008).

2.2 Motor Learning

Motor learning is the neurological process of using practice and assimilation to acquire the ability to produce or improve a motor task (Salmoni, Schmidt, & Walter, 1984; Ungerleider, Doyon, & Karni, 2002). Principles of motor learning have been used to re-establish motor function of muscles used for speech production in neurological disorders such as Parkinson disease, stroke, and Down syndrome. In a review paper, Ludlow et al. (2008) suggested that the development of effective treatment interventions for dysarthria should be guided by principles of neuroplasticity to address underlying mechanisms of symptomatic behaviors and increase the likelihood of long-term carryover (Ludlow et al., 2008). Maas et al. (2008) hypothesized that pre-morbid motor programs will not produce the intended output for the speaker with dysarthria, so the motor program specifications need to be modified through implementation of intensive speech motor practice to drive neuroplasticity (Maas et al., 2008). Although dysarthria is heterogeneous, the application of a treatment that incorporates principles of motor learning may be beneficial for improving deficiencies in speech (Fox, Ramig, Ciucci, McFarland, & Farley, 2006; Maas et al., 2008; Verdolini & Lee, 2004).

The present study is a translational study that integrated principles of motor learning into a specific treatment paradigm for an individual with spastic dysarthria to drive neuroplasticity changes of motor speech control. Our treatment targeted specific characteristics of the participant's speech, with the expectation that there would be

generalization of target speech behaviors outside of the treatment room in functional conversation. Therefore, principles of motor learning were incorporated into our treatment. The goal for incorporating principles of motor learning was to teach new motor programs for speech. Learning these skills required recruitment of complex cognitive processes so the administration of treatment was based on principles of motor learning and neuroplasticity that have been shown to drive changes in motor learning and neural control. Specific principles of motor learning that were used in the treatment study included:

Intensity of Practice

A large number of practice trials provide more opportunities to build relationships among muscles and speech production subsystems during speech production (Bhogal, Teasell, & Speechley, 2003; Fox et al., 2006; Maas et al., 2008). Intensity of practice was achieved through intensive dosage of treatment (four times a week for six weeks) and through maximizing the number of repetitions of treatment tasks within a treatment session.

Blocked Practice

Blocked practice was used during the treatment tasks because it aids in strengthening the complex motor act of clear speech to focus effort on the articulators. The participant completed each treatment task multiple times within one block of practice before progressing to the next treatment task; however, clear speech in the hierarchy of progressively longer and more complex speaking tasks was practiced with a random schedule of practice.

Use It or Lose It and Use It and Improve It

According to Ludlow et al., (2008), consistent usage of skills and training of a specific task is important to increase neural control of that function (Ludlow et al., 2008). Training in a specific task can enhance the structure and the function of the neural mechanisms involved in that behavior while neural circuits that are not actively engaged in training for long periods of time degrade (Kleim & Jones, 2008; Ludlow et al., 2008). Each treatment task was aimed at using the muscles that are needed for speech in order to improve speech production.

Skill Specificity

The treatment consisted of actual speech tasks that were specific to improving the intelligibility of speech. Although non-speech tasks were included in treatment to increase effort of articulation, the majority of treatment tasks consisted of real speech activities that varied by cognitive and linguistic demands ranging from relatively automatic tasks such as counting to conversation.

Saliency

Speech tasks used during the treatment sessions were generated specifically for the participant and were based on the participant's activities of daily living and interests to facilitate generalization of treatment outside of the treatment sessions.

Implicit Learning

The target of treatment was an external focus on the participant's production of speech sounds rather than on the specific elements that are needed to produce clear speech (such as slow your rate and over-articulate). The desired speech behavior was modeled for the participant during treatment to maintain an external focus on the

target acoustic goal of clear speech to minimize the cognitive demands of treatment (Winstein & Schmidt, 1990).

Augmented Feedback

The amount and type of feedback was carefully controlled to maximize generalization of motor speech behaviors. The participant was given frequent feedback about whether he met the target of clear speech in the early stages of the treatment during skill acquisition (Wulf, Shea, & Matschiner, 1998). Feedback was given less frequently during the later stages of the treatment sessions to transfer locus of control for motor speech production to the participant for generalization to functional communication (Lai & Shea, 1998; Winstein & Schmidt, 1990). Studies have shown that if feedback is delivered consistently throughout the treatment, the participant may rely on the feedback rather than his own ability to self-evaluate the accuracy of the skill in and outside of treatment (Schmidt & Lee, 2005).

CHAPTER 3

METHODOLOGY

3.1 Research Design

The current study used a pre-post-treatment single subject design. This design allowed an in-depth analysis of the effect of the treatment on the individual's pragmatics and speech characteristics by comparing the pre-evaluation data to the post-evaluation data. All treatment and evaluations took place at the University of Rhode Island's Speech and Hearing Center. Treatment evaluations were conducted in an IAC (Industrial Acoustics Company) sound-treated booth while treatment sessions were conducted in a clinical treatment room. Consent to participate in this study was received from the participant as well as a family member to ensure that the rights of the participant were being protected. This study was approved by the University of Rhode Island's Institution Review Board (project number HU1213-115).

3.2 Characteristics of the Study Population

The participant who completed the study (TST01) was a 48-year-old male who was four years post-injury and diagnosed with spastic dysarthria secondary to a traumatic brain injury that occurred following a fall. The participant's dysarthria was characterized by a diminished ability to control the muscles used for forming individual speech sounds resulting in imprecise consonants, distorted vowels, and slurred speech. He also displayed an excessive amount of muscle tone in his body, strained vocal quality, and hyper-nasality during speech. These impairments were consistent with a diagnosis of spastic dysarthria. The participant's language and cognition were assessed using the Western Aphasia Battery (WAB; Kertesz, 1982)

and the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 1998). TST01's AQ from the WAB was 85.6/100 reflecting relatively intact language skills accompanied by decreased fluency and naming secondary to dysarthria. The RBANS yields index standard scores based on subtest raw scores. RBANS index scores are metrically scaled, with a mean of 100 and a standard deviation of 15 for each age group. Therefore a score of 100 on any of these measures defines the average performance of individuals similar in age. Scores of 85 and 115 correspond to 1 SD below and above the mean respectively. RBANS results revealed immediate memory (Index score=100) and attention (Index score=95) were within 1 SD of the mean for a 48-year-old man with a college education. TST01's articulatory error patterns were assessed using the Goldman Fristoe Test of Articulation (GFTA; Goldman & Fristoe, 2000). The results from this assessment showed that the participant produced multiple speech sound errors characterized by substitutions, omission, and distortions. An analysis of speech sound errors was used to select sounds for minimal pairs in treatment targeting: /t/, /g/, /b/, and /d/. In addition, TST01 passed a hearing screening. TST01was included in this study because he demonstrated severe spastic dysarthria with relatively intact language and cognitive skills and because he was motivated to improve his intelligibility.

3.3 Data Collection Schedule

Data were collected during three pre-treatment evaluations that were administered the week immediately before treatment to establish a baseline for the participant. The participant then received six weeks of intensive speech therapy, which included weekly probe sessions to assess the participant's progress throughout the treatment

sessions. Three post-treatment evaluations were also collected immediately following the six-week treatment. During the evaluations, no cues or coaching were given to the participant. In addition, the person who conducted the evaluations was different from the treating clinician to avoid any biases in data collection during the evaluations.

3.4 Equipment Used

During the evaluation and the treatment stages of the study, the participant was fitted with a head-mounted microphone (Isomax B3) with a mouth to microphone distance of 8cm. A sound level meter (SLM), used to measure sound pressure level (SPL) (SLM- Bruel and Kjaer 2239A), was placed 40cm from the participant's mouth. These data were recorded and saved onto a flash recorder (Olympus Digital Voice Recorder WS-802). A Canon Digital Camcorder (FS40) was used to record each session.

3.5 Evaluation Tasks

The evaluation tasks consisted of both speech and non-speech tasks to assess the participant's communication characteristics before and immediately following treatment. Non-speech tasks were used to assess the performance of speech production subsystems. The weekly probes were administered to the participant once a week for thirty-minutes to assess the participant's progress throughout the treatment.

3.5.1 Pre- and Post-Treatment Evaluation Speech Tasks

Task 1: Speech Intelligibility Task:

The participant repeated a list of 50 single words and 20 randomly selected sentences from the Hearing in Noise Test (HINT- Nilsson, Soli, & Sullivan, 1994).

Task 2: Sentence Repetition:

The participant repeated the sentence. “The boot on top is packed to keep,” five times.

Task 3: Picture Description:

The participant was asked to describe a scenic picture (from the Western Aphasia Battery – Kertesz, 1997) in as much detail as possible for approximately one minute.

Task 4: Paragraph Reading:

The participant was asked to read aloud a 5-7 sentence paragraph from the Farm Passage (Crystal & House, 1982).

Task 5: Task Description/Monologue:

The participant was asked to discuss an assigned topic for approximately one minute.

3.5.2 Pre- and Post-Treatment Evaluation Non-Speech Tasks

Task 6: Sustained Vowel Phonation:

The participant was asked to sustain the vowel “ah” for six trials.

Task 7: Lip and Tongue Pressure:

The bulb of the Iowa Oral Pressure Instrument (IOPI®) was placed in two locations: between the participant’s tongue and the roof of his mouth to measure tongue pressure, and between the participant’s cheek and teeth at the corner of the mouth to measure lip pressure. The participant was asked to squeeze the bulb of the IOPI as hard as he could 3-6 times (for each placement of the bulb) for five seconds with the goal of obtaining three values that vary by no more than 10% from each other.

Task 8: Maximum Inspiratory and Expiratory Pressures (MIP & MEP):

A respiratory pressure meter (RPM01, Micro Direct; Lewiston, ME) was placed between the participant’s lips and teeth. The participant was asked to inhale and exhale as much air as possible into the respiratory pressure meter. A nose clip was

used to prevent air from escaping through the nose. The participant was asked to repeat this task 3-6 times with the goal of obtaining three values that differ no more than 10% from each other.

Task 9: Visual Analog Scale (VAS):

The participant and his wife each completed a VAS evaluating behavioral aspects of speech and communication the week before the treatment began and the week immediately after the treatment ended.

Task 10: Grip Force:

The participant was asked to place his arm on the table with his elbow at a 90° angle. A Jamar dynamometer (Patterson Medical Holdings, Inc.: Warrenville, IL) was placed into the participant's dominant hand. The participant was asked to squeeze the dynamometer as hard as he could 3-6 times with no more than 10% difference between the obtained values.

3.5.3 Treatment

Task 1: Lip and Tongue Effort x10 each (10-14 minutes):

This task was used to focus effort on the articulators to produce clear speech. The participant completed ten trials for this task using 70% maximal effort. *Principles of Motor Learning Used*: intensive practice, use it or lose it, skill specificity, and augmented feedback.

Task 2: Vowel Prolongation x5 (5 minutes):

The participant sustained the vowel "ah" at a normal pitch for as long he could for five trials. This task focused on increasing respiratory support for speech, strengthening vocal fold adduction, and improving the coordination of respiration and phonation.

Principles of Motor Learning Used: intensive practice, skill, specificity, implicit learning, and augmented feedback.

Task 3: Counting x5 (5 minutes):

The participant counted from one to fifteen using "clear speech." The participant repeated this task five times using the same effort that he used during the lip and tongue exercises. This task was done to bring the increased articulatory effort from the first two tasks into speech production. *Principles of Motor Learning Used*: intensive practice, use it or lose it, skill specificity, implicit learning, and augmented feedback.

Task 4: Minimal Word Pairs x2 (5 minutes):

This task consisted of single word pairs obtained from the participant's sound errors during the initial evaluation. During this task, the participant read from a list of minimal pair using, "clear speech." This task was repeated twice while producing effortful and over-articulated speech. *Principles of Motor Learning Used*: intensive practice blocked practice, use it or lose it, skill specificity, saliency, implicit learning, and augmented feedback.

Task 5: Reading Salient Sentences x3 (10-15 minutes):

The participant read a list of 12 to 15 salient sentences using, "clear speech." These sentences are functional sentences and were based on the participant's errors during speech. The sentences are specific to the participant to increase the likeliness of generalizing these sentences outside of treatment sessions. *Principles of Motor Learning:* intensive practice, blocked practice, use it or lose it, skill specificity, saliency, implicit learning, and augmented feedback.

Task 6: Reading Structured Dialogues, Phrases, and Conversations (10-15 minutes):

The participants read from a list of salient words, phrases, and situational dialogues/conversations that increased in length and complexity based on the participant's performance. *Principles of Motor Learning Used*: intensive practice, blocked practice, use it or lose, skill specificity, saliency, implicit learning, and augmented feedback.

Task 7: Homework and Carryover Assignments (5 minutes):

Homework and carryover assignments were given to generalize the treatment outside of the treatment room and to ensure that the participant was practicing at home. These assignments were given daily and were to be completed twice a day for 15 to 20 minutes each. The homework assignments included lip and tongue exercises, using the IOPI bulb (6x each), vowel prolongation (x5), counting (5), salient sentences (x3), structured dialogue/conversation, and a carry-over assignment (this task was specific to the participant and increased in length and complexity as the treatment sessions progressed). *Principles of Motor Learning Used*: use it or lose it, saliency, specificity, blocked practice, and intensive practice.

3.5.4. Weekly Probes

The weekly probes consisted of 6 tasks: sentence reading (x5), picture description, IOPI (x3), maximum inspiratory and expiratory pressures (x3 each), grip force (x3), and discourse analysis (10 minutes). The discourse analysis was novel to this treatment study. During the discourse analysis, the participant's speech and behavior were recorded during a 10-minute non-structured conversation.

3.6 Data Analysis

A single-subject pre-post research design was used to allow an in-depth examination of the participant's response to the treatment. Results from the pre-treatment evaluations were compared to the results from the post-treatment evaluations for data analyses. Individual data analyses were conducted for each independent variable. Visual inspection of the data was used to determine baseline stability, trend analyses, and to analyze changes between data from pre- and post-evaluation data. The effect size was calculated to determine the strength of a treatment effect if one was present.

In addition, paired sample t-tests and the Wilcoxon Signed Ranks non-parametric test, were used to determine statistical significance between the pre-treatment evaluations and post-treatment evaluations. The Wilcoxon Signed Ranks test was used to account for any issues with normality of the data. A one-tailed test was used because these data were expected to increase. A significance (α) level of 0.01 was used to reduce the chance of artificially inflating the type 1 error of getting a statistically significant value, even if one is not present. Inter-rater reliability was completed to assess consistency of the results and the degree to which the raters agreed when examining the data.

3.6.1 Dependent Variables

1. Speech Intelligibility:

The intelligibility of the participant's speech was measured using single word intelligibility and sentence intelligibility (20 sentences from the HINT). Five participants, or listeners, who were not familiar with the participant, were asked to

participate in the study. Each listener was required to pass a hearing test and spoke English as his/her first language.

Single word intelligibility was measured using a list of single words produced by the participant. These words were played for the listeners from a recoding in a quiet room with the volume adjusted to a comfortable listening level. The listeners were asked to circle the word that he/she heard, or to write in the word that he/she believed they heard. Sentence intelligibility was measured using sentences from the HINT. The listeners were played a recording of the sentences produced by the participant and asked to transcribe each sentence that they heard. Percent accuracy was calculated by dividing the number of words correct by the total number of words on the list or in the sentence.

Rationale: This measurement was used to determine if the intelligibility of the participant's speech was improved following treatment. Identifying and transcribing words produced by the participant allowed the examiners to determine if there was a difference in the intelligibility of the participant's speech when comparing pre- and post-evaluation data. Speech intelligibility was expected to increase following treatment.

2. Discourse Analysis:

Discourse during the unstructured conversations in the probe sessions was analyzed using the Right Hemisphere Language Battery Discourse (RHLB) Analysis Rating Scale (Bryan, 1989), a 5-point scale with ratings from 0-4. The following discourse skills were rated: supportive routines (behaviors involved with politeness: greetings, saying thank you), humor (using humor or jokes during the conversation as well as a

humorous tone during appropriate times), questions (requests clarification or more information), assertive routines (correcting his or someone else's behavior and/or speech), narrative (length of sentences and conversations as well as the amount of detail used in the conversation and maintenance of the topic), variety (changing the content of the topic), formality (level of formality used and the nature of the information discussed), turn-taking (balanced interactions between the participant and his wife), meshing (the timing of the interaction, topic initiation), discourse comprehension (is the participant able to understand the speaker's speech), prosodic ratings, organization (is the speech structured), completeness of speech and topics during the conversation, appropriate eye contact, and gestures. An additional rating of discourse comprehension (listener) was added to investigate whether the listener's ability to understand the participant speech was increased throughout the sessions. Each session began by asking the participant, "What did you do this week?" The sessions were recorded using a Canon Digital Camcorder (FS40) and analyzed by four different raters for inter-rater reliability.

Rationale: Discourse analysis during conversation provided data to allow for pre- to post-treatment comparisons to evaluate the impact of treatment, if any, on speech and behavior. The Right Hemisphere Language Battery Discourse Analysis Rating Scale was used to conduct this analysis because it was designed specifically to detect communication disorders (Bryan, 1989). This assessment has been used in previous studies to assess communication disorders; however, the assessment was used in this study to evaluate how the participant's discourse and language use changed

throughout the study (Jodizio, Lojek, & Bryan, 2005). It was expected that the ratings of the behaviors analyzed during discourse would increase following treatment.

3. Perceptual Measures of Voice and Speech:

Sustained vowel phonation and repeated sentences were used to measure the perceptual measures of voice and speech using. Listener studies were conducted to determine the listener's perception of the participant's speech. The listener studies consisted of five or more participants, or listeners, who were not familiar with the participant used in the study. Each listener was required to pass a hearing test and spoke English as his/her first language.

During the listener study, two sentences were played for the listeners from a recording. The sentences could have consisted of two pre-evaluation sentences, two post-evaluation sentences, or one pre- and one post-treatment sentence. Listeners blind to the time of recording were asked to rate which sentence they preferred (which sentence they perceived as easier to understand) by rating sample A (sentence 1) in relation to sample B (sentence 2) on a continuum scale from -50 to +50. For example, if sample B was better than sample A, the participant would place a line on the positive end of the continuum scale; however, if sample B was worse than sample A, then the participant would place a line on the negative end of the continuum. A rating of zero on the scale suggested that there was no difference between the two samples. This same protocol was used during the listener perceptual study for the pre- and post-evaluation sustained vowels. The percentage for preference was calculated by determining how many samples were preferred out of the total number of samples by dividing the distance of the vertical line used on the continuum by the distance of the

total line provided information about how much each person preferred one sample to the other.

Rationale: The purpose of this measurement was to determine if listeners perceived an impact of treatment on the participant's speech. This variable was used to determine if listeners perceived a difference in the participant's speech when comparing post-treatment evaluations to the pre-treatment evaluations. The quality of the participant's speech was expected to improve following treatment.

4. Articulation Measures of the F1 and F2 Corner Vowels:

Articulation measures of the first two formants, F1 and F2, of the corner vowels /a/, /i/, and /u/ were used to calculate vowel space area extracted from multiple repetitions of the sentence, "The boot on top is packed to keep." A time frequency analysis software, or TF32, used linear predictive coding (LPC- a technique used to find the vowel space) to measure the vowel space for each corner vowel. The LPC peaks were identified and the values in kHz were recorded. The means, standard deviations, and effect sizes were calculated and compared and a paired sample t-test was used to determine if there were any statistically significant differences. Reliability was used to ensure consistency of the results by having 20% of the values analyzed by additional raters.

Rationale: The sentence, "The boot on top is packed to keep," was used because it contained all of the vowels (/a/, /i/, /u/) that were to be analyzed. The first and second formants, or F1 and F2, are important in measuring articulatory precision. Compressed vowel space has been associated with dysarthria; however, improved articulation is

associated with an increase in vowel space. Therefore, the vowel space of the corner vowels /a/, /i/, and /u/ was expected to increase following treatment.

5. Voice Measure: Vocal Sound Pressure Level (SPL) Analysis:

Vocal loudness represented by sound pressure level (dB SPL) was measured using the following tasks: picture description, paragraph reading, sustained "ah", and task description/monologue. A sound level meter was used to detect the sound pressure level. Means, standard deviations, and a paired sample t-test were calculated and compared, and the effect size was calculated to determine the strength of the treatment effect.

Rationale: The data from these tasks were used to determine if vocal loudness increased when comparing the results from the post-evaluation data to the pre-evaluation data. Vocal loudness is a sign of increased respiratory support and was expected to increase following treatment.

6. Acoustic Measures of Phonatory Stability:

Phonatory stability was measured during sustained vowel phonation task as a measure of vocal fold vibration. Visual inspection of the data was completed for trend analysis and to determine any effect of treatment. The means and standard deviations for the pre- and post-evaluation data were calculated and compared. The effect size was calculated to determine the strength of the treatment. The relative average perturbation (RAP) and pitch perturbation quotient (PPQ) was collected as a measure of vocal fold vibration and analyzed using MDVP Advanced (CSL 4500) software.

Rationale: This measure was used to determine treatment effects of phonatory stability. A decrease of phonatory stability is a sign of weakness of the vocal folds,

while an increase in phonatory stability is consistent with an increase in vocal fold adduction. As a result of the treatment, the phonatory stability, or vocal fold vibration, was expected to increase following treatment. Higher PPQ and RAP percentages represent a higher cycle-to-cycle variability. Therefore, a lower percentage would suggest an increase in phonatory stability.

7. Lip and Tongue Pressures:

The Iowa Oral Performance Instrument (IOPI ®- Northwest Company; Redmond, WA), a device used to measure lip and tongue effort, was used to measure the maximal force production of the tongue and lips. The participants obtained values from the IOPI (measured in kPa) were collected. Means, standard deviations, and a paired sample t-test were calculated and compared, and the effect size was calculated to determine the strength of the treatment effect.

Rationale: Lip and tongue exercises focused effort on the articulators used to produce clear speech. Therefore, lip and tongue strength were measured to determine whether a change in the participant's lip and tongue effort was observed following treatment. Lip and tongue pressures were expected to increase following treatment.

8. Maximum Inspiratory and Expiratory Pressures (MIP & MEP):

MIP & MEP, the maximum amount that the participant could inhale and exhale, were measured using a respiratory pressure meter in cm H_20. The means and standard deviations were calculated and compared. A paired sample t-test was used to determine if there were any statistically significant differences between the pre- and post-evaluation data and the effect size was calculated to determine the strength of the treatment effect.

Rationale: Speech requires a sufficient amount of respiratory support from the lungs and coordination of respiration and phonation for clear speech. Therefore, MIP and MEP were measured to determine if there was a change in the amount inspiratory and expiratory pressures TST01 could create. MIP and MEP values were expected to increase following treatment.

9. Visual Analog Scale (VAS):

The participant and his wife each completed VAS ratings independently of the participant's communication characteristics. The VAS consisted of a continuum scale with each end defined as an extreme of the communication behavior assessed such as "Always a shaky voice" and "Never a shaky voice". The participant and his wife placed a line on the continuum, which best represented their answer to the question. The line was then measured and divided by the length of the continuum to find a percentage. The mean percentage was collected and compared.

Rationale: This scale was used to determine if there were any functional changes in the participant's speech following the treatment. Questions such as, "When I speak I am always loud enough or never loud enough," were asked to determine if the treatment had a functional impact on the individual's speech. It was expected that the participant and his wife would rate positive improvements in communication characteristics following treatment.

CHAPTER 4

RESULTS

4.1. Findings

The findings for this study are based on a comparison of pre-treatment and post-treatment data collection for the independent variables. Paired sample t-tests were used to compare means and determine whether there was a statistically significant difference between each pre- and post-evaluation dependent variables. Effect sizes were also calculated to determine the magnitude of the treatment. The results were based on three pre-treatment evaluations and three post-treatment evaluations. The results are described in the following sections.

4.1.1. Speech Intelligibility

Speech intelligibility was measured using single words and sentences. Data showed that there was an increase in the number of words correctly identified for both single words intelligibility (2%) and sentence intelligibility (19%). The effect size for single words was 0.40 suggesting the magnitude of the treatment effect was medium. Sentences had an effect size of 0.96 suggesting that the magnitude of the treatment effect was large.

Table 1. Speech Intelligibility

Measure % Accuracy	Pre-Treatment	Post-Treatment	p-value	Cohen's d	Effect Size r
Single Words	69%	71%	0.11	0.86	0.40
Sentences (HINT)	27%	46%	0.04	7.24	0.96

4.1.2. *Discourse Analysis*

The discourse in each probe session was analyzed using the Right Hemisphere Language Battery (RHLB) Discourse Rating Scale, a 5-point scale using ratings from

0-4. The ratings from each probe session were compared to determine whether the behaviors changed over the course of treatment. These data showed that there were improvements for many of the behaviors; however, some discourse behaviors including supportive routines, meshing, prosodic ratings, discourse comprehension (participant), organization, and eye contact remained consistently high throughout the sessions.

Ratings for humor, variety, formality, and completeness are displayed in Figure 1. The data showed that there was a one-point increase in the ratings for each behavior. Data for humor and formality showed an increase in ratings for probe sessions 3 through 6 (ratings= 4) when compared to probe session 1 (ratings = 3). The ratings for completeness were also increased during probes sessions 3-6 (rating= 3) when compared to probe session 1 (rating=2). The ratings for variety were consistent across sessions 1-5 (rating=3), then increased one point during session 6 (rating=4).

The ratings for questions and turn taking are displayed in Figure 2. These were the only two behaviors that showed a decrease in the ratings as the treatment sessions progressed. The ratings for questions remained consistent throughout the sessions (rating = 3), except during probe session 4 where the rating was decreased by one point. Turn taking, however, began at a rating of 3 and increased to 4 during sessions 3 and 4. The rating for turn taking then decreased during session 5 by one point, but increased back to 4 by probe session 6.

Assertive routines and narrative, in Figure 3, showed a 2-point increase in ratings. During assertive routines, probe session 1 was rated a 2, while probe sessions 3-6 were all rated as 4. Ratings for narrative showed an increase in ratings as the

sessions progressed. The behavior was rated a 2 during probe session 1; however, probe sessions 3 through 5 were rated a 3 and probe session 6 was rated a 4. Ratings for discourse comprehension (listener) showed a 1-point increase in the listener's comprehension of the participant's speech throughout the sessions.

Reliability for RHLB ratings was calculated to measure the extent to which the three raters agreed when rating the participant's discourse. Reliability was calculated by dividing the number of times the raters agreed by the total number of ratings. The results showed that the raters agreed 51% of the time when rating the participant's behavior.

Table 2. Discourse Ratings Using the RHLB during five probe sessions

Behaviors Assessed	RHLB Discourse Ratings 0-4				
	Probe 1	Probe 3	Probe 4	Probe 5	Probe 6
Supportive Routines	4	4	4	4	4
Humor	3	4	4	4	4
Questions	3	3	2	3	3
Assertive Routines	2	4	4	4	4
Narrative	2	3	3	3	4
Variety	3	3	3	3	4
Formality	3	4	4	4	4
Turn Taking	3	4	4	3	4
Meshing	4	4	4	4	4
Discourse Comprehension (Listener)	2	2	2	3	3
Discourse Comprehension (Participant)	4	4	4	4	4

Prosodic Ratings	**4**	**4**	**4**	**4**	**4**
Organization	**4**	**4**	**4**	**4**	**4**
Completeness	**2**	**3**	**3**	**3**	**3**
Eye Contact	**4**	**4**	**4**	**4**	**4**
Gestures	**4**	**4**	**4**	**4**	**4**

Figure 1. Humor, Variety, Formality, and Completeness Ratings Using the RHLB during five probe sessions.

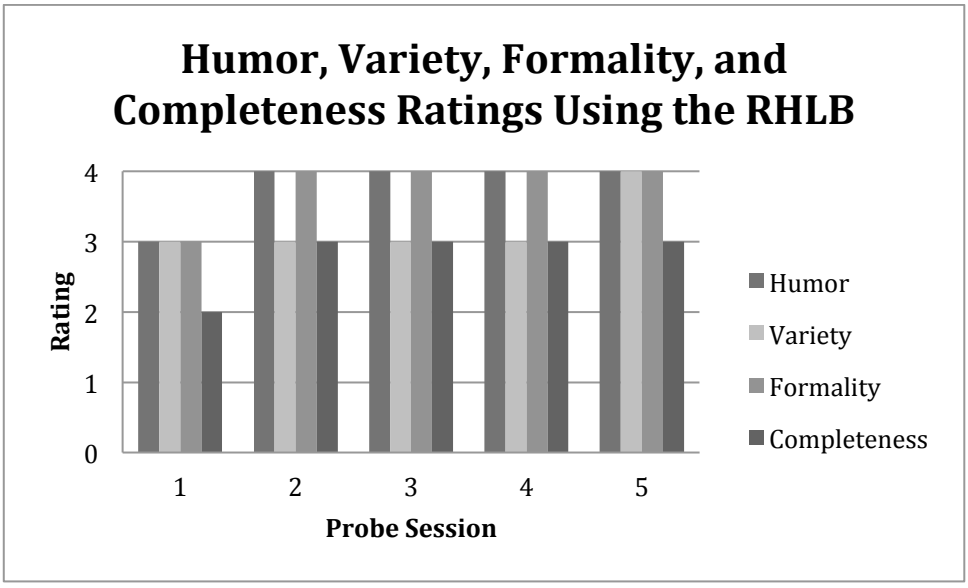


Figure 2. Questions and Turn-Taking Ratings Using the RHLB

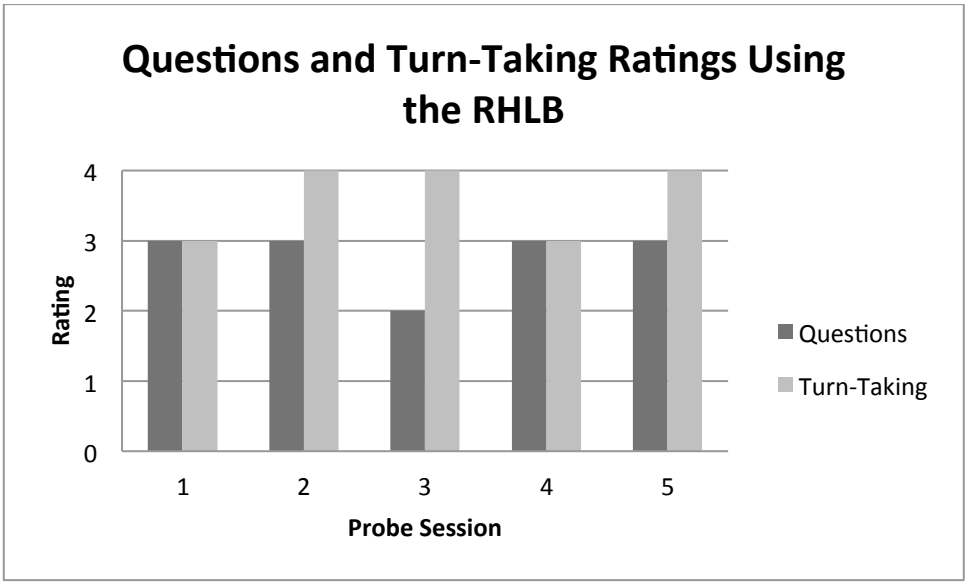
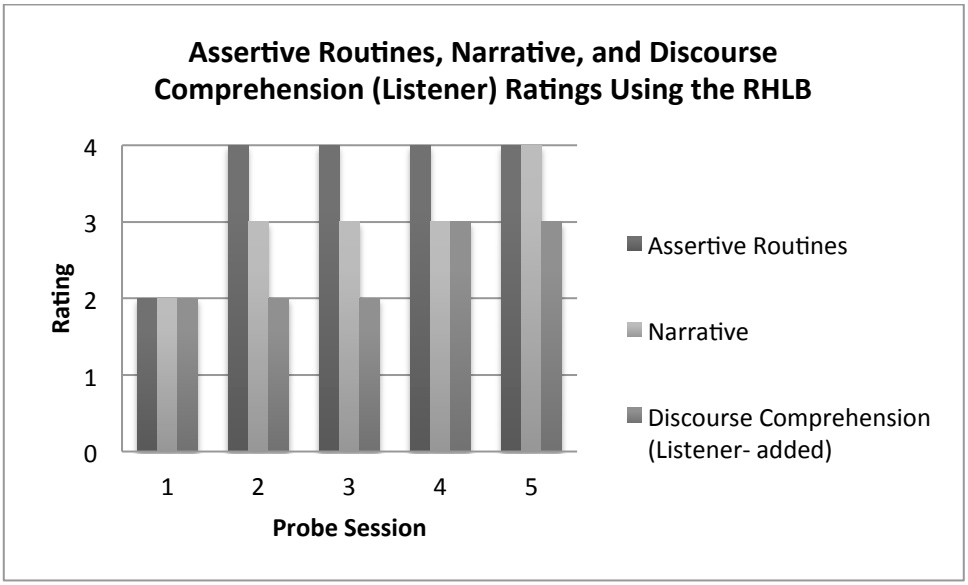


Figure 3. Assertive Routines, Narrative, and Discourse Comprehension (Listener) Ratings Using the RHLB



4.1.3. *Perceptual Measures of Voice and Speech*

Perceptual measures of voice and speech were measured using sentence repetition, and sustained vowel phonation. The listener preference data for sentences showed that listeners preferred 57/70 samples of the treated speech samples compared

with pre-treated speech samples. Data for sustained vowel phonation showed that the participants preferred 28/80 of the treated speech samples to the pre-treated speech samples. A summary of the perceptual measures of voice and speech can be found in Tables 3.

Table 3. Perceptual Measures of Voice and Speech: Listener Preference

Measure %	Pre/Post Preference
Sentences Repeated	81%
Sustained Vowel Phonation	29%

4.1.4. *Articulation Measures of the F1 and F2 Corner Vowels*

F1 and F2 of the corner vowels, /a/, /i/, and /u/, were obtained from the sentence, "The boot on top is packed to keep." The results showed that there was a statistically significant increase in the averages for the F2 corner vowel /i/ ($p<0.01$). Although not statistically significant, there were also increases in the F2 corner vowels for /a/ (335.87Hz) and /u/ (113.33 Hz). There were no statistically significant increases in the F1 of corner vowels or the duration of the vowels.

Two different raters measured reliability for vowel analysis. Reliability was calculated by dividing the number of times the raters agreed by the total number of ratings. The results showed that the raters agreed 17% of the time when analyzing F1 and F2 of the corner vowels.

Table 4. Articulation Measures of the F1 Corner Vowels

Vowels (Hz)	**Average Pre (SD)**	**Average Post (SD)**	p-value	**Cohen's d**	**Effect Size**
/a/	599.00 (51.85)	647.40 (22.27)	0.10	1.21	0.52
/i/	317.33 (12.60)	295.53 (9.11)	0.10	1.98	0.70
/u/	443.40 (11.89	455.13 (20.26)	0.14	0.71	0.33

Table 5. Articulation Measures of the F2 Corner Vowels

Vowels (Hz)	Average Pre (SD)	Average Post (SD)	p-value	Cohen's d	Effect Size
/a/	1029.60 (105.47)	1365.47 (47.50)	0.02	4.11	0.90
/i/	975.53 (49.98)	2327.00 (102.02)	0.00	16.82	0.99
/u/	888.00 (20.70)	1001.33 (84.14)	0.05	1.85	0.68

4.1.5. *Voice Measure (Vocal dB SPL)*

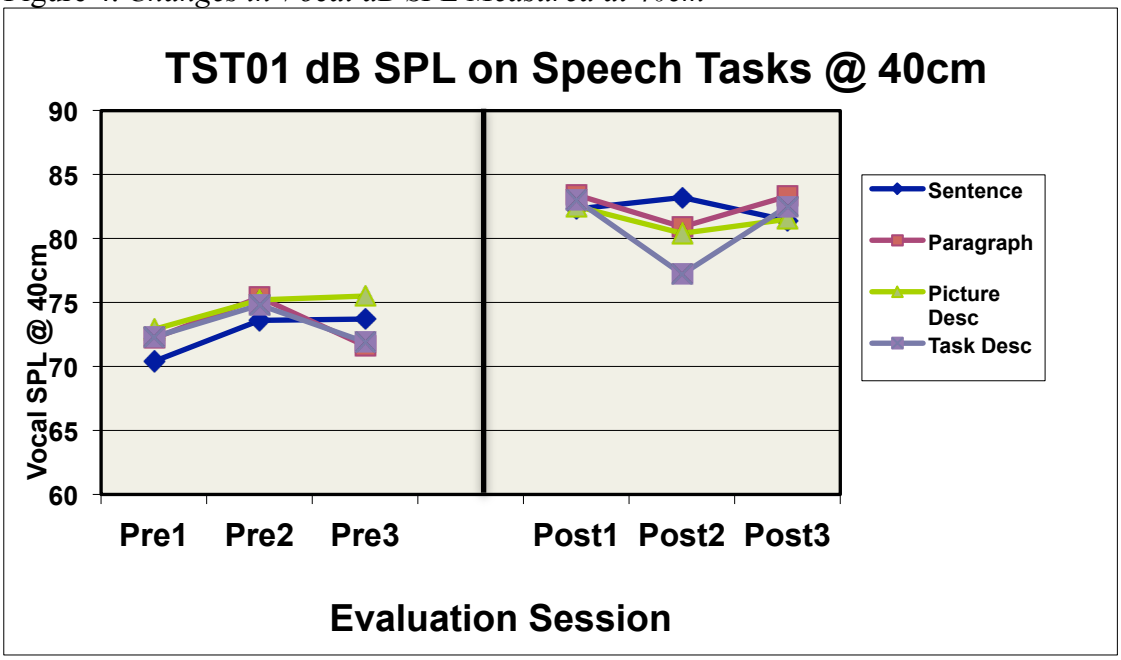
Vocal loudness was measured in dB SPL during sustained vowel phonation, sentence repetition, paragraph reading, picture description, and task description/monologue. The results showed that there were statistically significant increases in loudness for single words and sentence repetition following treatment. The effect size for single words was 0.67 indicating a medium treatment effect. Sentence repetition had an effect size of 0.96 indicating that the magnitude of the treatment effect was large. There were increases in loudness for single words (8.80 dB SPL), paragraph reading (9.46 dB SPL), picture description (6.94 dB SPL), and task description/monologue (7.90 dB SPL) following treatment. A summary of quantitative changes in vocal dB SPL form pre- to post-evaluation is presented in Table 6.

Table 6. Quantitative Changes in Vocal dB SPL Measured at 40cm

Measure dB SPL	Average Pre (SD)	Average Post (SD)	p-value	Cohen's d	Effect Size r
Single Words	71.50 (4.56)	79.80 (4.65)	0.00	1.80	0.67
Sentence Repetition	72.57 (1.88)	82.30 (0.90)	0.01	7.02	0.96
Paragraph Reading	73.07 (2.04)	82.53 (1.42)	0.02	5.38	0.94
Sustained Vowel	83.23	81.50	0.28	0.55	0.27

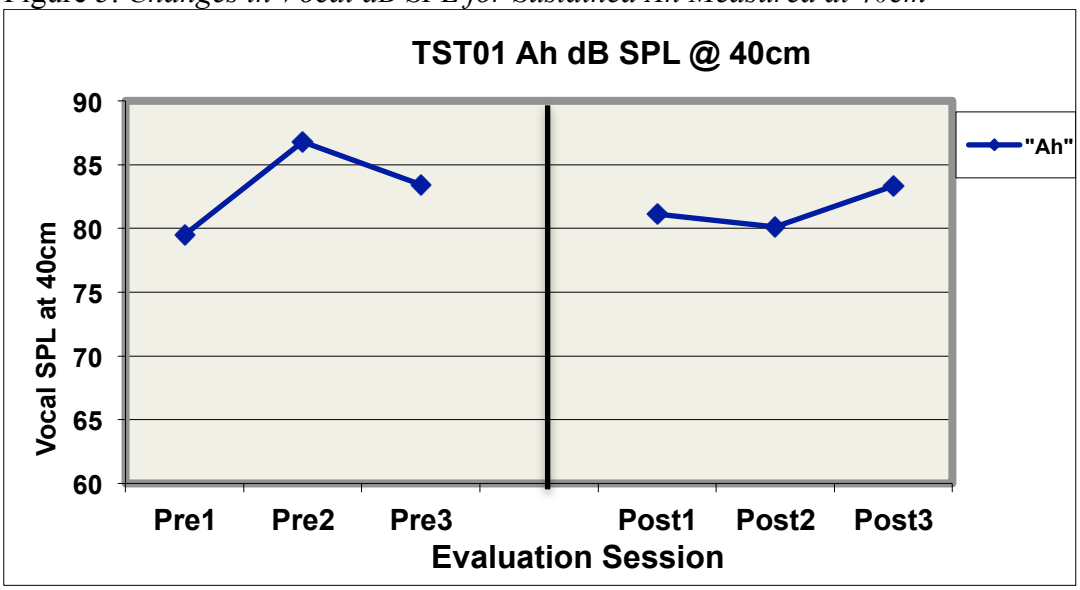
Phonation	(3.65)	(1.64)			
Picture Description	74.53 (1.42)	81.47 (1.05)	0.02	5.56	0.94
Task Description/ Monologue	73.00 (1.57)	80.90 (3.21)	0.05	3.08	0.84

Figure 4. *Changes in Vocal dB SPL Measured at 40cm*



Note: The solid line represents the treatment phase of the study.

Figure 5. *Changes in Vocal dB SPL for Sustained Ah Measured at 40cm*



Note: The solid line represents t he treatment phase of the study.

4.1.6. *Acoustic Measures of Phonatory Stability*

A comparison of pre- and post-evaluation means and standard deviations showed that there were no statistically significant differences between the RAP and PPQ values following treatment; however, the values for both were decreased. The average of RAP decreased 0.36% while the PPQ average decreased 0.53%. The effect size for the participant was small for RAP (0.21) and PPQ (0.30). Both RAP and PPQ values were above threshold (RAP = 0.68; PPQ = 0.84). The pre- and post-evaluation means for RAP and PPQ are reported in Table 7.

Table 7. Quantitative Changes in MDVP Values During Sustained Vowel Phonation

Measure %	Average Pre (SD)	Average Post (SD)	p-value	Cohen's d	Effect Size r	Threshold
RAP%	1.37 (0.87)	1.01 (0.84)	0.37	0.42	0.21	0.68
PPQ%	1.45 (0.94)	0.92 (0.75)	0.32	0.62	0.30	0.84

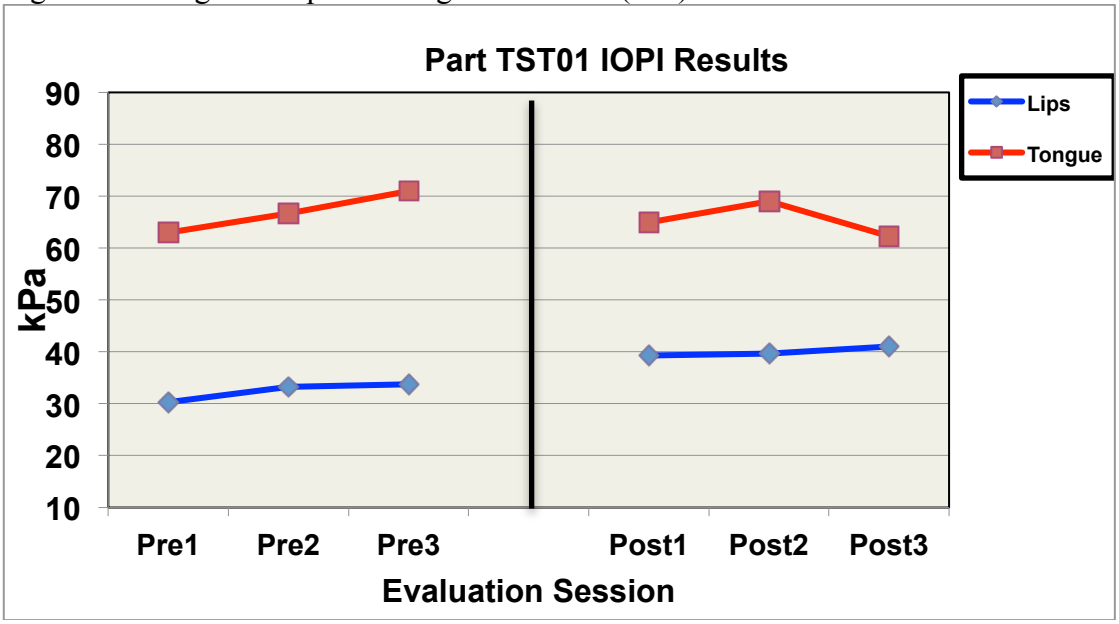
4.1.7. *Lip and Tongue Pressures*

A t-test assessing the values between pre- and post-evaluation data showed that there were no statistically significant differences lip or tongue pressures following treatment. However, the average between the lip pressure for pre- and post-treatment increased (7.00 kPa). The effect size for lip pressure was large (0.93) suggesting that the magnitude of the treatment effect for lip pressures was large. Table 8 shows the quantitative changes in lip and tongue strength.

Table 8. Quantitative Changes in Lip and Tongue Pressures (kPa)

Measure kPa	Average Pre (SD)	Average Post (SD)	p-value	Cohen's d	Effect Size r
Lips	32.43 (1.86)	39.43 (1.50)	0.02	5.19	0.93
Tongue	66.90 (4.00)	65.43 (3.37)	0.36	0.39	0.19

Figure 6. Changes in Lip and Tongue Pressures (kPa)



Note: The solid line represents the treatment phase of the study.

4.1.8. *Maximum Inspiratory and Expiratory Pressures*

A paired sample t-test showed there were no statistically significant differences between pre- and post-evaluation values for MIP and MEP following treatment. However, the maximum pressure for inspiration was increased (12.50 cmH20). There was a medium effect size for inspiratory pressure (0.64) indicating that the magnitude of the treatment effect was medium. Table 9 shows the quantitative changes for inspiratory and expiratory pressures.

Table 9. Quantitative Changes for Maximum Inspiratory and Expiratory Pressures (cmH20)

Measure cmH20	Average Pre (SD)	Average Post (SD)	p-value	Cohen's d	Effect Size r
MIP	127.3 (8.86)	139.77 (6.00)	0.14	1.64	0.64
MEP	172.7 (7.65)	172.67 (32.40)	0.50	0.00	0.00

4.1.9. *Visual Analog Scale*

Ratings from the Visual Analog Scale showed there were many differences between pre- and post-evaluation percentages. The results showed that the participant perceived himself as having a less shaky voice (43%), being less monotone (18%), slurring less (98%), having a less strained vocal quality (93%), and mumbling less (50%) following treatment. In addition, the participant also perceived an increase in loudness (52%), speaking so that others can understand, participating in a conversation (50%), and starting a conversation (45%). The participant's wife perceived decreases in the shakiness of the participant's voice (18%), monotone speech (18%), mumbling (31%), and strained vocal quality during speech (14%). In addition, the participant's wife also perceived increases in the participant's ability to speak so that others can

understand, (27%) participating in a conversation (44%), and starting in a conversation (32%).

Table 10. Visual Analog Scale Results

Perceptual Ratings	Client Pre	Client Post	Spouse Pre	Spouse Post
Always loud enough	33%	85%	87%	65%
Always finds the right words	87%	80%	52%	51%
Always a shaky voice	95%	52%	47%	29%
Always monotone	21%	3%	51%	33%
Always slurs	98%	0%	52%	33%
Always a "strained" voice	97%	4%	47%	33%
Always mumbles	93%	43%	65%	34%
Always speaks so others can understand	33%	83%	55%	82%
Always participates in a conversation	100%	99%	33%	77%
Always starts a conversation	22%	67%	27%	59%

Figure 7. Participant Visual Analog Scale Results

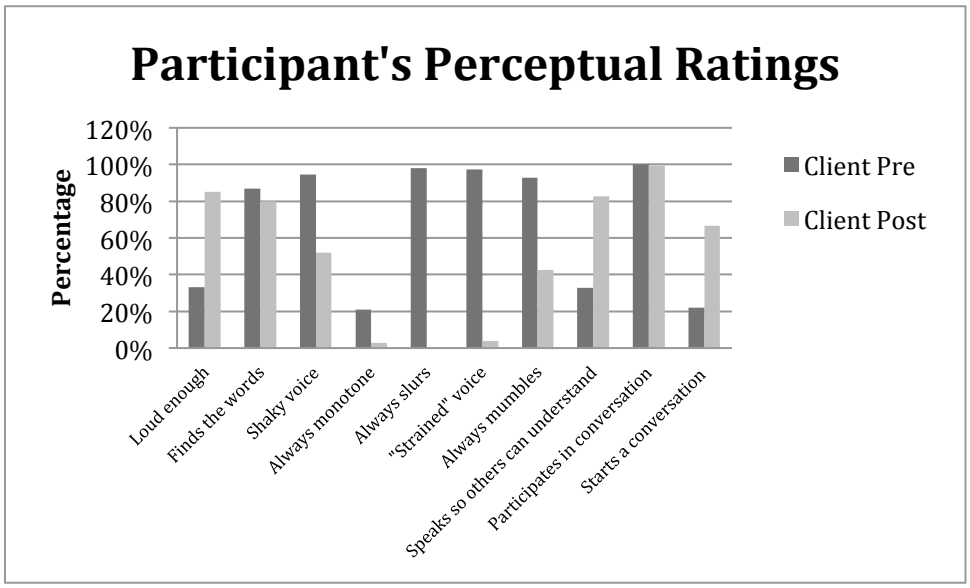
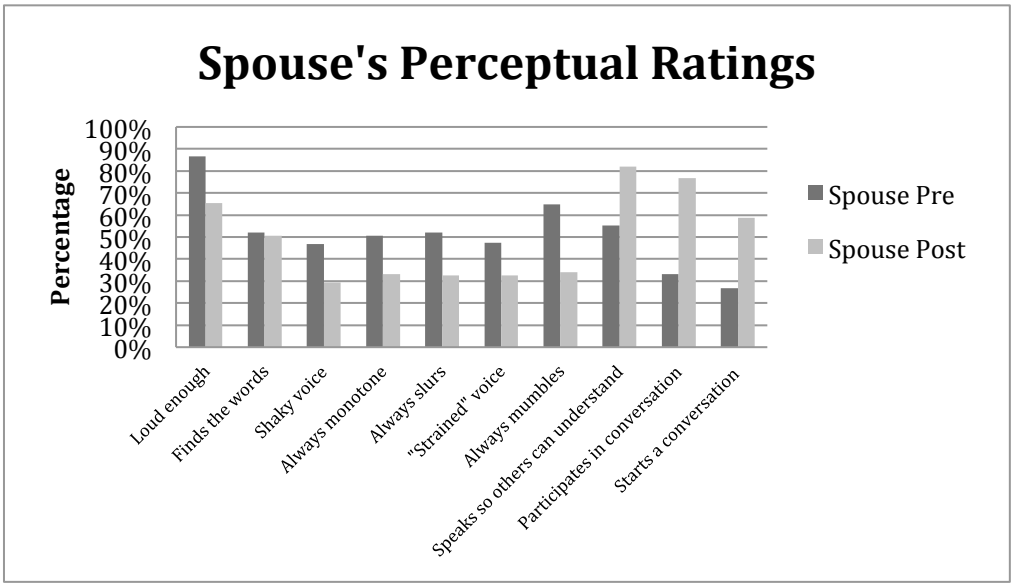


Figure 8. Participant's Spouse Visual Analog Scale Results



4.1.10. *Dynamometer*

Results from the independent variable grip strength showed there was not a statistically significant difference for the pre- and post-evaluation averages following the treatment (5.63 lbs). The effect size of this treatment was 0.55, which suggests that the magnitude of this treatment effect was medium.

Table 11. Quantitative Changes for Grip Strength (lbs)

Measure (lbs)	Average Pre (SD)	Average Post (SD)	p-value	Cohen's d	Effect Size r
Grip Strength	112.77 (2.65)	107.14 (5.36)	0.07	1.33	0.55

CHAPTER 5

DISCUSSION

The purpose of this study was to examine the impact of a novel behavioral speech treatment that incorporates principles of motor learning on speech characteristics of an individual with spastic dysarthria secondary to a traumatic brain injury. The results of this study showed that there were improvements in the intelligibility of the participant's speech at the sentence level, and improvements in the ratings for variety, narrative, completeness, and discourse comprehension (listener). Statistically significant differences were found between the pre- and post- evaluation data for the F2 corner vowel /i/, and for dB SPL in sentence repetition. The participant and his wife reported that there were clinically significant improvements in the perceptual ratings on the visual analog scale for: speaks so others can understand, participates in a conversation, and starts a conversation. They also reported clinically significant decreases in shaky voice, monotone, slurs, and strained voice on the visual analog scale. These results suggest that this treatment could have a functional and social impact on the communication of individuals with non-progressive spastic dysarthria.

5.1.1. *Speech Intelligibility*

The results showed that there was an increase in sentence intelligibility but not word intelligibility. Sentences may have been easier for the listeners to comprehend than single words because sentences provide the listeners with more context than just single words. An increase in sentence intelligibility is beneficial because it closely resembles speech during a typical conversation.

5.1.2. Discourse Analysis

Many of the discourse ratings remained consistent throughout the sessions, while the other ratings either increased or fluctuated. The variability in the participants discourse could have been attributed to a number of factors including the topics presented during each session and the participant's comfort level throughout the probe sessions. The participant could have become more comfortable with the evaluators during the probe sessions, and as a result, opened up more during the discourse as the sessions progressed. Increases in the participant's comfort level could lead to an increase in the length of the narrative and a decrease in formality during the discourse. Assertive routines, requests for clarification, completeness of sentences, and even humor could also be a result of increased comfort during the sessions.

Topics during the discourse varied which could have led to variability in the participant's responses and behaviors. Many of the discussions were led and directed by the participant's wife, which could have also affected the participant's responses during the discourse. Listener comprehension was increased throughout the sessions. Evaluators may have become more familiar with the participant throughout the sessions, and as a result, were better able understand the participant's speech and some of the gestures that he used during speech.

Reliability for discourse analysis was 51%. Variations in the evaluators' ratings could have been due to disagreements and/or confusion about how the participant's behavior should have been rated using the scale. A training session for evaluating each behavior should have been included to ensure that each evaluator was rating the participant's behavior the same way. In addition, the behaviors analyzed were rated 0-

4 on the rating scale; however, 5 points may not have been enough points to efficiently measure changes in the participant's behavior. This scale may not have been sensitive enough to measure the changes that we would like to observe.

Overall, this treatment may have had a positive effect on the participant's pragmatics during discourse sessions. The behaviors that remained consistent throughout the sessions show that there was not a deficit in those behaviors due to his injury. Behaviors that showed an increase in ratings as the sessions progressed suggests that improving the characteristics of speech may also improve pragmatic behaviors that are associated with speech.

5.1.3. Perceptual Measures of Voice and Speech

Listener preference data for sentences showed that more people preferred the participant's treated speech to the pre-treated speech. This may suggest that additional aspects of speech other than intelligibility such as vocal quality, loudness, and prosody had a positive impact on speech characteristics. These results indicated that this speech treatment may have had a functional impact on communication for this participant.

5.1.4. Articulation Measures of the F1 and F2 Corner Vowels

Results showed that there were large increases in the post-evaluation averages for the F2 corner vowels /a/, /i/, and /u/. Since F2 is important in measuring articulatory precision, an increase in the averages of these vowels may suggest that there was an improvement of the participant's tongue movement for more precise articulation. The results from this variable may have contributed to an increase in listener perceptual studies for intelligibility at the sentence level.

5.1.5. Voice Measure (Vocal dB SPL)

Results showed a statistically significant increase in dB SPL for single words and sentence repetition. Loudness also increased for paragraph reading, picture description, and task description/monologue. Reduced loudness can be one of the effects of dysarthria. Speech that is produced at a reduced loudness is often less intelligible. Therefore, an increase in loudness in speech could allow communication to be more effective. Increases in loudness could have carry over effects during conversations and speech produced outside of the treatment room. These results showed that this treatment may have an impact on vocal loudness, which would have a functional impact on communication and social interactions.

5.1.6. Acoustic Measures of Phonatory Stability

The results from the RAP and PPQ percentages showed that although there were no statistically significant differences for the percentages between the pre- and post-treatment evaluations, there were decreases in the values for both. Decreases in RAP and PPQ percentages suggest an increase in phonatory stability. This increase in phonatory stability could have carry over effects for increased phonation and prosody. Increases in these speech production systems would have a major effect on the communication produced by the participant by reducing the strained-strangled vocal quality that is present in individuals with spastic dysarthria and by increasing the stress and intonation that is placed on speech. These improvements in speech production systems could lead to improvement in the intelligibility of speech.

5.1.7. Lip and Tongue Pressures

The results showed that there was an increase in the averages for lip pressures. Average lip pressure increased by 7.00 kPa, but this increase was not statistically

significant. This may suggest that there was an increase in the amount of effort placed onto the articulators during speech production.

5.1.8. Maximum Inspiratory and Expiratory Pressures

Average inspiratory pressure increased by 12.6 cmH20, but this increase was not statistically significant. This increase suggests that there was an increase in respiratory support for speech, which could provide increased respiratory support required increased loudness that could contribute to more precise articulation (Sapir, Spielman, Ramig, Story, & Fox, 2007).

5.1.9. Visual Analog Scale

The participant and his wife's responses to the VAS showed that there were clinically significant changes in the perception of the participant's speech characteristics including decreases in shaky voice, slurring during speech, monotone speech, and strained vocal quality, and increases in their ratings for speaks so that others can understand, participates in conversations, and starts conversations. These changes in the participant's and his wife's perception of the participant's speech characteristics suggest that this treatment may have had a social and functional impact on the participant's ability to communicate efficiently.

5.1.10. Dynamometer

The results from grip strength showed that there were no statistically significant differences between the pre- and post-evaluation averages. Grip Strength was the dependent variable that was expected remain consistent throughout the treatment sessions. Changes in the pre- and post averages could be due to variations in the spasticity in the participant's arm.

CHAPTER 6

CONCLUSIONS

This study consisted of three aims that were targeted throughout the study. The first aim of the study was to assess whether the treatment would have a functional impact on the intelligibility of the participant's speech. Increases in sentence intelligibility and listener perception studies suggest that there were improvements in the comprehension of the participant's speech following treatment. Increases in the participant's and his spouse's ratings on the VAS suggested that there were improvements in the participant's speech characteristics, vocal quality, and participation during conversations. These results may indicate that treatment had a functional impact on the intelligibility of the participant's speech.

The second aim of this study was to assess the impact of treatment on pragmatic behaviors during communication interactions with the participant's wife. Improvements in the ratings of the behaviors analyzed indicate that behaviors that are associated with speech may be improved as a result of improvements in speech. These results suggest there was a positive functional impact on pragmatics and social communication following treatment.

Aim three was to assess the feasibility of a novel comprehensive speech treatment using principles of motor learning for an individual with dysarthria secondary to a traumatic brain injury. TST01 completed all tasks in all 24 sessions of treatment and consistently completed homework and carryover activities. Therefore,

this novel treatment incorporating motor learning principles, such intensity of practice, saliency, skill specificity, and blocked practice, into the treatment tasks was feasible for this participant. The results showed increases in the dependent variables when comparing pre-and post-evaluation data and TST01 and his wife reported they were satisfied with the treatment.

The final aim of this study was to assess the impact of treatment on acoustic parameters of speech. Vocal dB SPL and acoustic measures of phonatory stability increased during the treatment. Articulation measures of the F2 corner vowels were also increased. These results suggest that this treatment may have a functional impact on communication and social interactions, and that this treatment could be useful in improving the acoustic parameters of speech, and pragmatic behaviors that may be associated with speech.

Collectively, these results provided evidence to support our hypothesis that an intensive speech treatment using principles of motor learning could have a positive impact on the intelligibility of speech and pragmatics following treatment for someone with non-progressive spastic dysarthria.

5.3. Limitations

Limitations of the study included the duration and severity of the participant's communication disorders, the health of the participant, and the participant's cognitive deficits. It should be noted that TST01 was sick with a cold during the post-treatment evaluations, which may have had an effect on measurements of vocal quality, articulation, loudness, and strength during the evaluation sessions. Illness during an evaluation session could prevent the participant from performing at his best, which

could affect the results during data collection. TST01's cognitive-linguistic deficits may also have contributed to the impact of treatment on generalization outside the treatment room by diminishing his ability to understand the directions given during the treatment and/or evaluation tasks and affecting his behaviors during the discourse sessions.

The dependent variables chosen for this study may not have been sensitive enough to detect the changes in the speech characteristics that we wanted to see. The reliability and validity of these variables should also be assessed to ensure that we are really measuring what we want to measure. Additional measures should be used to fully capture changes in the characteristics of the participant's speech.

5.4. Future Directions

Future studies should include collecting follow-up data at three and six months after the completion of treatment to measure generalization and maintenance effects. The sample size should be increased to determine the consistency of these results within this population. The effectiveness of this treatment should also be measured in participants with other dysarthria types.

APPENDIX A.

A summary of the components of speech. Each component must work efficiently for adequate speech production.

Respiration: Respiration provides a steady supply of air pressure from the lungs to the vocal folds on exhalation. The vocal folds vibrate when they are adducted for the production of speech. Changes in respiration provide adjustments in subglottic air pressure necessary to increase the loudness of speech. In individuals with spastic dysarthria, the ability to provide adequate amounts of respiratory support is often diminished. This would result in speech that has reduced loudness, shorter phrase lengths, and a breathy sounding voice.

Phonation: Phonation is the production of voiced phonemes through vocal fold vibration. Therefore, phonation also requires respiratory support. Phonation requires complete adduction of the vocal folds in order to work efficiently. When this is not functioning correctly, individuals with dysarthria's speech may sound breathy, harsh, strained, and strangled. It would also result in the inability to change pitch or loudness.

Resonance: Resonance consists of the proper placement of oral or nasal tone onto phonemes. When the velum is raised, oral resonance occurs; however, when impaired, the velum is weak and lower than usual. If the timing of the coordination of speech is off, then there will not be complete velopharyngeal closure. This would result in a nasal phoneme, or hypernasality.

Articulation: Articulation is the shaping of the vocal airstream into phonemes. Articulators are muscles and include the tongue, lips, cheeks, nose, and alveolar ridge. Each one of the articulators must move at the correct time and speed for accurate

articulation. If impaired, the individual with spastic dysarthria will experience speech that has imprecise consonants, distorted vowels, a slow rate of speech, and irregular articulatory breakdowns.

Prosody: Prosody is the stress and the intonation that is used during connected speech to convey meaning. Stress is accomplished by changing the pitch, loudness, and the duration of speech while intonation is accomplished through change in pitch and stress. Deficits in prosody will lead to speech that has irregular and/or mono-pitch, mono-loudness, and a decrease in the duration of phrases.

APPENDIX B.

A summary of the data collection schedule and tasks administered during each session.

Data Collection Schedule			
	Week 1	**Week 2-7**	**Week 8**
Session	Pre-Evaluations:	6 Week Intensive Speech Treatment:	Post-Evaluations:
Description of Sessions	4 sessions the week immediately before treatment	4 one-hour sessions each week for a total of 24 individual treatment sessions	4 sessions the week immediately after treatment
Tasks Administered During Session	• Sentence Reading Paragraph Reading • Picture Description • Speech Intelligibility • Task Description • Vowel Prolongation • Lip & Tongue Effort • Maximum Inspiratory & Expiratory Pressures • Grip Force	• Exercising of the Lips and Tongue • Vowel Prolongation • Counting • Minimal Pairs • Salient Sentences • Reading Structured Dialogues and Conversations	• Sentence Reading Paragraph Reading • Picture Description • Speech Intelligibility • Task Description • Vowel Prolongation • Lip & Tongue Effort • Maximum Inspiratory & Expiratory Pressures • Grip Force

APPENDIX C.

A description of the dependent variables assessed during the Total Speech Treatment.

Dependent Variables Assessed			
Task	**Dependent Variable**	**Description of Task**	**Rationale**
Speech Intelligibility Tasks	Perceptual Measures of Speech Intelligibility	Repeated a list of 50 single words and 40 randomly selected sentences	To determine whether listeners perceived a difference in the intelligibility of the participant's speech
Sentence Reading	Articulation measures of the F1 and F2 Corner Vowels	The sentence, "The boot on top is packed to keep," was repeated five times	To evaluate the effects of treatment on vowel space
Picture Description	Voice Measure of Vocal Loudness	Described a picture in as much detail as possible for approximately one minute	To determine whether vocal loudness increased as a result of treatment
Paragraph Reading	Voice Measure of Vocal Loudness	Read aloud a 5-7 sentence paragraph from the Farm Passage	To determine whether vocal loudness increased as a result of treatment
Task Description/ Monologue	Measure of Vocal Loudness	Discussed an assigned topic for approximately one minute	To determine whether vocal loudness increased as a result of treatment
Sustained Vowel Phonation	Acoustic Voice Measures of Phonatory Stability	The vowel "ah" was sustained for six trials	Phonatory stability was used to measure vocal fold vibration
Lips & Tongue Pressure	Effort of Lips and tongue	The participant squeezed the bulb of the IOPI as hard as he could for five seconds	This task was used to focus effort on the articulators to produce clear speech
Maximum Inspiratory & Expiratory Pressures	Measurement of Respiratory Pressure	The participant inhaled and exhaled as much air as possible into the RPM	To determine if changes in the amount of air that the participant could fill his lungs with occurred as a result of the treatment
Visual Analog Scale (VAS)	Qualitative Measures on Functional	The participant and his wife rated changes in	To measure any perceptual changes in

	Communication	the participant's communication.	the participants speech
Discourse Analysis	Behavioral Analysis	The participant's speech and behavior were recorded during a non-structured session	To measure any changes in behavior during speech as a result of treatment

APPENDIX D.

A summary of the tasks used during the Total Speech Treatment and the principles of motor learning that were used during each task.

Total Speech Treatment Tasks and Principles of Motor Learning Used		
Task	**Description Of Task**	**Principles Of Motor Learning Used**
Lips and Tongue Effort	The participant squeezed the bulb of the IOPI with maximum effort for five seconds	Intensive Practice Use It or Lose It Skill Specificity Augmented Feedback
Vowel Prolongation	The vowel "ah" was sustained for five trials	Intensive Practice Skill Specificity Implicit Learning Augmented Feedback
Counting	Counted from one to fifteen using "clear speech	Intensive Practice Use It or Lose It Skill Specificity Implicit Learning Augmented Feedback
Minimal Pairs	Read from the list of minimal pairs using "clear speech."	Intensive Practice Blocked Practice Use It or Lose It Skill Specificity Saliency Implicit Learning Augmented Feedback
Salient Sentences	Read a list of 12 to 15 salient sentences using "clear speech	Intensive Practice Blocked Practice Use It or Lose It Skill Specificity Saliency Implicit Learning Augmented Feedback
Reading Structured Dialogues and Conversations	Discussed an assigned topic for approximately one minute	Intensive Practice Blocked Practice Use It or Lose It Skill Specificity Saliency Implicit Learning Augmented Feedback

Homework Assignments	Assignments were given daily and were to be completed twice a day for 15 to 20 minutes each.	Use it or Lose It Saliency Specificity Blocked Practice Intensive Practice

APPENDIX E.

A summary of the definitions for each behavior assessed and how the behaviors were rated using the Right Hemisphere Language Battery (Bryan, 1989).

Behaviors Analyzed Using the RHLB

1. **Supportive Routines:**

Behaviors concerned with politeness (greeting, saying "thank you," etc.)

4 Appropriate use of expected routines

3 Use of routines is reduced due to aphasia

2 Some reduction in supportive routines- not associated with aphasia or out of proportion to the speech disorder

1 Important routines performed infrequently or inadequately, or inappropriate routines used

0 Essential routines omitted, e.g. interaction begins without greetings or little acknowledgement of the speaker

2. **Humor:**

Using humor or jokes during the conversation; using a humorous tone during appropriate times

4 Normal appropriate humor

3 Reduction in humor but no negative impression created

2 a) Content/interaction rather serious – little humor shown or appreciated

b) Humor slightly unexpected or not appearing quite logical

1 a) Very little humor shown or appreciated

b) Increase in humor- unexpected or inappropriate

0 a) No humor shown

b) Humor inappropriate, e.g. offensive and difficult to manage in the interaction or the subject takes offense unexpectedly

3. Questions:

Requests for clarification or more information

4 Normal use of varied questions

3 Reduction in questioning due to aphasia

2 Reduction in questioning (few or unvaried questions) not associated with aphasia or exceeding the level of speech difficulty

1 Questions irrelevant, inappropriate or unexpected

0 a) Few or no questions – little two-way interaction

b) Continually asks questions- becomes unpleasant and it is difficult for the interaction to progress

4. Assertive Routines:

Correcting his or someone else's behavior and/or speech; making comments, complaints, advise, disagreeing, and persuading.

4 Normal level of assertion- making comments and complaints, disagreeing, giving command advise, refusing and persuading

3 Low use of assertive routines that is compatible with aphasia

2 a) Low use of routines- not due to aphasia or exceeding the level of speech reduction

b) Some increases in the use of assertive routines

1 a) Very few assertive routines

b) Significantly increased assertion [in both (a) and (b) interaction is one-sided as the subject rarely or very frequently contributes]

0 a) No assertive routines used

b) Interaction hardly achieved

5. Narrative:

Length of sentences and conversations; amount of detail used in the conversation; maintenance of topic

4 Normal length of utterance with appropriate level of detail and narrative following a theme

3 Narrative constrained by aphasia

2 Narrative brief or a little lengthy, but not creating an abrupt or unfavorable impression

1 a) Utterances very short- creating an abrupt or clipped impression

b) Very lengthy with great detail and embellishment- can become difficult to follow

0 a) Abnormally brief- No real narrative, may be mono-syllabic

b) Abnormally lengthy speech and embellishments, confabulations few pauses, and little regard for the listeners reactions- can become difficult for the interaction to proceed

6. Variety:

Changing the content of the topic

4 Normal and appropriate variety of topics

3 Variety of content lacking, but not uninteresting

2 Too little variety of content

1 a) Abnormally invariable content, repetitive, the listener becomes irritated

b) Variety of content, but no logical progression of subjects

0 a) No variation- content all of one type

b) Excessive variation- difficult to follow with no real subjects for discussion emerging

7. Formality:

Level of formality used and the nature of the information discussed

4 Normal level of formality for the situation

3 Rather formal, but functioning well in the situation

2 More personal or intimate than would be expected

1 a) Inappropriately formal or distant- uncomfortable for the listener

b) Inappropriately personal or emotional- uncomfortable for the listener

8. Turn-Taking:

Balanced interactions between the participant and his wife

4 Normal turn-taking; conversation is appropriately two-way

3 Examiner (Wife) takes the lead and guides turn taking due to aphasic problems

2 a) Examiner (Wife) takes the lead- not due to aphasia

b) Subject tends to take the lead more frequently than would be expected

1 a) Subject frequently fails to contribute where expected

b) Subject is abnormally frequent in taking the lead

0 Little or no turn-taking routines/interactions achieved

9. Meshing:

The timing of the interaction; topic initiation

4 Normal meshing (timing or response)

3 Responses delayed due to aphasia, e.g. word finding problems

2 a) Responses slightly delayed- not due to aphasia

b) Occasionally interrupts

1 a) Responses too delayed- negative impressions created

b) Too many interruptions- negative impressions created

0 a) Responses very abnormally delayed

b) Abnormally frequent or long interruptions- annoying for the listener

10. Discourse Comprehension (Listener)*

Was the listener able to understand the participant's speech?

4 Normal comprehension without speaker/listener misunderstanding

3 Reduced comprehension- compatible with aphasia

2 Occasionally misses the point or fixes to one point, but usually a logical digression

1 Often misses the point or fixes to an unconnected item, i.e. an incidental point or illogical digression (this may indicate a lack of overall coherence)

0 Very frequent misunderstandings, comments may not appear to be related to the subject and the essential subject is not grasped

11. Discourse Comprehension (Participant)

Was the participant able to understand the speaker?

4 Normal comprehension without speaker/listener misunderstanding

3 Reduced comprehension- compatible with aphasia

2 Occasionally misses the point or fixes to one point, but usually a logical digression

1 Often misses the point or fixes to an unconnected item, i.e. an incidental point or illogical digression (this may indicate a lack of overall coherence)

0 Very frequent misunderstandings, comments may not appear to be related to the subject and the essential subject is not grasped

12. Prosodic Ratings for 1-5

Was prosody used appropriately during speech?

4 normal tone, pitch and volume with production of appropriate stress and intonation

3 Reduction in prosody that is compatible with aphasia

2 a) Some reduction in stress or lack of intonation

b) Some increased stress or exaggerated intonation

1 Abnormally increased prosody- very emphatic, unexpected stressing, unexpected volume changes

0 Virtually monotone- little or no variation in tone and pitch, little or no stress

13. Organization

Was the speech structured?

4 Normal expected organization of themes and content

3 Story/message essentially organized as expected.

Occasional errors in organization corrected or insignificant

2 Some significant details/information occurring before or after the information is required but the listener is able to infer the intended meaning

1 Essential information omitted or given after it was required by the listener to fully comprehend the meaning

0 Little or no organization of unconnected statements

14. Completeness

Completeness of speech and topics during the conversation

4 Normal- as much information as would be expected

3 Story/message essentially completed with a few omissions or irrelevancies

2 Some significant details/information missing, but the listener can infer meaning

1 Essential information missing

0 Main point of the output not given

15. Eye Contact

Did the participant make appropriate contact during the discourse?

4 Normal expected use of eye contact

3 Eye contact established but slightly lacking

2 Reduced or increased eye contact

1 Frequent failure of eye contact

0 No eye contact

16. Gestures:

Were gestures used/understood?

4 Normal expected use of gesture during discourse

3 Reduced variety of gestures but essentially normal

2 Reduction in the use of gestures or use of unexpected gestures

1 Inappropriate gestures used

0 No gestures used

*This behavior was not included in the RHLB, but was added to this study for additional behavioral analysis.

BIBLIOGRAPHY

Beukelman, D., Burke, R., Ball, L., & Horn, C. (2002). Augmentative and alternative communication technology learning part 2: Preprofessional students. *Augmentative and Alternative Communication, 18*, 250-254.

Bhogal, S. K., Teasell, R., & Speechley, M. (2003). Intensity of aphasia therapy, impact on recovery. *Stroke*, *34*, 987-993.

Brookshire, R.H. (2007). Introduction to neurogenic communication disorders (7th ed). Missouri: Mosby Elsevier. 413-414.

Bryan, K.L. (1989). The right hemisphere language battery (2nd ed). Retrieved November 5, 2013 from http://www.surrey.ac.uk/healthandsocialcare/people/Files/Language%20battery/Right%20hemisphere%20langauge%20battery.pdf

Crystal, T. H., & House, A.S. (1982). Segmental durations in connected speech signals: Preliminary results. *Journal of the Acoustical Society of America, 72,* 705-716.

Duffy, J.R. (2005). Motor speech disorders: Substrates, differential diagnosis, and management (2nd ed.). Missouri: Elsevier Mosby. Chapter 1: Defining, understanding, and categorizing motor speech disorder, 1-16.

Duffy, J.R. (2005). Motor speech disorders: Substrates, differential diagnosis, and management (2nd ed.). Missouri: Elsevier Mosby. Chapter 2: Neurologic bases of motor speech and its pathologies, 17-67.

Duffy, J.R. (2005). Motor speech disorders: Substrates, differential diagnosis, and

management (2nd ed.). Missouri: Elsevier Mosby. Chapter 5: Spastic Dysarthria, 143-162.

Dysarthria. (2013). American speech-language-hearing association (ASHA). (Retrieved September 5, 2013 from http://www.asha.org/public/speech/disorders/dysarthria/

Fox, C. M., Ramig, L. O., Ciucci, M. R., Sapir, S., McFarland, D.H., & Farley, B.G. (2006). The science and practice of LSVT/LOUD: Neural plasticity-principled approach to treating individuals with Parkinson disease and other neurological disorders. *Seminars in Speech and Language,* 27, 283-99.

Goldman, R. & Fristoe, M. (2000). *Goldman-Fristoe Test of Articulation, 2nd Edition*. Minneapolis, MN, NCS Pearson.

Injury and prevention control: Traumatic brain injury. (2012). Center for Disease Control and Prevention (CDC). (retrieved 6-5-13 from http://www.cdc.gov/TraumaticBrainInjury/index.html).

Jodizio, K., Lojek, E., & Bryan, K. (2005). Functional and neuroanatomical analysis of extralinguistic disorders in right hemisphere-damaged patients. *Psychology of Language and Communication*, 9, 55-73.

Kertesz, A. (1982). *Western Aphasia Battery*. Psychological Corporation.

Kleim, J. A., & Jones, T. A. (2008). Principles of experience-dependent neural plasticity: Implications for rehabilitation after brain damage. *Journal of Speech, Language and Hearing Research*, 51(1), S225.

Lai, Q., & Shea, C. H. (1998). Generalized motor program (GMP) learning: Effects of

reduced frequency of knowledge of results and practice variability. *Journal of Motor Behavior*, 30(1), 51-59.

Ludlow, C.L., Hoit, J., Kent, R., Ramig, L.O., Shrivastav, R., Strand, E., Yorkston, K., & Sapienza, C.M. (2008). Translating principles of neural plasticity into research on speech motor control recovery and rehabilitation. *Journal of Speech, Language, and Hearing Research, 51,* S240-S258.

Maas, E., Robin, D. A., Austermann Hula, S. N., Freedman, S. E., Wulf, G., Ballard, K. J., & Schmidt, R. A. (2008). Principles of motor learning in treatment of motor speech disorders. *American Journal of Speech-Language Pathology*, 17(3), 277-298.

Mahler, L.A., & Jones, H.N. (2012). Intensive treatment of dysarthria in two adults with Down syndrome. *Developmental Neurorehabilitation, 15*: 44-53.

Mahler, L.A., & Ramig, L.O. (2012). Intensive treatment of dysarthria secondary to stroke. *Clinical Linguistics & Phonetics*, 26: 681-694.

Mahler, L. A., Ramig, L. O., & Fox, C. (2009). Intensive Voice Treatment (LSVT (R) LOUD) for dysarthria secondary to stroke. *Journal of Medical Speech-Language Pathology*, *17*(4), 165-182.

McNeil, M.R. (1997). Clinical management of sensorimotor speech disorders. Retrieved March 1, 2014 from http://books.google.com/books?id=BgCvQjO6Cg4C&dq=spastic+dysarthria&lr=&source=gbs_navlinks_s

National Library of Medicine. (NLM). (2013). Traumatic brain injury. (retrieved 6-5-

13 from http://www.nlm.nih.gov/medlineplus/traumaticbraininjury.html).

Menon, D.K., et al. (2010). Position statement: Definition of traumatic brain injury.

Archives of Physical Medicine and Rehabilitation, 9, 1637-1640.

National Institutes of Health. (NIH). (1999). Rehabilitation of persons with traumatic brain injury. *Journal of the American Medical Association, 282,*974-983.

Palmer, R., Enderby, P. (2007). Methods of speech therapy treatment for stable dysarthria: A review. *Advances in Speech-Language Pathology, 9,* 140-153.

Payton, K.L., Uchanski, R.M., & Braida, L.D. (1993). Intelligibility of conversational and clear speech in noise and reverberation for listeners with normal and impaired hearing. *The Journal of the Acoustical Society of America, 95,*1581-1592.

Picheny, M.A., Durlach, N.I., Braida, L.D. (1986). Speaking clearly for the hard of hearing II. *Journal of Speech, Language, and Hearing Research, 29,* 434-446.

Ramig, L., Countryman, S., Thompson, L., & Horii, Y. (1995). Comparison of two forms of intensive speech treatment for Parkinson's Disease. *Journal of Speech and Hearing Research*, 38, 1232-1251.

Ramig, L., Sapir, S., Countryman, S., Pawlas, A.A., O'Brien, C., Hoehn, M., Thompson, L.L. (2001). Intensive voice treatment (LSVT ®) for patients with Parkinson's disease: A two year follow-up. *Journal of Neurology, Neurosurgery, and Psychiatry, 73,* 493-498.

Roy, N., Leeper, H.A., Blomgren, M. (2001). A description of phonetic, acoustic, and

physiological changes associated with improved intelligibility in a speaker with spastic dysarthria. *American Journal of Speech-Language Pathology, 10,* 274-290.

Salmoni, A.W., Schmidt, R.A., Walter, C. B. (1984). Knowledge of results and motor learning: A review and critical reappraisal. *Psychological Bulletin, 95,* 335-386.

Sapir, S., Spielman, J.L., Ramig, L.O., Story, B.H., Fox, C. (2007). Effects of intensive voice treatment (the Lee Silverman Voice Treatment [LSVT]) on vowel articulation in dysarthric individuals with Idiopathic Parkinson Disease: Acoustic and perceptual findings. Journal of Speech, Language, and Hearing Research, 50, 899-912.

Schmidt, R.A., & Lee, T. (2005). Motor control and learning. (5th ed) Retrieved November 2, 2013 from http://books.google.com/books?hl=en&lr=&id=vBP091HCz38C&oi=fnd&pg=PA393&dq=Schmidt+%26+Lee,+2005&ots=rvzvJ0YzXz&sig=krUwyYZ3FRLaFnxQrQ_njznS1iM#v=onepage&q=Schmidt%20%26%20Lee%2C%202005&f=false

Sellars, C., Hughes, T., & Langhorne, P. (2002). Speech and language therapy for dysarthria due to nonprogressive brain damage: A systematic Cochrane review. *Clinical Rehabilitation*, 16, 61-68.

Tamplin, J. (2008). A pilot study into the effect of vocal exercises and singing on dysarthric speech. *NeuroRehabiliton*, 23, 207-216.

Tjaden, K., & Wilding, G.E. (2004). Rate and loudness manipulations in dysarthria:

Acoustic and perceptual findings. *Journal of Speech, Language, and Hearing Research, 47*, 766-783.

Traumatic brain injury. (2012). Mayo Clinic. (retrieved 6-5-13 from http://www.mayoclinic.com/health/traumatic-brain-injury/DS00552/DSECTION=symptoms).

Ungerleider, L.G., Doyon, J., Karni, A. (2002). Imaging brain plasticity during motor skill learning. *Neurobiology of Learning and Memory, 78,* 553-564.

Verdolini, K., & Lee, T.D. (2004). Motor learning principles of intervention. *For Clinicians by Clinicians: Vocal Rehabilitation in Medical Speech-Language Pathology,* 403-446.

Wenke, R.J., Theodoros, D., & Cornwell, P. (2008). The short-and long-term effectiveness of the LSVT® LOUD for dysarthria following TBI and stroke. *Brain Injury*, 22, 339-352.

Winstein, C. J., & Schmidt, R. A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16* (4), 677-691.

Wulf, G., Shea, C. H., & Matschiner, S. (1998). Frequent feedback enhances complex motor skill learning. *Journal of Motor Behavior*, *30* (2), 180-192.

Yorkston, K.M. (1996). Treatment efficacy: Dysarthria. *Journal of Speech, Language, and Hearing Research, 39, S46-S57.*

Yorkston, K.M., Hammen, V.L., Beukelman, D.R., Traynor, C.D. (1990). The effect of rate control on the intelligibility and naturalness of dysarthric speech. *Journal of Speech and Hearing Disorders, 55,* 550-560.