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The Feasibility of Script Based Audio-Visual Speech Entrainment

for the Treatment of Nonfluent Aphasia

by

Jeanna Ritter

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the Department of Communication Sciences & Disorders

Idaho State University

Summer 2018

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Jeanna Ritter find it satisfactory and recommend that it be accepted.

_____

Victoria Scharp, Ph.D., CCC-SLP
Major Advisor

_____

Diane Ogiela, Ph.D., CCC-SLP
Committee Member

_____

Curt Anderson, Ph.D.
Graduate Faculty Representative

Human Subjects Committee Approval

September 8, 2017

Jeanna Ritter
Comm Sci Disorders/Deaf Educ
MS 8116

RE: regarding study number IRB-FY208-19: The Feasibility of Script Based Audio-Visual Speech Entrainment for the Treatment of Nonfluent Aphasia

Dear Ms. Ritter:

I have reviewed your request for expedited approval of the new study listed above. This is to confirm that I have approved your application.

Notify the HSC of any adverse events. Serous, unexpected adverse events must be reported in writing within 10 business days.

You may conduct your study as described in your application effective immediately. The study is subject to renewal on or before Sep 8, 2018, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; email humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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The Feasibility of Script Based Audio-Visual Stimulation for the Treatment of Nonfluent Aphasia

Thesis Abstract - Idaho State University (2018)

Individuals with aphasia often suffer from long-term disability which requires extensive rehabilitation (Des Roches, Mitko, & Kiran, 2017). Adults with aphasia tend to engage in fewer social interactions, have a higher rate of depression, and have a lower probability of returning to work (Flamand-Roze et al., 2011). Nonfluent aphasia is characterized by short, effortful, agrammatic productions (Brookshire, 2007). Evidence indicates that a residual visuo-motor network can be activated with audio-visual stimulation and that activation can facilitate fluent speech production (Fridriksson et al., 2009; Venezia et al., 2016). Fridriksson et al. (2012) refer to this phenomenon as *speech entrainment.* This study was conducted to determine the feasibility of implementing speech entrainment principles to treat individuals with nonfluent aphasia in a rural university clinic setting.

Keywords: nonfluent aphasia, audio-visual stimulation, script therapy

Chapter I: Overview

Stroke

Stroke is the fifth most commonly occurring disease in the United States (Mozaffarian et al., 2016). It is caused by a disruption of blood flow to the brain, which results in cell death due to the deprivation of oxygen and nutrients. The cause of the disruption determines whether a stroke is classified as ischemic or hemorrhagic. Hemorrhagic strokes are less common and are caused from a rupture of a vessel within or on the surface of the brain (Brookshire & McNeil, 2015). Ischemic strokes are far more common accounting for 87% of all strokes (American Stroke Association, n.d). Ischemic strokes occur when a clot disrupts blood flow to the brain (Brookshire & McNeil, 2015). Although stroke remains among the top five leading causes of death, between 2003 and 2013 the mortality rate declined by 33.7%. The decline is due in part to medical advancements such as tissue plasmisogen activator (tPA; Mozaffarian et al., 2016; Johnston et al., 2014). However, although medical advancements have decreased the mortality rate, many individuals are disabled after a stroke. Between 50% and 70% of stroke survivors regain functional independence, while 15% to 30% of stroke survivors are left permanently disabled (Carod-Artal & Egido, 2009). One of the most common disabilities of stroke survivors is aphasia.

Aphasia

Aphasia affects 25% to 40% of stoke survivors (National Aphasia Association, 2011). It is an acquired language disorder that occurs from damage to the regions of the brain that are responsible for the production and comprehension of language

(Helm-Estabrooks, Albert, & Nicholas, 2014). Aphasia can be subdivided into fluent and nonfluent classifications depending on the aspects of language that are most affected (Helm-Estabrooks et al., 2014). Although aphasia does not affect intelligence, some individuals do experience cognitive decline as a result of the neurological damage that caused the disorder. Many individuals with aphasia experience difficulty with reading and writing (National Aphasia Association, 2011). Individuals with aphasia tend to engage in fewer social interactions, have a higher rate of depression, and a have a lower probability of returning to work (Flamand-Roze et al., 2011). They often suffer from long-term disability which requires extensive rehabilitation (Des Roches, Mitko, & Kiran, 2017).

Stroke Recovery

After a stroke, spontaneous recovery may occur in the first days or weeks as a result of swelling reduction, improved circulation, and preservation of partially damaged neurons (Katz, 2010; Palmer et al., 2015). Clinicians devote their attention and effort to maximizing speech and language improvement during this acute phase (Katz, 2010). The extent and duration of spontaneous recovery cannot be predicted, but changes typically continue for three to twelve months post-stroke (Basso, 1992; Brookshire & McNeil, 2015; Holland & Fridriksson, 2001). Recovery slows after the acute stage of spontaneous recovery. However, the injured brain can potentially re-learn skills during the chronic stage as the result of neuroplasticity (Palmer et al., 2015). Neuroplasticity is the ability of undamaged nerve axons to grow new nerve endings and connect to undamaged nerve cells (Palmer et al., 2015; Bruno-Petrina, 2014). The process is slow, so more time and money are required to achieve significant improvements (Katz, 2010). The majority of

therapeutic intervention occurs during the acute stage of recovery. Unfortunately, reduced resources (i.e. time, money, and transportation) limit the availability of intervention during the chronic stage of recovery (Cherney, Halper, Holland, & Cole, 2008; Palmer et al., 2015; Bruno-Petrina, 2014) and the most feasible and efficacious therapy approach is difficult to predict.

Chapter II: Background

Neuroanatomy of Language

Early assumptions of the neurological organization of language proposed a modulated organization of the regions of the brain that are responsible for the perception and production of speech (Anderson et al, 1999; Brookshire & McNeil, 2015; Hickok & Poeppel, 2007). Based on this traditional view, language was a left hemispheric function and was made up of Broca's area (BA 44/45), the arcuate fasciculus, and Wernicke's area (BA 22). Broca's area, located next to the primary motor cortex in the posterior inferior frontal lobe, was believed to control the muscles that are used for speech production. Wernicke's area, on the other hand, is located near the primary auditory cortex on the surface of the temporal lobe in the Sylvian fissure. It was believed to be responsible for perceptual aspects of speech including storage and retrieval of words, word meanings, and grammatical and linguistic rules (Anderson et al, 1999; Brookshire & McNeil, 2015). Wernicke's area is connected to Broca's area by the arcuate fasciculus (Anderson et al., 1999; Brookshire & McNeil, 2015). The arcuate fasciculus is a bundle of nerve fibers that connect the auditory association area of the temporal lobe to the frontal motor association cortex. The arcuate fasciculus was believed to be the primary route for the linguistic

messages that were formulated in Wernicke's area extending to Broca's area where they would be produced (Anderson et al., 1999; Brookshire & McNeil, 2015; Hickok & Poeppel, 2007).

While this traditional view does provide general information regarding the neural regions associated with the production and perception of speech, it is incomplete in light of recent discoveries as the result of technological advances. Although the traditional view of modulated language regions is not without merit, research that utilizes neuroimaging techniques indicates that language is not organized entirely in a modulated manner. Rather, language is a much more complex process (Basilakos et al., 2014). Healthy individuals have a series of neural networks that are responsible for both the production and comprehension of speech (Ardila, Bernal, & Rosselli, 2017; Basilakos et al., 2014; Hickok & Poeppel, 2007). These neural networks include: the reticular activating system, cerebellum, basal ganglia, limbic system, regions of the right hemisphere, and the left lateral frontal, pre-Rolandic, suprasylvian region (Brookshire & McNeil, 2015; Helm-Estabrooks et al., 2014).

Nonfluent Aphasia

Based on the neural connectivity across the language networks, speech and language deficits are generally not tied to a singular neural region. Therefore, nonfluent aphasia occurs as the result of a lesion in the neural networks responsible for the production of speech. This region, traditionally known as Broca's area, is located in the lower part of the premotor cortex. It is adjacent to the primary motor cortex which controls the muscles required for speech (Brookshire & McNeil, 2015). Although many

systems are involved, focal lesions in or near this area, typically result in the clinical characteristics consistent with a nonfluent aphasia (Helm-Estabrooks et al., 2014).

Individuals with nonfluent aphasia are unable to consistently translate a language code into speech production (Fridkrisson et al., 2012). This is due, in part, to anomia. Anomia is a greater-than-normal problem with word-retrieval and is the core symptom of nonfluent aphasia. The severity of anomia can range from mild difficulties to the complete inability to produce language. An aphasia diagnosis generally begins with the documentation of anomia that cannot be attributed to a thought disorder, memory problem, or motor speech disorder (Dignam et al., 2007). While individual clinical characteristics vary, nonfluent aphasia typically results in reduced phrase lengths, impaired grammatical forms, impaired speech prosody, and impaired articulatory agility (Helm-Estabrooks et al., 2014). Individuals speak in short phrases of one to three words, multisyllabic words may be produced syllable by syllable, and pauses and misarticulations are common (Brookshire & McNeil, 2015). Production is described as telegraphic or agrammatic because it consists primarily of content words (i.e. nouns, verbs, adjectives, and adverbs) while function words (i.e. conjunctions, articles, and prepositions) are produced infrequently (Brookshire & McNeil, 2015; Speer & Wilshire, 2013). Written materials of individuals with nonfluent aphasia typically reflect their poor language production abilities. On the other hand, auditory and written comprehension is considered a relative strength of individuals with nonfluent aphasia because the regions of the brain that are responsible for perception and comprehension usually remain relatively unaffected (Albert et al., 1981; Brookshire & McNeil, 2015; Helm-Estabrooks et al., 2014).

Neuroanatomy of nonfluent aphasia. One approach to minimizing the effects of nonfluent aphasia includes capitalizing on the residual neural networks that are not affected by the lesion (Basilakos et al., 2014). One such network is the visuo-motor pathway. This pathway plays a key role in speech production and develops in infancy as the result of audio-visual stimulus integration. According to Venezia et al. (2016), visual speech perception refers to the time-varying and pictorial cues of a speaker's head, face, and mouth during articulation. During development, exposure to these forms of visual speech stimulation during the simultaneous acquisition of speech production establishes a neural network that links visually perceived articulatory gestures to the speech motor system (Venezia et al., 2016). As a result, speech sounds are recognized through the motor representations of how the sounds are physically produced (Moulin-Frier & Arbib, 2013). Therefore, the regions of the brain that are responsible for the production of speech are also linked to the visual perception of speech. This visuo-motor network continues to function into adulthood (Venezia et al., 2016).

The role of the visuo-motor network is supported by studies that utilized neuroimagining techniques to examine neural activation (Fridriksson et al., 2012; Pulvermuller, 2006; Skipper et al, 2007; Venezia et al, 2016). Visual perception of labial and lingual articulators activates the regions of the motor cortex that are specialized for speech production (Pulvermuller, 2006). Furthermore, cortical motor regions are activated in response to visual speech stimulation but are not activated in response to auditory stimulation (Skipper, Wassenhove, Nusbaum, & Small, 2007). Finally, activation of motor regions associated with speech production occurs in response to multimodal audio-visual stimulation to a greater degree than to auditory and visual

stimulation in isolation (Skipper et al., 2007). This evidence suggests that, for individuals with nonfluent aphasia, the residual visuo-motor network associated with speech perception and production could be activated through multimodal, audio-visual speech stimulation (Venezia et al., 2016).

Speech Entrainment

Fridriksson et al. (2012) refer to the fluent production of speech due to the support of audio-visual stimulation as *speech entrainment.* Speech entrainment incorporates auditory stimulation through digitally recorded speech and visual stimulation in the form of a moving human mouth. The principles of speech entrainment were initially examined by targeting either the auditory or visual modality in isolation. Visual-only speech entrainment yields virtually no accurate speech production, even in healthy individuals (Fridriksson et al., 2012). Similarly, audio-only speech entrainment results in poorer speech production in comparison to audio-visual speech entrainment (Fridriksson et al., 2012). Critically, when both the auditory and visual modalities were combined in a picture naming task, individuals with nonfluent aphasia demonstrated a statistically significant improvement by correctly producing 11.32 (standard deviation, *SD*=9.76) words compared to 9.0 (*SD*=7.0) words during audio-only stimulation (Fridriksson et al., 2009). Similar results were demonstrated via post hoc analysis of Fridriksson et al.'s (2012) study of the effects of speech entrainment using scripts as the stimulus material. During multi-modal audio-visual speech entrainment, individuals with nonfluent aphasia were able to produce 66% of the target script in comparison to only 41% of the target script during audio-only stimulation. Although there is limited data to support the use of

audio-visual speech entrainment to improve fluency and speech production, the preliminary results are promising.

Audio-visual speech entrainment studies are beginning to emerge and have encouraging results. In the Aphasia Lab at the University of South Carolina, several individuals with nonfluent aphasia have been able to mimic a speaker in real time despite their severely impaired ability to produce fluent speech (Fridriksson et al., 2012). The results of the emerging evidence include gains in the speech production and fluency of individuals with nonfluent aphasia with both trained and untrained stimuli as well as during spontaneous speech production (Fridriksson et al., 2009; Fridriksson et al., 2012). In addition, post treatment carry over effects have been demonstrated using audio-visual speech entrainment (Fridriksson et al., 2012). For example, at one-week post-treatment, Fridriksson et al. (2012) noted a significant increase in the number of different words produced during a spontaneous speech condition. Additionally, Fridriksson et al. (2012) also reported a significant improvement at one and six weeks post treatment in the ability to produce an untrained script with the support of audio-visual speech entrainment. Finally, a significant increase in the number of words produced during a spontaneous speech task was noted at one week post treatment (Fridriksson et al., 2012). These results collectively show that, not only does audio-visual speech entrainment improve the production and fluency during direct stimulation, but it can also improve the production of spontaneous speech. These improvements indicate that speech entrainment could be tapping into spared neural connections necessary for fluent speech production (Fridriksson et al., 2012).

Neuroanatomy of speech entrainment. Increased cortical activation of the motor-speech region is associated with auditory and visual speech stimulation (Skipper et al., 2007). Interestingly, this increase is primarily triggered by visual stimulation of observing the movements of a human mouth (Skipper et al., 2007). This increased activation indicates that visual stimulation provides crucial sensory information that is required for fluent speech production (Venezia et al., 2016). According to Fridriksson et al. (2012) the visual component of audio-visual speech entrainment is believed to stimulate a gating mechanism that is responsible for binding the temporal, lexical, and visceral functions (e.g. respiration) of speech. Although this gating mechanism cannot be tied to a single anatomical structure, Fridriksson et al. (2012) suggest that it combines temporal gating (Broca's area) with lexical processing (BA 37) and on-line modification of visceral functions (anterior insula/BA 47) (Fridriksson et al., 2012). These regions are part of a ventral network that includes the middle temporal gyrus, superior temporal gyrus, and dorsal region of Broca's area. While the arcuate fasciculus is often damaged in individuals with nonfluent aphasia, these regions are below the typical site of lesion and therefore are often spared (Fridriksson et al., 2012).

Script Therapy

Script therapy is the process of understanding, remembering, and recalling the temporal organization of events (Cherney et al., 2008). It is based on the theory of automatization (Logan, 1988) which suggests that complete, context-bound, practice facilitates the mastery of a skill (Cherney et al., 2008). Based on the theory of automatization, a skill is more easily learned as a whole rather than being broken down

into individual components (Cherney et al., 2008; Youmans, Youmans, & Hancock, 2011). This complete, context bound rehearsal improves the amount and speed of word retrieval (Logan, 1988). Individuals with nonfluent aphasia benefit from script therapy because the processes of understanding, remembering, and recalling temporal organization remain relatively intact (Cherney et al., 2008).

A feature of script therapy is the ability to create scripts that are personal to the individual. Personalization improves participant motivation by increasing the recognition and meaningfulness of the target material (McKlevey et al., 2010). Additionally, scripts that are personalized can accommodate an individual's pre-stroke speaking style or specific communication intent (Harper et al., 2010). Personalized scripts are best developed in a collaborative process with the person with aphasia. Most individuals with aphasia choose to talk about their life experiences with an emphasis on their communication impairments, reconnecting with family, personal testimonies, and communication to support everyday interactions (Holland, Halper, & Cherney, 2010). While personalized script development has its merits, it can be a timely and costly. Instead, Kaye & Cherney (2016) propose the use of semi-personalized scripts which are developed to accommodate likely social encounters and can be individualized by inserting participant specific information. In doing so, the target material becomes more meaningful to the person with aphasia and treatment time is not dominated by creating a novel script (Kaye & Cherney, 2016).

Script Therapy and Speech Entrainment Comparison

Script therapy and audio-visual speech entrainment both capitalize on multimodal stimulation but they differ in form and delivery of this multimodal stimulation. Script

therapy utilizes graphemic cues as visual stimulation in combination with auditory stimulation which is provided by the clinician. Multimodal stimulation in script therapy is achieved when the individual listens to and reads in tandem with the clinician before independently producing the script. In contrast, a recording of a model of a human mouth serves as the visual stimulation of speech-entrainment. Multimodal stimulation is achieved by watching, listening to, and speaking in tandem with the human model as it produces the target message. This visual articulatory model is believed to activate the residual visuo-motor network which, in turn, facilitates fluency and speech production (Fridriksson et al., 2012; Venezia et al., 2016). Speech entrainment depends on the use of a digital device to record and present the visual articulatory model (Fridriksson et al., 2009; Fridriksson et al., 2012). In contrast, script therapy does not require supplemental materials beyond the graphemic representation of the script. However, digital devices have been used successfully to perform script therapy and an increasing amount of research is being dedicated to studying the effects of technology for this therapeutic approach (Cherney et al., 2008; Cherney et al., 2010; Cherney et al., 2015; De Luca et al., 2014).

Technology in Speech-Language Therapy

The use of technology offers unique benefits which can be combined with clinician delivered treatment during therapy. Digital devices, such as iPads, personal computers, smart phones, and tablets can be used to employ therapeutic programs. The specific stimulus material varies just as it would in clinician-only therapy. Depending on what the device can support, stimulus material can range from pictures, words, and audio recordings to a digitally simulated clinician. Digitally delivered therapy can be divided

into two groups: computer-assisted treatment and computer-only treatment (Katz, 2010). Computer-only treatment (COT) allows an individual to practice at any time and for any duration without the supervision of a trained clinician, the restrictions of the clinical environment, or access to transportation (Fridriksson et al., 2012; Katz, 2010). Additionally, it has relatively few costs beyond the purchase of the device and initial instructional training (Cherney, 2010; Katz, 2010). COT interventions have already proved to be successful. For example, digitally delivered Oral Reading for Language in Aphasia (ORLA) has been shown to be as efficacious as the same therapy delivered by a clinician to individuals with chronic nonfluent aphasia (Cherney, 2010). Similarly, improvements have been reported for digitally delivered script therapy in the areas of content, grammatical productivity, and rate of speech (Cherney et al., 2008). Finally, through the use of COT, individuals with chronic nonfluent aphasia have demonstrated improved language functions, communication ability, and mood (De Luca et al., 2014).

Although COT offers unique benefits to the therapeutic process, it falls short of the immediate feedback, modifications, and instruction that a clinician is able to provide. An alternative to COT is computer-assisted treatment. During computer-assisted treatment, the digital device is used as a supportive tool by the clinician who retains the traditional responsibilities of designing, administering, monitoring, and modifying the intervention (Katz, 2010). The use of technology in nonfluent aphasia therapy is especially of interest considering the time and costs associated with therapy delivered beyond the acute stage of recovery.

Therapy Dosing Schedule

Speech-language treatment can be both costly and time consuming, so determining the most efficacious dosing schedule is of strong interest in the research community (Helm-Estabrooks et al., 2014). At this time, the optimal treatment intensity is unknown because patient success is highly dependent on individual characteristics and environmental variables. Furthermore, although artificial classifications have been created based on meta-analyses and reviews, a standard definition of intensity does not exist (Cherney, 2012). Despite the absence of a clear definition of intensity, treatment is generally divided into intensive and non-intensive therapy schedules. Some short-term intensive aphasia programs offer participants approximately three to six hours of treatment per day for at least five days a week for a period of four to six weeks (Helm-Estabrooks et al., 2014; Winans-Mitrik et al., 2014; Rodriguez et al., 2013). While intensive aphasia treatment programs have been shown to be beneficial, based on Robey's (1998) meta-analysis of aphasia treatment studies, treatment can still be effective in as little as two, one-hour sessions per week.

Several aphasia intervention studies using a non-intensive treatment schedule have resulted in positive outcomes. Youmans et al.'s (2011) study of script training to treat individuals with apraxia of speech produced positive outcomes with a treatment schedule of two or three, 60-minutes sessions per week with at least 30-minutes of that time being dedicated to concentrated script practice. Youmans et al. (2005) also saw positive outcomes for script therapy and automaticity using a treatment schedule of three 30-45 minutes sessions per week. Additionally, Cherney's (2010) study of clinician-directed and computer delivered ORLA resulted in positive outcomes using a treatment schedule of two to three one-hour sessions per week. Finally, Goldberg, Haley, and Jacks

(2012) used a treatment schedule of three, 30-minute sessions a week to successfully implement clinician-directed and videoconferencing script therapy. These outcomes indicate that speech-language therapy can be successful using a non-intensive treatment schedule.

Script Based Audio Visual Speech Entrainment

Stroke survivors who are diagnosed with aphasia often require long-term rehabilitation. The greatest amount of rehabilitative success is seen during the acute stage of recovery and recovery trajectories often slow and virtually plateau after one year (Basso, 1992). Due to the amount of time and resources that are necessary to see improvement during the chronic stage, few therapeutic options exist (Basso, 1992; Cherney et al., 2008; Katz, 2010). With the advancements of neuroimaging techniques, a greater understanding of the neural circuitry of language has emerged (Helm-Estabrooks et al., 2014; Brookshire & McNeil, 2015). The visuo-motor network connects the neural regions associated with the production and perception of speech (Venezia et al., 2016). Audio-visual stimulation capitalizes on this residual network and facilitates fluency and speech production in individuals with nonfluent aphasia (Venezia et al., 2016). One therapy approach that taps into this residual network is audio-visual speech entrainment (Fridriksson et al., 2009; Fridriksson et al., 2012; Venezia et al., 2016). Speech entrainment delivers auditory and visual stimulation by way of a human verbal and articulatory model. Individuals watch, listen to, and attempt to mimic a human mouth in real time as it produces the target material. Although this approach is relatively new, it has already rendered positive outcomes (Fridriksson et al., 2009; Fridriksson et al., 2012).

Although audio-visual speech entrainment is relatively new, script therapy is well researched and has been successfully implemented (i.e. Cherney et al., 2008). Like speech entrainment, script therapy provides audio-visual stimulation. However, the visual stimulation associated with script therapy is presented as a graphemic representation of the target material. Despite this difference, individuals with nonfluent aphasia benefit from script therapy because the networks that support comprehension and automatization are typically not severely impacted (Cherney et al., 2008; Logan, 1988). These residual networks are capitalized on by using audio-visual speech stimulation to present the scripted material (Fridriksson et al., 2012). Perhaps the most encouraging outcome of script based audio-visual speech entrainment is the improvements on both untrained scripts and during spontaneous speech production (Fridriksson et al., 2012). To date, little research exists to support the use of script based audio-visual speech entrainment stimulation to improve the fluency and speech production of individuals with nonfluent aphasia.

The aim of this study is to examine the feasibility of using script based audio-visual speech entrainment to improve the speech production and fluency in individuals with nonfluent aphasia. It is hypothesized that audio-visual stimulation can be used to train semi-personalized scripts to improve the speech production and fluency of individuals with nonfluent aphasia in a rural university clinic setting. Feasibility is based on the convenience and practicality of implementing the therapy approach throughout the treatment period. The null hypothesis is that it is not feasible to implement script-based audio-visual speech entrainment in a rural university clinic to treat individuals with nonfluent aphasia.

Chapter III: Methodology

Experimental Design and Procedures

This feasibility study was conducted to examine the outcomes of audio-visual speech entrainment therapy. The institutional review board at Idaho State University approved the study protocol (see Appendix A). A single-subject experimental design was used in which the participants served as their own control. The treatment scripts were counterbalanced to control for order effects (Christensen, 2004). Trained graduate-level student clinicians administered the assessment materials, experimental treatment, and comprehensive speech-language therapy under the supervision of a certified and licensed speech-language pathologist (SLP). Sessions were recorded either with an electronic digital recorder or with the Video Audio Learning Tool (Intelligent Video Solutions, 2018). The recordings were stored electronically in password protected systems that were only accessible to the student clinicians, clinical supervisors, and lab personnel. The sessions took place in the clinical rooms at Idaho State University, Speech-Language and Hearing Clinic (ISU-SLHC) in Pocatello, Idaho and in the Idaho State University, Speech-Language Clinic (ISU-SLC) in Meridian, Idaho. The participants were seen by the same graduate-level student clinician throughout the protocol.

Participants. Four participants were recruited from the ISU-SLHC and the ISU-SLC and provided informed consent for inclusion in the study (see Appendix B). Inclusionary criteria required that participants be right hand dominant, native English speakers, who were at least six months post left hemispheric cerebrovascular accident (CVA) as verified by medical records and neuroimaging reports. They were diagnosed

with nonfluent aphasia based on their performance on the Comprehensive Aphasia Test (CAT; Swinburn, Porter, & Howard, 2016).

Experimental schedule. See Table 1 for experimental schedule and task completion details. The study consisted of three main phases: pre-treatment, treatment phase, and a no treatment phase during which no experimental treatment or speech-language therapy was administered. Performance probes were administered after treatment phase one and after the no treatment phase. The university clinic setting implements a non-intensive intervention schedule which is consistent with traditional outpatient therapy (Cherney, 2010; Goldberg et al., 2012; Youmans et al., 2005; Youmans et al., 2011). Participants received two individual 50-minute therapy sessions in addition to two 50-minute group therapy sessions per week. Thirty minutes of each individual therapy session was dedicated to the treatment protocol. The remaining 20 minutes of each session were used to implement evidence-based aphasia therapy that was chosen by the student clinician based on participant's individual needs.

Pre-treatment. The pre-treatment phase required three to five 50-minute sessions. Descriptive and diagnostic assessments were administered, the three original scripts were created, and baseline and control data were gathered. Baseline script production performance revealed the need for longer, more complex scripts for three of the four participants. New scripts were created and baseline script production performance with the support of audio-visual stimulation was established. Descriptive assessments included a pure-tone hearing screening, a visual acuity screening, and an orofacial examination. The Disability Questionnaire of the Comprehensive Aphasia Test (CAT) was used to qualitatively measure the impact of aphasia on daily life. The Apraxia Battery for Adults-

Second Edition (ABA-2) was administered to diagnose the presence and severity of apraxia (Dabul, 2002). The Comprehensive Aphasia Test (CAT; Swinburn et al., 2004) was administered as the primary diagnostic assessment to classify the presence and severity of nonfluent aphasia. Baseline performance of spontaneous speech was gathered based on the participant's performance on the Picture Description subtest of the CAT. Finally, the Visual Form Discrimination test was administered to serve as a control measurement to gauge the effects of treatment (VFD; Benton, Hamsher, Varney, Spreen, 1994). Detailed information regarding the descriptive and diagnostic assessments, baseline, and control measures can be found in the designated heading in subsequent sections of this document.

***Treatment phase*.** The treatment phase began after stable baseline performance was established. Stable baseline was defined as script production that was equal to or less accurate than the previous attempt(s) across two sessions (Christensen, 2004). Refer to the Scripts section for information regarding script scoring procedures. During the treatment phase, two scripts were targeted using audio-visual speech stimulation. A phonemic treatment cueing hierarchy was used to train incorrectly produced words as outlined below (Linebaugh, Shisler, & Lehner, 2005; Youmans, Holland, Munoz, & Bourgeois, 2005). At the end of treatment phase, regardless of the level of script mastery, post-treatment data was gathered for the trained scripts and the untrained script was re-administered to measure generalization. The Picture Description subtest of the CAT was re-administered to measure spontaneous speech production and the Disability Questionnaire of the CAT was re-administered to gather qualitative data regarding the impact aphasia.

***Maintenance*.** Following the treatment phase, the ISU-SLHC and ISU-SLC were closed for Thanksgiving break and services were suspended. That week served as the no-treatment phase.

Follow-up. After the one-week maintenance phase, the two treatment scripts and the untrained script were re-administered to measure retention. The CAT Picture Description subtest (Swinburn et al., 2004) was re-administered to measure spontaneous speech production, and the VFD (Benton et al., 1994) control measure was re-administered.

Table 1

Experimental Schedule According to Phase

Phase	Task
Pre-treatment: Diagnostic and descriptive assessment and baseline measures	**Day 1:** Hearing Screening: Descriptive assessment Visual Screening[a]: Descriptive assessment Orofacial Examination: Descriptive assessment Visual Form Discrimination[b]: Control baseline Picture Description (CAT)[c]: Spontaneous speech baseline Develop Scripts 1, 2, and 3
	Day 2: Visual Form Discrimination: Control baseline Picture Description (CAT): Spontaneous speech baseline Scripts 1, 2, 3: Baseline Comprehensive Aphasia Tests (CAT): Diagnostic measure

	Day 3: Scripts 1, 2, 3: Baseline Comprehensive Aphasia Test: Diagnostic Measure Apraxia Battery for Adults-Second Edition[d]: Descriptive assessment Disability Questionnaire (CAT): Qualitative information
Treatment Phase: Target treatment scripts	Scripts 1 and 2 (Trained): Audio-visual speech entrainment and a phonemic treatment cueing hierarchy
Post Treatment Phase: Performance probes	Scripts 1 and 2 (Trained): Treatment data Script 3 (Untrained): Generalization to an untrained script Picture Description (CAT): Spontaneous speech production Disability Questionnaire (CAT): Qualitative information
Maintenance: Clinic closed due to Thanksgiving break	No therapy was provided
Follow-up: Performance probes and outcome measures	Scripts 1 and 2 (Trained): Retention Script 3 (Untrained): Generalization retention Picture Description (CAT): Spontaneous speech production Visual Form Discrimination: Control

[a]Refer to Figure 1
[b]Benton, A.L., Sivan, A.B., Hamsher, K.S., Varney, N.R., Spreen, O. (1994). *Contributions to Neuropsychological Assessment.* New York: Oxford University Press. Visual Form Discrimination. 65-72
[c]Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.
[d]Dabul, B. (2002). Apraxia battery for adults (2nd ed.). Austin, TX: PRO-ED.

Assessment

See Appendix C for detailed information regarding the instructions and procedures of the assessment material. Diagnostic and descriptive procedures were administered during the pre-treatment period.

Diagnostic procedures. The Comprehensive Aphasia Test (CAT; Swinburn et al., 2016) was used to diagnose the participants with nonfluent aphasia. The CAT

provided an analysis of the cognitive and linguistic processing deficits for each participant. It included 34 subtests that are grouped into a Cognitive Screen, Disability Questionnaire, and a Language Battery that was further divided into expressive and receptive language abilities (Howard, Swinburn, & Porter, 2010; Swinburn et al, 2016). The participants' performance was evaluated according to scoring manual protocols. Clinical characteristics of nonfluent aphasia typically include relatively good auditory comprehension and poor speech production abilities. Therefore, the participants were expected to perform better on receptive language tasks that include visual and auditory comprehension. In contrast, they were expected to perform relatively poorly on tasks that required expressive language abilities such as naming objects and actions, and spoken picture description.

Raw scores were converted into T-scores which were based on the performance of a large sample of people with aphasia (N=266. Converting the raw scores into T-scores enabled the direct comparison of scores across subtests. The scores had a normal distribution with a mean of 50 and standard deviation of 10. A T-score of 50 represented the 50th percentile while a score of 60 was one standard above the mean and represents the 84th percentile. A score of 70 was two standard deviations above the mean and represented the 98th percentile. The same distribution occurred for scores falling below the mean. Cut-off scores represented the performance that 95% of typical individuals exceeded. Therefore, a classification of aphasia was represented by scores that fell below the cut-off scores. An overall severity rating of impairment was estimated by calculating the mean T-score across the eight modalities of the language battery. A modality mean of less than 68.2 was a very strong indication of aphasia (Swinburn, et al., 2016).

Descriptive measures. Due to the heterogeneity of individuals with nonfluent aphasia, descriptive assessments were administered to depict each participant with as much detail as possible. The participants were expected to pass the descriptive procedures to ensure that they were able to perform the experimental tasks. If they were unable to pass the procedures after two attempts across different sessions, they would be referred to the appropriate source (i.e. an audiologist) for further evaluation. Descriptive procedures included a pure-tone hearing screening, visual acuity screening, orofacial examination, the CAT Disability Questionnaire (Swinburn et al., 2016), and the Apraxia Battery for Adults-Second Edition (ABA-2; Dabul, 2000).

Hearing screening. Post CVA hearing ability was assessed by reviewing the participant's medical records and administering a pure-tone hearing screening. The screening was performed at 30 dB at 500, 1000, and 2000 Hz and was presented through over-the-ear earphones (Adult Hearing Screening, n.d.; Cherney et al., 2008; Cherney, 2010).

Visual screening. Refer to Figure 1 for the visual acuity screening tool. Post CVA visual acuity was assessed by reviewing the participant's medical records and administering a visual screening task. The participants were asked to match colored photographs depicting phoneme production (Ling, 1989). The pictures were a human model of the mouth in different visual phonemic postures which were representative of the experimental task. Visual acuity was considered sufficient for inclusions if the participant correctly matched at least 4 of 6 pictures.

Figure 1. **Visual Accuity Screening**

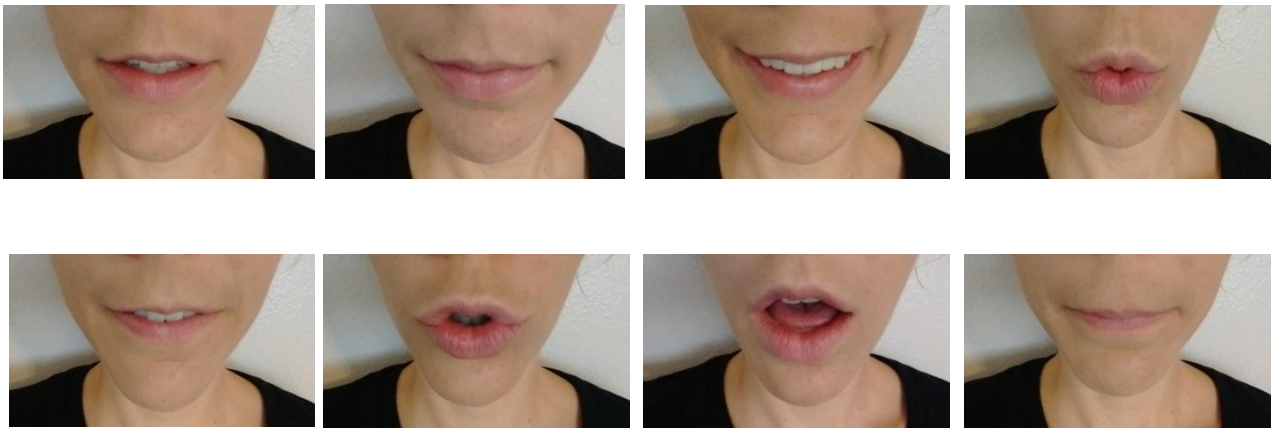

Figure 1. Stimuli for the visual acuity screening matching task.

***Orafacial examination*.** An orofacial examination was performed to identify any abnormalities or weakness in the oral mechanism that might affect a participant's ability to perform the experimental tasks (Hedge & Freede, 2017).

***Disability Questionnaire*.** The CAT Disability Questionnaire (Swinburn et al., 2016) provided quantitative information regarding disability and the emotional consequences associated with living with aphasia. It was not an in-depth assessment but rather highlighted the key features of the impacts of aphasia from the perspective of a person with aphasia. The questionnaire was subdivided into four separate but interrelated parts. The first part addressed how the participant viewed Daily Communication that required expression, comprehension, reading, and writing. Intrusion examined the participant's perception of difficulties in everyday life. Self-image evaluated how the participant's confidence, self-esteem, sense of isolation, and level of anxiety were affected by aphasia. Finally, Emotional Consequences examined the emotional effects that aphasia caused. The subtests were scored and divided into a disability score and an

impact score. As the Disability Questionnaire was a self-rating scale, there were no T-score conversions. Generally speaking, a higher score indicates a greater degree of impact. The greater the score the more the participant perceived that aspect of aphasia to negatively affect their life (Swinburn, Porter, & Howard, 2016).

***Apraxia screening*.** The Apraxia Battery for Adults-2nd Edition (ABA-2; Dabul, 2002) was administered to determine the presence and severity of apraxia. The ABA-2 included six subtests and rendered a severity rating of mild, moderate, or severe for each area that is assessed. The subtests examined: diadochokinetic rate, the ability to repeat words of increasing lengths, limb and oral apraxia, latency and utterance time for polysyllabic words, repeated trials, and an inventory of articulation characteristics of apraxia (Dabul, 2002).

Control measure. See Appendix C for detailed information regarding the instructions and procedures for administering the control measure. Control data was gathered during the pre-treatment phase and was re-administered post-treatment. The VFD (Benton et al., 1994; Blake et al., 2015) because aphasia generally does not impact the cognitive domain of visuo-spatial awareness. Additionally, script based audio-visual speech entrainment does not directly target spatial awareness. Therefore, if performance changes were observed in speech production and fluency, but not in visuo-spatial awareness, it would point to gains as the result of treatment.

The VFD was administered twice during pre-treatment to establish stability and again post-treatment to determine the effects of treatment. Change in the VFD was considered to have occurred if the post-treatment score exceeded the variability of the baseline scores (Blake et al., 2005).

Baseline measures. Baseline measures were administered during the pre-treatment phase and included the Picture Description subtest of the CAT (Swinburn et al, 2016) and the production of the three experimental scripts. The tasks were clearly explained and the script production measures were administered with no teaching, feedback, or support. Refer to Appendix C for detailed information regarding the instructions and procedures for baseline administration.

***Spontaneous speech production*.** The Picture Description subtest of the CAT (Swinburn et al, 2016) was administered as a baseline measurement of spontaneous speech production. The subtest was systematically scored per the instructions in the CAT manual and compared to the performance of a larger population of individuals with and without aphasia. Specifically, the number of appropriate and inappropriate information carrying words (ICWs), the level of syntactic variety, grammatical well-formedness, and speed were examined (Swinburn et al, 2016). Performance that rendered a T-score that was below, equal to, or one T-score above the previous performance score was considered stable (Christensen, 2004).

Script production. Baseline performance of the three personalized scripts was gathered to assess the potential effects of treatment and the degree of generalization and retention. Script production was measured as a percentage of correctly produced words. The percentage was established by dividing the number of words correctly produced by the total number of words per script and multiplying the quotient by 100 (Youmans et al., 2011). Refer to the Data Analysis section below for detailed information regarding the criteria for correct productions. Stability was defined as a performance percentage that

was worse than, equal to, or 5% better than the previous attempt across at least two sessions (Cherney et al., 2008; Youmans et al., 2011).

Script Development

See Appendix D for examples of the personalized scripts and the prompts that were used during script development. Semi-personalized scripts were developed for, and in collaboration with, each participant. The participant was invited to include a family member or friends in the script development process (Holland et al., 2010). The scripts were written in conversational English and included each participant's stoke story, an introduction of themselves, and a description of an outside interest or hobby (Holland et al., 2010). Scripts varied in length depending on the individual participant's production abilities.

The scripts were read aloud by the student clinician and recorded using an iPad so that the clinician's mouth was made visible in isolation from the rest of the face. The scripts were read at a slightly slower rate of speech of 100-130 syllables per minute (Rodero, 2012). Audio-visual speech entrainment stimulation was achieved by playing the recordings aloud and in view of the participant. The participant was instructed to listen to, watch, and attempt to speak in tandem with the recording (Fridriksson et al., 2009; Fridriksson et al., 2012).

Treatment Cueing Hierarchy

Although the script based audio-visual speech entrainment stimulation was delivered via an iPad, the student clinician provided instructional feedback, modifications, and cues in real time as therapy progressed (Fridriksson et al., 2012; Youmans et al., 2005). A treatment cuing hierarchy of phonemic cues ranging from

minimal to maximal support was used to train misarticulated words (Linebaugh et al., 2005; Youmans, et al., 2005).

First, the participant watched and listened to the recorded script as it played on the iPad. After the participant watched the script, it was replayed and the participant attempted to speak in tandem with the recording. When the participant misarticulated a word, the script was paused, and the word was trained using a phonemic cueing hierarchy. The phonemic cueing hierarchy was implemented as follows: silent articulation of the target word, presentation of the first sound of the target word, and presentation of the entire target word (Linebaugh et al., 2005; Youmans et al., 2005; Youmans et al., 2011). The participant was instructed to mimic the clinician as the target word was produced in the carrier phrase at each level of the cueing hierarchy.

Considering the principles of automaticity (Logan, 1988), the portion of the script that contained the misarticulated word was used as a carrier phrase. Massed practice of the target word promoted automatization while practicing the target word in a carrier phrase supported the coarticulation that was required for the production of fluent connected speech. The cues progressed from minimal to maximal support until the target word was correctly produced. Once the word was produced, the hierarchy was worked in reverse (De Riesthal, 2018).

Treatment continued after the participant successfully produced the target word, or upon completion of the cueing hierarchy. The participant was redirected to the iPad and attempted to produce the script including the target word in tandem with the recording. The phonemic cueing hierarchy was applied to the next word that was

misarticulated and the same word was not targeted multiple times regardless of production accuracy.

Script mastery was defined as 80% accuracy over three consecutive attempts (Blake et al., 2015). A calculation of the percentage of the scripts correctly produced was rendered by dividing the total number of correctly produced words by the total number of words in the script and multiplying the quotient by 100 (Youmans et al., 2011). If the participant achieved mastery before the end of the treatment phase, a new personalized script was created. If each word of the script was targeted in the cueing hierarchy before mastery was achieved, the treatment process began again from the beginning of the script.

Data Analysis

Data analysis of script production was based on Youmans et al. (2001) study of script therapy for the treatment of apraxia. Script production was analyzed before and after treatment and was compared to determine if there was a significant degree of change. Script based intervention was utilized to target speech fluency. Since pauses and self-corrections disrupt fluency, the participants' first production attempt was evaluated and extraneous productions were not considered in the scoring and treatment protocol.

Participant productions that approximated the target production well enough to convey the intended meaning were considered correct. To be considered an acceptable approximation, the production could contain no more than one sound production error (substitution, distortion, addition, or omission). If the error changed the meaning of the production, or was so distorted that it was judged unintelligible by the clinician, the production was considered incorrect. For example, if the target production "bake" was

pronounced as "pake" it would be considered acceptable because it contains only one sound production error and does not change the target meaning. However, if the target word "bake" was produced as "take" it will not be considered acceptable because it changes the target meaning of the word. Extraneous productions and productions that carry no content were not counted (Youmans et al., 2011). Additionally, if the production omitted a grammatical morpheme that was required to convey meaning, it was counted as incorrect. For example, if the target production "walking" was pronounced as "walk" it would be considered incorrect. Treatment outcomes were measured by comparing the total number of words produced correctly pre and post-treatment. Clinically relevant improvements are not defined in the literature. For the purposes of this study it was defined as a performance that was 10% or greater than the baseline attempt.

A portion of the treatment sessions was spent training incorrectly produced words (Linebaugh et al., 2005; Youmans et al., 2005) using a cueing hierarchy. Therefore, the scripts were not targeted in their entirety during each session. The percentage of the script that was targeted in each session was recorded in addition to the percentage of the script that was correctly produced.

Spontaneous speech production. The participants' spontaneous speech production was analyzed by comparing pre and post-treatment performance on the Picture Description of the CAT. Productions were scored according to the guidelines of the CAT scoring manual based on the number of appropriate and inappropriate information carrying words (ICWs), the level of syntactic variety, grammatical well-formedness, and speed (Swinburn, Porter, & Howard, 2016). Categorical and subtest scores were directly compared and an overall performance score was rendered. Per the

diagnostic manual, clinically relevant improvement included a post-treatment T-score that was eight or more increments greater than the pre-treatment T-score (Swinburn, Porter, & Howard, 2016).

Control measure. The VFD (Benton et al., 1994) was re-administered after completion of the treatment period. A significant degree of change was considered a performance score that fell one point above the pre-treatment performance range.

Chapter IV: Results

A total of four participants met the inclusion criteria and consented to participate in the study. The performance of each participant is detailed in the following sections.

Participant LH

LH was a 61-year-old male who was three years post-onset of a single left hemisphere stroke. He met inclusionary criteria for native language, handedness, and corrected to normal hearing and visual acuity. LH passed the pure-tone hearing screening, visual acuity screening, and his orofacial examination was unremarkable. His performance on the VFD (Benton, 1994) before treatment was 8/16 correct and after treatment was 6/16 correct.

LH's communication profile was consistent with moderate nonfluent aphasia shown in Table 2. LH achieved T-Score totals of 54 (cut-off=60) and 52 (cut-off=57-58) respectively on the Visual Comprehension and Auditory Comprehension subtests of the CAT (Swinburn et al., 2016) which indicated that his receptive language abilities were below normal. Although his receptive language abilities were below normal levels, they were comparatively better than his expressive language abilities which is consistent with

nonfluent aphasia. LH achieved T-Score totals of 52 (cut-off=67) on the Repetition subtests, 45 (cut-off=60) on the Naming subtest, 47 (cut-off=63), and 51 (cut-off=58) on the Writing subtest of the CAT (Swinburn et al., 2016). Finally, LH achieved a T-Score of 60 (cut-off=66) on the Written Picture Description subtests of the CAT (Swinburn et al., 2016). These scores were below normal limits and suggest a diagnosis of moderate nonfluent aphasia.

Table 2

Comprehensive Aphasia Test[a] *- Cognitive Screen, Expressive and Receptive Language Scores - Participant LH*

Test	Cognitive Screen Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Cognitive Total	29.5	38	---	---
Line Bisection	-1.5	+/- 6	48	41
Semantic Memory	5	10	38	51
Word Fluency	1	*Unlimited*	43	58
Recognition Memory	10	10	59	48
Gesture Object Use	12	12	68	55
Arithmetic	3	6	49	44
Test	Receptive Language Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Visual Comprehension Total	**48**	**62**	**54**	**60**
Comprehension of Written Words	28	30	55	59
Comprehension of Written Sentences	20	32	54	59
Auditory Comprehension Total	**50**	**66**	**52**	**57-58**
Comprehension of Spoken Words	25	30	51	53
Comprehension of Spoken Paragraphs	3	4	49	49

Comprehension of Spoken Sentences	22	32 (16)	54	61

Test	Expressive Language: Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Repetition Total	**56**	**50**	**52**	**60**
Repetition of Words	32	32	58	57
Repetition of Complex Words	4	6	52	62
Repetition of Nonwords	6	10	53	53
Repetition of Digit Strings	8	7	50	55
Repetition of Sentences	6	6	48	63
Naming Total *(objects+actions+fluency)*	**25**	**45**	**45**	**63**
Naming Objects	20	48	50	62
Naming Actions	5	10	52	63
Reading Total	**25**	**35**	**47**	**61**
Reading Words	17	48	46	62
Reading Complex Words	0	6	40	61
Reading Nonwords	2	10	49	58
Reading Function Words	6	6	62	49
Writing Total	**51**	**76**	**51**	**58**
Writing: Copying	18	27	46	52
Writing Picture Names	15	21	51	55
Writing to Dictation	18	28	53	59

	Written Picture Description: Total Raw Score	T-Score	T-Score Cut-Off
Appropriate ICW's	8	58	65
Inappropriate ICW's	0	57	34
Well-Formedness	3	58	62
Total	**12**	**60**	**66**

[a]Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.
[b] There is no upper limit to the raw score for the Written Picture Description subtest

LH's communication profile was consistent with moderate apraxia of speech shown in Table 3. LH demonstrated severe apraxia during the production of multisyllabic words, moderate apraxia during the production of words of increasing length, and mild apraxia during the production of repeated trials and alternating motion tasks.

Table 3

Apraxia Battery for Adults-Second Edition[a] *- Participant LH*

Subtest	Raw Score	Severity Rating
Diadochokinetic Rate	19	Mild
Increasing Word Length	3	Moderate
Limb Apraxia and Oral Apraxia	47	None
Latency Time and Utterance Time for Polysyllabic Words	100	Severe
Repeated Trials Test	26	Mild

[a] Dabul, B. (2002). *Apraxia battery for adults.* (2nd ed.). Austin, TX: PRO-ED.

The pre and post-treatment scores of the Disability Questionnaire of the CAT (Swinburn et al., 2016) can be found in Table 4. LH reported a combined Disability and Impact score of 50 before treatment and a total combined score of 48 after treatment which suggests essentially no change in the influence of aphasia on his life.

Table 4

Comprehensive Aphasia Test[a] *- Disability Questionnaire - Participant LH*

	Disability				
	Expression	Comprehension	Reading	Writing	Total
T-Score Pre-Treatment	58	49	57	52	54
T-Score Post-Treatment	51	47	54	54	51

	Impact			
	Intrusion	Self-Image	Emotional Consequences	Total
T-Score Pre-Treatment	51	44	52	48
T-Score Post-Treatment	49	42	51	47

	Disability Questionnaire Total		
	Disability	Impact	Total
T-Score Pre-Treatment	54	48	50
T-Score Post-Treatment	51	47	48

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

The pre and post-treatment scores of the Spoken Picture Description subtest of the CAT (Swinburn et al., 2016) can be found in Table 5. LH achieved a pre-treatment T-score of 53 and post-treatment T-score of 60 which suggests a diagnosis of nonfluent aphasia. A clinically significant margin of improvement of spontaneous speech production for the CAT Picture Description is a T-score change of eight points and the participant's score improved by seven points on this measure (Swinburn et al., 2016). After the one week maintenance period, LH spontaneous speech production remained at a T-score of 60. Based on the client's Picture Description scores, the skills did not generalize to this spontaneous speech measure.

Table 5

Comprehensive Aphasia Test[a] *- Spoken Picture Description - Participant LH*

	T-Score			T-Score Cut-Off
	Pre-Treatment	Post-Treatment	Maintenance	
Appropriate ICW's	53	53	53	56
Inappropriate ICW's	62	40	45	56
Syntactic Variety	46	53	58	58
Well-Formedness	49.5	48	48	56
Speed	45	45	48	56
Total	**53**	**60**	**60**	**61**

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

Pre-treatment baseline production of Script 1 (126 words) was 56% and was established after two sessions. For Session 3, 55% of the script was targeted during treatment achieving 92% accuracy for the portion of the script that was treated. A larger percentage of the script was targeted as the treatment sessions progressed with a slight drop at Session 6. During the sixth treatment session, LH produced Script 1 with 95% accuracy and 81% of the script was targeted. At the end of the treatment period, the script was played in its entirety and LH produced it with 79% accuracy. After the one-week maintenance period, LH produced Script 1 in its entirety with 86% accuracy (see Figure 2).

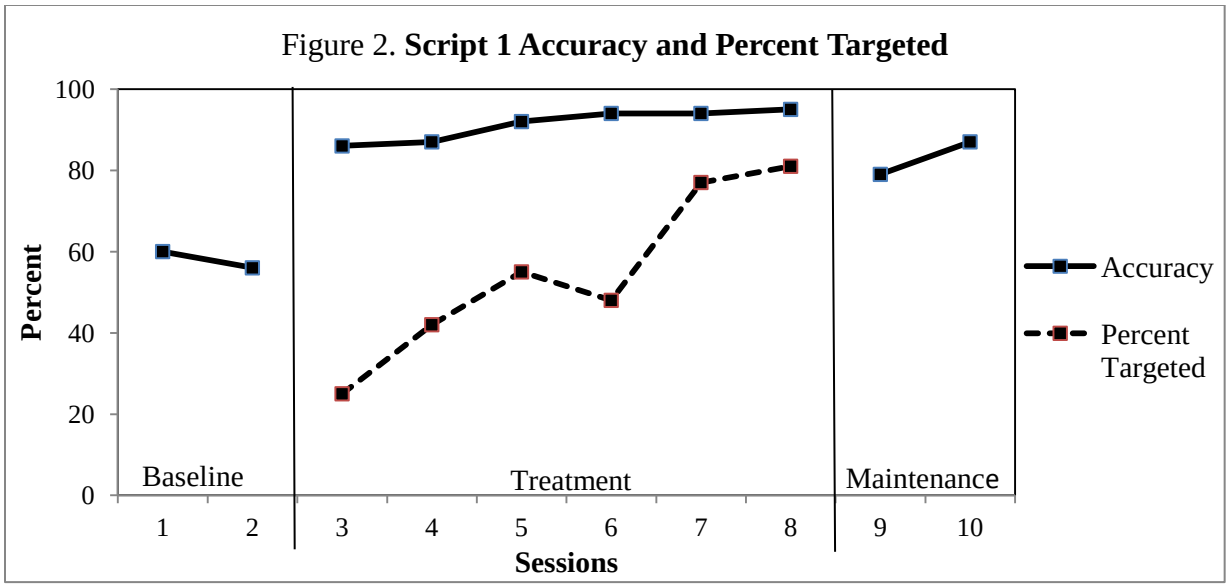

Figure 2. Script 1 Accuracy and Percent Targeted - Participant LH.

Pre-treatment baseline production of Script 2 (149 words) was 41% and was established after two sessions. For Session 1, 22% of the script was targeted during treatment achieving 75% accuracy for the portion of the script that was treated. A larger percentage of the script was targeted as the treatment sessions progressed. During the third treatment session, LH produced 43% of Script 2 with 91% accuracy. At the end of the treatment period, the script was played in its entirety and LH produced it with 73% accuracy. After the one-week maintenance period, LH produced Script 2 in its entirety with 81% accuracy (see Figure 3).

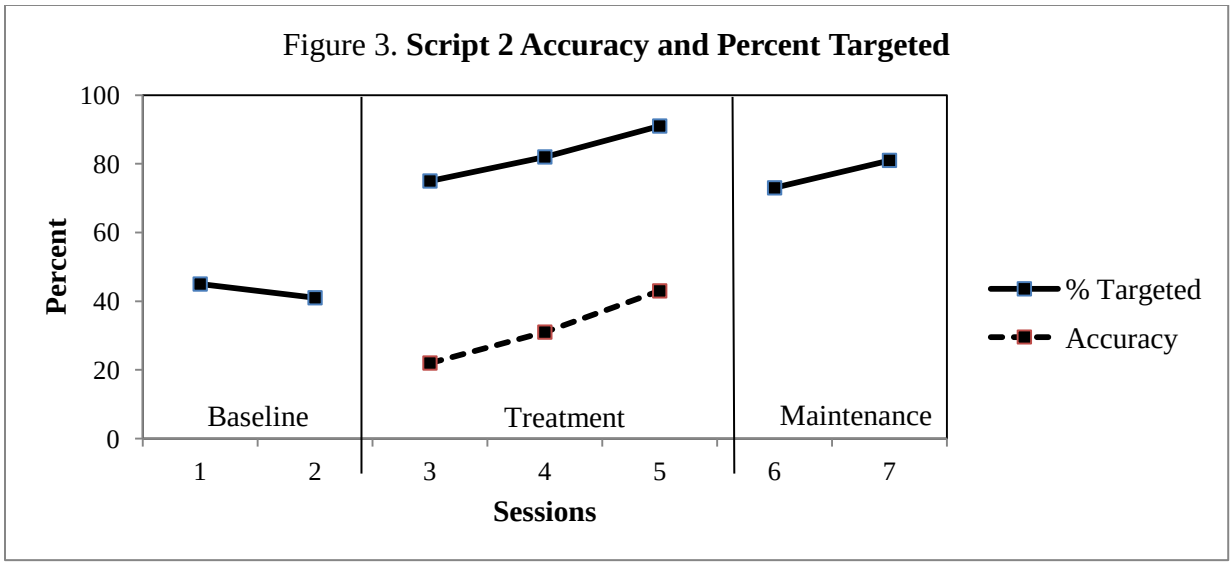

Figure 3. Script 2 Accuracy and Percent Targeted - Participant LH.

Pre-treatment baseline production of Script 3 (113) was 61% and was established after three sessions. Script 3 was not targeted during the treatment period because it served as the generalization script. After the treatment period, LH produced Script 3 in its entirety with 86% accuracy. After the maintenance period, LH produced Script 3 in its entirety with 88% accuracy (see Figure 4).

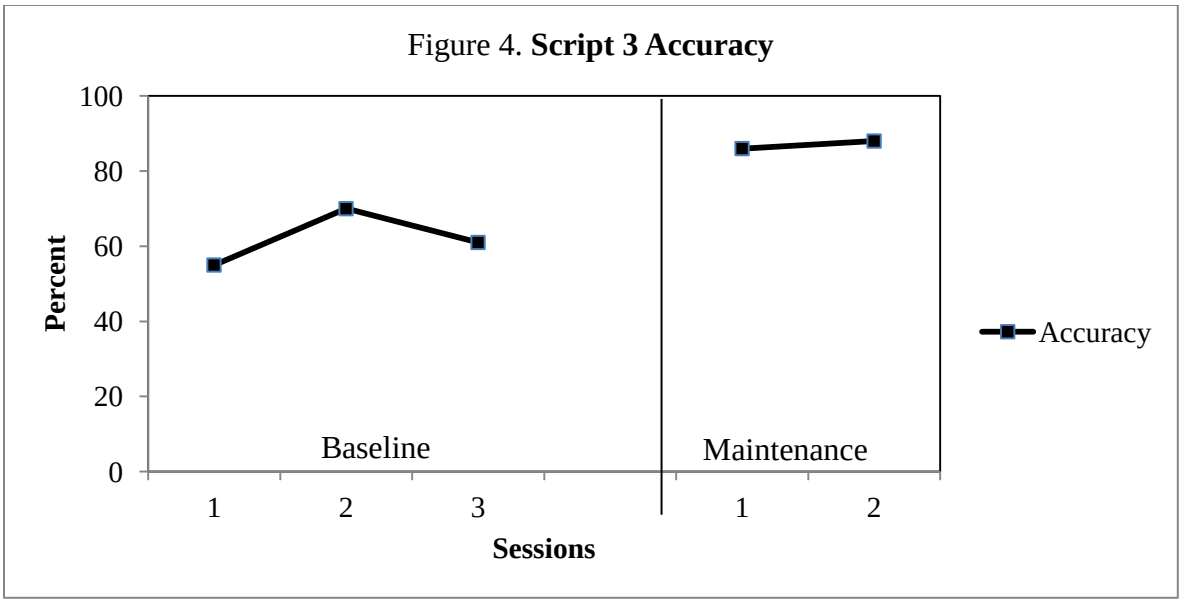

Figure 4. Script 3 Accuracy and Percent Targeted - Participant LH.

Participant MH

MH was a 59-year-old male who was two years post-onset of a single left hemisphere stroke. He met inclusionary criteria for native language, handedness, and corrected to normal hearing and visual acuity. MH passed a pure-tone hearing screening, visual acuity screening, and his orofacial examination was unremarkable.

MH's communication profile was consistent with moderate nonfluent aphasia shown on Table 6. MH achieved T-Score totals of (cut-off=60) and (cut-off=57-58) respectively on the Visual Comprehension and Auditory Comprehension subtests of the CAT (Swinburn et al., 2016) which indicated that his receptive language abilities were below normal. Although his receptive language abilities were below normal levels, they were comparatively better than his expressive language abilities, consistent with nonfluent aphasia. MH achieved T-Score totals of 45 (cut-off=60) on the Repetition subtests, 46 (cut-off=63) on the Naming subtest, (cut-off=63), and 41 (cut-off=58) on the

Writing subtest of the CAT (Swinburn et al., 2016). Finally, MH achieved a T-Score of 42 (cut-off=66) for the Written Picture Description subtest of the CAT (Swinburn et al., 2016). These scores were below normal limits and suggest a diagnosis of moderate-severe nonfluent aphasia.

Table 6

Comprehensive Aphasia Test[a] *- Cognitive Screen, Expressive and Receptive Language Scores - Participant MH*

Test	Cognitive Screen Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Cognitive Total	33	38	---	---
Line Bisection	3	+/- 6	39	41
Semantic Memory	10	10	60	51
Word Fluency	4	*Unlimited*	48	58
Recognition Memory	10	10	59	48
Gesture Object Use	11	12	60	55
Arithmetic	2	6	44	44
Test	Receptive Language Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Visual Comprehension Total	**13**	**62**	**37**	**60**
Comprehension of Written Words	13	30	40	59
Comprehension of Written Sentences	---	32	---	59
Auditory Comprehension Total	**29**	**66**	**41**	**57-58**
Comprehension of Spoken Words	17	30	41	53
Comprehension of Spoken Paragraphs	---	4	34	49
Comprehension of Spoken Sentences	12	32 (16)	44	61
Test	Expressive Language Total Raw	Total Possible Raw Score	T-Score	T-Score Cut-Off

	Score			
Repetition Total	**27**	**50**	**45**	**60**
Repetition of Words	17	32	46	57
Repetition of Complex Words	1	6	46	62
Repetition of Nonwords	5	10	51	53
Repetition of Digit Strings	4	7	43	55
Repetition of Sentences	0	6	39	63
Naming Total *(objects+actions+fluency)*	**13**	**45**	**46**	**63**
Naming Objects	12	48	46	62
Naming Actions	0	10	39	63
Reading Total	**2**	**35**	**42**	**61**
Reading Words	2	48	40	62
Reading Complex Words	0	6	40	61
Reading Nonwords	0	10	40	58
Reading Function Words	0	6	35	49
Writing Total	**9**	**76**	**41**	**58**
Writing: Copying	5	27	40	52
Writing Picture Names	3	21	45	55
Writing to Dictation	1	28	44	59

	Written Picture Description		
	Total Raw Score	T-Score	T-Score Cut-Off
Appropriate ICW's	0	42	65
Inappropriate ICW's	0	57	34
Well-Formedness	0	43	62
Total	**0**	**42**	**66**

[a]Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.
[b]There is no upper limit to the raw score for the Written Picture Description subtest

MH's communication profile was consistent with moderate-severe apraxia of speech shown in Table 7. MH demonstrated severe apraxia during the production of increasing word length and repeated trials, and moderate apraxia of alternating productions and multisyllabic words.

Table 7

Apraxia Battery for Adults-Second Edition[a] *- Participant MH*

Subtest	Raw Score	Severity Rating
Diadochokinetic Rate	3	Moderate
Increasing Word Length	16	Severe
Limb Apraxia and Oral Apraxia	78	Mild
Latency Time and Utterance Time for Polysyllabic Words	3	Moderate
Repeated Trials Test	---	Severe

[a] Dabul, B. (2002). *Apraxia battery for adults.* (2nd ed.). Austin, TX: PRO-ED.

The pre and post-treatment scores of the Disability Questionnaire of the CAT (Swinburn et al., 2016) can be found in Table 8. MH reported a combined Disability and Impact score of 59 before treatment and a total combined score of 61 after treatment suggesting virtually no change in the influence of aphasia on his life after participating in the treatment protocol.

Table 8

Comprehensive Aphasia Test[a] *- Disability Questionnaire - Participant MH*

	Disability				
	Expression	Comprehension	Reading	Writing	Total
T-Score Pre-Treatment	72	59	55	54	60
T-Score Post-Treatment	---	---	---	---	60

	Impact			
	Intrusion	Self-Image	Emotional Consequences	Total
T-Score Pre-Treatment	54	56	59	65
T-Score Post-Treatment	---	---	---	62

	Disability Questionnaire Total		
	Disability	Impact	Total
T-Score Pre-Treatment	60	65	59
T-Score Post-Treatment	60	62	61

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

The pre and post-treatment scores of the Spoken Picture Description subtest of the CAT (Swinburn et al., 2016) can be found in Table 9. MH achieved a pre-treatment T-score of 47 and post-treatment T-score of 46 which suggests a diagnosis of nonfluent aphasia. A clinically significant margin of improvement of spontaneous speech production for the CAT Picture Description (Swinburn et al., 2016) is a T-score change of eight points and the participant's score decreased by 1 point on this measure. After the one week maintenance period, MH achieved a T-score of 47 which was equal to his pre-treatment T-score. Based on the client's Picture Description scores, the skills did not generalize to spontaneous speech.

Table 9

Comprehensive Aphasia Test[a] *- Spoken Picture Description - Participant MH*

	T-Score			T-Score Cut-Off
	Pre-Treatment	Post-Treatment	Maintenance	
Appropriate ICW's	46	45	46	56
Inappropriate ICW's	56	56	54	56
Syntactic Variety	39	39	39	58
Well-Formedness	37	37	37	56

Speed	42	42	42	56
Total	**47**	**46**	**47**	**61**

[a]Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

Pre-treatment baseline production of Script 1 (163 words) was 57% and was established after two sessions. For Session 1, 8% of the script was targeted during treatment achieving 7% accuracy for the portion of the script that was treated. MH's accuracy quickly increased and by the third session, 100% of the script was targeted with 98% accuracy. Accuracy remained relatively stable during the following two sessions. At the end of the treatment period, the script was played in its entirety and MH produced it with 97% accuracy. After the one-week maintenance period, MH produced Script 1 in its entirety with 92% accuracy (see Figure 5).

Figure 5. **Script 1 Accuracy and Percent Targeted**

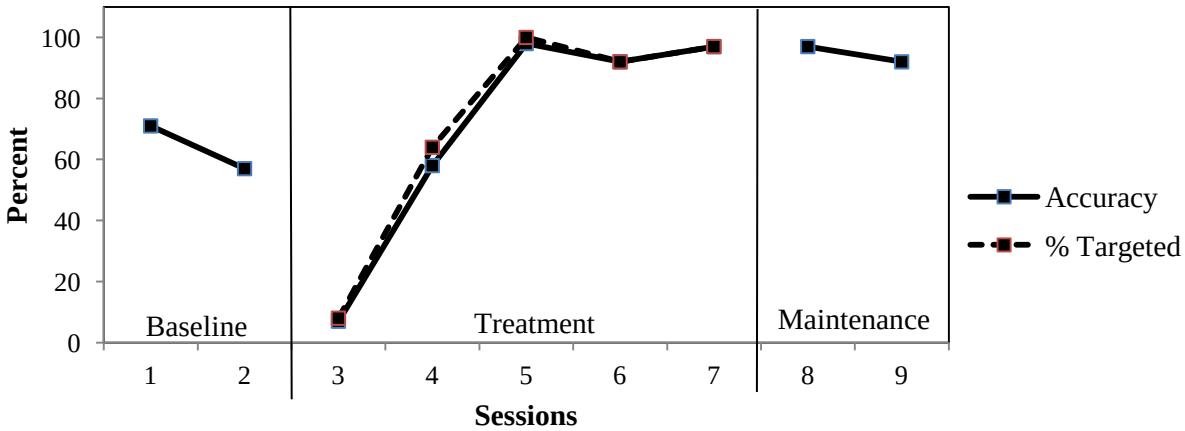

Figure 5. Script 1 Accuracy and Percent Targeted - Participant MH.

Pre-treatment baseline production of Script 2 (163 words) was 57% and was established after three sessions. For Session 1, 57% of the script was targeted during treatment achieving 56% accuracy for the portion of the script that was treated. MH's accuracy steadily improved and by the fourth session, 99% of the script was targeted with 99% accuracy. At the end of the treatment period, the script was played in its entirety and MH produced it with 94% accuracy. After the one-week maintenance period, MH produced Script 2 in its entirety with 96% accuracy (see Figure 6).

Figure 6. **Script 2 Accuracy and Percent Targeted**

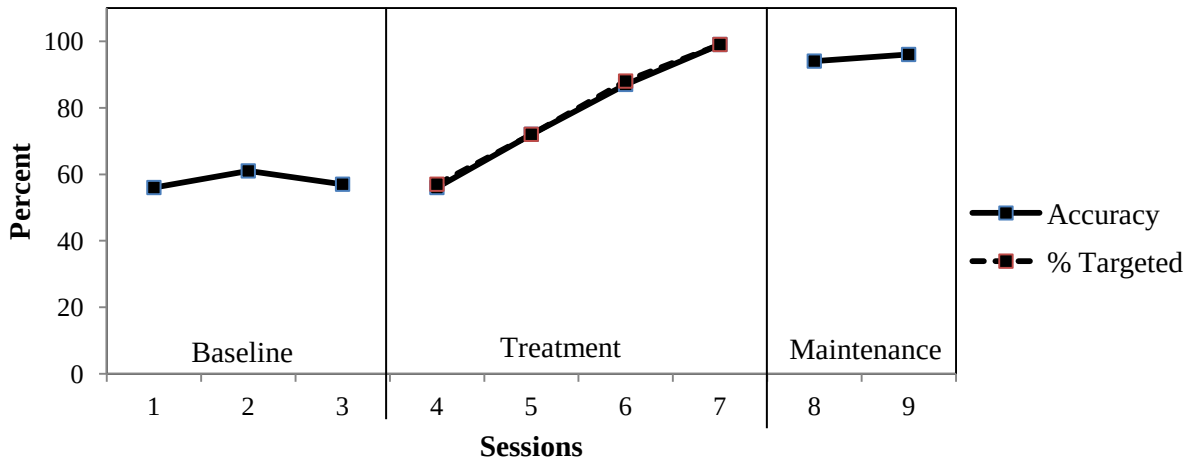

Figure 6. Script 2 Accuracy and Percent Targeted - Participant MH.

Pre-treatment baseline production of Script 3 (168 words) was 21% and was established after 2 sessions. Script 3 was inadvertently targeted twice during the treatment period and performance increased from 3% to 26% accuracy. After the treatment period, MH produced Script 3 in its entirety with 83% accuracy. After the one-

week maintenance period, MH produced Script 3 in its entirety with 63% accuracy (see Figure 7).

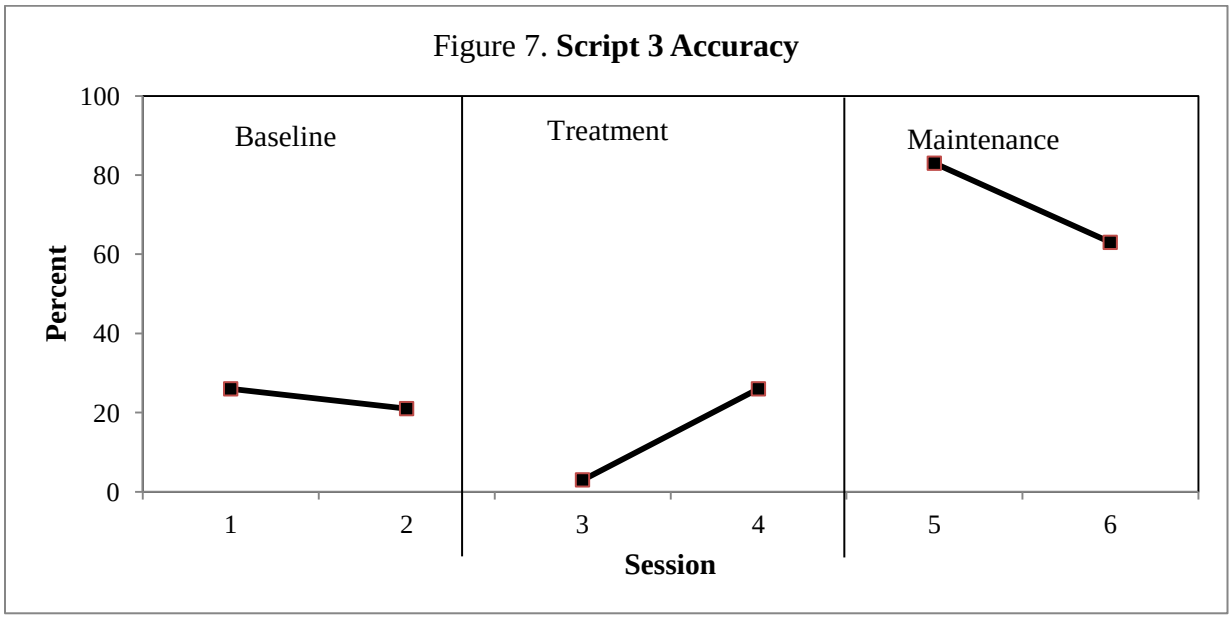

Figure 7. Script 3 Accuracy - Participant MH.

Participant NW

Participant NW was a 59-year-old male who was five years post-onset of a single left hemisphere stroke. He met inclusionary criteria for native language, handedness, and corrected to normal hearing and visual acuity. He passed a pure-tone hearing screening after two attempts, a visual acuity screening, and his orofacial examination was unremarkable. NW used a personal iPad for communication by typing single high frequency words and short phrases.

NW's communication profile was consistent with severe nonfluent aphasia shown on Table 10. NW achieved T-Score totals of 60 (cut-off=60) and 52 (cut-off=57-58) respectively on the Visual Comprehension and Auditory Comprehension subtests of the

CAT (Swinburn et al., 2016) which indicated that his receptive language abilities were slightly below normal. Although his receptive language abilities were below normal levels, they were comparatively better than his expressive language abilities which is consistent with nonfluent aphasia. NW achieved T-Score totals of 32 (cut-off=60) on the Repetition subtests, 35 (cut-off=63) on the Naming subtest, 38 (cut-off=61) on the Reading subtest, and 60 (cut-off=58) on the Writing subtest of the CAT (Swinburn et al., 2016). Finally, NW achieved T-Score of 62 (cut-off=66) on the Written Picture Description subtest of the CAT (Swinburn et al., 2016). These scores were well below normal limits and suggest a diagnosis of severe nonfluent aphasia.

Table 10

Comprehensive Aphasia Test[a] *- Cognitive Screen, Expressive and Receptive Language Scores - Participant NW*

Test	Cognitive Screen Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Cognitive Total	37	38	---	---
Line Bisection	1	+/- 6	53	41
Semantic Memory	10	10	60	51
Word Fluency	0	*Unlimited*	37	58
Recognition Memory	10	10	59	48
Gesture Object Use	11	12	60	55
Arithmetic	6	6	65	44
Test	Receptive Language Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Visual Comprehension Total	**54**	**62**	**60**	**60**
Comprehension of Written Words	30	30	65	55
Comprehension of Written Sentences	24	32	59	59

Auditory Comprehension Total	**52**	**66**	**52**	**57-58**
Comprehension of Spoken Words	28	30	58	53
Comprehension of Spoken Paragraphs	4	4	60	49
Comprehension of Spoken Sentences	20	32	52	61

Test	Expressive Language: Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Repetition Total	**0**	**50**	**32**	**60**
Repetition of Words	0	32	35	57
Repetition of Complex Words	0	6	35	62
Repetition of Nonwords	0	10	38	53
Repetition of Digit Strings	0	7	35	55
Repetition of Sentences	0	6	39	63
Naming Total *(objects+actions+fluency)*	**0**	**45**	**35**	**63**
Naming Objects	0	48	37	62
Naming Actions	0	10	39	63
Reading Total	**0**	**35**	**38**	**61**
Reading Words	0	48	38	62
Reading Complex Words	0	6	40	61
Reading Nonwords	0	10	40	58
Reading Function Words	0	6	35	49
Writing Total	**71**	**76**	**60**	**58**
Writing: Copying	27	27	61	52
Writing Picture Names	20	21	62	55
Writing to Dictation	24	28	57	59

	Written Picture Description: Total Raw Score	T-Score	T-Score Cut-Off
Appropriate ICW's	13	63	65
Inappropriate ICW's	0	57	34
Well-Formedness	2.5	57	62
Total	**15.5**	**62**	**66**

[a]Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.
[b]There is no upper limit to the raw score for the Written Picture Description subtest

NW's communication profile was consistent with severe apraxia of speech shown on Table 11. Due to this participant's strong preference for communicating via iPad, the

graduate student clinician was not able to elicit productions for the subtests of the ABA-2 (Dabul, 2002) that required verbal output.

Table 11

Apraxia Battery for Adults-Second Edition[a] *- Participant NW*

Subtest	Raw Score	Severity Rating
Diadochokinetic Rate	---	Severe
Increasing Word Length	---	Severe
Limb Apraxia and Oral Apraxia	50	None
Latency Time and Utterance Time for Polysyllabic Words	91	Severe
Repeated Trials Test	---	Severe

[a]Dabul, B. (2002). *Apraxia battery for adults.* (2nd ed.). Austin, TX: PRO-ED.

The pre and post-treatment scores of the Disability Questionnaire of the CAT (Swinburn et al., 2016) can be found in Table 12. NW reported a combined Disability and Impact score of 50 before treatment and a total combined score of 50 after treatment indicating no change in his perceived impact of aphasia following the study.

Table 12

Comprehensive Aphasia Test[a] *- Disability Questionnaire - Participant NW*

	Disability				
	Expression	Comprehension	Reading	Writing	Total
T-Score Pre-Treatment	53	49	42	54	50
T-Score Post-Treatment	55	52	57	62	58

	Impact			
	Intrusion	Self-Image	Emotional Consequences	Total
T-Score Pre-Treatment	65	48	51	52
T-Score Post-Treatment	51	42	47	46

	Disability Questionnaire Total		
	Disability	Impact	Total
T-Score Pre-Treatment	50	52	50
T-Score Post-Treatment	58	46	50

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

The pre and post-treatment scores of the Spoken Picture Description subtest of the CAT (Swinburn et al., 2016) can be found in Table 13. NW achieved a pre-treatment T-score of <39 and post-treatment T-score of <39 which suggests a diagnosis of severe nonfluent aphasia. A clinically significant margin of improvement of spontaneous speech production for the CAT Picture Description (Swinburn et al., 2016) is a T-score change of eight points and the participant's score improved by 7 points on this measure. After the one-week maintenance period, NW achieved a T-score of 46. Based on the client's Picture Description scores, the skills did not generalize to spontaneous speech.

Table 13

Comprehensive Aphasia Test[a] *- Spoken Picture Description - Participant NW*

	T-Score			T-Score Cut-Off
	Pre-Treatment	Post-Treatment	Maintenance	
Appropriate ICW's	43	43	44	56
Inappropriate ICW's	53	50	54	56
Syntactic Variety	39	39	39	58
Well-Formedness	37	37	37	56

Speed	42	42	42	56
Total	**<39**	**<39**	**46**	**61**

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

Pre-treatment baseline production of Script 1 (53 words) was 0% and was established after two sessions. NW's accuracy remained relatively stable during the first three sessions and then began to steadily improve. By Session 6, 34% of the script was targeted with 44% accuracy. At the end of treatment period, the script was played in its entirety and NW produced it with 8% accuracy. After the one-week maintenance period, NW produced Script 1 in its entirety with 4% accuracy (see Figure 8).

Figure 8. **Script 1 Accuracy and Percent Targeted**

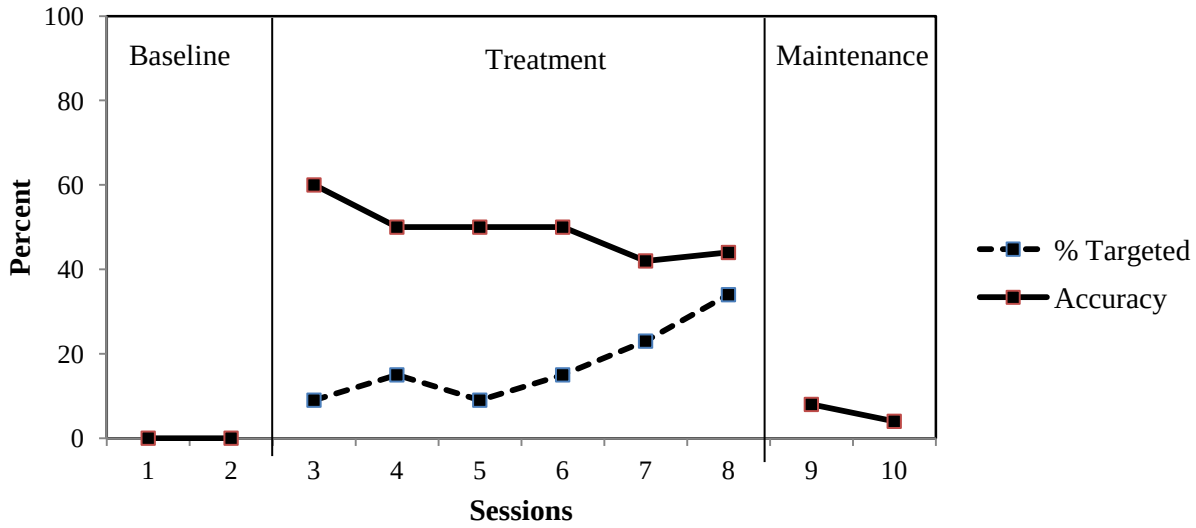

Figure 8. Script 1 Accuracy and Percent Targeted - Participant NW.

Pre-treatment baseline production of Script 2 (48 words) was 0% and was established after two sessions. Script 2 was targeted twice in treatment. By Session 2, 35% of the script was targeted with 53% accuracy. At the end of treatment period, the

script was played in its entirety and NW produced it with 17% accuracy. After the one-week maintenance period, NW produced Script 1 in its entirety with 19% accuracy (see Figure 9).

Figure 9. **Script 2 Accuracy and Percent Targeted**

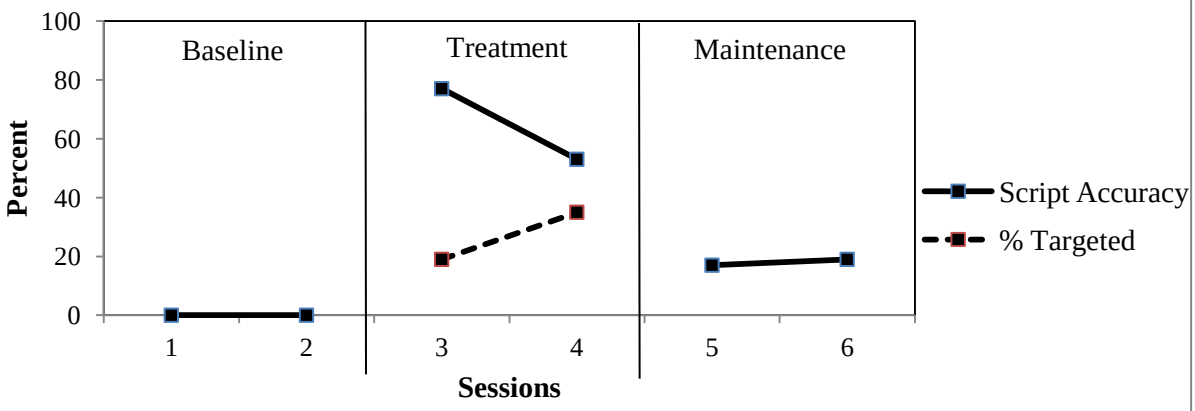

Figure 9. Script 2 Accuracy and Percent Targeted - Participant NW.

Pre-treatment baseline production of Script 3 (57 words) was 0% and was established after two sessions. After the treatment period, NW produced Script 3 in its entirety with 12% accuracy. After the maintenance period, NW produced Script 3 in its entirety with 12% accuracy (see Figure 10).

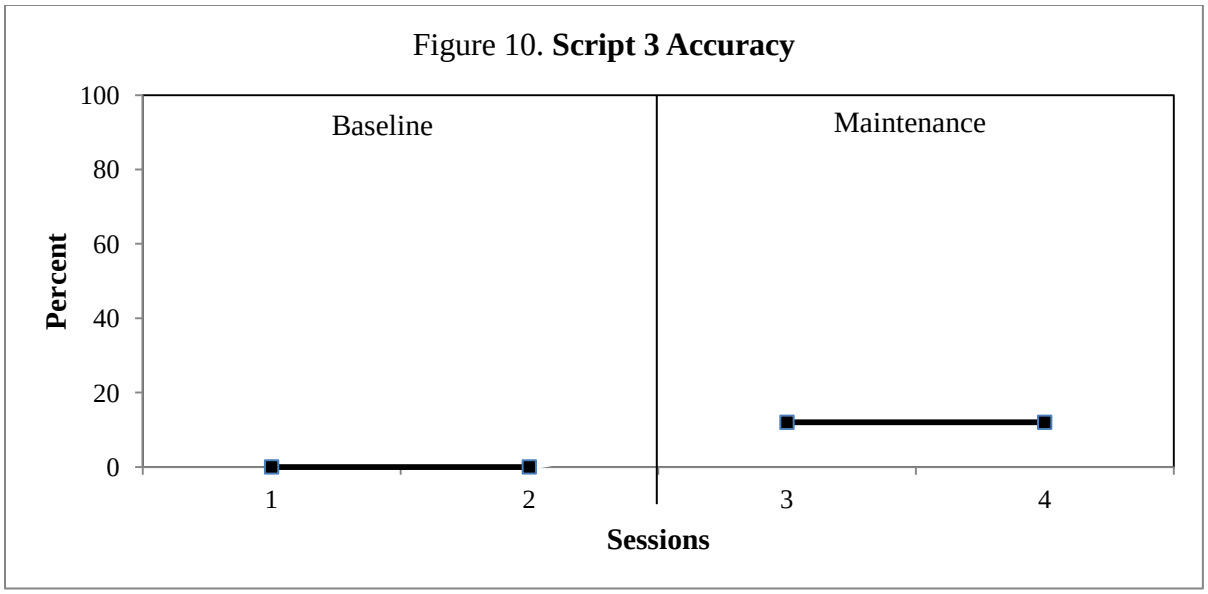

Figure 10. Script 3 Accuracy and Percent Targeted - Participant NW.

NW did not return to the clinic to complete the VFD (Benton et al., 1994). Despite not having a post-test control measurement, given his extremely limited pre-treatment verbal output and the small but steady speech production improvements observed throughout the treatment process, it is very likely that treatment positively impacted his performance. These gains appear noteworthy given that NW also had frequent absences throughout the treatment period. His overall attendance included a total of nine treatment sessions compared to an average of thirteen treatment sessions for the other three participants in the study.

Participant KB

KB was a 49-year-old female who was three years post-onset of a single left hemisphere stroke. She met inclusionary criteria for native language, handedness, and corrected to normal hearing and visual acuity. KB passed the pure-tone hearing

screening, visual acuity screening, and her orofacial examination revealed low tone and mild discoordination of the tongue, lips, and cheeks. KB participated in roughly fifteen weeks of script based audio-visual stimulation four months prior to the treatment period, therefore her outcomes were influenced via prior exposure to the treatment method.

KB's communication profile was consistent with mild to moderate nonfluent aphasia shown on Table 14. KB achieved T-Score totals of 48 (cut-off=60) and 46 (cut-off=57-58) respectively on the Visual Comprehension and Auditory Comprehension subtests of the CAT (Swinburn et al., 2016) which indicated that her receptive language abilities were below normal. Although her receptive language abilities were below normal levels, they were comparatively better than her expressive language abilities, consistent with nonfluent aphasia. KB achieved T-Score totals of 49 (cut-off=60) on the Repetition subtests, 50 (cut-off=63) on the Naming subtest, 50 (cut-off=63), and 48 (cut-off=58) on the Writing subtest of the CAT (Swinburn et al., 2016). Finally, KB achieved a T-Score of 57 (cut-off=66) on the Written Picture Description subtest of the CAT (Swinburn et al., 2016). These scores were below normal limits and suggest a diagnosis of mild to moderate nonfluent aphasia.

Table 14

Comprehensive Aphasia Test[a] *- Cognitive Screen, Expressive and Receptive Language Scores - Participant KB*

Test	Cognitive Screen			
	Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Cognitive Total	34	38	---	---
Line Bisection	-2	+/- 6	44	41

Semantic Memory	10	10	60	51
Word Fluency	5	*Unlimited*	49	58
Recognition Memory	9	10	48	48
Gesture Object Use	9	12	51	55
Arithmetic	3	6	49	44

Receptive Language

Test	Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Visual Comprehension Total	**37**	**62**	**48**	**60**
Comprehension of Written Words	26	30	51	59
Comprehension of Written Sentences	11	32	45	59
Auditory Comprehension Total	**41**	**66**	**46**	**57-58**
Comprehension of Spoken Words	28	30	58	53
Comprehension of Spoken Paragraphs	0	4	34	49
Comprehension of Spoken Sentences	13	32	45	61

Expressive Language

Test	Total Raw Score	Total Possible Raw Score	T-Score	T-Score Cut-Off
Repetition Total	**45**	**50**	**49**	**60**
Repetition of Words	30	32	57	57
Repetition of Complex Words	3	6	49	62
Repetition of Nonwords	6	10	53	53
Repetition of Digit Strings	6	7	46	55
Repetition of Sentences	0	6	39	63
Naming Total *(objects+actions+fluency)*	**32**	**45**	**50**	**63**
Naming Objects	27	48	51	62
Naming Actions	0	10	39	63
Reading Total	**10**	**35**	**45**	**61**
Reading Words	8	48	45	62
Reading Complex Words	0	6	40	61
Reading Nonwords	0	10	40	58
Reading Function Words	2	6	46	49
Writing Total	**39**	**76**	**48**	**58**
Writing: Copying	27	27	63	52
Writing Picture Names	8	21	47	55
Writing to Dictation	4	28	46	59

Written Picture Description

	Total Raw Score	T-Score	T-Score Cut-Off
Appropriate ICW's	13	63	65
Inappropriate ICW's	4	31	34
Well-Formedness	0	43	62
Total	**9**	**57**	**66**

[a]Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.
[b]There is no upper limit to the raw score for the Written Picture Description subtest

KB's communication profile was consistent with moderate apraxia of speech shown in Table 15. KB demonstrated severe apraxia during the production of multisyllabic words, moderate-severe apraxia during the production of words of increasing length, and mild apraxia during the production of repeated trials and alternating motion tasks.

Table 15

Apraxia Battery for Adults-Second Edition[a] *- Participant KB*

Subtest	Raw Score	Severity Rating
Diadochokinetic Rate	15	Mild
Increasing Word Length	19	Mod-Severe
Limb Apraxia and Oral Apraxia	12	Moderate
Latency Time and Utterance Time for Polysyllabic Words	31	Severe
Repeated Trials Test	27	Mild

[a] Dabul, B. (2002). *Apraxia battery for adults.* (2nd ed.). Austin, TX: PRO-ED.

The pre and post-treatment scores of the Disability Questionnaire of the CAT (Swinburn et al., 2016) can be found in Table 16. KB reported a combined Disability and Impact score of 51 before treatment and a total combined score of 55 after treatment indicating relatively no change on the influence of aphasia on her life as a result of the treatment.

Table 16

Comprehensive Aphasia Test[a] *- Disability Questionnaire*[a] *- Participant KB*

	Disability				
	Expression	Comprehension	Reading	Writing	Total
T-Score Pre-Treatment	51	34	55	54	50
T-Score Post-Treatment	53	42	59	45	54

	Impact			
	Intrusion	Self-Image	Emotional Consequences	Total
T-Score Pre-Treatment	54	48	58	53
T-Score Post-Treatment	53	55	56	55

	Disability Questionnaire Total		
	Disability	Impact	Total
T-Score Pre-Treatment	50	53	51
T-Score Post-Treatment	54	55	55

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

The pre and post-treatment scores of the Spoken Picture Description subtest of the CAT (Swinburn et al., 2016) can be found in Table 17. KB achieved a pre-treatment T-score of 50 and post-treatment T-score of 53 which suggests a diagnosis of nonfluent aphasia. A clinically significant margin of improvement of spontaneous speech production for the CAT Picture Description (Swinburn et al., 2016) is a T-score change

of eight points and the participant's score improved by 3 points on this measure. After the one-week maintenance period, KB's achieved a T-score of 49 which was one T-score below her pre-treatment performance. Based on the client's Picture Description scores, the skills did not generalize to spontaneous speech.

Table 17

Comprehensive Aphasia Test[a] *- Spoken Picture Description - Participant KB*

	T-Score			T-Score Cut-Off
	Pre-Treatment	Post-Treatment	Maintenance	
Appropriate ICW's	52	53	48	56
Inappropriate ICW's	62	56	56	56
Syntactic Variety	39	46	39	58
Well-Formedness	37	37	37	56
Speed	42	42	42	56
Total	**50**	**53**	**49**	**61**

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

Baseline measures of script production were inadvertently not established before the initiation of treatment. Script production accuracy for this participant was initially quite high, likely due to her prior exposure of the treatment method. During the first session, KB produced 47% of Script 1 (136 words) with 81% accuracy. Her production abilities gradually increased and by Session 7 when 100% of the script was targeted with greater than 90% accuracy. By the end of the treatment period, KB produced 100% of the

script with 95% accuracy. After the one-week maintenance period, KB produced Script 1 in its entirety with 95% accuracy (see Figure 11).

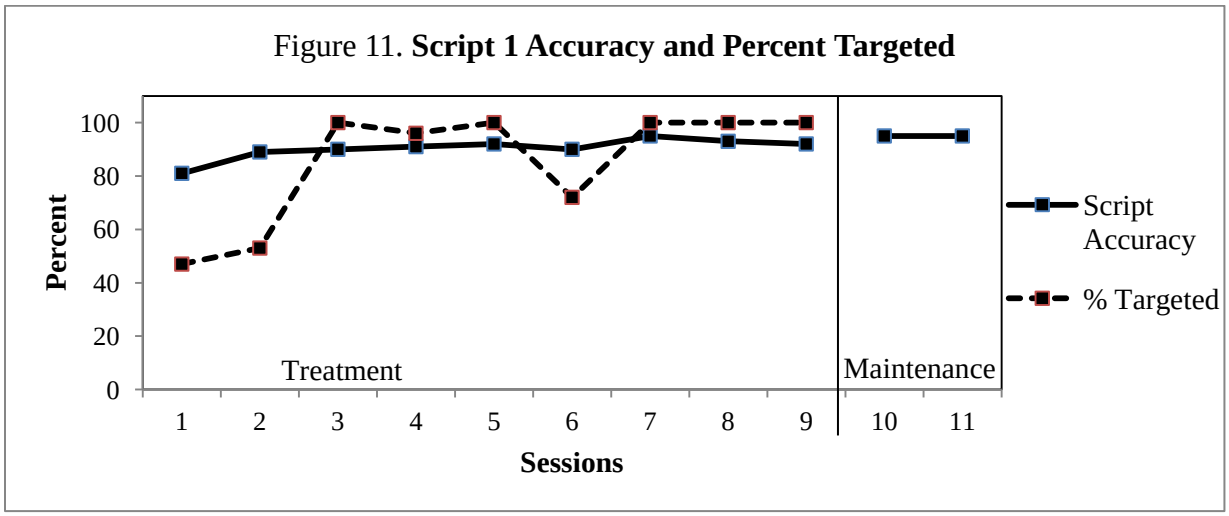

Figure 11. Script 1 Accuracy and Percent Targeted - Participant KB.

KB produced Script 2 (120 words) with 90% accuracy during the first treatment session. During the fourth treatment session, KB produced 100% of Script 2 with 95% accuracy. At the end of the treatment period, the script was played in its entirety, and KB produced it with 92% accuracy. After the one-week maintenance period, KB produced Script 2 in its entirety with 88% accuracy (see Figure 12).

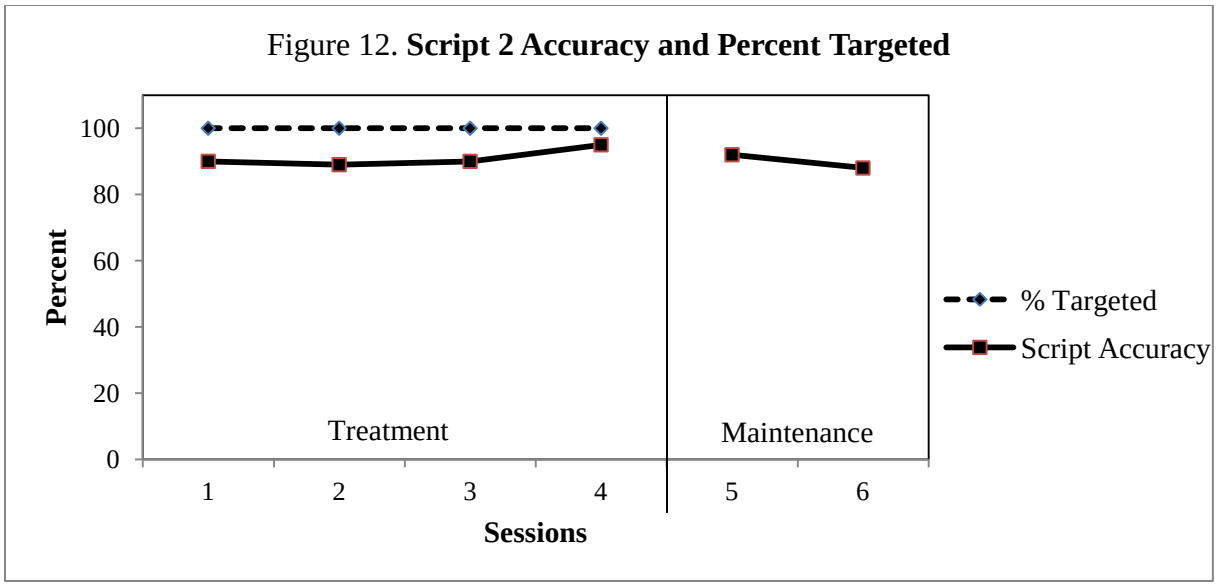

Figure 12. Script 2 Accuracy and Percent Targeted - Participant KB.

Script 3 was not targeted during treatment since it served as the generalization script. After the treatment period, KB produced Script 3 (144 words) in its entirety with 93% accuracy. After the one-week maintenance period, KB produced Script 3 in its entirety with 88% accuracy (see Figure 13).

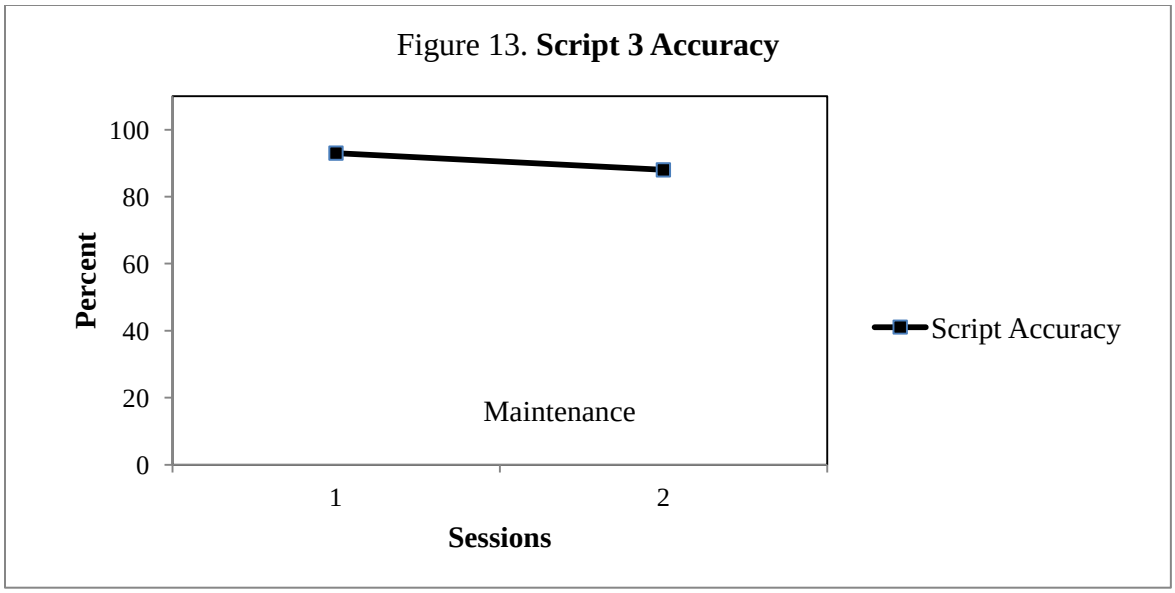

Figure 13. Script 3 Accuracy and Percent Targeted - Participant KB.

Results Summary

Four participants were diagnosed with non-fluent aphasia and apraxia of speech that ranged in severity from mild-moderate to severe. As expected, individual variations in the participants' pre-treatment abilities and post-treatment outcomes were observed. Participant KB and LH were able to repeat single words and nonwords at or slightly above the cut-off score that would indicate aphasic performance. Similarly, participant NW's visual comprehension and written expressive language abilities were above the range that would indicate aphasia although his spoken expressive language abilities were severely impaired. Finally, all of the participants demonstrated deficits in their ability to produce words of increasing lengths and pollysyllabic words.

Baseline script production varied amongst the participants. NW's script production baseline was established at 0% accurate. Based on clinical observation, NW's baseline performance reflected his expressive abilities during conversational speech. NW

did not consistently and reliably attend therapy sessions. He participated in only 9 treatment sessions during the 7 week treatment period. MW and LH had baseline script production abilities that ranged between 21-61% accuracy. Baseline was not established for participant KB before the initiation of treatment, although her pre-treatment script production abilities ranged from 80-90% accurate when approximately half of the script was targeted. Participant NW made limited gains of 8-17%, LH made moderate gains of 27-40%, MH made moderate gains of 40-62%, and KB met and exceeded mastery of the treatment scripts. All of the participants demonstrated generalization of the skill to an untrained script. They had varying degrees of success following the one-week maintenance period. Participant MH's production of Script 2 declined by 20% while Script 1 and 3 improved by 2-5%. Participant NW's productions declined by 2-3%, participant LH's productions increased by 2-8%, and participant KB's productions remained stable or declined by 5%.

None of the participants demonstrated clinically significant changes in their production of spontaneous speech on the Picture Description subtest of the CAT (Swinburn et al., 2016). Similarly, the participants did not report clinically significant changes regarding the impacts of aphasia on their lives as measured by the Disability Questionnaire of the CAT (Swinburn et al., 2016). Despite those outcomes, KB, MH, and LH indicated that they found the therapy approach to be beneficial and motivating.

Table 18

Comprehensive Aphasia Test[a] - *Spoken Picture Description*

Participant	Pre-Treatment	Post-Treatment	Maintenance	T-Score Cut-Off
KB	50	53	49	61
NW	<39	<39	46	
LH	53	60	60	
MH	47	46	47	

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

Table 19

Participant	Pre-Treatment	Post-Treatment
KB	51	55
NW	50	50
LH	50	48
MH	59	61

Comprehensive Aphasia Test[a] - *Disability Questionnaire*

[a] Swinburn, K., Porter, G., & Howard, D. (2016). *Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

Reliability. Fifteen percent of the recorded baseline, treatment, and follow-up sessions were randomly selected and labeled for reliability purposes. A graduate level student clinician was trained on the treatment protocol and implementation of the cueing hierarchy. The clinician reviewed the recordings and analyzed them for procedural integrity. The percentage of agreement was 97%.

Limitations and deviations. The treatment protocol was carried out by first year graduate clinicians in two locations, so there were inconsistencies in the administration of the assessment material, treatment procedures, and scoring of script productions. The clinicians participated in pre-treatment training to attempt to control for these deviations but the individual characteristics of the clinicians inherently influenced the implementation of the protocols.

Several deviations to the projected study protocol occurred. The deviations included an oversight in establishing baseline performance before the initiation of treatment (i.e. KB) the use of the untreated script during the treatment process (i.e. MH) previous exposure to audio-visual therapy (i.e. KB), and inconsistent administration of post-treatment outcome measures. These deviations are detailed below.

Participant KB had roughly 15 weeks of previous exposure to script-based audio-visual stimulation that likely affected her performance. KB's pre-treatment script production abilities were exceptionally high and almost met the level of mastery despite increasing the length and complexity of her scripts. Since her speech production was high, the student clinician targeted articulatory precision in addition to verbal output. Three semi-personalized scripts were created for client KB and baseline measures were gathered. Baseline production of the scripts exceeded 80% accuracy, so longer and more

complex scripts were created. A stable baseline was not established for the new scripts and the treatment phase began immediately. Therefore, there were no baseline production measures to compare the participant's post-treatment performance. Nevertheless, KB's performance throughout the treatment period showed steady improvement indicating that treatment did have a positive influence on her speech production abilities.

Two of the three personalized scripts were developed for use during treatment and the third script was not used in treatment in order to measure generalization. MH's untreated script was used during treatment across two consecutive sessions, so a true measure of generalization could not be interpreted. Although true generalization could not be measured, MH's speech production did improve throughout the treatment process, and that progress did carry over to the production of an untrained script.

Post-treatment measurements included script production performance, the Disability Questionnaire and Picture Description of the CAT (Swinburn et al., 2016), and the VFD (Benton et al., 1994). While the total scores of the Disability Questionnaire were reported for participant MH, the individual subtest scores were not. Consequently, the overall decrease of the impacts of aphasia cannot be tied to specific influences. Finally, there was a five-week delay in the re-administration of the VFD across participants and participant NW did not return to the ISU-SLHC so the VFD was not re-administered.

Chapter V: Discussion

Existing research indicates that audio-visual speech entrainment can be used to improve the speech production abilities of individuals with nonfluent aphasia (Fridriksson et al., 2009; Fridriksson et al., 2012). The current study was conducted to determine if this

treatment approach could be implemented in a rural university clinic. It was hypothesized that it is feasible to implement script based audio-visual speech entrainment to treat individuals with nonfluent aphasia in a rural university clinic setting. Feasibility was the ability to implement the therapy approach conveniently and practically throughout the treatment period. The null hypothesis was that it is not feasible to implement script based audio-visual speech entrainment in a rural university clinic setting to treat individuals with nonfluent aphasia.

Four participants demonstrated gains in their production of personalized scripts with the support of audio-visual stimulation. Those improvements generalized to an untrained script and were maintained during a one-week no-treatment period. By the end of the treatment period, none of the participants demonstrated clinically significant improvements of spontaneous speech production, and each participant reported relatively stable measures regarding the impact of aphasia on their lives. Based on these outcomes the null hypothesis can be rejected.

Nonfluent aphasia treatment options are limited for individuals who are in the chronic stage of recovery. This is due in part to limited resources including time, money, and transportation. Emerging research indicates that speech production can be improved through the use of audio-visual stimulation (Fridriksson et al., 2009; Fridriksson et al., 2012). Until the completion of this study, data were not available regarding the implementation of audio-visual stimulation therapy using a non-intensive treatment schedule in a rural setting. The current study examined the feasibility of implementing this therapy approach in a rural university setting to treat four individuals with nonfluent aphasia who were in the chronic stage of recovery.

Based on the outcomes of the current study, script based audio-visual stimulation is a feasible treatment method. All four of the participants demonstrated improvements in speech production abilities on the treated scripts and those gains generalized to the untreated script and were maintained after one week of no treatment. In addition, the student clinicians reported that the treatment method was no more challenging to implement than other treatment options and that it was encouraging to see the clients make gains. The current study reflects the growing body of evidence that supports the use of digital script based audio-visual stimulation to treat individuals with nonfluent aphasia (Cherney et al., 2008; Fridriksson et al., 2012; Youmans et al., 2012). The positive gains in script production abilities of the current study indicate that it is a viable treatment method to use in a rural university clinic setting. Furthermore, this study suggests that treatment can be effective beyond the acute phase of recovery and that a non-intensive treatment schedule is adequate to affect change.

Clinical Implications

The results of the current study indicate that audio-visual stimulation can be used to train personalized scripts. While the study protocol was based on existing research (i.e. Cherney et al., 2008; Cherney et al., 2015; Fridriksson et al., 2009; Fridriksson et al., 2012; Holland & Cherney, 2010; Youmans et al., 2005), elements of the study protocol were tailored to implement the treatment in a rural university setting. Those elements included: the evaluation method of spontaneous speech production, the personalization of the scripts, the length of the scripts that were trained, the intensity of the treatment schedule, and the implementation of a phonemic cuing hierarchy to train incorrectly

produced words. Modifying these factors in the current study contribute to the growing body of research regarding audio-visual stimulation therapy.

Spontaneous speech measure. Fridriksson et al.'s foundational research identified speech entrainment as a viable treatment option for individuals with nonfluent aphasia (Fridriksson et al., 2012). A contributing factor to this claim is the finding that speech entrainment training can generalize to spontaneous speech production (Fridriksson et al., 2012). Since the skills can be generalized, it is probable that improved speech production is possible even in the absence of audio-visual stimulation.

The current study used the Picture Description of the CAT (Swinburn et al., 2016) to systematically measure spontaneous speech production. The participants' spontaneous speech production abilities remained relatively stable before and after the treatment period. Although the CAT allowed for systematic scoring and comparison, it may have limited speech production due to the inherent limitations of standardized testing. To complete the Picture Description, the participants were expected to describe a dynamic line drawing of a scene. The drawing may have been uninteresting to the participants and the content of the scene may have limited the variety and complexity of the language that was used.

Instead of standardized analysis, a systematic analysis of language samples may have resulted in a more accurate depiction of the participants' spontaneous speech abilities. Language samples could be generated by prompting the participant to speak about general topics or describe a personally relevant picture and those samples could be coded and systematically analyzed using a program such as SALT (Armstrong et al., 2011; Fridriksson et al., 2012; Miller & Iglesias, 2008). Analysis of language samples

could provide more detailed information regarding the participants' use of morphemes, syntactic productivity, semantic diversity, and complexity. Future investigations should consider alternative measures and analysis methods to gauge the effects of treatment on spontaneous speech production.

Script personalization. Research suggests that personally relevant information facilitates performance in aphasia therapy (Cherney et al., 2015; Kaye & Cherney, 2016; Goldberg et al., 2012; McKelvey et al., 2010; Palmer et al., 2015). Based on this evidence, the current study developed personally relevant scripts for each of the participants based on their case file and input from the participant and their family members. The majority of the participants reported that they were highly motivated to learn the scripts which improved participation and engagement. The foundational speech entrainment research of Fridriksson et al. (2012) rendered positive speech production outcomes despite not using personally relevant information for script development. While personally relevant information may not be necessary to train scripts with audio-visual stimulation, it may improve participation and motivation.

Script length. Increasing length inherently increased the complexity and difficulty of fluent speech production. Fridriksson et al. (2012) trained short scripts of 48 to 58 total words while Holland et al. (2010) trained scripts of up to 100 total words. The current study trained scripts that ranged from 48 to 149 total words. Three of the four participants required the creation of longer, more complex scripts due to their high baseline performance. Those scripts exceeded the total length of the scripts that have been documented in the existing research. This finding supports the need for future

studies to address the length and degree of complexity of the scripts that can be trained with audio-visual stimulation.

Cueing hierarchy. A body of research exists to support the use of cueing in nonfluent aphasia therapy (i.e. Cherney et al., 2011; Cherney et al., Des Roches et al., 2017; Kaye et al., 2016; Linebaugh et al., 2005; Magesh & Patil, 2013; Youmans et al., 2005). The current study used a least to most phonemic cueing hierarchy to train words that were incorrectly produced (Linebaugh et al., 2005; Youmans et al., 2005). While a least to most phonemic cuing hierarchy has been used successfully to train scripts, visual-only speech entrainment yields no effect on speech production abilities (Fridriksson et al., 2012). The influence of the auditory input is believed to be the vital component to audio-visual speech entrainment (Fridriksson et al., 2012). Fridriksson et al. (2012) did not report the use of a cuing hierarchy in their foundational speech entrainment research, yet still their work produced positive outcomes of speech production abilities. Furthermore, research suggests that there are no significant differences between the effects of high and low intensity cuing conditions for script therapy interventions. Considering the landscape of the existing research, further studies will be necessary to address how and to what degree cueing hierarchies can impact the participant's speech production abilities.

Treatment intensity. Based on a meta-analysis of aphasia treatment studies, treatment can be effective in as little as two, one-hour sessions per week (Robey, 1998). The frequency of therapy sessions and massed practice of the scripts is an important factor in developing automatization (Cherney et al., 2008; Goldberg et al., 2012). Non-intensive aphasia treatment programs have been successfully implemented to train scripts (Cherney, 2010; Youmans et al., 2005; Youmans et al., 2011). Due to the pre-determined

schedule of the university clinic setting, this study used a non-intensive treatment schedule. Three of the four participants consistently and reliably attended therapy and demonstrated gains in speech production. Participant NW did not consistently attend therapy sessions and demonstrated minimal gains in speech production. His infrequent attendance may have negatively affected his outcomes which would suggest that consistent attendance is important to successful therapy outcomes when a non-intensive schedule is implemented. While the non-intensive schedule of the current study was adequate for script training, a more intensive therapy schedule may have rendered different outcomes including improved script and spontaneous speech production.

Candidacy

Determining characteristics of ideal candidates for a given treatment method is important for successful therapy outcomes. Since the population of individuals with nonfluent aphasia is heterogeneous, identifying the characteristics that contribute to their performance can help identify candidates for treatment. The four participants of the current study presented unique profiles that offer insight into script based audio-visual therapy candidacy.

Participant motivation and the support of a family system appeared to influence treatment outcomes. Participant NW was a single male who did not have family in the immediate area. Since he did not have a strong support system, the personalized information that was included in his scripts was limited to only what he could provide. Consequently, his scripts contained less personalized content which may have decreased motivation and engagement during the treatment process. Unlike NW, the remaining three participants had strong family support systems. The family members provided input

during script development and attended several therapy sessions throughout the treatment period. Since the family members provided input during script development, they were highly personalized which likely increased motivation and engagement. Additionally, the participants may have been more encouraged by treatment gains since they were able to share the success with their family.

Research suggests that individuals with mild to moderate aphasia are good candidates for script based therapy (Cherney et al., 2008). Three participants of the current study were diagnosed with mild-moderate aphasia and they made gains in speech production abilities. The fourth participant was diagnosed with severe aphasia and he made minimal gains by the end of the treatment period. The participant characteristics of the current study reflect existing research which suggests that aphasia severity influences treatment outcomes.

While aphasia severity may influence treatment outcomes, participants' specific residual strengths may also have an influence. Based on pre-treatment assessment, the four participants had unique residual strengths. Participant KB and LH's word and non-word repetition abilities were within normal limits. Although their repetition abilities were considered aphasic with increasing word lengths, they were able repeat single word utterances. Since the treatment protocol involved elements of repetition, KB and LH's residual repetition abilities may have contributed to their strong performance during treatment. Their post-treatment speech production gains suggest that strong residual word repetition abilities may influence treatment outcomes.

While strong residual repetition abilities may indicate positive treatment outcomes, a diagnosis of severe apraxia of speech may impede gains. Participant NW's

pre-treatment speech production abilities were very limited and based on his performance on the ABA-2 (Dabul, 2002), he was diagnosed with severe apraxia of speech. NW demonstrated minimal gains by the end of the treatment period and his speech continued to consist only of over-learned responses including "yep" and "nope." According to Fridriksson et al. (2012), speech entrainment relies on residual motor speech planning abilities. Since apraxia impairs motor speech planning, individuals with severe apraxia may not be ideal candidates for speech entrainment therapy. NW's limited gains reflect the research of Fridriksson et al. (2012) which suggests that individuals who are diagnosed with severe apraxia of speech may not benefit from speech entrainment therapy.

Participant NW used a personal iPad for single word and short phrase communication. Interestingly, based on NW's pre-treatment CAT scores, he performed above the aphasic range for the comprehension and production of written communication. Those strong residual abilities likely facilitated his communicate through text on his iPad. Since NW was already accustomed to communication with a digital device, it was predicted that he would benefit from the treatment method. However, he made minimal gains. This may be due to several factors including NW's severely impaired speech production abilities, his comfort with and preference for text based communication, or his lack of motivation to practice the scripts because they were only semi personalized. These are all characteristics that may affect candidacy and participant outcomes and should be considered in future research.

Chapter VI: Future Investigations

The current study demonstrated the feasibility of implementing audio-visual therapy to treat individuals with nonfluent aphasia in a rural university setting. Continued research is required to develop a strong foundation for implementation and use of this treatment approach. Future investigations should consider the length and complexity of the personalized scripts, dosing and intensity of treatment, the potential impact of a home program, and the potential for outcome variations between monologues and dialogue based scripts. Each of these recommendations for future investigations are discussed in this chapter.

The scripts that were used for the current study ranged from 48 to 149 total words depending on the speech production abilities of the participants. Fridriksson et al. (2012) trained scripts that ranged from 48 to 58 total words while Holland et al. (2010) trained scripts of up to 100 total words. Future investigations could evaluate how total script length and the number of different scripts affects speech production outcomes. In addition to the length and total number of trained scripts, future investigations could consider the effects of script complexity. Increasing variety and frequency of grammatical morphemes, varying sentence types and structures, and increasing the number and variety of clauses could all affect speech production abilities.

Future investigations could also consider how varying dosing schedules affect the outcomes of audio-visual stimulation therapy. As this study occurred in a rural university clinic setting, the dosing schedule was limited to two, thirty-minute sessions a week. Evidence suggests that an intensive dosage approach yields positive outcomes for aphasia therapy (Cherney et al., 2008; Rodriguez et al., 2013; Winans-Mitrik et al. 2014).

However, intensive intervention may be unrealistic for both clients and clinicians due to third party reimbursement restrictions and scheduling constraints.

Similar to dosing schedules, the influences of home programming and practice should be considered. Home practice has been shown to render beneficial outcomes (Cherney et al., 2008; Cherney, 2012; Youmans et al., 2005) and may be as effective as clinician-based treatment (Cherney et al., 2008). Technological advancement has increased access to personal digital devices and decreased social stigma (Dietz et al., 2014). Since personal digital devices are common, home practice can be more easily implemented. Future investigations could evaluate the effects of home practice and the outcomes of a hybrid treatment approach that includes both clinician directed and home practice protocols.

Finally, future investigations could consider the variations of outcomes between monologue and dialogue based scripts. The current study had similar successful outcomes as the growing body of monologue script training therapy (Cherney et al., 2008; Fridriksson et al., 2012; Goldberg et al., 2012; Youmans et al., 2005). However, the ability to produce monologues has limited functional use in social contexts. Since conversation involves turn taking and repair, dialogue script practice may facilitate more natural interactions. Research indicates that it is possible to train dialogues using script training with individuals with nonfluent aphasia (Cherney et al., 2008; Cherney et al., 2012; Goldberg et al., 2012). Furthermore, the ability to produce scripted dialogue can generalize to conversation with partners who deviate from the original script (Goldberg et al., 2012; Youmans et al., 2005). Future investigations could evaluate generalization of monologue script training to conversational dialogue.

In conclusion, viable options of aphasia therapy are limited for individuals who are in the chronic stage of recovery. Script based audio-visual stimulation has been shown to improve the speech production abilities of individuals with nonfluent aphasia (Fridriksson et al., 2009; Fridriksson et al., 2012). The current study reflects and expands upon those findings with four participants. At this time, the primary factors to consider for implementation of script based audio-visual therapy include participant motivation, script length and complexity, the severity of aphasia and apraxia diagnoses, and residual communication strengths. Based on the outcomes of this study, script based audio-visual therapy is a feasible treatment method for individuals with nonfluent aphasia in a rural university clinic setting.

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Appendix A - Human Subjects Application

IRB #: IRB-FY2018-19

Title: The Feasibility of Script Based Audio-Visual Speech Entrainment for the Treatment of Nonfluent Aphasia

Creation Date: 8-10-2017

End Date: 9-8-2018

Status: Approved

Principal Investigator: Jeanna Ritter

Review Board: Human Subjects Committee

Sponsor:

Study History Submission Type: Initial Review

Type Expedited Decision: Approved

Key Study Contacts Member & Primary Contact: Jeanna Ritter Role, Principal Investigator

Contact: rittjean@isu.edu

Investigator: Victoria Scharp Role Investigator

Contact: scharp@isu.edu

Initial Submission

Investigator and Project Information

Use this form for new submissions of research projects to the Human Subjects Committee (HSC, also known as the Institutional Review Board or IRB). This form is used for studies eligible for a Certificate of Exemption or for expedited review, and for those requiring full-board review.

Office location: 1651 Alvin Ricken Dr., Pocatello, ID 83201 | Mailing: Stop 8046

To obtain IRB Review of a research project with human participants, submit this completed form with all of the indicated attachments. Allow sufficient time for review before starting the project. Please consult the IRB website and contact irb@cayuse.edu or (208) 282-2179 with any questions before submitting an application.

Research as used here means a systematic investigation designed to develop or contribute to generalizable knowledge. This includes research, development, testing, and evaluation. This does not typically include classroom exercises, demonstrations, or other course requirements that receive grades. Research does not include customer satisfaction surveys or similar data collections designed to improve the operations of a single institution.

Human Participants The Institutional Review Board (IRB) reviews all research projects at Idaho State University involving human participants. This means living individuals about whom and investigator obtains data through intervention or interaction with the individual or obtains identifiable private information from a separate source such as medical or school records or other individuals such as relatives.

✔ New Submission

Name of Study. Do not exceed 150 characters including spaces.

The Feasibility of Script Based Audio-Visual Speech Entrainment for the Treatment of Nonfluent Aphasia

Principal Investigator. Please identify the PI for this project.

Please note that the appropriate CITI training; i.e. Human Subjects Social/Behavioral, Data/ Lab Specimen or Biomedical must be completed before the study will be approved. (Responsible Conduct of Research, RCR, DOES NOT satisfy HSC requirements.)

Name: Jeanna Ritter Organization: Comm Sci Disorders/Deaf Educ Address: 921 S 8th Ave Stop 8116, Pocatello, ID 83209 Phone: (208) 240-0113

1. Is the Principal Investigator a current student?

   ✔ Yes

   Student Principal Investigators are required to include an endorsement from their faculty advisor. The signature below certifies that the faculty advisor has reviewed

2.

   and approved this complete Application and its attachments and accepts responsibility to supervise the work described herein in accordance with applicable institutional policies.

   Name: Victoria Scharp Organization: Comm Sci Disorders/Deaf Educ Address: 921 S 8th Ave MS 8116, Pocatello, ID 83209 Phone: (208) 282-4576

   Are there Co-Investigators on this project?

✔ Yes

Please identify Co-Investigators

4.a Name: Victoria Scharp Organization: Comm Sci Disorders/Deaf Educ Address: 921 S 8th Ave MS 8116, Pocatello, ID 83209 Phone: (208) 282-4576

3. Identify any others who will be involved as research personnel for this study.

Two to four graduate level student clinicians under, the supervision of a trained and certified Speech-Language Pathologist, will administer the therapeutic intervention. Additionally, one graduate level student clinicians who are not directly involved in the intervention will analyze and score the outcome data. All research staff are a part of Dr. Scharp's research lab and have completed the CITI training modules.

4. Please identify a primary administrative point of contact for this submission

Name: Jeanna Ritter Organization: Comm Sci Disorders/Deaf Educ Address: 921 S 8th Ave Stop 8116, Pocatello, ID 83209 Phone: (208) 240-0113

5. Lay Language Summary. Briefly describe the purpose of the proposed research so that someone outside your field would readily understand it. Avoid abbreviations and technical language.

The purpose of this study is to determine the feasibility of using script based multimodal auditory-visual stimulation to improve the fluency and speech

production of individuals with nonfluent aphasia. Stroke is the fifth most commonly occurring disease in the United States (Mozaffarian et al., 2016) and between 25% to 40% of stroke survivors consequently suffer from aphasia (National Aphasia Association, 2011). Aphasia is an acquired language disorder that occurs from damage to the regions of the brain that are responsible for the production and comprehension of language (Helm-Estabrooks, Albert, & Nicholas, 2014). It results in anomia which is the greater-than-normal 7. word retrieval problems (Dignam et al., 2007). Individuals with aphasia often suffer from long-term disability which requires extensive rehabilitation (Des Roches, Mitko, & Kiran, 2017). Nonfluent aphasia occurs as the result of a lesion in the neural networks responsible for the production of speech. Although individual clinical characteristics vary, nonfluent aphasia is typically characterized by good auditory comprehension, dysfluent speech production, poor ability to repeat speech, and short phrase productions of one to three words (Brookshire & McNeil, 2015; Helm-Estabrooks et al., 2014). To minimize the negative consequences of nonfluent aphasia, alternative neural networks must be capitalized on. One such neural network is the visuo-motor pathway. This pathway plays a key role in speech production and develops in infancy as the result of audio-visual stimulus integration (Venezia et al., 2016). This network can be accessed through audio-visual stimulation. Audio-visual speech stimulation enables some individuals with nonfluent aphasia to mimic a speaker in real time despite their severely impaired ability to produce speech (Fridriksson et al., 2012). Fridriksson et al. (2012) refer to this phenomenon as speech

entrainment. Speech entrainment combines an auditory stimulus through recorded speech with a recorded visual model of a moving human mouth. Audio-visual speech entrainment has been shown to improve the speech production and fluency of individuals with nonfluent aphasia during spontaneous speech production and during the production of trained and untrained scripts (Fridriksson et al., 2009; Fridriksson et al., 2012). Speech entrainment can be applied to script therapy to improve fluency and speech production. Script therapy is the process of understanding, remembering, and recalling the temporal organization of events (Cherney et al., 2008). It is based on the theory of automatization (Logan, 1988) which suggests that complete, context-bound, practice facilitates the mastery of a skill (Cherney et al., 2008). Individuals with nonfluent aphasia benefit from script therapy because the processes of understanding, remembering, and recalling temporal organization remain relatively intact (Cherney et al., 2008). Script therapy and speech entrainment can both be delivered via a digital device (Cherney, 2010; Fridriksson, 2012). The use of technology in nonfluent aphasia therapy is especially of interest considering the time and costs associated with therapy delivered past the acute stage of recovery. Digital devices can be used as a supportive tool by the clinician who retains the traditional responsibilities of designing, administering, monitoring, and modifying the intervention (Katz, 2010). This study will use an iPad to combine aspects of script therapy with audio-visual stimulation. Multimodal auditory and visual stimulation will be used to target the fluency and speech production of individuals with nonfluent aphasia.

This study will determine the feasibility of using this approach in a university clinical setting.

6. Has this project requested or received external funding?

✔ No

7. Do any of the researchers (principal investigator, co-principal investigators, or associated researchers) have any financial, non-financial, or commercial interest in the research? Research team members must submit an updated Conflict of Interest disclosure within 30 days of discovering or acquiring a new significant conflict of interest (financial or non-financial).

✔ No

8. Study site(s) Where will study procedures be carried out?

✔ Idaho State University (including the Pocatello, Idaho Falls, and Meridian campuses)

9. Are you applying for a Certificate of Exemption or for expedited review? Or does your study require review by the full board?

✔ I am applying for expedited review. Select the appropriate category of expedited review.

✔ Category 7 Research on group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. NOTE: Some

research in this category may be eligible for a Certificate of Exemption (see above). Select this category only if your research is not eligible for it. If an accidental breach of confidentiality could put participants at risk (because the study deals with sensitive issues or information), then the study does not qualify for Expedited Review. Select Full Board Review instead. Category 8 Continuing review of research previously approved by the Human Subjects Committee (using full board review) as follows: the research is permanently closed to enrollment of new subjects; all subjects have completed all research-related interventions; the research remains active only for the long-term follow-up of subjects; or where no subjects have been enrolled and no additional risks have been identified; or where the remaining research activities are limited to data analysis. Category 9 Continuing review of research not conducted under an investigational new drug application or investigational drug exemption where categories 2 through 8 (above) do not apply but the Human Subjects Committee has determined at a convened meeting that the research involves no greater than minimal risk and no additional risks have been identified. This study requires full board review.

10. Participant information. Please identify the types of participants for this study Please check all that apply

    ✔ Medical or other clinical patients/clients

11. Are any of the participants in this study people over whom the investigator has some sort of authority? (E.g., the investigator's students, patients, clients, employees, supervisees, etc.) Recruitment.docx

    ✔ No

12. Explain how participants will be identified and recruited for this study. If posters, billboards, radio or TV ads, internet ads, or other recruiting materials will be used, include an explanation of where these will be placed. Also, contact ISU Marketing & Communications for guidance about how to format your material. 208-282-4407

    Participants will be recruited from the free Idaho State University Speech-Language and Hearing Clinic (ISU-SLHC) from either Pocatello or Meridian. Current client files will be reviewed to identify individuals who meet match the inclusion criteria. Participants who qualify for the study will be at least six months post stroke, right-handed, native English speakers. At the beginning of the first scheduled therapy session, the clients will approached by the principle investigator and/or the clinical supervisor to describe the study, explain the procedures, and extend an invitation to participate. After the study is explained, if the client's agree to participate, they will sign an informed consent form. Attach any recruiting posters, email messages, letters, advertisements, etc. to be used. Include any recordings or videos to be used for radio, television, or internet. (This is NOT the place for attaching consent forms; that comes later.)

    14a. Will you use any posters, radio or TV advertisements, billboards, etc. for recruiting patients outside of the ISU campuses?

    ✔ No

13. Will subjects be paid or given anything of value in return for their participation?

✔ Participants will NOT receive anything of value in return for their participation.

14. Will participants in this study have to pay for anything (e.g., parking, medical services).

✔ No

Study Information -- Short Form

A. Study population Describe what sorts of subjects will be involved in the proposed study. Explain your inclusion and exclusion criteria.

Participants will be at least six months post stroke, right-handed, native English speakers. The medical records and neuroimaging reports that clients submit to the clinic will be reviewed and they will be diagnosed with nonfluent aphasia based on their performance on the Comprehensive Aphasia Test (CAT) (Swinburn, Porter, & Howard, 2016). The Apraxia Battery for Adults, Second Edition (ABA-2) will be administered to assess the presence and severity of apraxia (Dabul, 2002). Additionally, a pure tone hearing screening will be administered via over the ear earphones or sound-filled room if the participant wears hearing aids. The screening will be administered at 30dB at 500, 1000, and 2000 hz. Finally, a matching task will be used to screen the participant's visual acuity. The task will involve matching pictures of the same mouth used for visual stimulation in the position of different phonemic productions. Exclusionary criteria include an overall aphasia severity rating of greater than 62.9 on the CAT (Swinburn, Porter, & Howard, 2016), left-hand

dominance, non-native English speakers, or individuals who are less than six months post CVA.

B. Number of subjects How many people do you intend to recruit for your study? If you do not have a specific number in mind, provide a reasonable estimate or range. If research subjects will be divided into 2 or more groups, specify numbers (or estimates) for each group.

One to five individuals are anticipated to participate in the study.

C. Will this study use existing data, documents, records, and/or biological specimens?

✔ Yes

C.1 Describe the data, documents, records, specimens, etc. to be used. Explain how the data (or records, specimens, etc.) were collected.

Medical records, neuroimaging reports, and speech-language therapy data will be used in the study. Per the protocols of the ISU Speech-Language and Hearing Clinic (ISU-SLHC), the documents will be gathered and accessed with permission of the participants. Should the participant receive speech-language therapy outside of the clinic, their most recent records will be requested. Similarly, the participants' most recent medical records and neuroimaging reports will be requested and reviewed per the protocols of the ISU-SLHC.

C.2 Who is the owner or steward of the data, documents, records, specimens, etc. to be used?

The ISU Speech-Language and Hearing Clinic is the owner of the data, records, and reports that will be used.

C.3 Were the data, documents, records, specimens, etc. originally collected solely for research purposes?

✔ No

C.4 Are these data, documents, records, specimens, etc. publicly available? In this context, "publicly available" means that the general public can obtain the data, documents, etc. Sources should NOT be considered publicly available if access is restricted to special groups (e.g., clinicians, researchers).

✔ No

C.5 How are the data, documents, records, specimens, etc. identified when they are made available to your research team?

✔ Indirect identifier (An assigned code which could be used by the investigator or the source providing the data, document, etc. to identify a specific subject)

C.5.i When the data, documents, records, specimens, etc. are received:

✔ Any and all identifiers will be destroyed immediately, leaving a completely de-identified set of data, documents, etc. At least one identifier will be kept No identifier

C.6 Will any additional data, documents, records, specimens, etc. be added to the set once you begin your research?

✔ No

D. Study description. Describe what participants in your study will do. If participants will be divided into 2 or more groups, be sure to make clear the procedures for each group. If you will be using questionnaires, tests, or other data collection instruments, describe them here and attach them below. Explain how long it will take to complete each one. Also explain the setting in which they will be administered (e.g., classroom, mailed questionnaire, internet). If you will be conducting interviews, focus groups, etc., include the specific questions to be asked. If an open-ended approach is used, indicate the kinds of issues likely to be discussed.

This study will use a single-subject experimental design that will consist of four phases: pre-treatment, treatment phase one, a no treatment phase, and treatment phase two. The study will last for the duration of one semester. The first treatment phase, including assessment and baseline procedures, will last approximately seven weeks. The maintenance phase will last about one week of Thanksgiving break during which no treatment or therapy will be administered. Treatment phase two will include gathering outcome data and will last a total of five weeks. Script based speech entrainment stimulation does not directly target the cognitive domain of spatial awareness, therefore, the Visual Form Discrimination (VFD) test will be used as a control measure (Benton, Hamsher, Varney, Spreen, 1994). The Visual Form Discrimination test measures the ability to discriminate between complex visual configurations. It will be administered two times to establish an individualized range of stability. Assessment procedures

will include both diagnostic and descriptive measures. Participants will be administered Comprehensive Aphasia Test (CAT) to determine the presence and severity of nonfluent aphasia over two, 50-minutes sessions. The CAT includes 34 subtests which are grouped into a Cognitive Screen, Disability Questionnaire, and a Language Battery which is further divided into comprehension and production (Howard, Swinburn, & Porter, 2010; Swinburn, Porter, & Howard, 2004). The Apraxia Battery for Adults-Second Edition (ABA-2) will be administered to assess the presence and severity of apraxia (Dabul, 2004). The ABA-2 includes six subtests and takes roughly 30 minutes to administer. Additionally, a pure tone hearing screening will be administered via over the ear earphones or sound-filled room should hearing aids be required. The screening will be administered at 30dB at 500, 1000, and 2000 Hz. An orofacial examination will be performed to identify any weakness or abnormalities. Finally, a visual screening will be implemented via a matching task. The task will involve matching pictures of the same mouth used for visual stimulation in the position of different phonemic productions. The orofacial examination, hearing, and vision screening are anticipated to take between 15-30 minutes to administer. Baseline procedures will be administered without support until stability is achieved over two consecutive sessions. Baseline materials will include the two scripts that will be used in treatment as well as one script that will not be trained. Additionally, the Picture Description subtest of the CAT will serve as a baseline measurement of spontaneous speech production. Participants will attempt to mimic audio-visual stimulation in real time thereby improving their fluency and speech production.

An iPad will be used to administer the auditory-visual stimulation. Auditory stimulation will be delivered in tandem with the visual stimulation. Auditory stimulation will be the verbal production of the script while visual stimulation will be a human mouth in isolation from the rest of the face. The audio-visual stimulation will be used to present three semi-personalized scripts. The scripts will be recorded and will range from 25 to 60 words (Fridriksson et al., 2012; Goldberg et al., 2012). They will be read with normal intonation and at a slightly slower rate of speech of 130-160 words per minute (Rodero, 2012).

E. Attach any questionnaires or other data collection instruments to be used in this study. (Do NOT attach consent forms here.)

Visual Screening.docx Visual Form Discrimination.pdf Orofacial and Hearing Screening.pdf CAT_scoring_booklet (1).pdf Apraxia Battery for Adults-2nd Edition.pdf

F. Will participants be identifiable (names, photo or video images, recordings of voices, addresses, email addresses, etc.)?

✔ Yes

Explain how you will maintain participants' confidentiality.

A HIPAA compliant electronic program (Raintree Systems) will be used to compile personal records, reports, and data. Experimenters will be HIPAA certified and will comply with the confidentiality procedures of the ISU Clinic. Any hard copies of the participants identifying information will be kept in a locked filing cabinet inside of a keypad protected room. The room is only

accessible by individuals who have completed HIPAA certification as the CITI modules.

G. Will you make audio or video recordings of any participants?

✔ Yes

Explain what photos/videos/recordings will be made, and any steps you plan to take to conceal participants' identities.

For data analysis and tracking purposed, every session will be video and audio recorded using a HIPAA compliant system (Video Audio Learning Tool - Valt). Per the ISU Speech-Language and Hearing Clinic policies and procedures, Valt is password protected and can only be accessed by authorized personnel. The individuals who will be accessing the information on Valt are HIPAA certified and have completed the CITI training modules. No Explain how you will obtain the INFORMED CONSENT of participants. Adult Intake Protocol.pdf Patient authorization of release of PHI.pdf Consent for Participation.pdf Experiment Participation Consent.docx.

H. This might involve a consent form, information sheet, survey cover letter, script for verbal consent, letter (or email) to participants, etc. The participants will complete the ISU Clinic intake protocol which includes an information sheet, authorization for the release of PHI, and consent to receive treatment. In addition, the participants will be read an informed participation consent form. The form will be reviewed with the participant and they will be asked if they have any questions or concerns. To confirm consent, the participant will sign in the

presence of the providing clinician. Attach any consent form, information sheet, survey cover letter, verbal consent script, etc. that you plan to use.

H.1 Are you requesting a waiver of documentation of informed consent? (I.e., Participants will provide verbal consent but will not sign a consent form)

✔ No

H.2 Are you requesting a waiver of informed consent? (I.e., the study will be conducted without obtaining even the verbal consent of participants)

✔ No Risks

I. What risks will participants be exposed to? What protections are in place to minimize those risks?

The participants will be exposed to little to no risks. The only risk that the participants may be exposed to involve a breach of their confidential information. ISU Speech-Language and Hearing Clinic procedures will be followed to prevent a breach of confidential information including but not limited to the Raintree and Valt programs which are both password protected. Additionally, hard copies of the participant's information and data will be kept in a locked filing cabinet which is in a room that requires a keycode to enter. The only individuals who have access to the research lab have completed HIPAA and CITI training modules.

J. Benefits How will participants benefit directly from participation in this study? Don't assume that the study intervention will work if the purpose of the study is to test its efficacy. Don't include payments made to subjects; describe only benefits arising from the study procedures themselves. If there are no direct benefits to

participants, then say so. What benefits will there be to others (society, your field of study, etc.)? (Be realistic)

The direct benefits of script based audio-visual speech entrainment are unknown. However, in addition to the experimental approach, the participants will receive traditional speech-language therapy that is evidence based and supervised by a certified and licensed SLP.

K. Data Storage & Final Disposition Be sure to address all of the following: How will the data you collect be stored? What steps will be taken to protect it? Who will have access to it? What will be done with it at the end of the storage period?

The data will be stored per well established HIPAA compliant clinical protocols. Electronic data will be stored using the secure system, Raintree. Raintree requires a username and password to access and can only be accessed by approved personnel. Additionally, audio and video recordings will be stored using the HIPAA compliant online system, Valt. Hard copies of data that are obtained during throughout the experimental process will be stored in a locked filing cabinet in a keypad protected room. The thesis faculty chair, providing clinician, primary experimenter, clinical supervisors, and experimental supervisor will have access to the data. Hard copies of the data will be kept for up to seven years at which point it will be destroyed. Electronic data that is entered into the Raintree system will be kept indefinitely until the participant is no longer an active client of the ISU-SLHC.

Certification By signing below, the Principal Investigator and co-Principal Investigators (if any) assure the IRB that all procedures performed during this project will be conducted by individuals legally and responsibly entitled to do so, and that any significant systematic deviation from the submitted protocol (for example, a change in principal investigator, sponsorship[. research purposes, participant recruitment procedures, research methodology , risks and benefits, or consent procedures) will be submitted to the IRB for approval prior to its implementation By signing below, the Principal Investigator and co-Principal Investigators (if any) certify the following:

1. The information in this application is accurate and complete
2. I/we will comply with all federal, state, and institutional policies and procedures to protect human subjects in research
3. I/we understand the ethical responsibilities of research investigators and have received the required training in human research participant protection as specified at the IRB Website
4. I/we will assure that the consent process and research procedures as described herein are followed with every participant in the research
5. I/we will promptly report any deviations or adverse events to the IRB.
6. If a faculty advisor is required (see below), then I/we agree to meet regularly with the faculty advisor listed below to discuss the progress of the study and to address research issues as they arise.

✔I, and all others identified herein as members of the research team, have read and understand the above statement.

Faculty Advisor Applicable only when the Principal Investigator is not an assistant professor, associate professor, or professor (or their clinical counterparts) at Idaho State University. As faculty advisor for this study, I certify that I have read this application and that the information contained in it is complete and accurate. I will ensure that the principal investigator(s) listed above is/are competent to perform the procedures described. I agree to meet regularly with the principal investigator(s) to discuss the progress of the research and to address research issues as they arise. I will ensure that the research is carried out as described (including storage and destruction of data as described in the protocol), and that all applicable laws and policies will be followed.

✔I, as faculty advisor, have read and understand the above statement.

Appendix B - Informed Consent

Instruction. "In addition to speech-language therapy, you have the opportunity to participate in an experimental treatment program. We will still be working on your speech, but we will be using an iPad during therapy. Together, we will develop three few

scripts about you, your experiences with aphasia, and one of your favorite hobbies. The scripts will be recorded on the iPad and you will try to copy the iPad as it plays. We will spend thirty minutes of each session using the iPad to learn the scripts. Since this is a research study, you will need to provide your consent to participate. I am going to review the consent form with you now. Please feel free to ask me any questions you might have as we review it."

[Read the consent form. Ask the participant if they have any questions or concerns. Have the participant sign the form. You sign as a witness of informed consent.]

INFORMED CONSENT

CONSENT TO ACT AS A PARTICIPANT IN AN EXPERIMENTAL STUDY

TITLE: The Feasibility of Script Based Audio-Visual Speech Entrainment for the Treatment of Nonfluent Aphasia

PRINCIPLE INVESTIGATOR: Jeanna Ritter, B.S. (student)

RESEARCH ADVISER: Victoria Scharp, Ph.D., CCC-SLP

Department of Communication Science and Disorders

Idaho State University

Building #68, Office #314B

921 S 8th Ave, Mail Stop 8116

Pocatello, ID 83209

You are being asked to participate in a research study conducted by Jeanna Ritter, a graduate student from the department of Communication Sciences & Disorders at Idaho

State University. This research examines the effects of an alternative therapeutic treatment to improve speech production. There will be approximately four participants enrolled in this research project and your participation in this research is voluntary. Please read the information below, and ask questions about anything you do not understand, before deciding whether or not to consent to participation.

PURPOSE: The purpose of this study is to examine the feasibility of using script based audio-visual speech therapy to improve the speech production and fluency of individuals with nonfluent aphasia.

PROCEDURES: If you choose to participate in this study, you will be asked to complete the assessment protocols that are described below. Additionally, thirty minutes of each therapy session will be dedicated to the experimental therapy technique. We will review and update your medical records per the ISU Speech-Language and Hearing Clinic protocol. The assessment procedures that you will be asked to complete include:

1) The Comprehensive Aphasia Test which is a receptive and expressive language assessment used to diagnose aphasia. The subtests include auditory and written comprehension tasks as well as spoken language tasks ranging from single words to spontaneous speech production. The CAT also includes a brief cognitive screening and a disability questionnaire.

2) The Apraxia Battery for Adults-Second Edition identifies the presence and severity of apraxia. The subtests include tasks of repetition, speech production, oral-facial coordinated movements, and gesture use.

3) The Visual Form Discrimination test evaluates visual spatial awareness. The test requires the participant to match a line drawing of increasingly complex shapes to the same picture in an array of four.

4) A hearing and orofacial screening will be administered to ensure the structures function and integrity. The hearing screening will performed in a quiet room with a calibrated audiometer at 30 dB, 500, 1000, and 2000 Hz. During the orofacial screening, the participants will be asked to perform a variety of oral movements to assess range, strength, and coordination. Additionally, the structures of their mouth will be examined to identify any abnormalities.

5) Visual acuity will be screened through the use of a matching task. The participants will be asked to match six pairs of pictures that represent the visual stimuli of the experimental treatment.

These tasks will be administered over three, 50 minutes sessions. Your performance on these tasks along with your medical records will determine your eligibility to participate in the study.

EXPERIMENTAL TREATMENT: The experimental treatment program will be practiced for 30 minutes, two times per week during your regularly scheduled appointment. The remaining 20 minutes of your scheduled appointments will be dedicated to traditional speech-language therapy. The experimental treatment aims to improve speech production. Treatment will be guided by a graduate level student clinician under the supervision of a trained and certified speech-language pathologist. You will be asked to speak in tandem with an audio-visual recording of a person

speaking. The recordings will be short paragraphs that you develop in collaboration with your clinician so they are relevant to you and your interests.

RISKS AND BENEFITS: Other than the potential breach of confidentiality, there are no known risks associated with participation in this study, as the procedures are very similar to ordinary language or psychological testing. It is possible that you may be frustrated by some tasks, or experience fatigue. The clinician will be alert for these possibilities and will take breaks or reschedule sessions as necessary. Apart from the possibility of improved fluency and speech production, you will receive no direct benefit from participating in this study. However, if concerns arise regarding your vision, hearing, or orofacial mechanism, you may benefit from having us refer you to a specialist for a more complete evaluation.

COSTS AND PAYMENTS: The ISU-Speech-Language and hearing clinic is a free clinic, therefore, there are no costs to you for participating in this study. You will not be expected to pay for the services and your insurance will not be billed. You will not be paid for your participation.

CONFIDENTIALITY: As a participant in this research study, your right to privacy will be protected at all times. Any information obtained about you will be kept as confidential as possible. All records relating to your participation will be kept in a locked file cabinet in a password protected room and in a password protected computer program. All of the ISU Speech-Language and Hearing Clinic protocols will be followed to ensure that your information remains confidential.

RIGHT TO PARTICIPATION OR TO WITHDRAW FROM PARTICIPATION: Your participation in this study and the use and disclosure of your identifiable information is

completely voluntary. Whether or not you decide to participate will not affect your current or future relationship with the ISU-Speech-Language and Hearing Clinic. You will still have the option to receive speech-language therapy.

You may withdraw from the study at any time. If you choose to withdraw, any data or identifiable information obtained prior to the date of your withdrawal may be used for research purposes. To formally withdraw, you should provide a written and dated notice of this decision to Dr. Scharp at the address listed on the first page of this form.

VOLUNTARY CONSENT: I understand that my participation in this study is voluntary and in no way will affect my treatment at the ISU-SLHC. All of the above has been explained to me and all of my current questions have been answered. I understand that I am encouraged to ask questions about any aspect of the study throughout the treatment process. Any questions I have about my rights as a research participant will be answered by the researchers listed on the first page of this form.

By signing this form, I agree to participate in the research study.

_____ _____

Participant Signature Date

CERTIFICATION of INFORMED CONSENT: I certify that I have explained the nature and purpose of this research study to the above-named individual, and I have discussed the potential benefits and possible risks of study participation. Any questions of the participant has have been answered, and we will continue to address questions as they arise.

_____

_____

Printed Name of Person Obtaining Consent Role

_____

_____

Signature of Person Obtaining Consent Date

Appendix C - Experimental Instructions and Procedures

Hearing Screening. "Have you had any problems with your hearing? Do you have any pain in your ears? I am going to check how well you can hear. I will put these earphones over your ears and you will hear quiet beeps. You will only hear the beeps in one ear at a time and they will be really quiet. When you hear the beeps, raise your hand. Let's practice."

[DO NOT put the earphones on the participant's ears. Turn the audiometer up to 30 dB. Trigger the stimulus and raise your hand.]

"Do you have any questions? Remember, even if the beeps are really quiet, raise your hand when you hear them. Let's start."

[Start at 500 Hz at 30 dB. If the participant does not respond, move up to 30 dB at 1000 Hz. If the participant does not respond, turn the dB up to 35. Increase dB by increments of 5 (max 45) until the participant responds. Move back down to 30 dB at 1000 Hz. Rescreen at 30 dB at 500 Hz and screen at 30 dB at 2000 Hz. If the participant does not respond at 30 dB to 500, 1000, or 2000 Hz, they will be rescreened during the following session. If they fail the screening twice, they will be referred to an audiologist for further testing.]

Visual Screening. "Do you have any problems with your eyesight? Do you wear glasses or contact lenses? I am going to check how well you can see. I have some pictures. The pictures all look similar but each one is a little bit different. I want you to match the two pictures that go together. Let's practice"

[Lay down the 2 pairs/4 pictures of practice pictures so they are not directly next to the match. Point to one picture and then point to the match. Put the two pictures together and to the side. Do the same with the second pair of pictures]

"Do you have any questions? Ok, now it's your turn."

[Lay down one set of 6 pictures at random on one side of the table right side up to the participant. Lay the other set of 6 pictures at random on the other side of the table. The two groups of pictures should be no more than 24 inches away from the participant.]

"Ok, will you please match these pictures [gesture to one set of 6] with these pictures [gesture to the other set of 6]."

[If they are unable to pass the visual screening, they will be rescreened during the following session. If they fail the screening procedure twice, they will be referred to an optometrist.]

Orofacial Examination. "I am going to look inside your mouth to make sure everything looks healthy. I also want to make sure your mouth is working ok so we are going to do a few exercises. I will explain and show them all to you as we go. Please let me know if you have any questions at any point. Have you had any pain or injuries recently? Do you have any trouble eating or swallowing? Ok, let's get started."

[Use the Orofacial Examination protocol to guide your evaluation. Explain and then demonstrate each task to the participant.]

Visual Form Discrimination. "Now I am going to show you line drawings of some shapes. Then I will show you a page that has four separate drawings. I want you to match the first picture to the same picture from the group of four. Let's practice."

[Present the practice items. If the participant is incorrect, indicate the correct answer and ask the participant to then try again with the same pictures.]

"Do you have any questions? Ok, let's start."

Baseline Scripts Production. "I am going to show you a video of someone talking. You will be able to hear and see them talking at the same time. I want you to try to say the same thing that they are saying while you watch it. You will be talking at the same time as the recording. Let me demonstrate."

[Prop the iPad in front of yourself. Demonstrate the task using the sample script.]

"Do you have any questions? Ok your turn."

[Prop up the iPad on the table directly in front of the participant. The iPad should be no more than 24 inches away from the participant. The participant has one opportunity to produce the entire script.]

Appendix D - Script Examples and Developmental Prompts

Aphasia. I had a stroke on _____. I was only _____years old. I thought stroke only happened to old people. But it can happen to anyone at any age. Now I have a language disorder called aphasia. I have trouble talking and thinking of the exact word I want to say. Sometimes I have difficulty understanding what you say. It is especially hard when the conversation is fast. Aphasia does not affect a person's intelligence or personality. I am still the same _____. (i.e. Holland et al., 2010)

Prompts. What is it, what is it not, how to make communication easier, what makes communication hard, intelligence not affected, when/where it happened, feelings associated with it, age of onset, recovery, emotions involved, reaction of friends/family, etc.

About me. My name is _____ and I am _____ years old. I live in _____, ID. I like the mountains. But I don't like the heat. I have/haven't lived here my whole life. I used to live in _____. I have been married for ____ years and we have ____ children. Before my stroke, I worked as a ____. I liked ____ because _____ (i.e. Holland et al., 2010)

Prompts. Name, age, where do you live, do you like where they live, why/why not, where did they live before, married/not married, kids, where do the kids live, occupation, what they liked about their occupation, etc.

Favorite hobby. My favorite hobby is ____ (cooking). I enjoy ___ (making pie) in my free time. I started ___ when I was ___ years old. I started ____ because _____. I like to ___ because ___. I ___ at least ___ time per week/hours per day. I ___ by myself/with

___ and usually do it at ___. I wish I could do it more! (I spend a lot of time doing it.). The only problem with ___ is that ___. (i.e. Holland et al., 2010)

Prompts. Favorite hobby/interest, when did they start their hobby, how long have they been doing it, what's their favorite project/interest they have ever done, how often do they do it, why do they like it, is there anything they don't like about it, who do they do it with, where do they do it, etc.

Demonstration script. I like to eat scrambled eggs for breakfast. I like them because they are fast and easy. To make eggs I get out a pan and melt some butter over medium heat. I crack the eggs into the pan and stir. I like scrambled eggs best so I stir until they are done (Fridriksson et al., 2012).

Appendix E - Script Scoring Procedures

- Every word in the script is analyzed
    - BOTH function words and content words
- Correct production
    - Accurate and appropriate
    - Minor error: omission of grammatical morpheme ["walk" for "walked"] or a phonemic paraphasia ["tair" for "chair"]
- Incorrect production
    - Unintelligible or unrelated
    - Semantic or verbal paraphasia ["table" for "chair"]
    - Changes target meaning ["bear" for "chair"]
    - No response

Appendix F - Script Teaching and Cueing Hierarchy.

"We are going to practice saying the scripts. The scripts will be played on the iPad. You will be able to watch and listen to a speaker reading the script. First I want you to just watch and listen. Don't try to say anything yet. Just watch the speakers' mouth and listen to the words. Do you have any questions? Ok, let's start."

[Prop up the iPad no further than 24 inches away from the participant. Play the script. If the participant tries to mimic the script, get their attention (touch arm/say name) and put your finger to your lips to indicate they should be quiet. If they continue to try to say the script, pause it and re-explain the instructions.]

"Ok, now that you have listened to the script, I want you to try to say the same thing that the speaker is saying as the recording plays. You will be saying the same words at the same time as the recording. Do you have any questions? Ok, let's try."

[Rewind the script. Place the iPad in front of the participant. Play the script. Record the first word that the participant is unable to produce and pause the script.]

"Let's practice that word. I am going to say this part of the script and I want you to try to say it with me. Instead of watching the iPad, you will watch, listen to, and try to copy me as I speak. We will be speaking at the same time. Do you have any questions? Ok, let's try."

[Train the incorrectly produced word using the least to most phonemic cueing hierarchy. Instruct the participant to focus on your mouth and attempt to speak in tandem with you as you work through the hierarchy. Use the phrase of the script that contains the target word. Implement the hierarchy as follows: silent articulation of the target word, production of the first phoneme of the target word with silent articulation of the

remainder of the word, production of the entire target word. After the participant correctly produces the target word or after the entire hierarchy has been implemented, the hierarchy will be worked in reverse. After the hierarchy was been implemented, rewind the script to the beginning of the phrase that contains the target word, place the iPad in front of the participant, and replay the script. Record the next misarticulated word and use the phonemic hierarchy to train the word. Do not target the same word more than once during treatment.]

"Now that we have worked on the word _____, I want you to try to watch the iPad again."

[Each therapy session will begin by reviewing the script in its entirety. First, the participant will watch and listen to the recorded script as it is produced on the iPad. Next, the participant will be instructed to attempt to mimic the script in its entirety. Then, the script will be rewound and the participant will attempt to mimic it again. At that point, the phonemic cueing hierarchy will be implemented.]

Appendix G - Personalized Scripts

Participant KB

Hi, i'm XXX.
I had a stroke three years ago on XXX.
I was only XXX years old when it happen/ed.
Stroke doesn't just happen to old people.
It can happen to anyone at any age.
Because of my stroke, I have aphasia.
It makes it hard to talk.
But i'm still as sharp as ever.
I just have a hard time coming up with the right words.
Sometimes I need some extra time to think.
Even though it's hard for me to talk, I still understand what you say.
The stroke also made it harder for me to get around like I used to.
I'm still able to walk.
But I use a walker to make sure I don't lose my balance.
It doesn't hold me back though.
I'm still the same XXX.

I have so many hobbies that it's hard to pick a favorite.
Some of my favorites are reading, crocheting, and watching tv.
Before my stroke, I used to crochet all the time.
I was especially good at making hats.
Now my hands don't work as well as they used to.
So it is hard to crochet.
Something else I enjoy is watching tv.
There are a few different shows I like to watch.
I like Ellen, the price-is-right, and the nightly news.
I also really like to watch sport/s, especially if BYU is playing.
I went to college at BYU.
So I cheer for them no matter what.
If i'm not crocheting or watching tv, I really like to read.
My all time favorite books are the Harry Potter series.
They have the best character/s and story lines.
And I could read them over and over.

Hi, my name is XXX.
My birthday is XXX.

Which means that I am XXX years old.
I live in XXX.
But I used to live in Hawaii.
I went to college at BYU on the island of Oahu.
It was on the north shore, about thirty-five miles away from Honolulu.
I would like to go back and visit Hawaii sometime.
Before my stroke, I worked as a substitute teacher.
I worked mainly in elementary schools around XXX.
The kids were always so fun.
And they loved me.
So I really enjoyed my work.
The best part about my job was reading books to the kids.
To this day, reading is still one of my favorite activities.

Participant NW

My name is XXX.
I live in XXX.
But I haven't lived here my whole life.
I used to live in Aberdeen.
It is a small town that is 43 miles away.
Before my stroke, I worked at Lamb Weston.
It was a place that processed potatoes.

I like to watch sports.
My favorite sports are boxing and football.
I don't like basketball or soccer.
I watch football all day on Sunday.
I don't have a favorite player.
I cheer for the Jaguars and Eagles.
They are the best teams.
The Seahawks are the worst.
I like when they lose.

My name is XXX.
I had a stroke on XXX.
I was not very old.
I thought stroke only happened to old people.
But it can happen to anyone at any age.
Now I have aphasia.
I have trouble saying what I want to say.
Sometimes I write instead.
I am still the same XXX.

Participant LH

Hi, my name is XXX.
I had a stroke in XXX when I was only XXX years old.
I thought strokes only happened to old people.
I never thought it would happen to me.
But I guess it can happen to anyone at any age.
Because of the stroke, I have aphasia.
Aphasia makes it harder for me to talk.
I know exactly what I want to say.
I just can't get it out.
Sometimes I need extra time to think of the right word.
So please give me time.
And don't talk too fast.
Aphasia hasn't changed who I am though.
I'm still the same guy that I was before.

It's hard to pick a favorite hobby.
Because there are lots of things I like to do.
I can name a couple things I don't like doing though.
I don't really like to watch movies or listen to music.
There are just better things that I would rather be doing like boating or fishing.
Those are two of my favorite hobbies.
My in-laws got me into boating a long time ago.
We used to go as a family at least two times a month.
But my family and I don't go as often anymore.
I really liked boating.
Because I enjoyed the river.
And I like to fish.
The only bad part about boating is feeling unstable.
You wouldn't want to fall out of the boat!

Hi, my name is XXX.
And I'm XXX years old.
I was born in Idaho.
And have liveed in a couple different towns throughout the state.
I used to live in Nampa.
But now I live in XXX.
I like XXX because of the open space and farmland.
But i'll always love the city of Nampa.
I've been married for many years.
And my wife and I have two sons together.
My family says i'm a jokster.
I do like to make people smile by telling jokes.
I used to have some unique pets including a dog, a horse, and a llama.
I also used to have some pretty unique jobs.
I have worked as a truck driver and as a facility supervisor.
And I used to work in a glass door and window factory.

Now I just like to spend time with my family and enjoy the countryside.

Participant MH

Hi, my name is XXX.
I had a stroke.
So now it's harder for me to talk.
But I can still understand everything you say.
I have been married for 36 years.
And my wife and I have four children.
Our family is really close.
We love each other very much.
And since my accident, we have become even closer to god.
My wife and I live in XXX in a home that we designed ourselves.
One of my favorite parts about our home is the back deck.
It's so peaceful out there.
I like to sit on the deck in my zero gravity chair.
And listen to the birds, and the wind, and the water in our pond.
I like to feel the warmth of the sun.
And in the fall, I like to listen to the leaves rustle on the trees in the wind.
I'm proud of the home we have created.
And I love spending my life with my family.

I have lots of hobbies.
So it is hard to pick a favorite.
I used to really enjoy riding my mountain bike.
I would take it to trails with lots of hills.
Peddling to the top was always so hard.
But it felt so good to reach the top.
Then I would go as fast as I could down the hill.
So I could feel the wind in my face.
I also like to watch football.
I watch both the NFL and the college teams.
Since I watch football so often, by the end of the season, I know all of the players really well.
I know who is the best.
And who should stay on the bench.
I keep my mind and memory strong too.
I play brain games on the computer.
And recently tried to do a rubrics cube.
It's hard.
But I bet I can do it eventually.
Because it's all about math.
And I've always been good at math.

My family is one of the most important parts of my life.

They mean everything to me.
We have shared a lot of experiences together both good and bad.
My family really helped me after I had my stroke.
They surrounded me with love.
And we got through it together.
I think that we are closer now than we have ever been before.
We also have a lot of really great memories together too.
XXX is good at math just like I am.
He is teaching me how to do the rubrics cube.
He is really fast at solving it.
I need to keep practicing so that I can beat him someday.
One of my favorite memories with XXX is when we went turkey hunting.
We tried all day but just couldn't get it!
We still had a great time though.
We made each other laugh by shooting a log instead.
And saying, "take that you" in fake Scottish accents.
We didn't get a turkey.
But at the end of the day that didn't even matter.
My daughter and I both share a love of painting.
We are both artists.
I enjoy talking to her about it.
Because she understands how I feel when i'm painting.
It evokes a lot of emotions and is a good release.
I really do have the best family.
I love them.