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Use of an integrated multimodal communication treatment with individuals with severe traumatic brain injury

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USE OF AN INTEGRATED MULTIMODAL COMMUNICATION TREATMENT WITH INDIVIDUALS WITH SEVERE TRAUMATIC BRAIN INJURY

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ABSTRACT

USE OF AN INTEGRATED MULTIMODAL COMMUNICATION
TREATMENT WITH INDIVIDUALS WITH SEVERE TRAUMATIC BRAIN INJURY

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August 2016

Dissertation supervised by Dr. Sarah E. Wallace

People affected by severe traumatic brain injury (TBI) often live with co-occurring speech and language deficits, including apraxia of speech and dysarthria. Using augmentative and alternative communication (AAC) strategies (e.g., gesturing, writing, speech generating devices and applications) to communicate can help people with TBI compensate for deficits. The most effective method to teach people with TBI to use multiple strategies in resolving communication breakdowns has not been determined. However, recent research suggests the most effective method for teaching with people with aphasia to use AAC strategies to resolve communication breakdowns is an integrated multimodal treatment approach. This study used a multiple baseline, single participant design with 2 participants to measure the outcomes of an integrated multimodal treatment approach implemented with people with severe TBI. Therefore, the purpose of this study was to measure the effectiveness of a multimodal treatment designed to increase communication breakdown resolution and use of alternative communication modalities by individuals with severe TBI. The study included a total of 27 sessions comprised of 4 pre-treatment sessions, 20 treatment sessions, and 3 post-treatment sessions. The dependent variables included the total number of modalities produced in a modality probe task and three measures of communication breakdown resolution during a structured, functional task. The results of the study will lead to future research to improve communication treatment for people with TBI. After implementation of the multimodal treatment, both participants increased the number of modalities they produced during the modality probe. However, these changes only resulted in small or absent effects in communication breakdown resolution variables. Visual analysis suggests that the absence of significant effects may relate to the variability in the participants' performance and some potential gains were noted. Future research should examine use of external aids and cognitive profiles in relation to modality use and success of communicative repair for people with severe TBI.

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Chapter I

Introduction

The lives of people who have sustained severe traumatic brain injury (TBI) are often significantly affected by communication deficits such as those resulting from motor speech or language impairments. Additionally, communication deficits following TBI may result in reduced quality of medical care because individuals cannot effectively communicate about symptoms, preferences, goals, or treatment options. About one third of people with TBI will have resulting dysarthria and another one third of this population may have aphasia (Sarno, Buonaguro, & Levita 1986). Motor speech deficits, resulting in unintelligible or limited speech, can significantly reduce the success with which individuals with TBI engage with others and participate in important life activities. Although some people with TBI experience recovery of natural speech with cognitive improvement, many individuals with TBI do not recover natural speech to a level that meets their communication needs. Without the ability to engage and communicate in various life activities, individuals with TBI and their families may become withdrawn and frustrated, reducing their quality of life. People with TBI can use augmentative and alternative communication (AAC) strategies to supplement or replace insufficient speech (Wallace & Kimbarow, 2016). The use of AAC strategies (e.g., gesturing, writing, speech generating devices and applications) to convey messages may help people with TBI compensate for communication impairments. This study will examine an instructional approach to help people with severe TBI compensate for their communication impairments by using multiple modalities.

Review of Existing Literature

Alternative Communication Modalities & TBI. Currently, limited evidence is available to guide speech-language pathologists' instruction of people with TBI in the use of AAC to effectively express communication intents and repair communication breakdowns. Existing research for AAC interventions following TBI is limited and mostly addresses only two areas. First, researchers examined gesture comprehension by individuals with TBI and found that the participants' understanding improved when verbal information was combined with gestures compared with just verbal or gestural messages alone (Evans & Hux, 2011). However, in this study, the researchers did not examine the participants' production of gestures to communicate; researchers exclusively measured the participants' gesture comprehension. Additionally, researchers have also examined the best design and organization of high-tech AAC systems (i.e., speech generating devices) for people with TBI (e.g., Brown, Thiessen, Beukelman, & Hux, 2015; Snyder, & Hux, 2000; Wallace, Hux, & Beukelman, 2010). Design studies have, in turn, led to research on the acceptance of various AAC strategies for people with TBI (Fager, Hux, Beukelman, & Karantounis, 2006). Many of these studies have examined the use of individual modalities rather than a system of strategies to be used or treated together. However, individuals with TBI will likely require proficiency in a system of multiple strategies so they can flexibly adapt to situation and communication demands as needed (Wallace, Hux, & Beukelman, 2010). Currently, no evidence exists to guide clinicians in multimodality instruction for people with TBI.

Multimodal Treatment for Aphasia. Although the use of a multimodal treatment approach with individuals with severe TBI is not included in existing research, evidence suggests that an integrated approach improves the communicative success of people with aphasia (Carr, Wallace, & Staltari, 2013; Purdy & Van Dyke, 2011; Wallace, Purdy, & Skidmore, 2014; Purdy & Wallace, 2015). For example, Purdy and Van Dyke (2011) studied the effects of a multimodal communication training (MCT) program with two participants with chronic aphasia resulting from stroke. The goal of this MCT was to train the use of multiple communication modalities (i.e., speaking, writing, gesturing) at the same time; for one concept at a time. Results indicated that a MCT increased modality switching behavior for two participants with chronic aphasia. Through this treatment, the researchers intended to strengthen semantic networks and improve switching behavior during conversation.

Similarly, researchers found increased accuracy in the production of various communication modalities using a multimodal treatment approach for people with acute aphasia during inpatient rehabilitation (Wallace, Purdy, & Skidmore, 2014). These researchers studied the effects of a multimodal communication program (MCP) to improve communication modality instruction and to facilitate switching behavior to resolve communication breakdowns for people with aphasia during acute stroke rehabilitation. The results of this study indicated that participants' accuracy in producing various alternate communication modalities increased. However, only one participant displayed increased switching to an alternate modality when the first modality was not effective.

A study conducted by Carr (2013) examined the effects of a semantic + multimodal communication program on switching behavior for an individual with severe aphasia. The researcher found improvement in switching behavior and improved simultaneous modality use by the participant. During this study, improvements were not evident until the end of the 12 treatment sessions. The researcher hypothesized consideration of treatment dosage may be warranted given the delayed treatment effect.

Purdy and Wallace (2015) examined the effect of an intensive multimodality communication program on the prevention and repair of communication breakdowns. The participants' number of initial nonverbal successes and the success of communication breakdown repairs using alternative modalities were examined. The researchers found that participants increased their use of nonverbal modalities with some generalization to untrained targets. Two of three participants displayed increased switching to repair communication breakdowns.

In all of the aforementioned studies, all participants were diagnosed with various types and severities of aphasia resulting from stroke. None of the participants included had sustained a TBI or had significant motor speech impairments. Use of a multimodal communication treatment may be modified to be similarly successful for individuals with severe traumatic brain injury. Blake (2016) discusses steps to take when there is an absence of strong evidence for treatment of a population or disorder. These steps include creating treatments based upon theories for the underlying deficits or using treatments originally designed for other populations with similar deficits or needs. People with TBI may require a system of communication strategies and have difficulty with communication breakdown resolution and cognitive flexibility as do people with aphasia who have insufficient speech. Also, Purdy and Van Dyke (2011) discuss that the multimodal communication training (MCT) used in their research study may be more beneficial for individuals with fewer significant semantic deficits. Moreover, the authors emphasized the importance providing an integrated treatment for people with executive function impairments to use strategies to resolve communication breakdowns in functional settings. Specifically, the authors' integrated treatment involved teaching strategies simultaneously for a single concept rather than teaching one strategy to mastery before teaching the next. Although this study was completed for people with aphasia, individuals with TBI may present with similar needs but with intact semantic representations for targets (as opposed to someone with significant aphasia) and co-occurring executive function deficits.

Application to TBI.

The treatment examined within this study combines the limited existing knowledge about AAC strategies for people with TBI with evidence for an intervention found to be successful for some people with aphasia. A multimodal treatment may be appropriate for people with TBI for these three reasons: (1) these individuals might have difficulty problem solving and adapting flexibly to repair breakdowns, (2) people with TBI may have impaired learning resulting in less generalization of strategies practiced in a decontextualized manner, and (3) people with TBI without aphasia have intact semantic representations.

First, people who have cognitive communication problems following a TBI may present with difficulty problem solving and adapting flexibly to achieve a goal due to executive function impairments (Hux & Manasse, 2003). Individuals with TBI may not independently repair breakdowns in communication due to these impairments in executive functioning resulting in effective interactions. A study conducted by Chiou and Kennedy (2009) examined the switching abilities of people with and without aphasia during tasks with minimal language demands. The researchers found that people with aphasia displayed increased difficulty with switching behavior. Thus, the researchers determined that to increase communicative effectiveness, switching behavior must be addressed. Based upon this, integrated practice is believed to help with the executive function of switching as it relates to communication interactions. Therefore, using a multimodal treatment may be beneficial for individuals with severe TBI due to the integrated practice designed to facilitate connections and automaticity among various communications modalities.

Second, this study examined a multimodal treatment approach, with incorporated functional communication practice. Functional practice, described with further detail in the methods section, involved interactive practice where the participant use strategies to communicate messages to the examiner with specific feedback provided. Functional practice is important to incorporate into treatment approaches for people with TBI as people in this population may have impaired learning resulting in less generalization of strategies practiced in a decontextualized manner (Hux, 2011). To maximize the amount of generalization to everyday use, this approach will incorporate simulated communication exchanges throughout treatment. These treatment tasks are also appropriate for this population as the tasks utilize procedural memory, a skill which is often relatively intact in people with TBI (Wallace & Kimbarow, 2016).

Third, people with TBI who do not have moderate to severe aphasia will likely have intact semantic representations of concepts. That is, people with TBI who only present with mild language impairments will likely have intact or mostly intact semantic representations because the underlying cognitive deficits will not affect semantic representations. According to Purdy and Van Dyke (2011), multimodal communication training is built upon three assumptions: (1) all nonverbal and verbal responses are extensions of semantic representations of concepts, (2) effective training involves contacting existing semantic representations, and (3) the training involves flexible movement between these verbal and nonverbal modalities. Therefore, as people with TBI and low intelligibility may have higher levels of semantic representations of concepts than people with aphasia, incorporating strategies may improve communicative effectiveness.

Purpose & Research Questions

Integrated, evidence-based instruction in the use of multiple communication modalities (verbal and nonverbal) may result in improved use of modalities to effectively communicate and repair communication breakdowns. This approach may consequently reduce communication breakdowns, thus increasing the person's participation in life activities and successful communication of medical information despite acquired speech and language deficits. The purpose of this study is to measure the effectiveness of a multimodal treatment designed to increase communication breakdown resolution and use of alternative communication modalities by individuals with severe TBI. The following questions will be addressed in this study:

1. What is the effect of a multimodal communication treatment on the use of alternative modalities (e.g., gesturing, drawing, writing, selecting messages on a mobile device) in individuals with severe traumatic brain injury and poor intelligibility?
2. What is the effect of a multimodal communication treatment on communication breakdown resolution, modality switching, and correct initial nonverbal productions in individuals with severe traumatic brain injury and poor intelligibility?

Chapter II

Methods

Study Design

This study examined an innovative treatment approach to compensate for diminished communication abilities in people with severe TBI using a multiple baseline, single-participant, ABBA design. This design is appropriate for a preliminary study of the treatment effects of a multimodal communication treatment for individuals with severe TBI. The single-participant design of this study, including two participants, is appropriate due to the population's heterogenic nature and the study's exploratory purpose.

The three primary dependent variables of this study included one variable measured during a modality probe (total production of modalities) and three variables measured during the referential communication task (RCT). The three RCT variables included: 1.) the percentage of successfully repaired communication breakdowns (communicative repair score), 2.) percentage of modality switching, and 3.) correct initial nonverbal productions of modalities. All primary dependent variables are outlined in Table 1 below.

Table 1. Dependent Variables by Study Task

Dependent Variables by Study Task	
Modality Probe	Referential Communication Task
• Total Production of Modalities	• Communicative Repair Score • Percentage of Modality Switching • Correct Initial Nonverbal Productions

Participants

Two participants with severe TBI resulting in reduced intelligibility and unmet communication needs were recruited for study participation. To participate in the study, individuals were required to be at least 6 months post-severe TBI and be between 18 and 65 years of age. Severe TBI was judged as self- or caregiver-reported lost consciousness for more than 1 day as well as post-traumatic amnesia for over 1 week (Fortuny, Briggs, Newcombe, Ratcliff, & Thomas, 1980). Participants were required to pass visual and hearing screenings to be included in the study. All participants demonstrate behaviors consistent with at least a Level V on the Ranchos Los Amigos (RLA) Scale of Cognitive Functioning (Hagen, 2000). Finally, participants were required to demonstrate less than 75% intelligibility on the *Assessment of Intelligibility of Dysarthric Speech* (AIDS) (Yorkston, & Beukelman, 1984). These measurements ensured that participants included in the study had a need to utilize modalities other than speech. Participants' written naming abilities and fine motor abilities were screened using the *Cognitive Linguistic Quick Test* (*CLQT*) (Helm-Estabrooks, 2001) confrontation naming subtest, responding with writing rather than speech. For inclusion, participants had to perform at a minimum level of 70% accuracy (correctly writing the name of at least 7/10 items). As a written naming task, this also screened the participants' motor skills to ensure they could use at least one hand during treatment. The *Comprehensive Aphasia Test* (*CAT*) (Swinburn, Porter, & Howard, 2005) subtest for sentence level comprehension was used to screen the participants' auditory comprehension level for treatment. Participants had to achieve a minimum of 70% accuracy on the sentence level subtest of the *CAT*; participants scoring less than 90% accuracy on the sentence level subtest of the *CAT* were provided clinician support to aid comprehension. The *CAT* Disability Questionnaire communication subtest was administered to both participants to confirm the presence of unmet communication needs.

Exclusionary criteria included self-reported history of speech, language, or cognitive deficits prior to sustaining a severe TBI, and self-reported history of hospitalization for depression or psychiatric disorders in the last 6 months.

Participants were recruited from the Duquesne University Speech-Language-Hearing Clinic and local facilities that provide services to people with TBI. Two individuals met study criteria. A third individual was recruited, consented, and completed a screening session but did not meet study criteria due to significant expressive and receptive language impairments.

Participant 1. Participant 1 was a 21year old male who sustained a TBI 50 months prior to the study following a motor vehicle accident (see Table 2). Prior to his accident, he completed 11^{th} grade and returned to high school following his injury until 21 years of age. He currently resides with his immediate family, is unemployed, and participates in various community support groups for people with TBI. Upon his injury, he experienced a loss of consciousness for 49 days and post traumatic amnesia for approximately 2 weeks. His mother reported that he experienced global and diffuse brain damage. Participant 1's RLA Scale of Cognitive Functioning Level was VII at the time of the study. He had co-occurring right side hemiplegia and spasticity in his right hand. Participant 1's speech at the word and sentence level was found to be 56.3% intelligible to a naïve listener. His low intelligibility was secondary to mixed dysarthria. He scored 87.5% accuracy on the CAT sentence level comprehension subtest and achieved 100% accuracy during the CLQT confrontation naming subtest (modified to allow for written instead of verbal response). He also completed the CAT Disability Questionnaire which showed unmet communication needs (expressive and receptive) when communicating with unfamiliar people and writing single words to communicate. He rated his level of worry regarding his communication skills as 3 out of 4 and feeling isolated as 2 out of 4 (4 indicating a "major problem"). Prior to his injury, participant 1 was right handed but he currently uses both hands for functional tasks such as writing.

Table 2. Participant 1 Profile

Participant 1	
Age	21
Gender	Male
Time Post-Injury	50 Months
Loss of Consciousness	49 Days
Post-Traumatic Amnesia	2 Weeks
Handedness Prior to Injury	Right
Handedness Post-Injury	Right and Left
Ranchos Los Amigos Scale of Cognitive Functioning Level	Level VII
Assessment of Intelligibility of Dysarthric Speech (Word and Sentence Level)	56.3%
Comprehensive Aphasia Test (CAT)- Sentence Level Comprehension Subtest	87.5%
Cognitive Linguistic Quick Test (CLQT)- Confrontation Naming Subtest Modified for Written Responses	100%

Participant 2. Participant 2 was a 62 year old male who was 149 months post right frontal lobe TBI (Table 3). He experienced a loss of consciousness for 2 weeks and post-traumatic amnesia for 2 additional weeks. He demonstrated behaviors consistent with a RLA Level of VI at the time of the study. He was unemployed and resided at a long-term care facility. Following his injury, participant 2 presented with apraxia of speech, mild to moderate aphasia, and dysphagia. He was nonverbal, aphonic, and unable to approximate words due to his severe vocal and oral apraxia and apraxia of speech. Therefore, participant 3 scored 0% intelligible using the AIDS. Participant 2 achieved 87.5% accuracy on the CAT sentence level comprehension subtest and 75% accuracy on the CLQT confrontation naming subtest (modified as written). Participant 2's unmet communication needs were confirmed using the CAT disability questionnaire. He reported difficulty communicating (expressively) with the person closest to him, close friends and family, and higher levels of difficulty communicating with strangers. He

also reported trouble understanding strangers as well as 3-4 friends and family, and difficulty writing to communicate (word level). Participant 2 reported that his communication deficits (specifically talking) interfere at a level 3 out of a 4 (4 being "a lot"). When asked about self-image, he reported that his communication skills cause worry and affect his confidence "a lot" (4 out 4 on the scale).

Table 3. Participant 2 Profile

Participant 2	
Age	62
Gender	Male
Time Post-Injury	149 Months
Loss of Consciousness	2 Weeks
Post-Traumatic Amnesia	2 Weeks
Handedness Prior to Injury	Right
Handedness Post-Injury	Right
Ranchos Los Amigos Scale of Cognitive Functioning Level	VI
Assessment of Intelligibility of Dysarthric Speech (Word and Sentence Level)	0%
Comprehensive Aphasia Test (CAT)- Sentence Level Comprehension Subtest	87.5%
Cognitive Linguistic Quick Test (CLQT)- Confrontation Naming Subtest Modified as Written	75%

Materials

Materials for this study included screening materials, assessments tools and experimental stimuli including an iPad with the text-to-speech application, *Predictable*.

Screening materials. Screening materials included a demographic form, vision screening, intelligibility measures, measures of auditory comprehension and cognitive skills, and a questionnaire for unmet communication needs. The researcher used a demographic form to collect information regarding the participants' medical history (See Appendix B). The vision screening involved having the participants circle their names, among others, in various positions on a piece of paper (See Appendix C).

Additionally, the researcher used an intelligibility measure to determine if participants met study criteria. Administration of the *AIDS* included recordings of the participants orally reading single words and sentences that were judged by blind, novel, listeners to determine intelligibility.

The researcher used the *CAT* comprehension of spoken words and comprehension of spoken sentences subtests to ensure the participants had adequate auditory comprehension skills to participate in this study. The communication portion of the Disability Questionnaire from the *CAT* confirmed the presence of unmet communication needs.

Finally, the researcher used the CLQT confrontation naming subtest, modified to have the participants perform written confrontation naming as a screening for severe word finding or motor abilities that would interfere with study tasks.

Assessment tools. Administration of formal assessments before and after intervention provided descriptive information of the participants' cognitive and communication abilities as well as measured any changes in those skills following intervention. Formal assessment tools included the *CLQT* and the *Communicative Abilities of Daily Living-Second Edition* (*CADL-2*) (Holland, Frattali, & Fromm, 1999).

The researcher administered the CLQT subtests to determine various cognitive skills of participants. Subtests included those that do not require verbal responses such as Symbol Cancellation, Clock Drawing, Symbol Trails, Design Memory, Mazes, and Design Generation subtests.

The researcher administered the *CADL-2* to determine the participants' functional communication ability. This assessment was particularly relevant to this study because it allows participants to use multiple modalities (point, write, draw, gesture, and verbalize) to express responses to functional questions.

Experimental Stimuli

Experimental stimuli included word lists, an iPad with the *Predictable* text-to-speech application, and images. Additionally, video recording equipment was used throughout the study for data collection and verification of study procedures.

Word Lists. Three word lists of 30 target nouns were utilized during the study. The target words were randomly divided into three balanced word lists with 10 words each. Each word list was balanced for complexity of production of communication modalities, number of syllables, frequency of occurrence (Francis & Kucera, 1982), and naming reaction time (http://elexicon.wustl.edu/). Word lists were used across baseline, probe tasks, treatment, and post-treatment sessions. List A was treated during treatment phase 1, while list B was probed and List C (untreated list) was probed the first session of phase 1 and 3 sessions prior to the completion of phase 1. During treatment phase 2, List B was treated, List C was probed, and List A was probed the first session of phase 2 and 3 sessions prior to the completion of phase 2. By not training list C, a measure of generalization to untreated words and control for frequent probing was in place. Refer to Table 4, below, for an outline of how each word list was used.

Table 4. Word List and Treatment Phase Outline.

<table>
<tr><th>List</th><th>Baseline</th><th>Treatment Phase 1</th><th>Treatment Phase 2</th><th>Post-Treatment</th></tr>
<tr><td>A</td><td rowspan="3">Probe All Lists Baseline Sessions</td><td>Treat & Probe Sessions 1 to 10</td><td>Probe Sessions 11, 18, 19, & 20</td><td rowspan="3">Probe All Lists Post-Treatment Sessions</td></tr>
<tr><td>B</td><td>Probe Sessions 1 to 10</td><td>Treat & Probe Sessions 11 to 20</td></tr>
<tr><td>C</td><td>Probe Sessions 1, 8, 9, & 10</td><td>Probe Sessions 11 to 20</td></tr>
</table>

iPad Application. The use of *Predictable,* a text-to-speech application, on the iPad was incorporated into the training of multiple communication modalities. This application uses a touch screen keyboard complete with word prediction features and various voice and selection settings. All participants in this study used the direct touch access selection setting. The entire alphabet is available on the same screen, there is a speak button, and the size of the buttons was approximately ¾ inches by ¾ inches. The iPad used was an iPad Air version 8.4 with a 6.6 by 9.4 inch size screen and OtterBox® Defender protection case.

Images. Images were used to represent each of the 30 target words included in the three word lists. One set of 30 colored photographs was used during treatment. A second set of 30 line drawings were used during the modality probes. A third set of 30 colored photographs was used during the RCT probes by the participant. The communication partner used the set of 30 line drawings from the modality probes. The images used were primarily line drawings online (Snodgrass & Vanderwart, 1980) and photographs available on the internet closely matching the line drawings.

Procedures

This study was conducted at Duquesne University's Speech-Language and Hearing Clinic for participant 1 and at a local care facility for participant 2.

Each participant completed a total of 27 sessions during the study, each lasting approximately 2 hours. The 20 treatment sessions occurred across two treatment phases (10 sessions per phase). Treatment sessions lasted 90-minutes and occurred 2 times per week. Each session began with an additional 30 minutes allotted for probes tasks. Four pre-treatment assessment sessions took place to administer screenings and collect baseline data. Three post-treatment assessment sessions followed the second treatment phase. An outline of study sessions is displayed in Table 5. Baseline and post-treatment assessments included identification of functional communication skills, cognitive skills, and performance on the RCT and modality probes described below.

Table 5. Outline of Study Sessions.

Pre-Treatment Assessment Sessions	**Treatment Phase 1**	**Treatment Phase 2**	**Post-Treatment Assessment Sessions**
- 4 sessions - about 2 hours each	- 10 sessions - about 2 hours each	- 10 sessions - about 2 hours each	- 3 sessions - about 2 hours each

Screening session. Prior to baseline sessions and inclusion in the study, each participant completed screening procedures to determine if he met criteria for inclusion. The researcher conducted a medical history interview, guided by the demographic form, with each participant to determine severity, time post-onset of TBI, and record any premorbid deficits in speech, language, or cognition. Absence of hearing impairments that could interfere with participation in treatment were determined through conversation and self-report. To ensure participants had adequate vision to engage in treatment, a vision screening was conducted. The *AIDS* was administered to ensure low intelligibility and the participants' need for multimodal communication strategies. To complete the *AIDS*, novel listeners examined a recording of the participants' speech and wrote what they perceived to have been said. The researcher compared these responses to the key to determine a percentage of intelligibility. The CLQT confrontation naming subtests (modified to use written responses rather than spoken), the *CAT* comprehension of spoken words and comprehension of spoken sentences subtests, and disability questionnaire were administered to ensure the participants possessed adequate written naming, auditory comprehension skills, and unmet communication needs respectively.

Baseline sessions. The four baseline sessions each lasted approximately two hours. The first baseline session occurred immediately following the screening tasks for both participants. During baseline sessions, the researcher administered the *CLQT* and *CADL-2*. The participant also completed the RCT and modality probes during each baseline session. Probes for all three word lists were completed during each baseline session.

Modality probe task. The modality probe involved the examiner asking the participant to produce each target word by using as many modalities as possible. However, the researcher did not specify the modalities to produce for each target. Instead she prompted the participants with the following same instruction every five targets: "Tell me the picture using any way you can. You can gesture, draw, write, speak, and use the iPad." Targets were presented to participants using pictures on index cards. Each participant was given up to 2 minutes to produce each target using any modality possible. The examiner recorded the modality type used as well as the accuracy of the participants' productions. From the modality probe, the researcher determined which modalities are used accurately as well as the total number of modalities used throughout the study.

Referential communication task. The researcher, the participant, and a communication partner (blind to treated versus untreated stimuli) participated in the RCT. The examiner provided the following instructions to each participant: "I am going to show you a picture. The communication partner has many similar pictures to choose from. You need to help her make a match. To create a match, you will ask her for the picture in any way you can. She will give you the wrong picture if she misunderstands. You can help her understand." The examiner presented the participant with a photograph depicting one of the target words without allowing the communication partner to see the target picture. The participant was given a pen and paper for drawing and the iPad with *Predictable* displayed. This interaction was similar to the game of "go fish" and assessed the participants' abilities to repair and request during communication breakdowns using various modalities. The examiner recorded correct initial nonverbal attempts, modality switching and a communicative repair score from this task.

Probe sessions. Probe sessions took place immediately prior to each treatment session during both treatment phases. Probe sessions were identical to the baseline sessions. During these sessions, the modality probe was completed followed by the RCT for two to three word lists. Refer back to Table 4 for an outline of the probe schedule by word lists.

Modality Probe. The modality probe was completed, as described in the baseline section, during each probe session to monitor treatment effects on each participant's use of alternative modalities.

Referential Communication Task. The RCT occurred as described above. The RCT probe measured treatment effects on the accuracy of modality use, which modalities were used, and the participants' ability to repair communication breakdowns. Therefore, treatment effects on the participants' ability to alternate modalities for successful communication was measured. The percent of successful breakdown resolutions on the second communication attempt was calculated as the communicative repair score. The researcher also examined the number of first communication attempts in which the participants used nonverbal modalities and the number of modality switches (from one modality on the first attempt to a new modality on the second attempt) that occurred. This may indicate whether the participant recognized his need to use nonverbal modalities; immediately choosing to utilize the various nonverbal strategies or switching to a new strategy to repair. Variables examined during the RCT are outlined in Table 1 on page 8.

Treatment sessions. Prior to each treatment session, the modality and RCT probes were completed. The examiner conducted a total of 20 sessions, across 2 phases of 10 sessions each. Each treatment session was completed in a similar structure, including two parts as described below.

Treatment Part One. Part one of each treatment session emphasized the multimodal training of target items. The goal of the multimodal training is to facilitate acquisition and switching of various modalities for the participants to express the target concepts. The participant was presented with a chart (Appendix A) listing the various modalities an individual could use to express a specific concept. The modalities included: state the name, gesture its function, draw a picture, write, and type word on a text-to-speech application (e.g., *Predictable*). Then, the researcher showed the participant a pictured stimulus and demonstrated methods to communicate the target using each modality. The participant imitated the clinician's behavior with verbal cues and hand-over-hand prompting as needed. After all required responses were elicited for the first target, a new target was introduced and the process of demonstration and imitation repeated. Overtime, the researcher faded her support and prompted the participant to complete the task without a model provided.

Treatment Part Two. The second part of each treatment session involved training the communicative use of targets; thus incorporating pragmatic and functional practice into the multimodal treatment as the individual requested targets and repaired breakdowns in communication. The training for communicative use of targets incorporated principles of Promoting Aphasic's Communicative Effectiveness (PACE) treatment (Davis & Wilcox, 1985). Here, the examiner provided communicative practice by prompting the participant to express targets using any modality. For example, the participant was shown a target and prompted to communicate the target to the examiner. The examiner responded to the communication attempt by showing a matching pictured target if the modality used was clear (e.g., a clear gesture for bat). If the attempt was unclear, the examiner expressed confusion and prompted the participant to try another modality to get his message across (e.g., switch from gesturing to writing). Then, the examiner gave feedback on the participants' production and encouraged attempts using other modalities if the message was not understood. For example, the examiner responded as follows: "That was a good gesture. If I did not understand your gesture, what else could you do to help me understand?" As the modalities were practiced in an integrated manner (participant taught to alternate from one modality to another), the goal was to make the process of switching among modalities become automatic.

Individualization of Treatment. The researcher slightly altered treatment protocol to allow for personalized modifications to cueing for participant. Each participant required specific cueing strategies to participate in the intervention. The need for these modifications was evident during the baseline evaluation sessions and therefore, they were implemented across all intervention sessions for each participant.

Participant 1, due to memory deficits, benefitted from use of errorless learning cueing to learn TTS use on the iPad during intervention sessions. Errorless learning involved the examiner teaching use of TTS while allowing participant 1 to make as few errors as possible. The examiner had the participant practice the same pattern to access messages and delete typed targets each practice attempt. Additionally, the examiner used verbal cues and modeling as needed to demonstrate the sequenced use to type into the app. Participant 2 benefitted from rate control strategies and increased verbal or hand-over-hand cueing to redirect perseverative and impulsive behaviors. For example, when writing, participant 2 often continued to write a word in a repetitive manner until the examiner placed her hand over top of his and redirected his behavior to something new.

Post-treatment sessions. Three post-treatment sessions took place following the completion of the second treatment phase. Formal assessments administered include the *CLQT* subtests and *CADL-2*. The RCT and modality probes were also completed during each post-treatment session. Refer to Table 6 below for an outline of the task schedule within study sessions used for both participants.

Table 6. Task Schedule within Study Sessions.

<table>
<tr>
<td><u>Screening/Baseline 1</u>
• Demographic Form
• Vision Screening
• AIDS
• CAT
• Baseline Modality (1)
• Baseline RCT (1)</td>
<td><u>Baseline 2</u>
• CADL-2 (1)
• Baseline Modality (2)
• Baseline RCT (2)</td>
<td><u>Baseline 3</u>
• CADL-2 (2)
• CLQT
• Baseline Modality (3)
• Baseline RCT (3)</td>
<td><u>Baseline 4</u>
• CADL-2 (3)
• Baseline Modality (4)
• Baseline RCT (4)</td>
</tr>
<tr>
<td colspan="4"><u>Treatment Sessions 1-10 (Treatment Phase 1)</u>
• Modality Probe
• RCT Probe
• Treatment for List A
• List C probed sessions 1, 8, 9, & 10; List A &B probed sessions 1-10</td>
</tr>
<tr>
<td colspan="4"><u>Treatment Sessions 11-20 (Treatment Phase 2)</u>
• Modality Probe
• RCT Probe
• Treatment for List B
• List A probed sessions 11, 18, 19, & 20; List B & C probed sessions 11-20</td>
</tr>
<tr>
<td><u>Post-Treatment 1</u>
• Modality Probe (1)
• RCT Probe (1)
• CLQT</td>
<td><u>Post-Treatment 2</u>
• Modality Probe (2)
• RCT Probe (2)
• CADL-2</td>
<td colspan="2"><u>Post-Treatment 3</u>
• Modality Probe (3)
• RCT Probe (3)
• CAT (Disability Questionnaire Only)</td>
</tr>
</table>

Data Collection, Organization, & Analysis

Data was recorded using the video and audio recording in the Duquesne University Speech-Language-Hearing Clinic and from a portable video camera. The researcher collected two types of data: performance during experimental tasks and performance on standardized assessment tools. Specifically, the researchers evaluated performance during the modality and RCT probes to determine treatment effects on alternate modality use and communication breakdown resolution. The researcher conducted an assessment of reliability, treatment fidelity, and procedural integrity.

Total modality production analysis. Participants' production of targets using possible modalities was examined during the modality probe task. The number of accurate productions and type of modalities used was recorded for each target. Data collected was analyzed for effect sizes, calculated as described by Beeson and Robey (2006), pre and post-treatment. Baseline scores were averaged to represent (A_1) and calculated to determine the standard deviation (S_1). Post-treatment scores were averaged (A_2). The following formula was used to measure effect size:

$$Effect\ Size = \frac{A_2 - A_1}{S_1}$$

A visual analysis of the data as described by Kratochwill and colleagues (2010) was also conducted to determine the relationship between use of alternative modalities and a multimodal communication approach. The visual analysis was used to determine level, trend, variability, overlap between phases, and immediacy of effect across treatment phases. Level included visualizing the mean for all data points within a phase (e.g., baseline, treatment phase 1, treatment phase 2, and post-treatment) was determined by calculating the average and ` Trend was determined using the best fit line of data points for each phase and word list. The variability is reported as the range of 1 standard deviation above and below the trend line during each study phase. The degree of overlap between phases was analyzed as the number of data points within a phase that overlapped with the highest point of data from the previous phase. The researcher examined the degree of overlap between adjacent study phases for each word list. Researchers visually compared the last three data points of one phase and the first three data points of the next phase using shapes (i.e., ovals, rectangles and triangles) to observe the immediacy of effect for total production of modalities.

Referential communication task (RCT) analysis. The researcher analyzed the participants' data related to initial nonverbal communicative attempts, percentage of modality switching, and communication repair within the RCT. Communicative modality switching involved two important components (Purdy, & Wallace, 2015). First, the use of an initial nonverbal communication modality potentially suggests that the person predicted his need to use a nonverbal modality rather than the more automatic verbal modality and therefore used a nonverbal modality as an initial communicative attempt. Second, when a first communication attempt (either verbal or nonverbal) is unsuccessful, if the person switches to another modality to successfully communicate a message the person is said to be using a component of switching called communication repair.

The number of accurate initial non-verbal attempts was recorded. Additionally, the researcher measured the type of nonverbal modality used. The communicative repair score was calculated as the percentage of successful second attempts out of the number of repairs needed. For the percentage of modality switching, the researcher divided the number of opportunities to repair (2^{nd} attempts) by the number of second attempts where the participant switched to a different modality for each word list.

Each participant's pre and post-treatment scores were examined by calculating effect as described by Beeson and Robey (2006). Baseline scores were averaged to represent (A_1) and calculated to determine the standard deviation (S_1). Post-treatment scores were averaged (A_2). The same formula was used to measure effect size.

A visual analysis was conducted to determine the relationship between both types of switching and the multimodal communication approach as described by Kratochwill and colleagues (2010). The visual analysis determined level, trend, and variability across treatment phases.

Formal Assessment. Researchers used descriptive analysis of formal assessments (i.e., *CLQT* and *CADL-2*) to determine changes in performance between baseline and post-treatment sessions. The communication subtest of the *CAT* Disability Questionnaire was also administered pre and post-treatment to gather descriptive information about changes in participants' perception of their communication abilities.

Reliability

To improve reliability, measures were taken to ensure consistency of procedures across participants and trials. A second rater (speech-language pathology student) familiar with the multimodal treatment and blind to treated and untreated words scored 20% of collected session videos. First, the researcher and the second rater completed scoring for multiple sessions together to establish scoring guidelines. Then, for another 20% of videos they determined percent agreement. For all RCT variables their agreement was 100%. For the modality probe, their agreement was 97.8%. The researcher and second rater resolved discrepancies through discussion.

Treatment Fidelity and Procedural Integrity

A checklist of visible elements (e.g., presenting directions, randomized presentation of targets during treatment) that each treatment session should include was completed by two speech language pathology undergraduate students, familiar with the multimodal treatment but blind to treated and untreated words, for 20% of the treatment sessions. The undergraduate students determined that the researcher followed 100% of the guidelines for treatment sessions.

Chapter III

Results

Each study session was video-recorded and all nonverbal and verbal responses were transcribed from the modality probe tasks and RCT. Results include information from visual analysis and effect sizes for modality probes and RCT probes

Participant 1 Results

Modality probe. Participant 1's total production of modalities was assessed using regular modality probes throughout baseline, treatment, and post-treatment sessions. The maximum number of modalities Participant 1 could achieve was 50. For example, if he produced all 5 modalities for 10 words in a list, he would earn a score of 50. In contrast, if he produced 1 modality for 10 words in a list he would earn a score of 10. He improved his productions of the five modalities during the modality probe task with small effect sizes for word lists 1 and 3 (Table 7). He demonstrated most improvement in his use of gestures, drawings, and TTS (Figure 2). Figure 1 displays participant 1's total production of modalities across each word list. Participant 1's average total production of modalities ranged from 22.4 pre-treatment to 44.3 post-treatment for word list 1 and 24.6 pre-treatment to 40.7 post-treatment for word list 2 (both treated word lists). His average for word list 3 also increased from an average total production of 21.4 modalities at baseline to 38.7 modalities post-treatment.

Table 7. Participant 1 Total Production of Modalities

	Word List 1	Word List 2	Word List 3
Average Pre-Treatment	22.4	24.6	21.4
Average Post-Treatment	44.3	40.7	38.7
P1 Effect Size	5.27 (small)	3.71 (not significant)	6.39 (small)

*Cohen's (1998) d statistics as calculated by Busk and Serlin (1992)
**Benchmarks of 4.0, 7.0 and 10.1 for small, medium, and large effect sizes from lexical retrieval treatment studies with people with aphasia (Robey & Beeson, 2005)

Figure 1. Total Production of Modalities

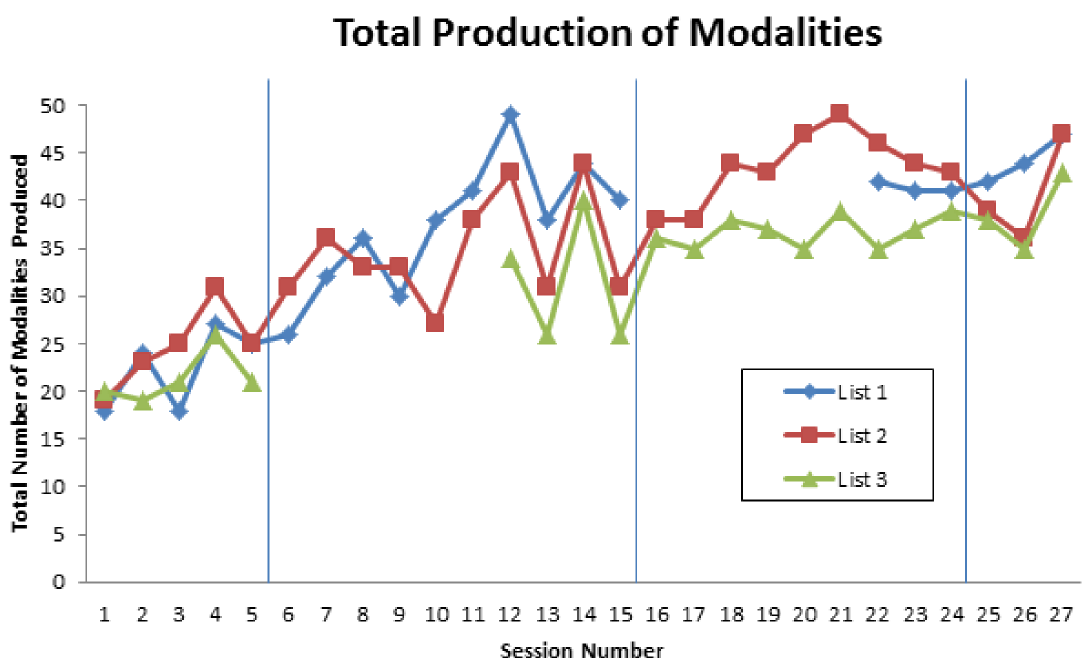
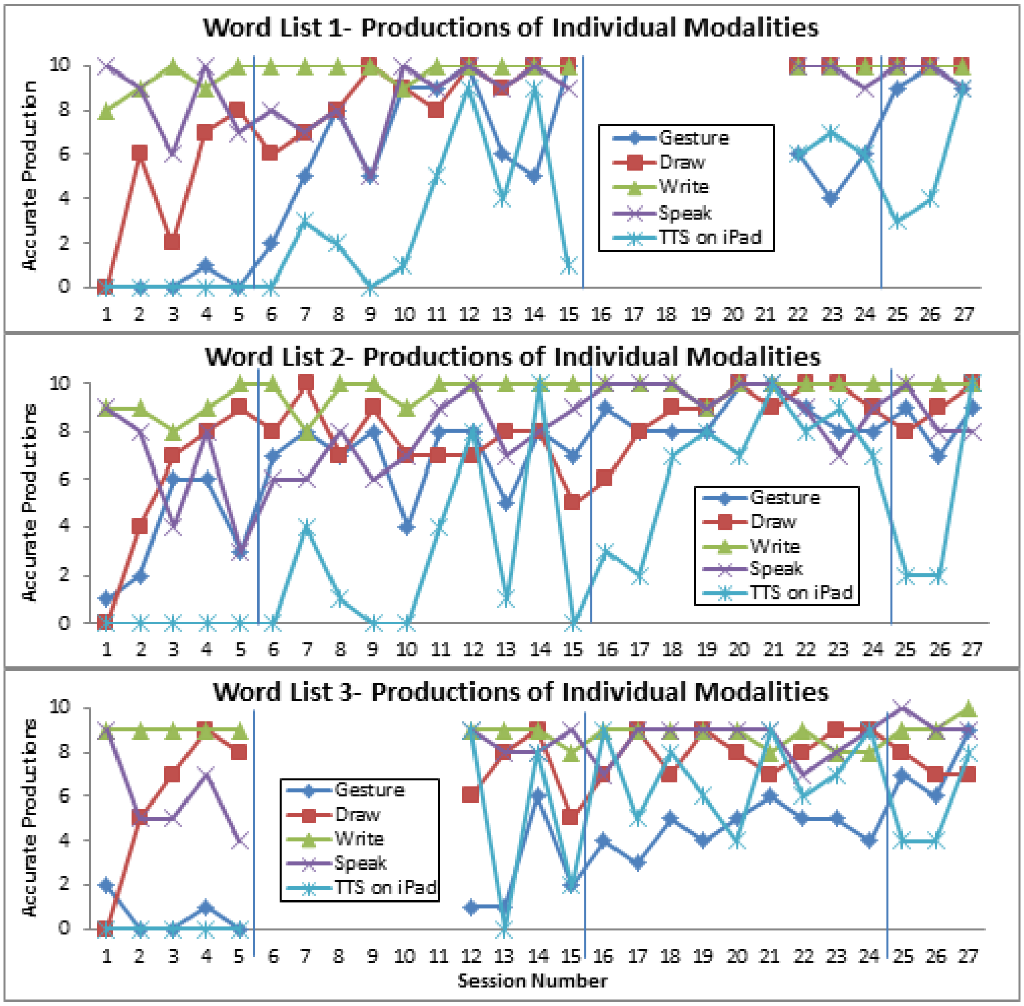


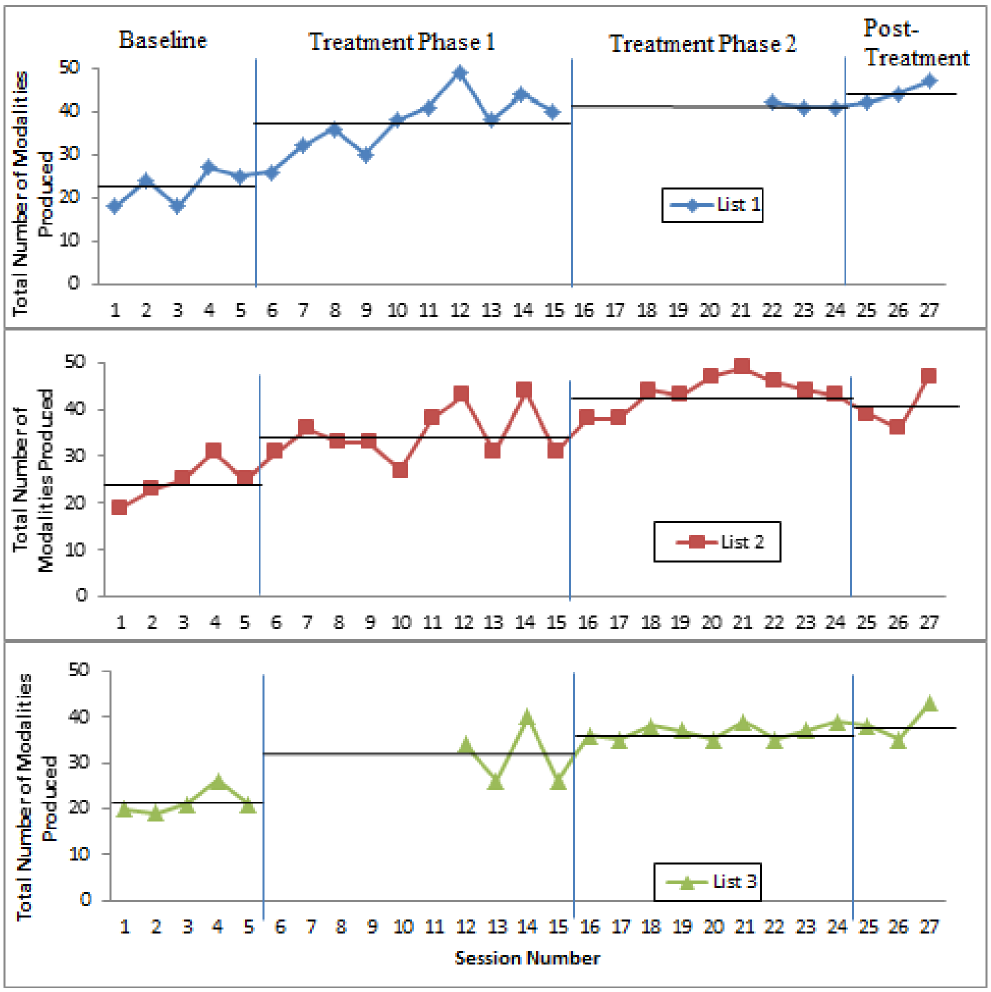
Figure 2. Participant 1 Production of Individual Modalities by Word List



Modality probe visual analysis. The researcher completed visual analysis for participant 1's total production of modalities including level, trend, variability, overlap between phases, and immediacy of the effect.

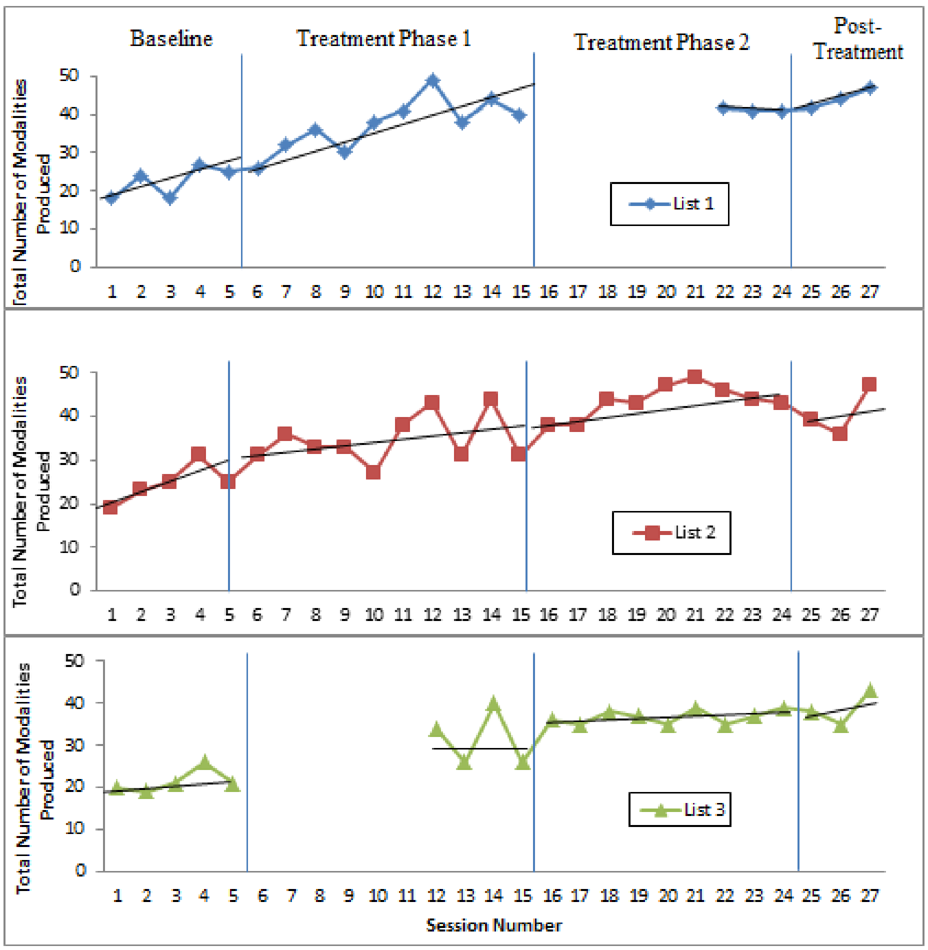
Level. For word list 1 (treated during phase 1), the mean number of modalities produced pre-treatment was 22.4, during treatment phase 1 was 37.1, during treatment phase 2 was 41, and post-treatment was 44.3. For word list 2 (treated during phase 2), the mean number of modalities produced pre-treatment was 24.6, during treatment phase 1 was 35.1, during treatment phase 2 was 42.3, and post-treatment was 40.1. Analysis of word list 3 (untreated) revealed a mean number of 21.4 total modalities at baseline, 33.3 total modalities during treatment phase 1, 35.7 during treatment phase 2, and 38.7 total modalities post-treatment. Figure 3, below, displays level by word list.

Figure 3. Participant 1 Total Production of Modalities Visual Analysis- Level



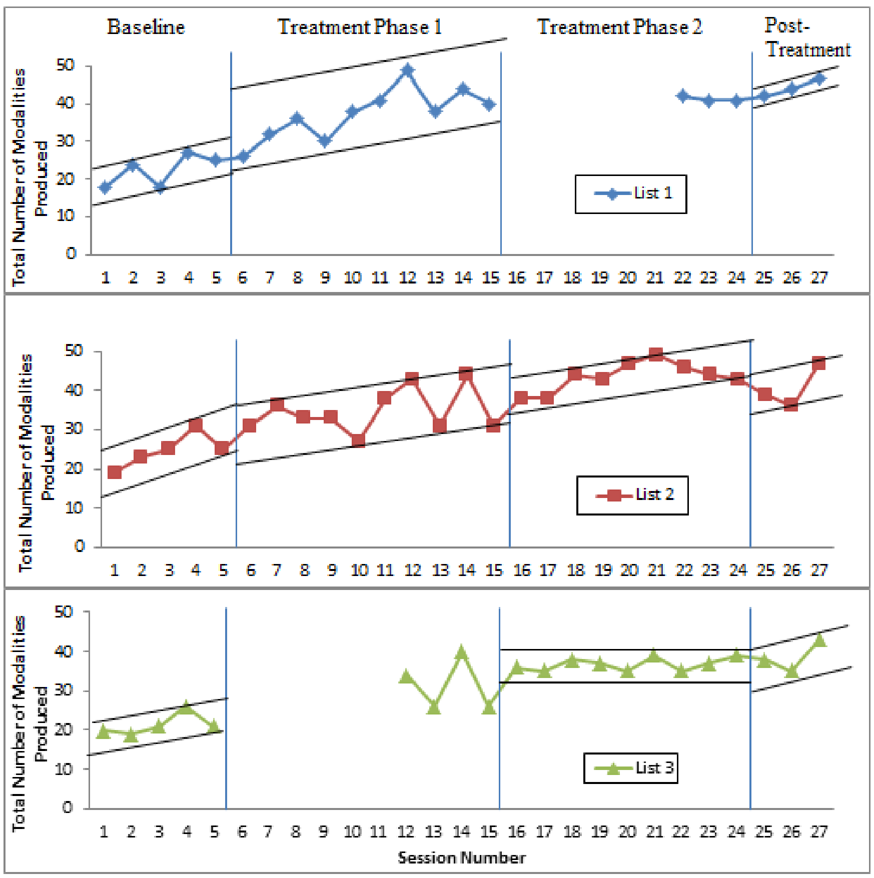
Trend. Trend was determined using the best fit line of data points for each phase and word list. A graph of the trend line for each word list for participant 1's total production of modalities is available, below, in Figure 4. The trend line at baseline for word list 1 showed a slight but stable increase in total number of modalities produced. For treatment phase 1, participant 1's trend line for total production of modalities displayed a positive increase in total number of modalities produced for word list 1 and word list 2 (more notable increase for list 1). Word list 2 continued to increase in a positive direction during treatment phase 2 while word list 3 (untreated) appeared to stabilize. Trend lines post-treatment revealed stable or continued minimal increases in participant 1's total production of modalities for all word lists following the conclusion of intervention.

Figure 4. P1 Total Production of Modalities-Trend



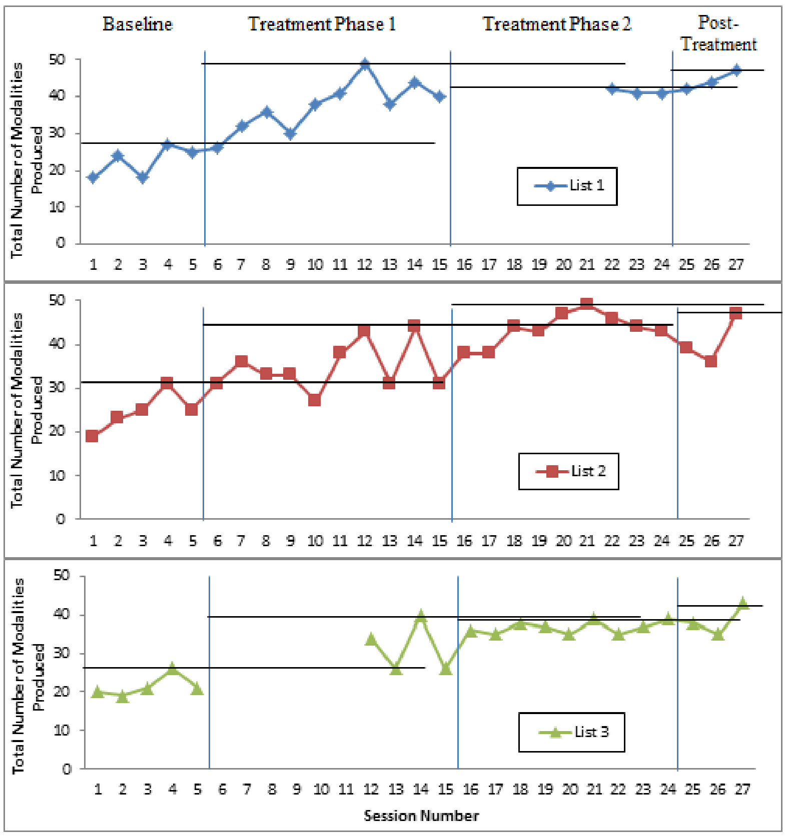
Variability. The variability is reported as the range of 1 standard deviation above and below the trend line during each study phase. Figure 5, below, displays participant 1's variability for total production of modalities across each word list. When contrasting participant 1's variability in total production of modalities at baseline and post-treatment, a notable decrease in variability is found following the conclusion of treatment for word list 1. Variability for word lists 2 and 3 remained the same or slightly increased post-treatment. However, during treatment phase 1, the start of intervention, his variability initially increased compared to baseline. During treatment phase 2, his variability on all word lists decreased and his performance appeared to stabilize for word list 3.

Figure 5. P1 Total Production of Modalities- Variability



Degree of overlap between phases. The degree of overlap between phases was analyzed as the number of data points within a phase that overlapped with the highest point of data from the previous phase. The researcher examined the degree of overlap between adjacent study phases for each word list. Participant 1's total production of modalities and degree of overlap between phases is displayed, below, in Figure 6. Between baseline and treatment phase 1, word list 1 had 1 overlapping data point (10%), word list 2 had 4 (40%), and word list 3 had 2 (20%). Between treatment phase 1 and treatment phase 2, word list 1 had 3 overlapping data points (100%), word list 2 had 6 (67%), and word list 3 had 9 (100%). Between treatment phase 2 and post-treatment, word list 1 had 1 over lapping data point (33%), word list 2 had 3 (100%), and word list 3 had 2 (67%). The least amount of overlapping occurred during treatment phase 1 suggesting that increased change in total production of modalities was most evident at this time.

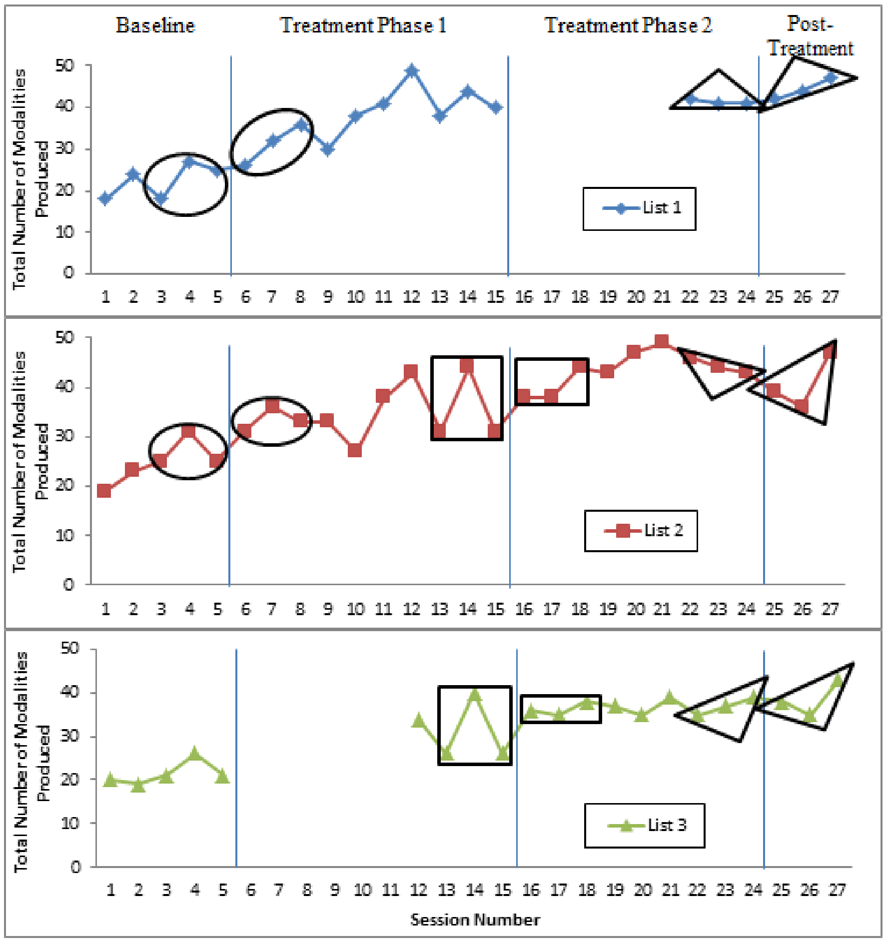
Figure 6. P1 Total Production of Modalities- Overlap Between Phases



Immediacy of effect. Researchers visually compared the last three data points of one phase and the first three data points of the next phase using shapes (i.e., ovals, rectangles and triangles) to observe the immediacy of effect for total production of modalities (Figure 7). Immediacy of effect was noted with a positive effect between pre-treatment and treatment phase

1 for word lists 1 & 2. Immediate decrease in variability was also noted for word lists 2 and 3 between treatment phases 1 and 2.

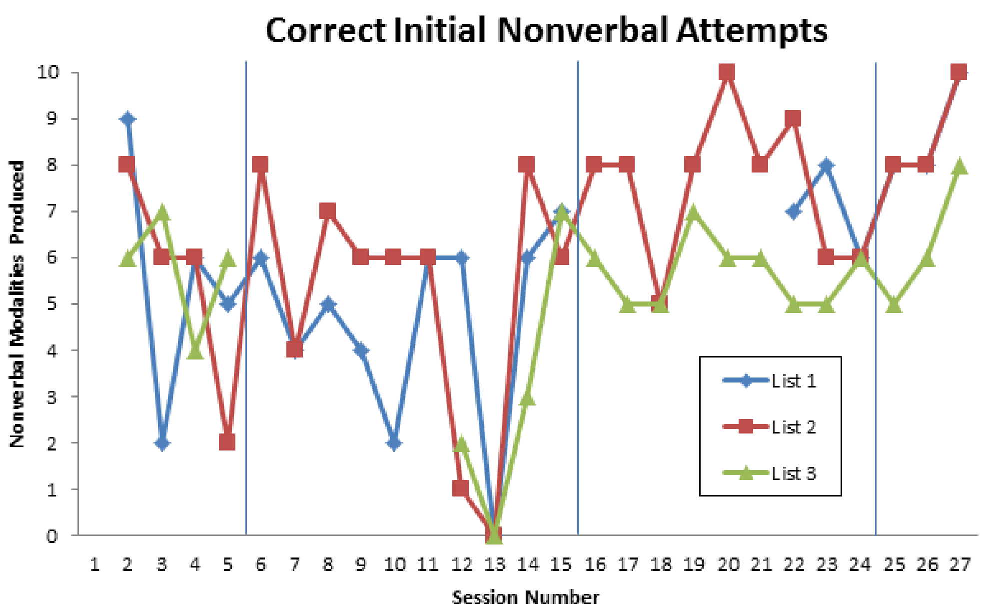
Figure 7. Participant 1 Total Production of Modalities- Immediacy of Effect



Referential Communication Task (RCT). Participant 1's performance on initial nonverbal successes, modality switching, and communicative repair score were analyzed from the RCT.

Correct initial nonverbal attempts. Participant 1's initial nonverbal modality use revealed no significant effect (Table 8) sizes as he was highly variable for all word lists during pre-treatment. Table 8 also displays minimal increases in average number of correct initial nonverbal modalities post-treatment and a decrease in standard deviation for this variable from pre to post-treatment for all word lists. However, during and after phase 2, Participant 1 consistently produced correct initial nonverbal attempts for at least 5 words from each list (Figure 8).

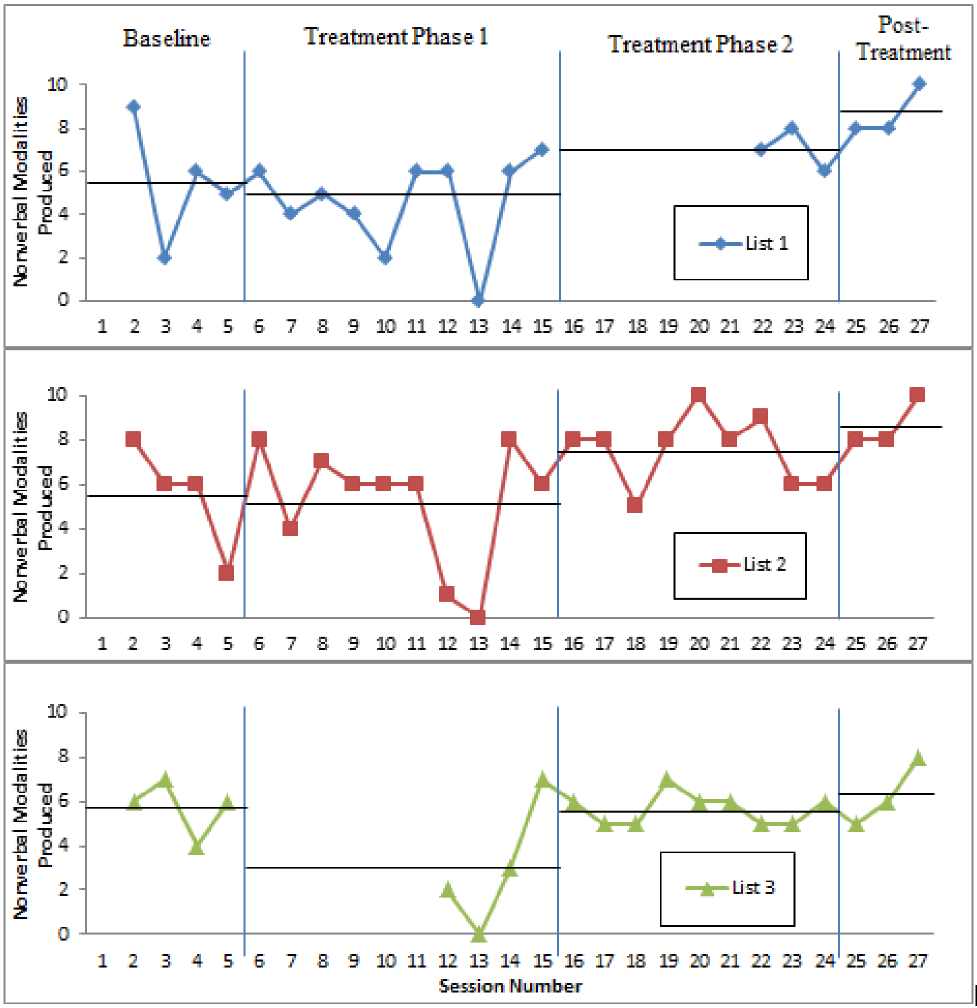
Figure 8. Participant 1 Correct Initial Nonverbal Attempts



Correct initial nonverbal attempts visual analysis. The researcher completed visual analyses for participant 1's correct initial nonverbal productions including level, trend, variability, overlap between phases, and immediacy of the effect.

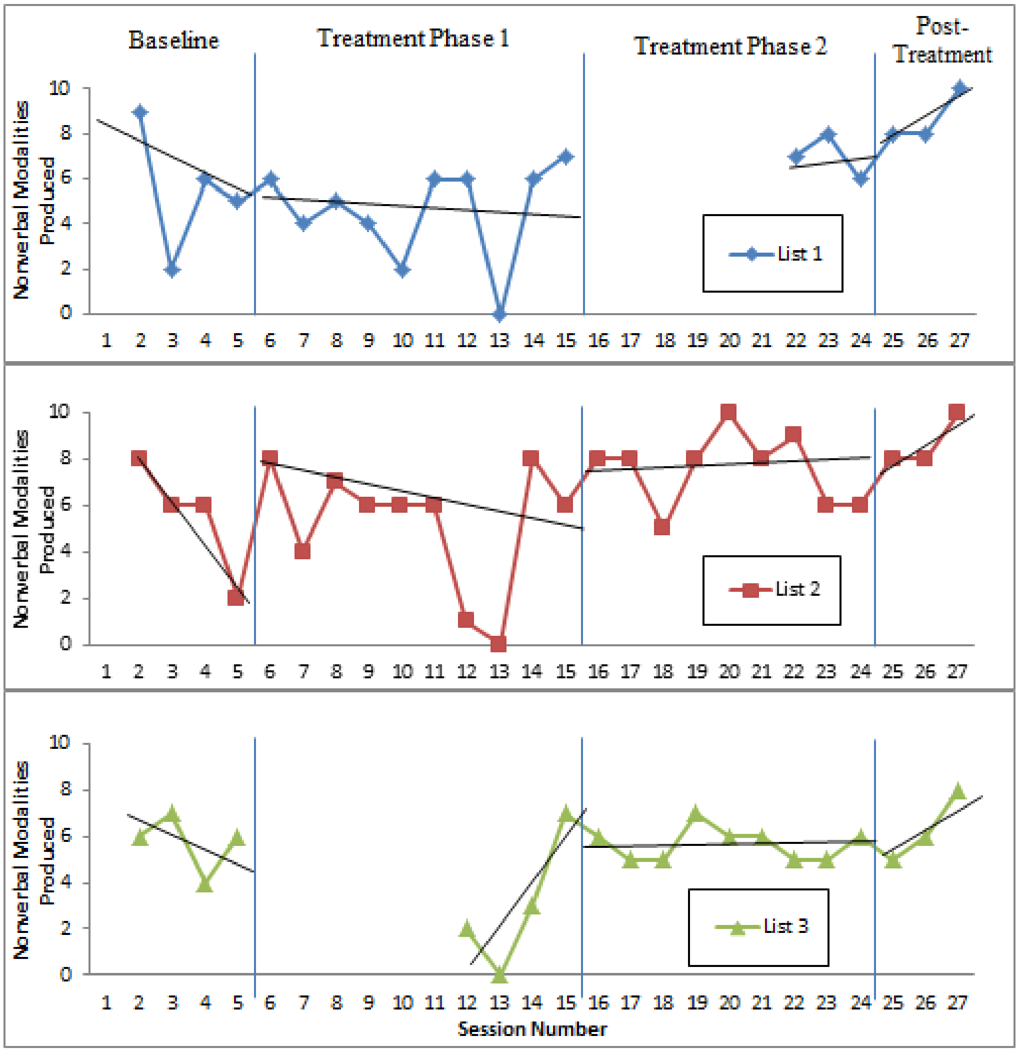
Level. Figure 9, below, displays the analysis of level for participant 1's correct initial nonverbal productions across each word list. From baseline to treatment phase 1, there was a small negative change in participant 1's mean number of correct initial nonverbal attempts (Table 8). From treatment phase 1 to treatment phase 2 there was a positive change in his mean number of correct initial nonverbal attempts that continued to increase post-treatment. For word list 1, his mean number of correct initial nonverbal modalities was 5.5 pre-treatment, 4.6 during phase 1, 7 during phase 2, and 8.67 post treatment. Analysis of level for word list 2 revealed a mean number of correct initial nonverbal modalities that was 5.5 pre-treatment, 5.2 during treatment phase 1, 7.5 during treatment phase 2, and 8.67 post-treatment. Word list 3 (untreated) displayed a negative change in level from baseline to treatment phase 1 but showed minimal gains throughout the remainder of the study (not as notable as with treated word lists).

Figure 9. Participant 1 Correct Initial Nonverbal Productions- Level



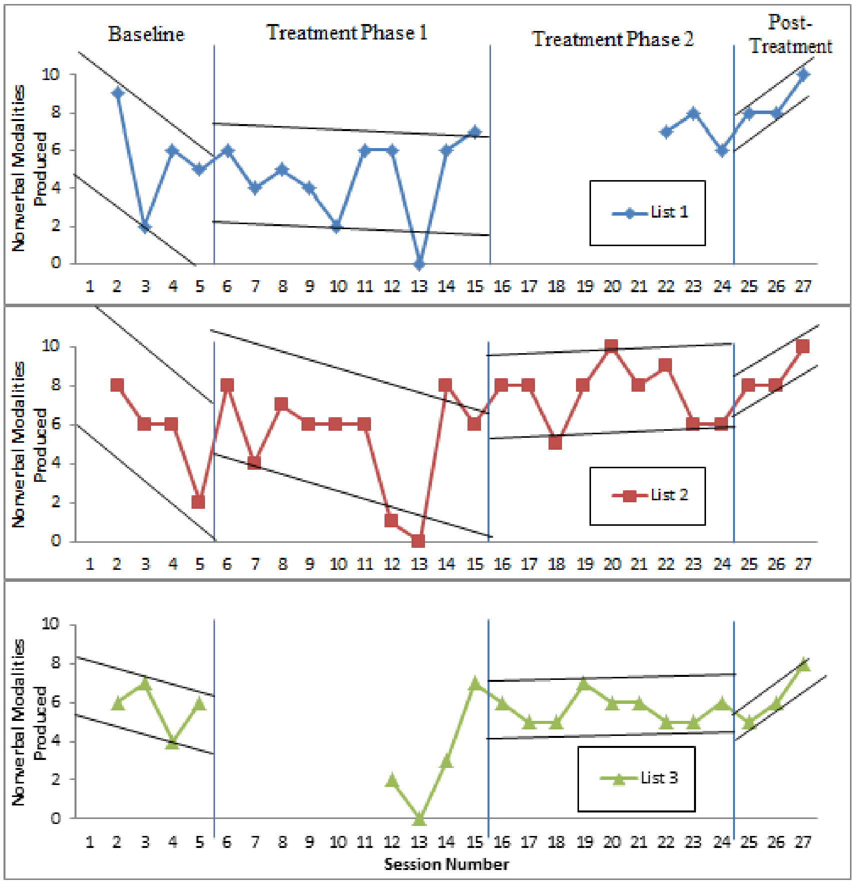
Trend. Trend was determined using the best fit line of data points for each phase and word list. A graph of the trend line for each word list for participant 1's correct initial nonverbal productions is available, below, in Figure 10. During baseline sessions, all word lists showed negative trend lines with less dramatic negative trend lines during treatment phase 1. Word lists 2 and 3 appeared to develop more stable trend lines with slight positive increases in correct initial nonverbal productions of modalities (word list 2) during treatment phase 2. All 3 word lists appeared to show positive increasing trend lines therefore increasing correct initial nonverbal productions post-treatment.

Figure 10. Participant 1 Correct Initial Nonverbal Productions- Trend



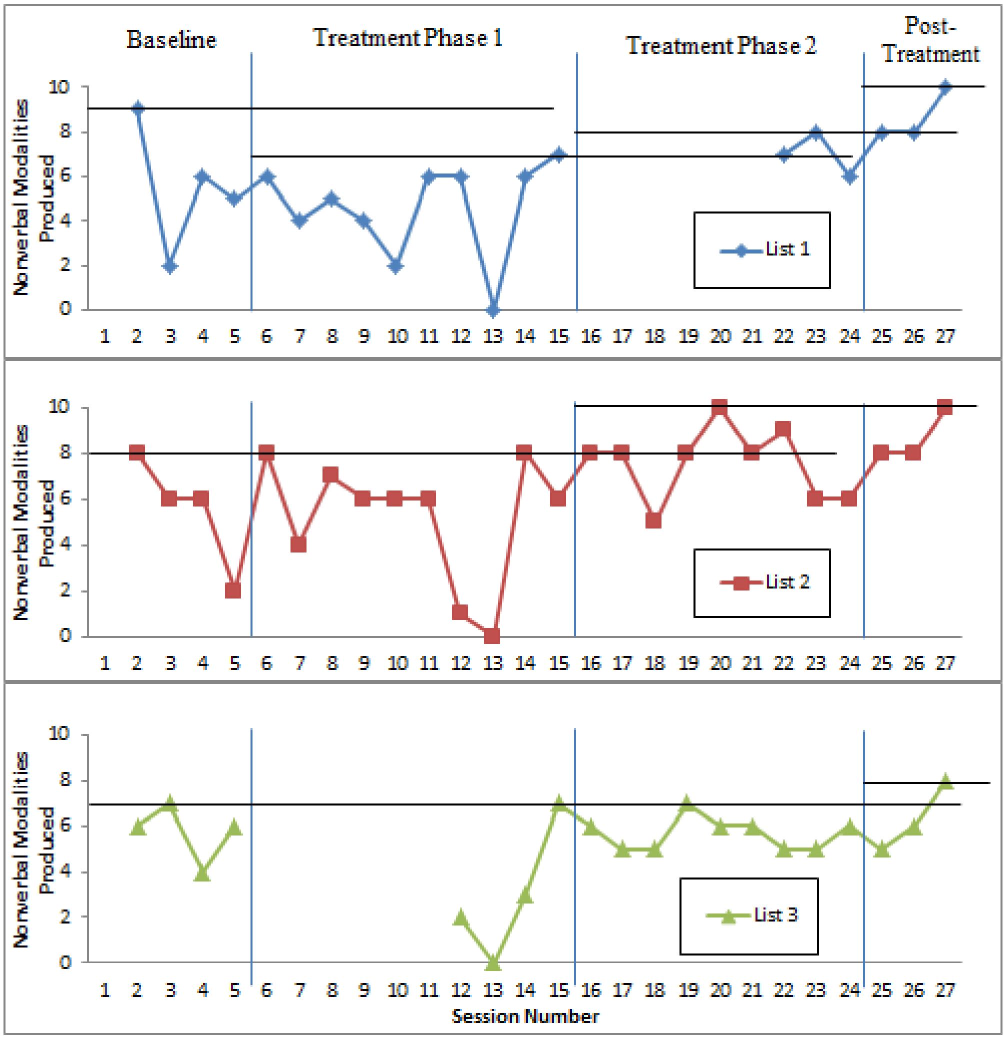
Variability. The variability is reported as the range of standard deviation above and below the trend line during each study phase. Figure 11, below, displays participant 1's variability for correct initial nonverbal productions across each word list. When comparing participant 1's correct initial nonverbal productions between baseline and post-treatment sessions, a notable decrease in variability was evident post-treatment (decreased standard deviation) for all 3 word lists. Participant 1 remained highly variable during treatment phase 1; however, variability decreased during treatment phase 2 and post-treatment for all word lists.

Figure 11. Participant 1 Correct Initial Nonverbal Productions- Variability



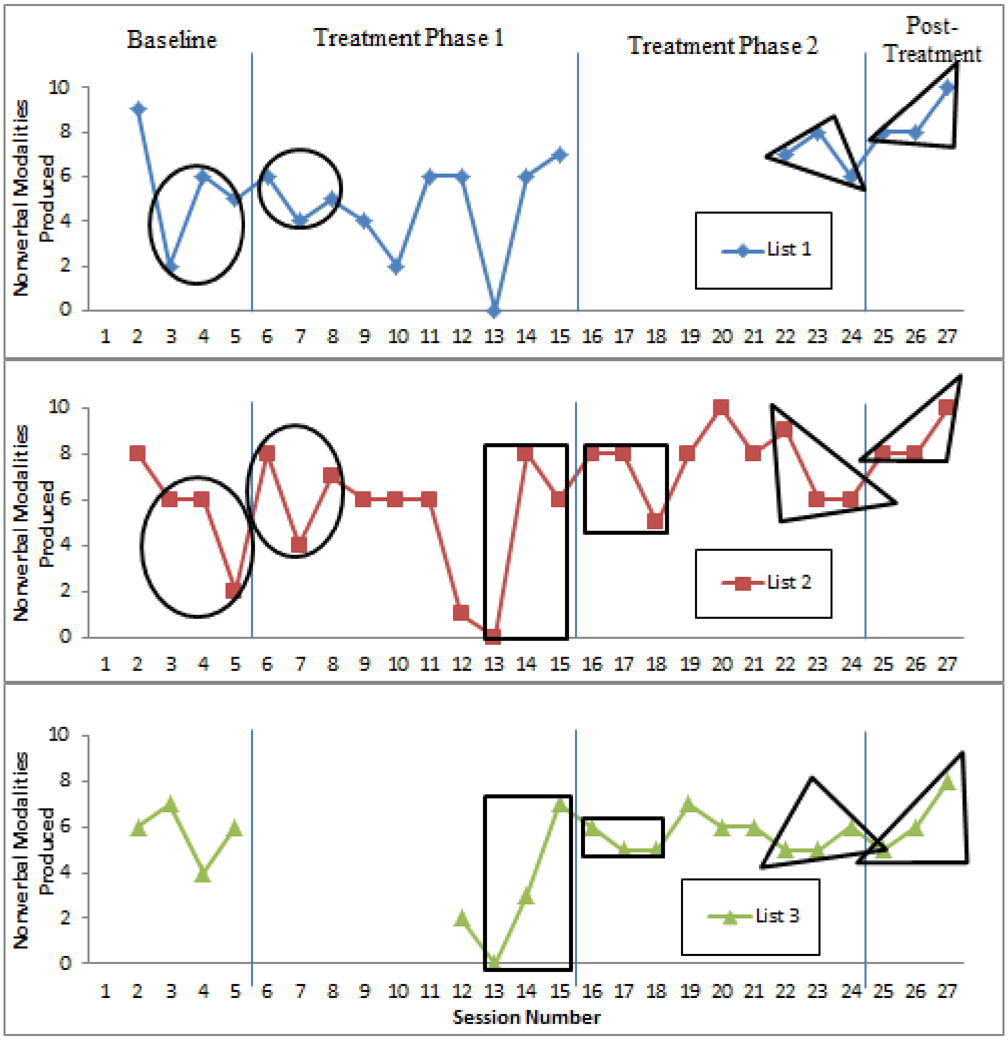
Degree of overlap between phases. The degree of overlap between phases was analyzed as the number of data points within a phase that overlapped with the highest point of data from the previous phase. The researcher examined the degree of overlap between adjacent study phases for each word list. Participant 1's correct initial nonverbal productions and degree of overlap is displayed below in Figure 12. Between pre-treatment and treatment phase 1, word list 1 had 10 overlapping data points (100%), word list 2 had 10 (100%), and word list 3 had 2 (67%). Between treatment phase 1 and treatment phase 2, word list 1 had 2 overlapping data points (67%), word list 2 had 7 (78%), and word list 3 had 9 (100%). Between treatment phase 2 and post-treatment, word list 1 had 2 overlapping data points (67%), word list 2 had 3 (100%), and word list 3 had 2 (67%). The fewest overlapping data points occurred for word list 2 during treatment phase 2.

Figure 12. Participant 1 Correct Initial Nonverbal Productions- Overlap Between Phases



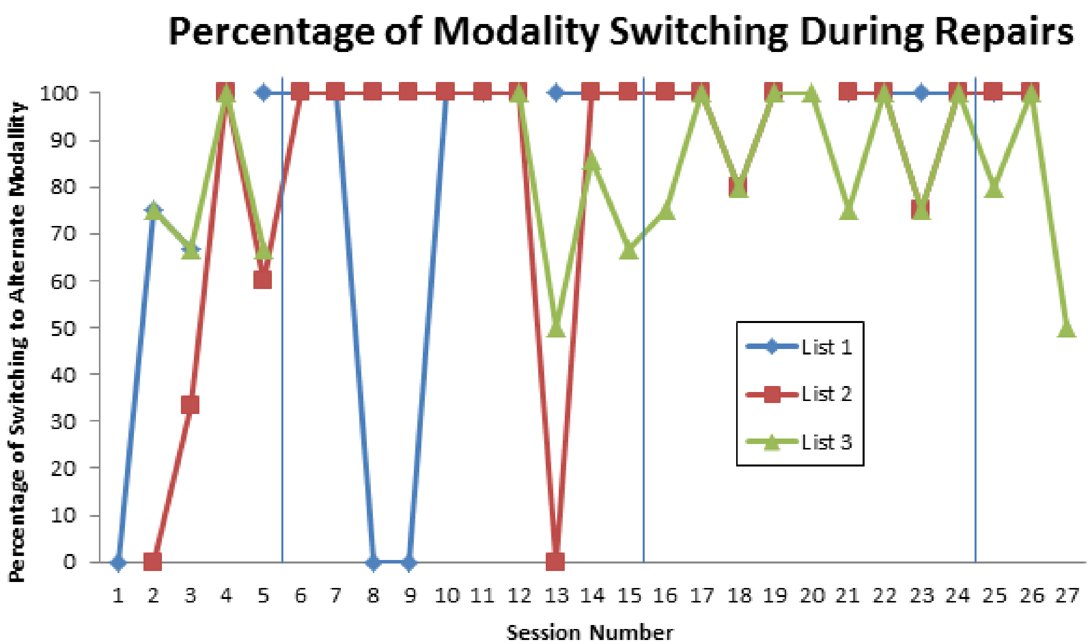
Immediacy of effect. Researchers visually compared the last three data points of one phase and the first three data points of the next phase using shapes (i.e., ovals, rectangles and triangles) to observe the immediacy of effect (Figure 13). Immediacy of effect was not found between baseline and treatment phase 1 across all three word lists. Word list 2 and 3 appeared to immediately decrease in variability between treatment phases 1 and 2. Positive changes for all three word lists was noted post-treatment.

Figure 13. Participant 1 Correct Initial Nonverbal Productions- Immediacy of Effect



Modality switching. Participant 1's percentage of modality switching revealed no significant effect sizes. However, his performance was variable pre-treatment but appeared to improve for lists 1 and 2 as the treatment study progressed (i.e., consistently at 80-100% post-treatment, standard deviations of 0 for word lists 1 and 2 post-treatment; Figure 14).

Figure 14. Participant 1 Percentage of Modality Switching



Communicative repair score. Participant 1's percentage of repaired communication breakdowns, or communicative repair score, was variable and revealed no significant effect sizes. However, this participant's mean communicative repair score for list 2 increased (Table 8, Figure 15) from pre-treatment (67.08%) to post-treatment (100%). Word list 1 had a higher baseline mean (91.7%) but also increased to 100% post-treatment.

Table 8. Participant 1 RCT Effect Sizes, Means, and Standard Deviations

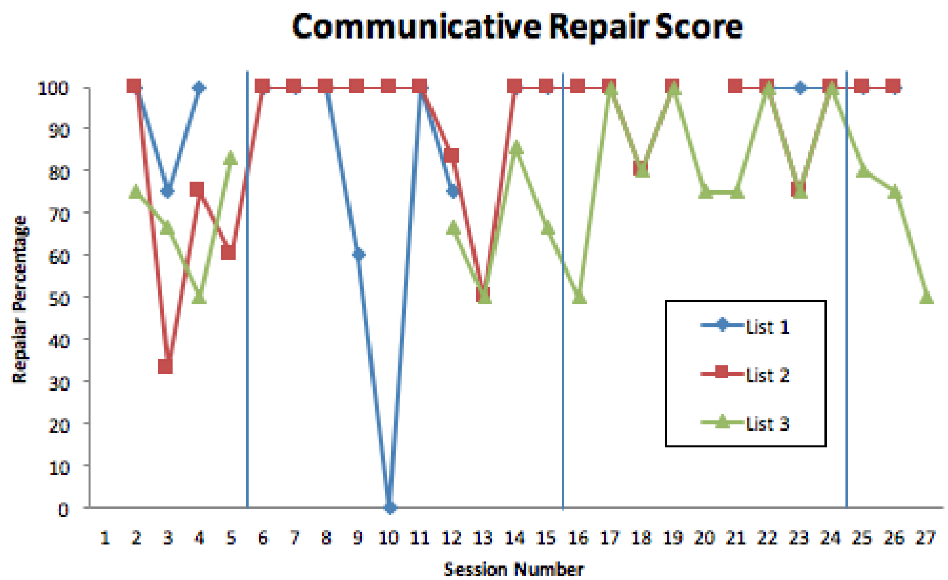
	Word List 1	Word List 2	Word List 3
Initial Nonverbal Successes			
Effect Size	1.1	1.26	0.46
Pre-Treatment Mean (SD)	5.5 (2.89)	5.5 (2.52)	5.75 (1.26)
Post-Treatment Mean (SD)	8.67 (1.15)	8.67 (1.15)	6.33 (1.53)
Percentage of Modality Switching			
Effect Size	1.28	1.22	-0.03
Pre-treatment Mean (SD)	47% (41)	48% (42)	77% (16)
Post-treatment Mean (SD)	100% (0)	100% (0)	77% (25)
Communicative Repair Score			
Effect Size	0.58	1.18	-0.03

Pre-treatment Mean (SD)	91.7% (14)	67% (28)	68.7% (14)
Post-treatment Mean (SD)	100% (0)	100% (0)	68.3% (16)

*Cohen's d statistics as calculated by Busk and Serlin (1992)

**Benchmarks of 4.0, 7.0 and 10.1 for small, medium, and large effect sizes from lexical retrieval treatment studies with people with aphasia (Robey & Beeson, 2005)
***Standard deviation=SD

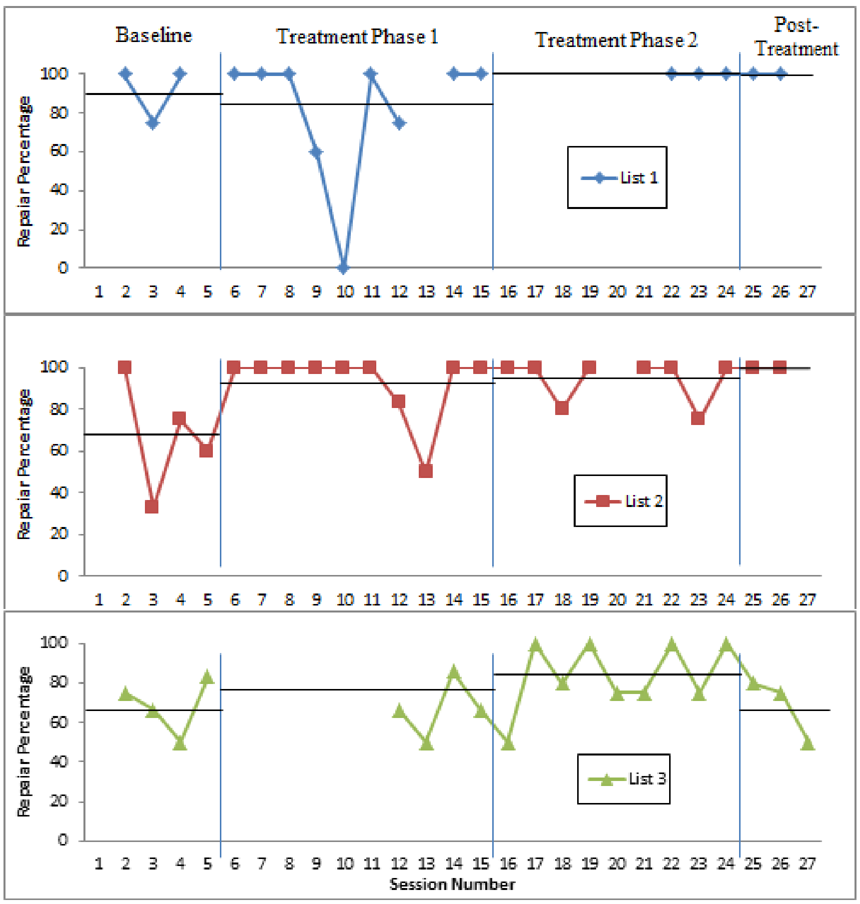
Figure 15. Participant 1 Communicative Repair Score



Communicative repair score visual analysis. Researchers completed visual analyses for participant 1's communicative repair score including level, trend, variability, overlap between phases, and immediacy of the effect.

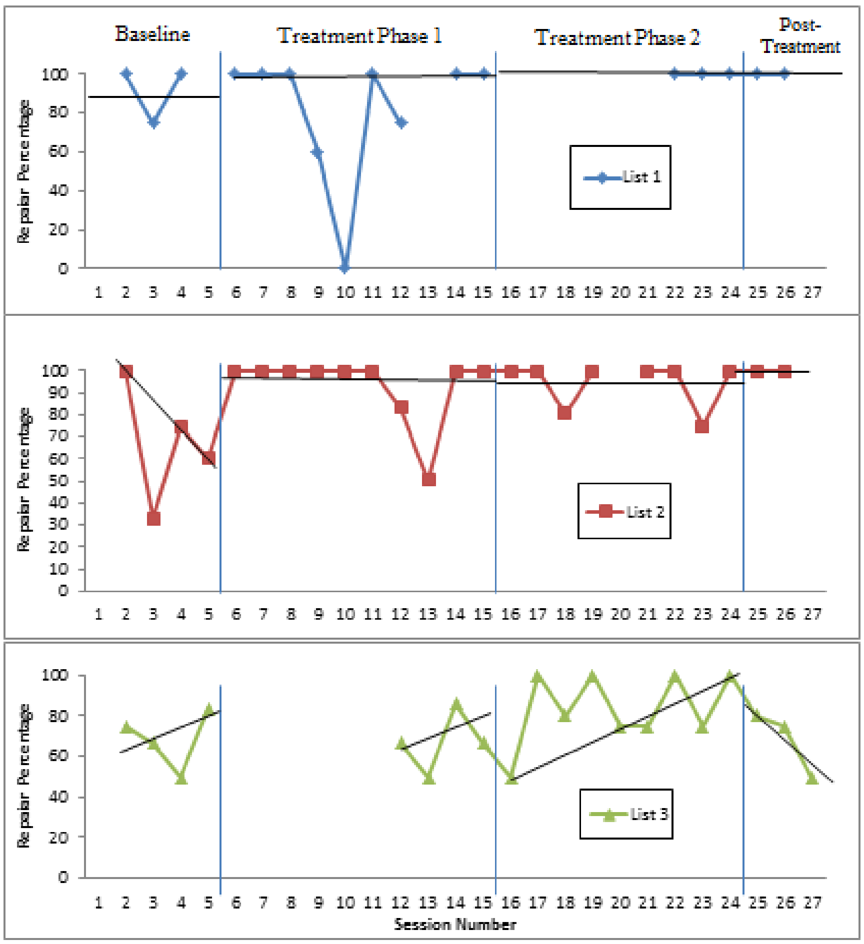
Level. Figure 16, below, displays the analysis of level for participant 1's communicative repair score across each word list. For word list 1 (treated list), the mean communicative repair score was 91.7% at baseline, 81.7% during treatment phase 1, and 100% during treatment phase 2 and post-treatment. Therefore, analysis showed a negative change from baseline to post-treatment but showed minimal gains and stabilization throughout the remainder of the study. His mean communicative repair score on word list 2 (treated list) was 67% at baseline, 93.3% during treatment phase 1, and 100% during treatment phase 2 and post-treatment. This indicates gradual positive increases in average communicative repair score with the progression of the study for word list 2. Analysis of level for participant 1's communicative repair score during word list 3 revealed a mean of 68.7% at baseline, 67.3% during phase 1, 83.9% during treatment phase 2, and a decrease to 68.3% post-treatment. Word list 3 (untreated) showed positive gains in mean communicative repair score throughout the study until a negative change was noted post-treatment.

Figure 16. Participant 1 Communicative Repair Score- Level



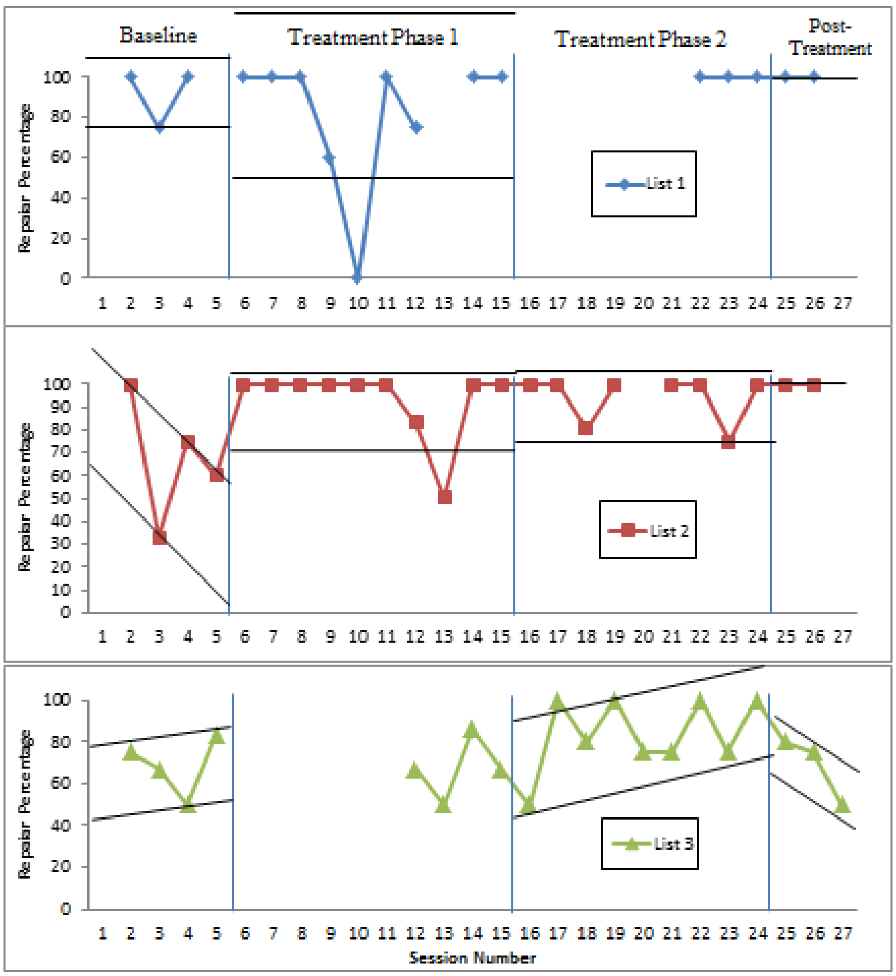
Trend. Trend was determined using the best fit line of data points for each phase and word list. A graph of the trend line for each word list for participant 1's communicative repair score is available, below, in Figure 17. At baseline, word list 1 appeared stable, word list 2 showed a negative trend line, and word list 3 showed a positive trend line. For the remainder of the study, word lists 1 and 2 had relatively stable and flat trend lines as participant 1 reached maximum accuracy for communicative repair score (100%) for the majority of communication breakdowns. word list 3 (untreated), in contrast, showed positive trend lines through treatment phase 2 but a negative change was evident post-treatment.

Figure 17. Participant 1 Communicative Repair Score- Trend



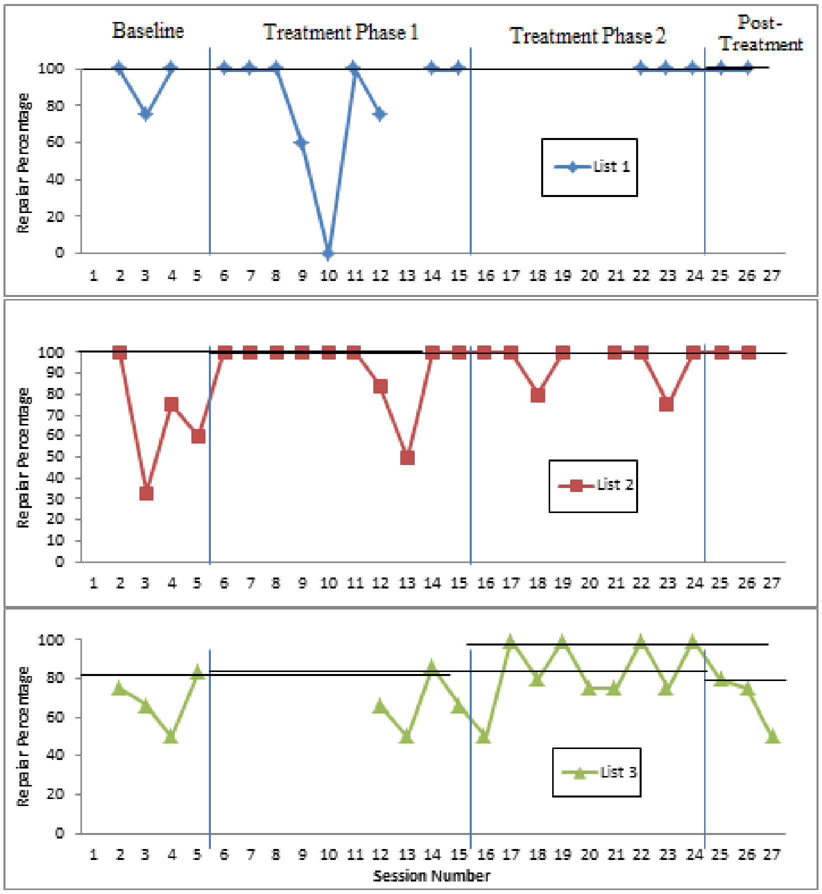
Variability. The variability is reported as the range of standard deviation above and below the trend line during each study phase. Figure 18, below, displays participant 1's variability for communicative repair score across each word list. For word list 1, the variability increased from baseline to treatment phase one but decreased to 0 thereafter as the participant was achieving 100% accuracy during treatment phase 2 and post-treatment. For word list 2, variability was largest at baseline and progressively decreased throughout the remainder of the study. At post-treatment, word list 2 also had no variability as participant 1 was repairing 100% of communication breakdowns. For word list 3 (untreated), variability increased as the study progressed.

Figure 18. Participant 1 Communicative Repair Score- Variability



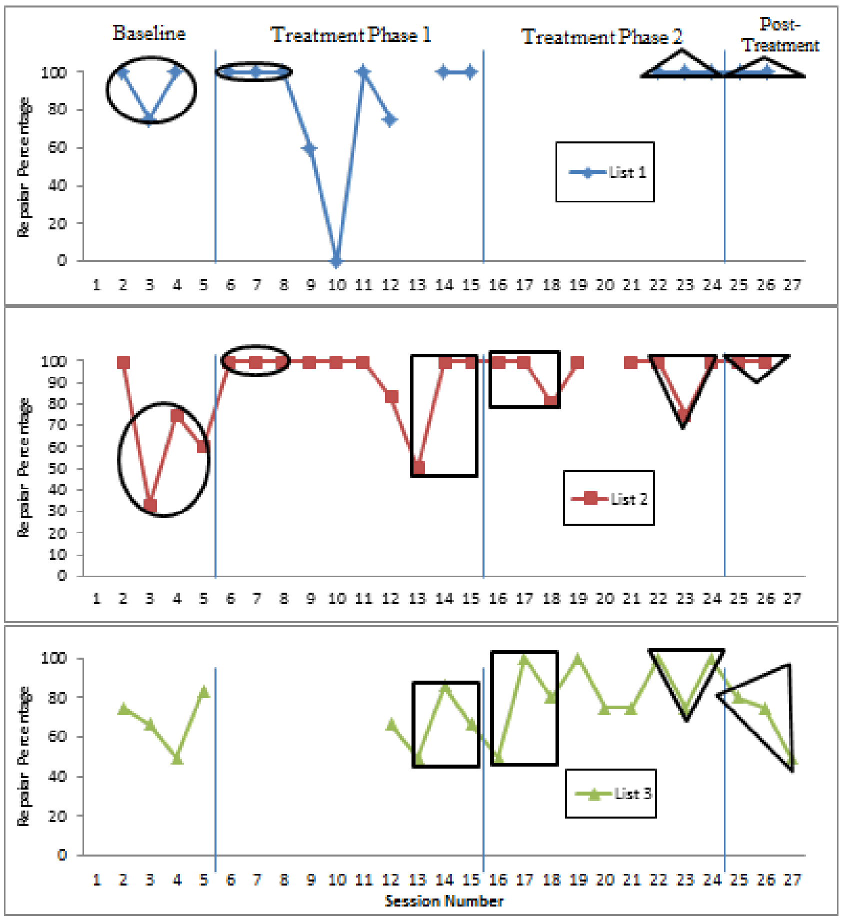
Degree of overlap between phases. The degree of overlap between phases was analyzed as the number of data points within a phase that overlapped with the highest point of data from the previous phase. The researcher examined the degree of overlap between adjacent study phases for each word list. Participant 1's communicative repair score and degree of overlap between phases is displayed below in Figure 19. Between baseline and treatment phase 1, word list 1 had 9 overlapping data points (100%), word list 2 had 10 (100%), and word list 3 had 3 (75%). Between treatment phase 1 and treatment phase 2, word list 1 had 3 overlapping data points (100%), word list 2 had 8 (100%) and word list 3 had 5 (56%). Between treatment phase 2 and post-treatment, word list 1 had 2 overlapping data points (100%), word list 2 had 2 overlapping data points (100%) and word list 3 had 3 overlapping data points (100%). The least amount of overlapping data points occurred during treatment phase 2. As the participant began to achieve the maximum, 100% accuracy, for communicative repair score, points consistently overlapped for the remainder of the study.

Figure 19. Participant 1 Communicative Repair Score- Overlap Between Phases



Immediacy of effect. Researchers visually compared the last three data points of one phase and the first three data points of the next phase using shapes (i.e., ovals, rectangles and triangles) to observe the immediacy of effect (Figure 20). Immediacy of effect was noted between baseline and treatment phase 1 for word lists 1 and 2 and between treatment phases for word list 2. It was also evident that variability immediately decreased for word list 2 between treatment phases 2 and 3 as well as post-treatment. Immediacy of effect was not present for the untrained word list (list 3).

Figure 20. Participant 1 Communicative Repair Score- Immediacy of Effect



Participant 1 formal assessments. Participant 1's performance on formal assessments pre- and post-treatment revealed negligible to minimal gains. Gains in performance on the CLQT were noted for visuospatial skills as he increased from a mild to within normal limits severity rating. His performance on clock drawing also improved slightly and moved from severe to moderate post-treatment. On the CADL-2, participant 1's stanine score increased post-treatment and he moved from the 80th to the 90th percentile. Participant 1's formal assessment results are displayed below in Table 9.

Table 9. Participant 1 Formal Assessment Results

	Cognitive Linguistic Quick Test							CADL-2		
	Symbol Cancellation (12)	Symbol Trails (10)	Design Memory (6)	Mazes (8)	Design Generation (13)	Visuospatial Domain Skills (105)	Clock Drawing Domain (13)	Raw Score	Stanine Score	Percentile
Pre-Treatment	12	10	4	5	6	81 Mild	7 Severe	87	6.67	80
Post-Treatment	11	10	5	6	6	86 Within Normal Limits	8 Mild	91	8	90

Participant 1 also completed the *CAT* disability questionnaire at baseline and post-treatment. In comparison to his report pre-treatment, the majority of his rankings remained the same from pre to post-treatment. However, he did report a ranking of 0 ("no problem") for writing single words to communicate and a decrease in his ranking for worry due to his communication difficulties post-treatment.

Participant 2 Results

Modality probe. Participant 2's total production of modalities was assessed using regular modality probes throughout baseline, treatment, and post-treatment sessions. He displayed improvement in his production of the various modalities during the modality probe task with small effect sizes (Table 10.) for trained word lists (list 1 & 2). He demonstrated most improvement in accurate productions of gestures and drawings (Figure 21). As participant 2 was nonverbal secondary to significant vocal apraxia and apraxia of speech, data for only four modalities (gesture, draw, write, & TTS) was collected. Therefore, a maximum of 40 total modalities could be achieved. Treatment encouraged vocalizations and speech but this modality was not observed at any point during the study.

Table 10. Participant 2 Total Production of Modalities

	Word List 1	Word List 2	Word List 3
P2 Effect Size	4.05 (small)	4.73 (small)	1.77 (not significant)

*Cohen's (1998) d statistics as calculated by Busk and Serlin (1992)
**Benchmarks of 4.0, 7.0 and 10.1 for small, medium, and large effect sizes from lexical retrieval treatment studies with people with aphasia (Robey & Beeson, 2005)

Figure 21. Participant 2 Total Production of Modalities

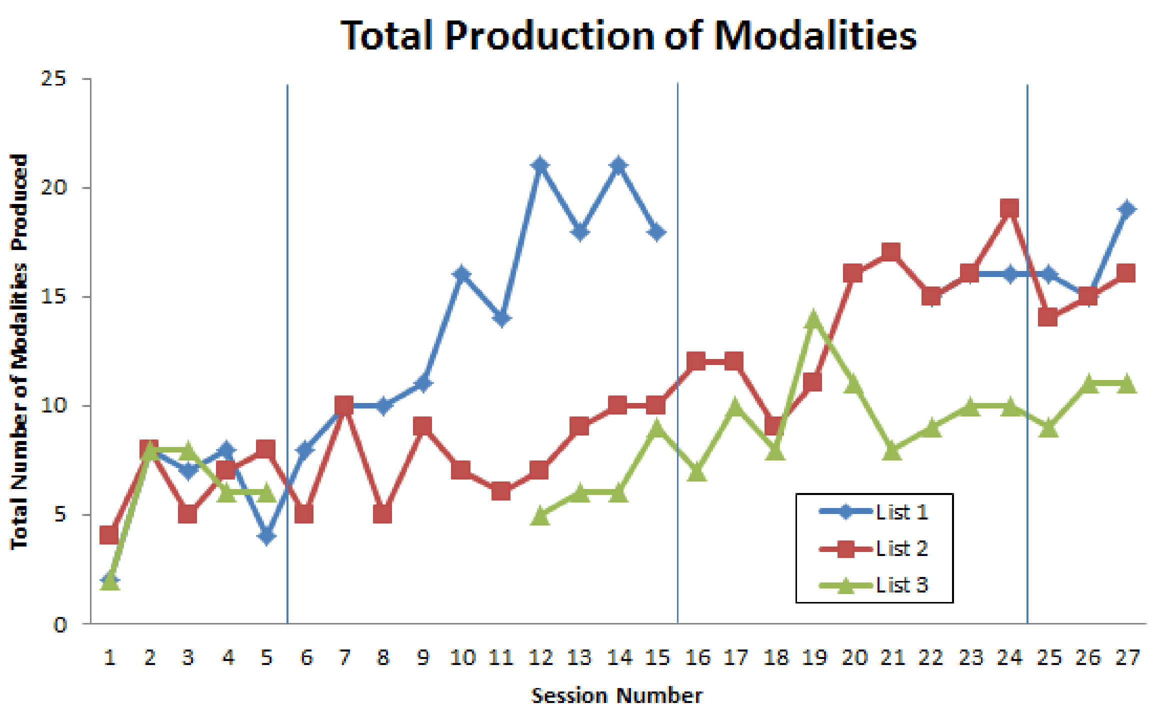
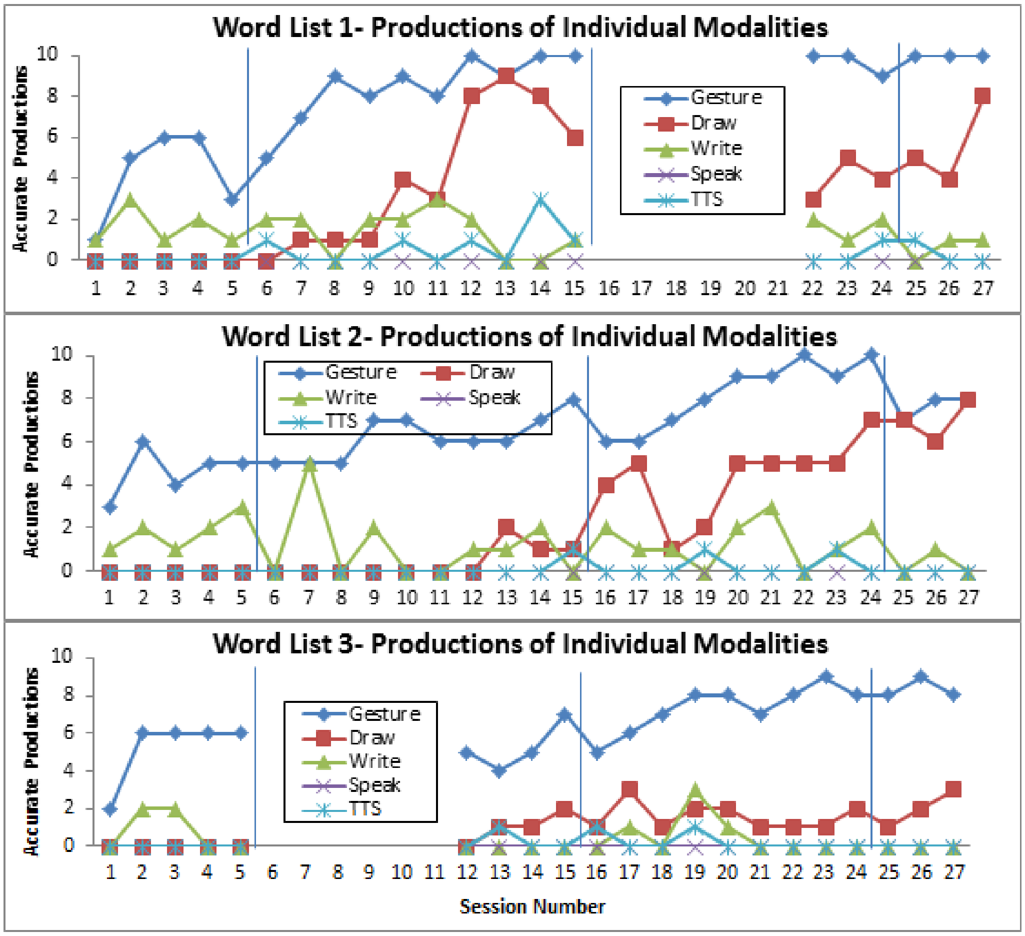


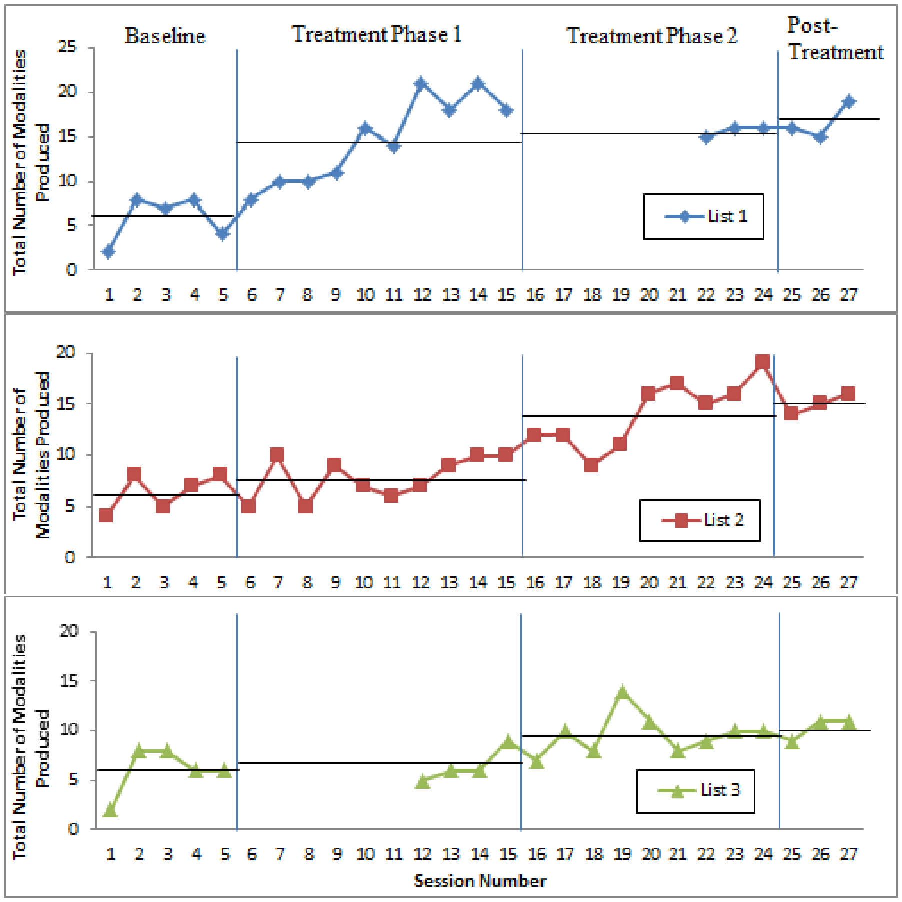
Figure 22. Participant 2 Production of Individual Modalities by Word List



Modality probe visual analysis. Researchers completed visual analyses for participant 1's total production of modalities including level, trend, variability, overlap between phases, and immediacy of the effect.

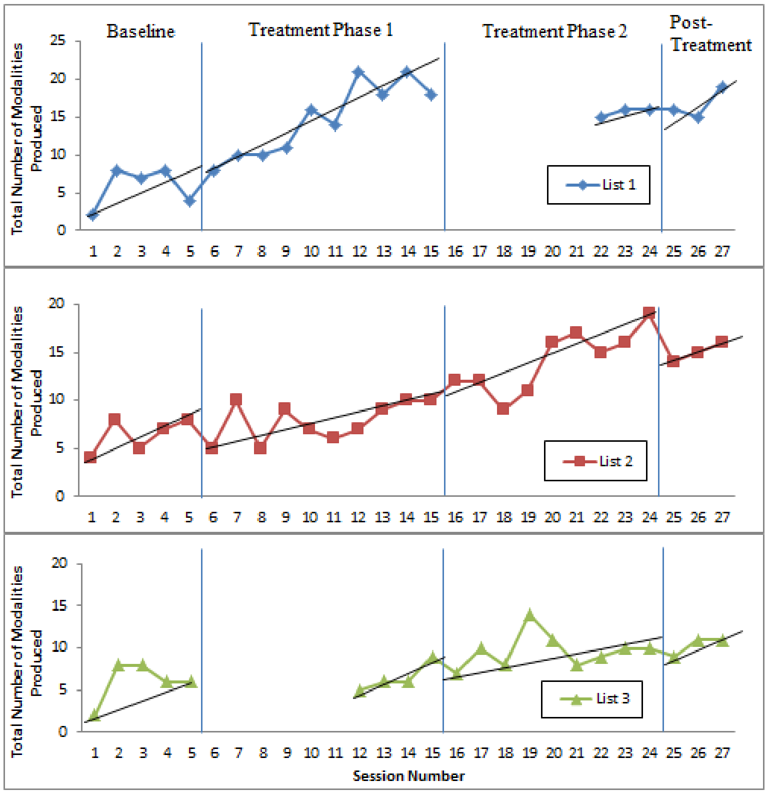
Level. For word list 1, participant 2's mean total production of modalities was 5.8 at baseline, 14.7 during treatment phase 1, 15.7 during treatment phase 2, and 16.7 post-treatment. On word list 2, his mean total production of modalities was 6.4 at baseline, 7.8 during treatment phase 1, 14.1 during treatment phase 2, and 15 post-treatment. His mean for word list 3 (untreated) was 6 at baseline, 6.5 during treatment phase 1, 9.7 during treatment phase 2, and 10.3 post-treatment. Figure 23, below, displays level for participant 2's total production of modalities by word list. For all three word lists, but more notably for word lists 1 and 2, participant 2 displayed a positive increase in level as the treatment progressed.

Figure 23. Participant 2 Total Production of Modalities- Level



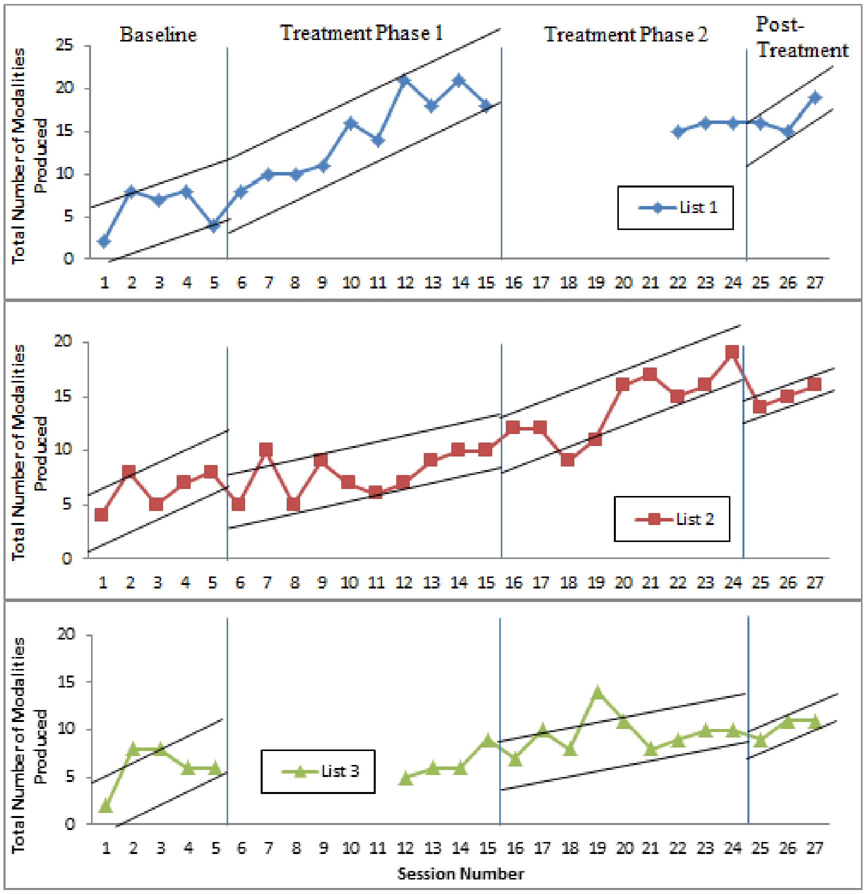
Trend. Trend was determined using the best fit line of data points for each phase and word list. A graph of the trend line for each word list for participant 2's total production of modalities is available, below, in Figure 24. All three word lists showed positive trend lines with the progression of the study with a more gradual positive trend line for word list 3 compared to the trained word lists (word lists 1 and 2).

Figure 24. Participant 2 Total Production of Modalities- Trend



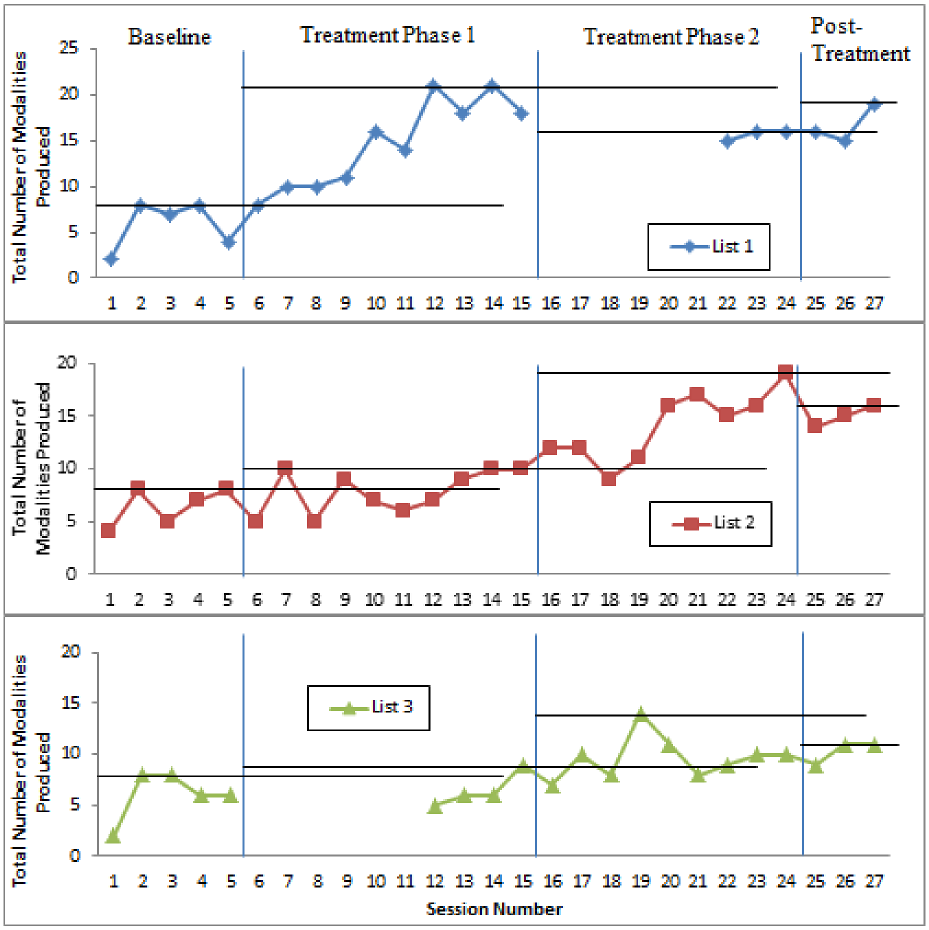
Variability. The variability is reported as the range of standard deviation above and below the trend line during each study phase. Figure 25, below, displays participant 2's variability for total production of modalities across each word list. Word lists 1 and 2 slightly increased in variability during treatment phases. However, for all 3 word lists, variability ultimately decreased from baseline to post-treatment.

Figure 25. Participant 2 Total Production of Modalities- Variability



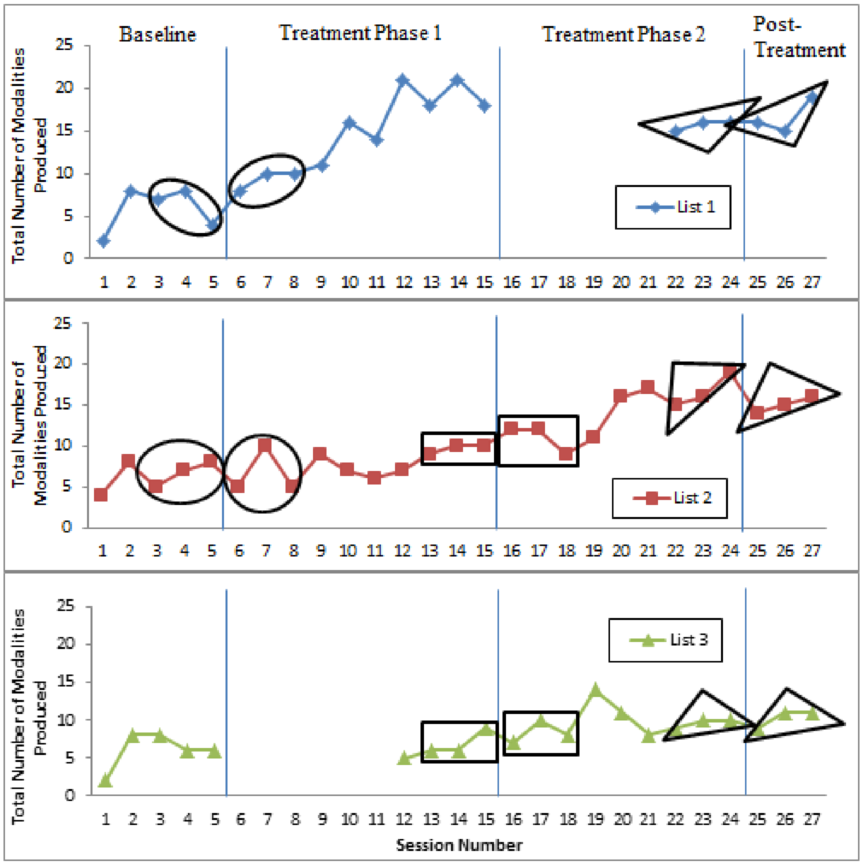
Degree of overlap between phases. The degree of overlap between phases was analyzed as the number of data points within a phase that overlapped with the highest point of data from the previous phase. The researcher examined the degree of overlap between adjacent study phases for each word list. Participant 2's communicative repair score and degree of overlap between phases is displayed below in Figure 26. Between baseline and treatment phase 1, word list 1 had 1 overlapping data point (10%), word list 2 had 5 (50%), and word list 3 had 3 (75%). Between treatment phase 1 and treatment phase 2, word list 1 had 3 overlapping data points (100%), word list 2 had 1 (11%), and word list 3 had 4 (44%). Between treatment phase 2 and post-treatment, word list 1 had 2 overlapping data points (67%), word list 2 had 3 (100%) and word list 3 had 3 (100%). Therefore, the least amount of overlapping data points for total production of modalities occurred during treatment phase 1.

Figure 26. Participant 2 Total Production of Modalities- Degree of Overlap



Immediacy of effect. Researchers visually compared the last three data points of one phase and the first three data points of the next phase using shapes (i.e., ovals, rectangles and triangles) to observe the immediacy of effect (Figure 27). No immediacy of effect of treatment on total production of modalities was found across all word lists. Positive change was noted for word list 1 from baseline to treatment phase 1.

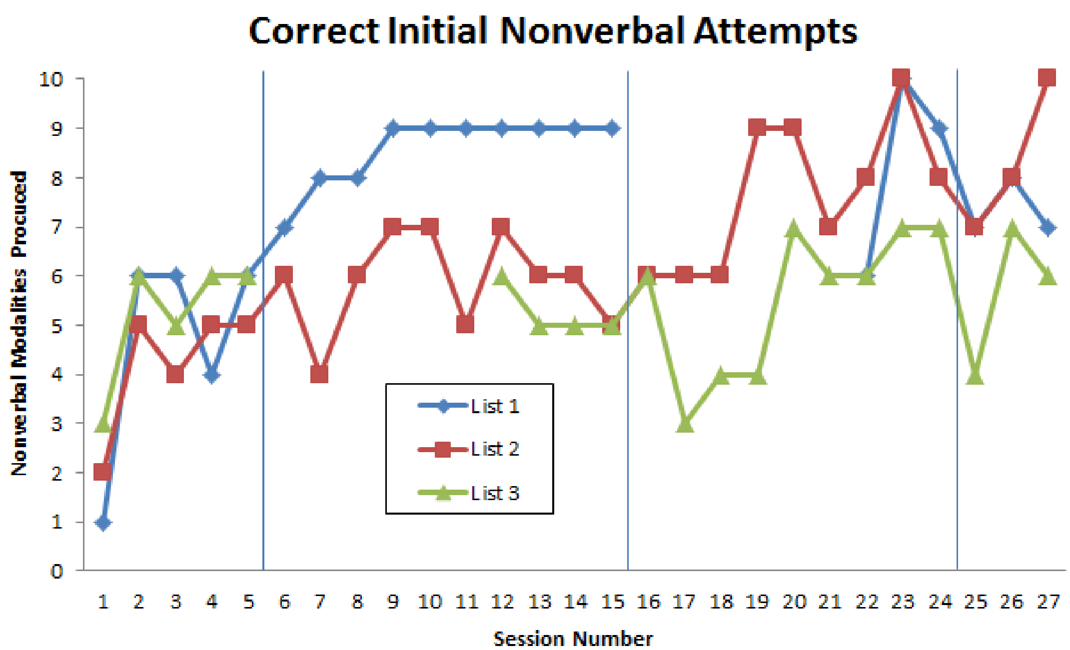
Figure 27. Participant 2 Total Production of Modalities- Immediacy of Effect



Referential communication task (RCT). Participant 2's performance on initial nonverbal successes, modality switching, and communicative repair score were analyzed from the RCT.

Correct initial nonverbal attempts. Participant 2's initial nonverbal modality use revealed no significant effect sizes as he was also highly variable for all word lists during pre-treatment. Similar to participant 1, during post-treatment, he consistently produced a minimum of 7 accurate initial nonverbal modalities (treated word lists only; Figure 28, Table).

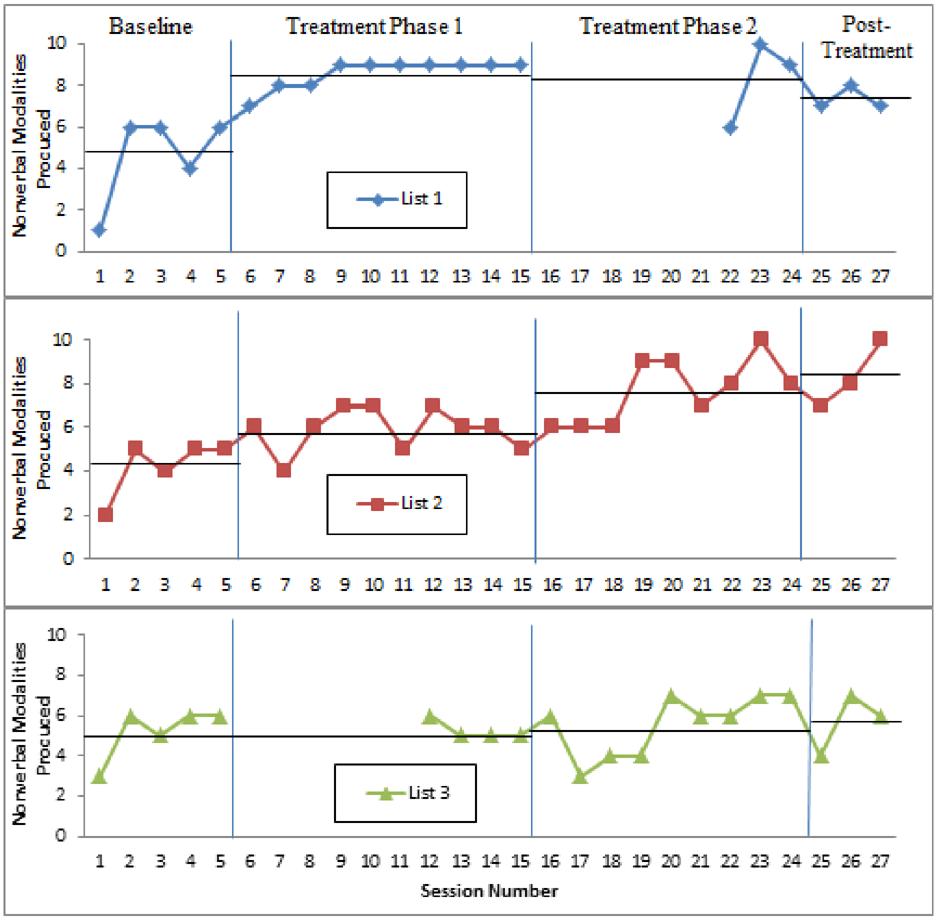
Figure 28. Participant 2 Correct Initial Nonverbal Attempts



Correct initial nonverbal attempts visual analysis. Researchers completed visual analyses for participant 2's correct initial nonverbal productions including level, trend, variability, overlap between phases, and immediacy of the effect.

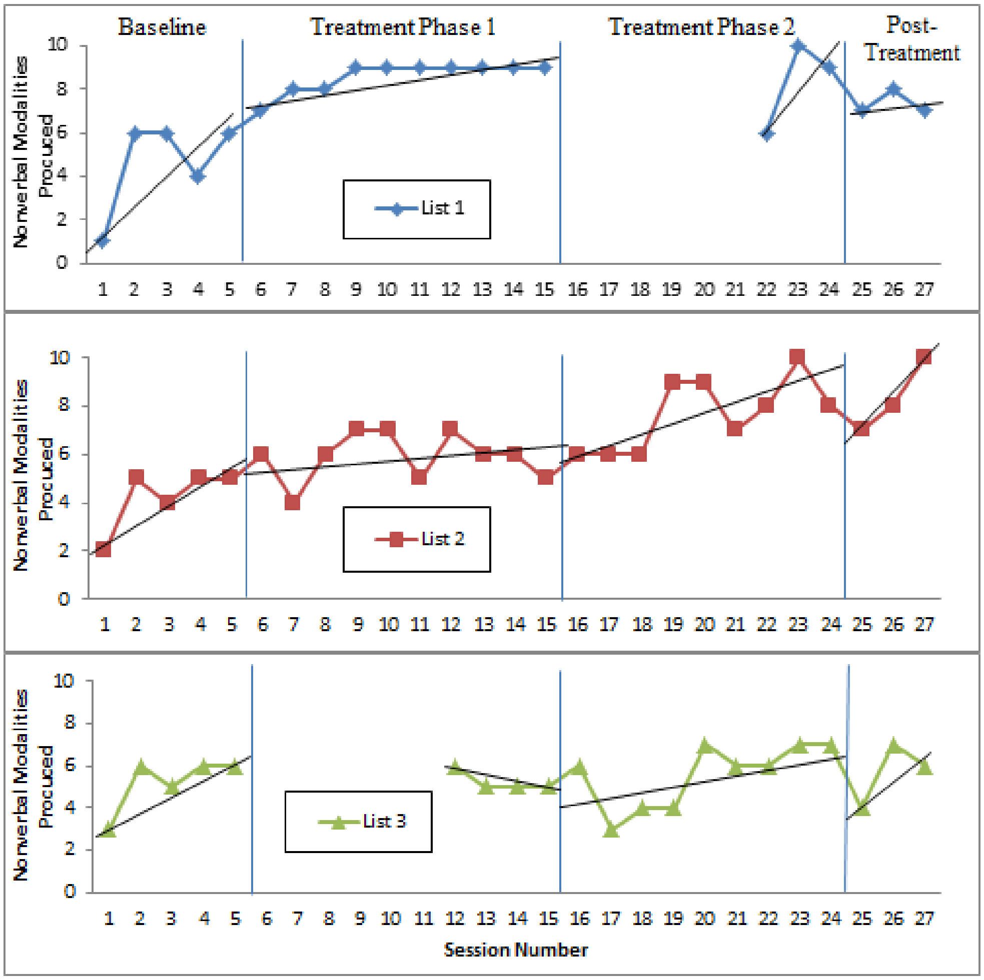
Level. Figure 29, below, displays the analysis of level for participant 2's correct initial nonverbal productions across each word list. For word list 1, his mean number of correct initial nonverbal attempts was 4.6 at baseline, 8.6 during treatment phase 1, 8.3 during treatment phase 2, and 7.3 post treatment. Therefore, he showed a positive increase in level during treatment phase 1 and maintained productions of correct initial nonverbal attempts above baseline the remainder of the study. He had a mean of 4.2 correct initial nonverbal attempts at baseline, 5.9 during treatment phase 1, 7.7 during treatment phase 2, and 8.3 post-treatment for word list 2. This indicates a positive increase in his average correct initial nonverbal productions across all study phases for word list 2. On word list 3, he had a mean of 5.2 at baseline, 5.25 during treatment phase 1, 5.6 during treatment phase 2, and 5.7 post treatment indicating no effect for level on correct initial nonverbal productions for the untreated word list.

Figure 29. Participant 2 Correct Initial Nonverbal Attempts- Level



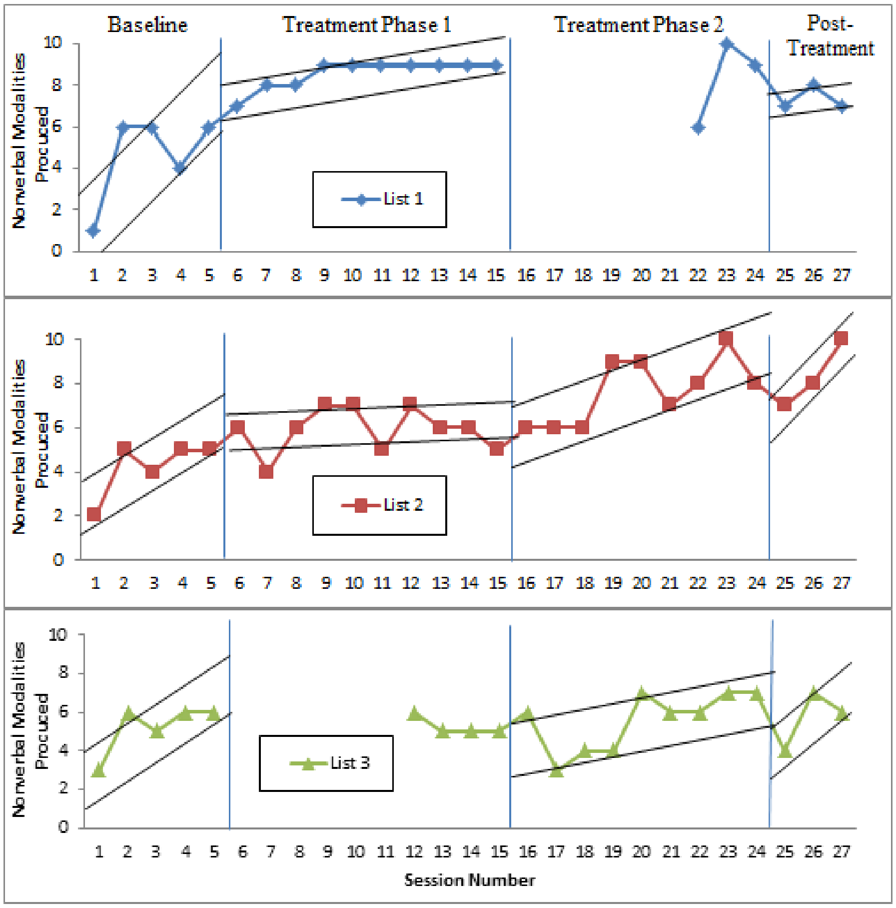
Trend. Trend was determined using the best fit line of data points for each phase and word list. A graph of the trend line for each word list for participant 2's correct initial nonverbal productions is displayed, below, in Figure 30. Trend lines for word lists 1 and 2 showed a positive effect across all study phases indicating that initial nonverbal productions for treated word lists improved as treatment progressed. Analysis of trend for word list 3 (untreated) revealed a positive trend line at baseline, treatment phase 2 and post-treatment but a negative trend line during treatment phase 1.

Figure 30. Participant 2 Correct Initial Nonverbal Attempts- Trend



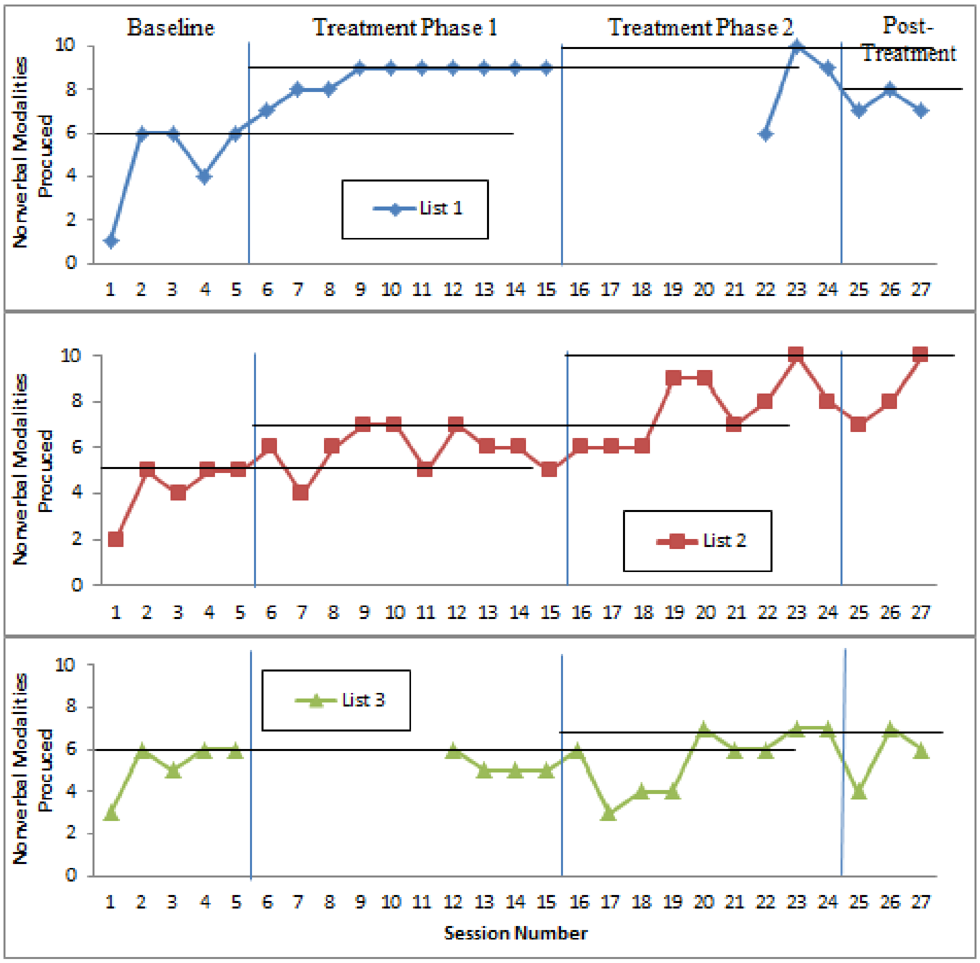
Variability. The variability is reported as the range of standard deviation above and below the trend line during each study phase. Figure 32, below, displays participant 2's variability for correct initial nonverbal attempts across each word list. For word lists 1, variability in participant 2's number of correct initial nonverbal productions decreased with each study phase. For word list 2 and 3, the variability reflected a standard deviation of 1 to 1.5 across all study sessions showing little to no effect of treatment on the variability of correct initial nonverbal attempts.

Figure 31. Participant 2 Correct Initial Nonverbal Attempts- Variability



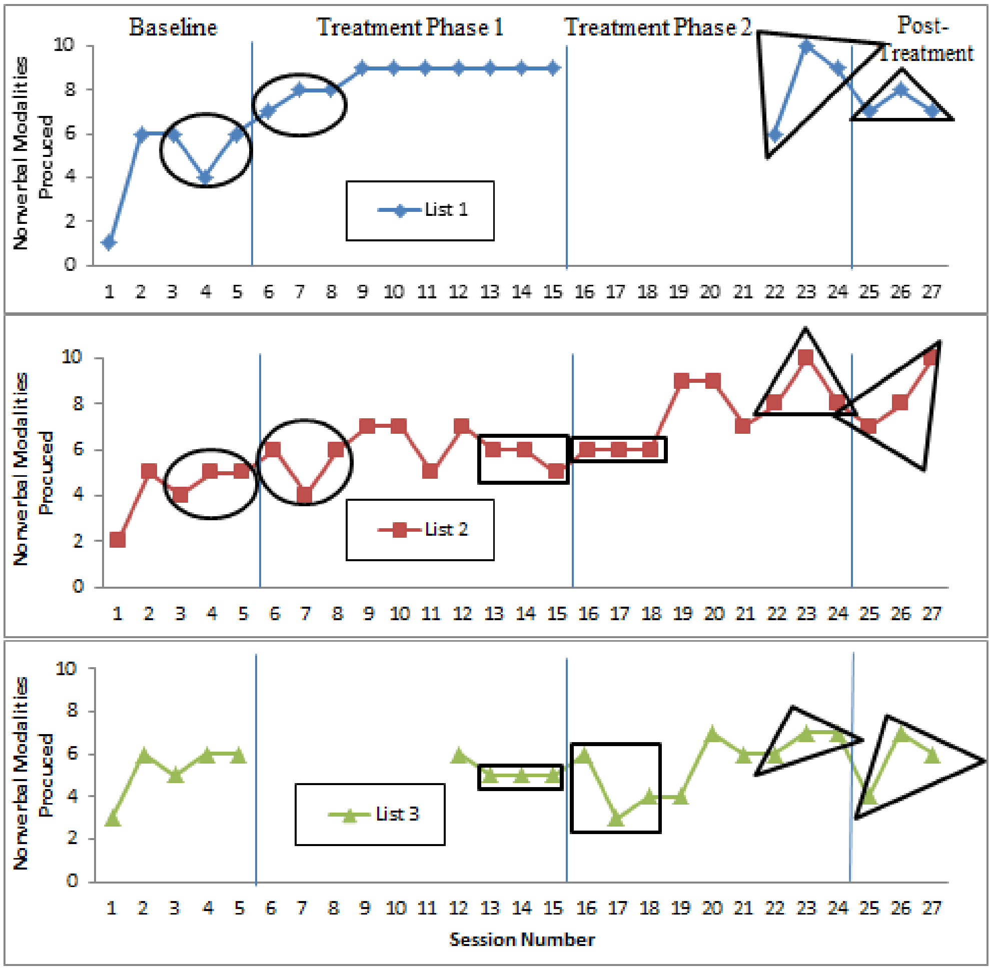
Degree of overlap between phases. The degree of overlap between phases was analyzed as the number of data points within a phase that overlapped with the highest point of data from the previous phase. The researcher examined the degree of overlap between adjacent study phases for each word list. Participant 2's number of correct initial nonverbal attempts and degree of overlap between phases is displayed below in Figure 33. Between baseline and treatment phase 1, word list 1 had 0 (0%) overlapping data points, word list 2 had 3 (27%), and word list 3 had 4 (100%). Between treatment phase 1 and treatment phase 2, word list 1 had 2 overlapping data points (67%), word list 2 had 4 (44%), and word list 3 had 6 (67%). Between treatment phase 2 and post-treatment, all 3 word lists had 3 overlapping data points (100%). The least amount of overlapping data points for participant 2's correct initial nonverbal productions occurred during treatment phase 1.

Figure 32. Participant 2 Correct Initial Nonverbal Attempts- Degree of Overlap



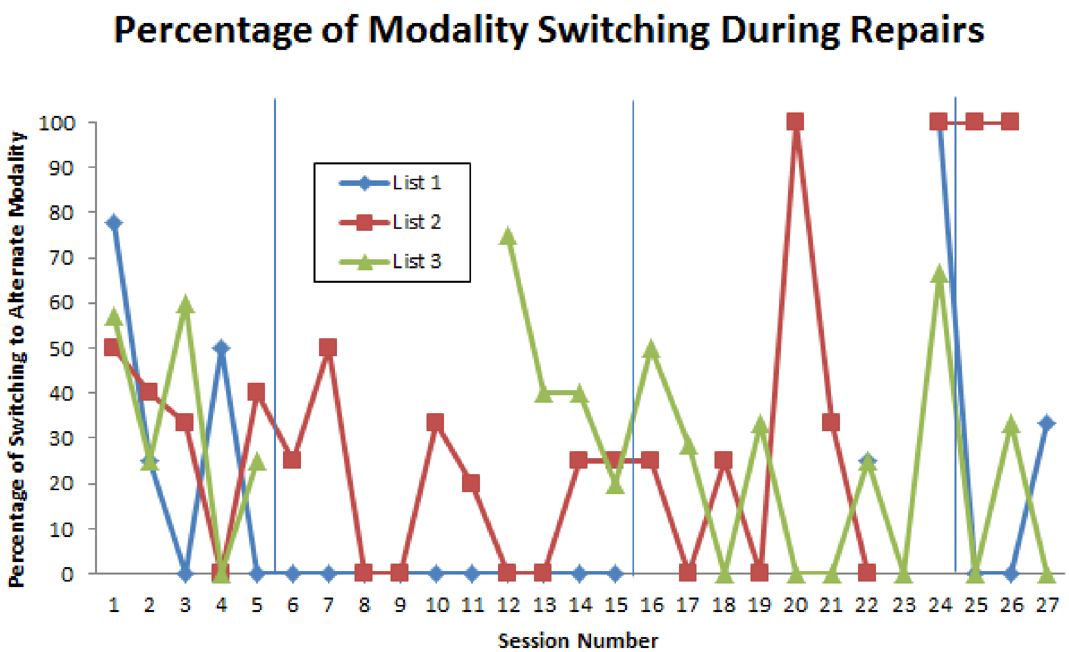
Immediacy of effect. The researcher visually compared the last three data points of one phase and the first three data points of the next phase using shapes (i.e., ovals, rectangles and triangles) to observe the immediacy of effect (Figure 34). Immediate effect of treatment on participant 2's correct initial nonverbal attempts were found between baseline and treatment phase 1 for word list 1. No other positive immediate effects were noted.

Figure 33. Participant 2 Correct Initial Nonverbal Attempts- Immediacy of Effect



Modality switching. Participant 2's percentage of modality switching (Figure 35, Table 11) revealed no significant effect sizes. His performance was variable at baseline for all word lists and post-treatment for word lists 1 and 3. Word list 2 increased in occurrences of modality switching and decreased in variability post-treatment. Both treated word lists had a decrease in standard deviation from 33.6 (list 1) and 19.2 (list 2) at baseline to 19.2 (list 1) and 0 (list 2) post-treatment. Word list 3 remained variable post-treatment.

Figure 34. Participant 2 Percentage of Modality Switching



Communicative repair score. Similar to participant 1, participant 2's number of repaired communication breakdowns, or communicative repair score, was variable and revealed no significant effect sizes (Figure 36, Table 11). Variability appeared to decrease for his communicative repair based upon standard deviations calculated for treated word lists 1 and 2 (both trained word lists) (Table 11). His mean communicative repair score for list 2 increased from 25.5% (pre-treatment) to 100% (post-treatment) (Figure 36). Minimal gains in pre and post-treatment averages were also noted for list 3. Participant 2 consistently showed a preference for gesturing and drawing during RCT probes.

Figure 35. Participant 2 Communicative Repair Score

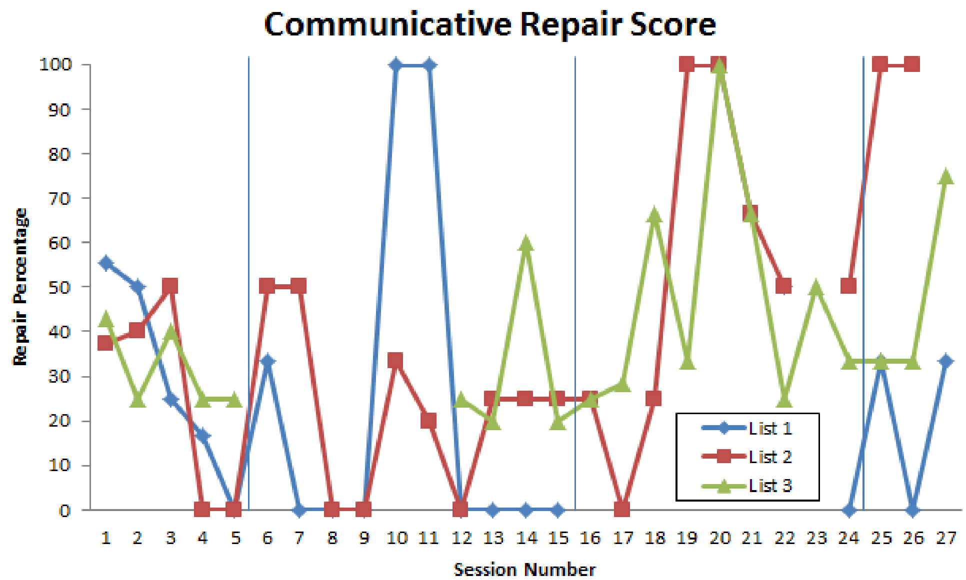


Table 11. RCT Effect Sizes, Means, and Standard Deviations- Participant 2

	Word List 1	Word List 2	Word List 3
Initial Nonverbal Successes			
Effect Size	1.25	3.37	0.358
Pre-Treatment Mean (SD)	4.6 (2.19)	4.2 (1.3)	5.2 (1.3)
Post-Treatment Mean (SD)	7.33 (0.58)	8.6 (1.53)	5.67 (1.53)
Percentage of Modality Switching			
Effect Size	-0.57	3.51	-0.89
Pre-Treatment Mean (SD)	30.5% (33.6)	32.7% (19.2)	33.4% (25.1)
Post-Treatment Mean (SD)	11.1% (19.2)	100% (0)	11.1% (19.3)
Communicative Repair Score			
Effect Size	-0.14	3.14	1.73
Pre-Treatment Mean (SD)	29.4% (52.7)	25.5% (23.7)	31.6% (9.05)
Post-Treatment Mean (SD)	22.2% (19.2)	100% (0)	47.2% (24.1)

*Cohen's d statistics as calculated by Busk and Serlin (1992)

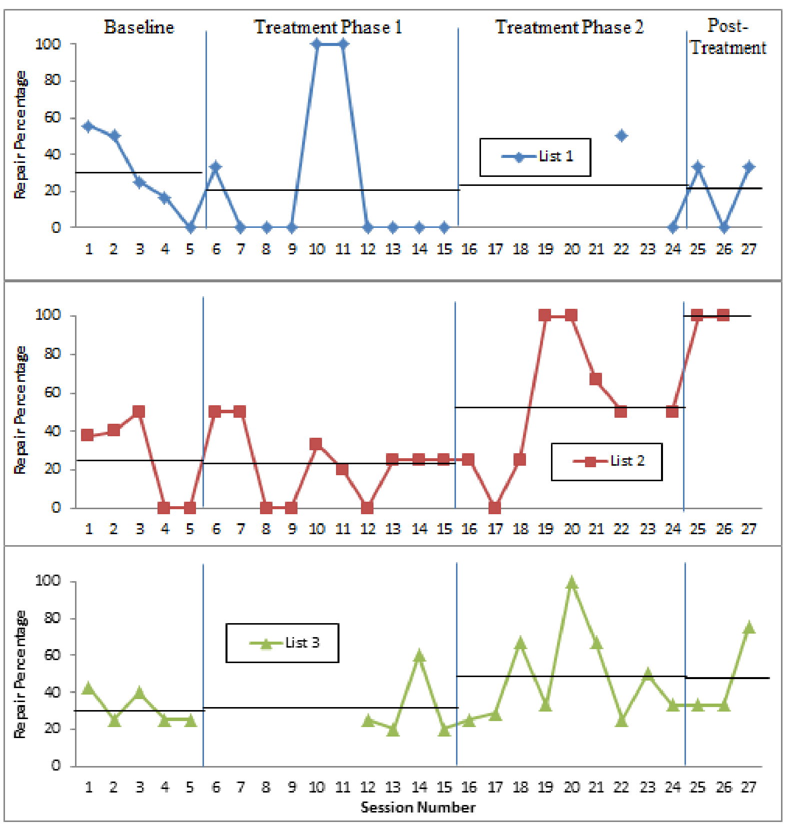
**Benchmarks of 4.0, 7.0 and 10.1 for small, medium, and large effect sizes from lexical retrieval treatment studies with people with aphasia (Robey & Beeson, 2005)

***Standard deviation=SD

Communicative Repair Score Visual Analysis. Researchers completed visual analyses for participant 2's communicative repair score including level, trend, variability, overlap between phases, and immediacy of the effect.

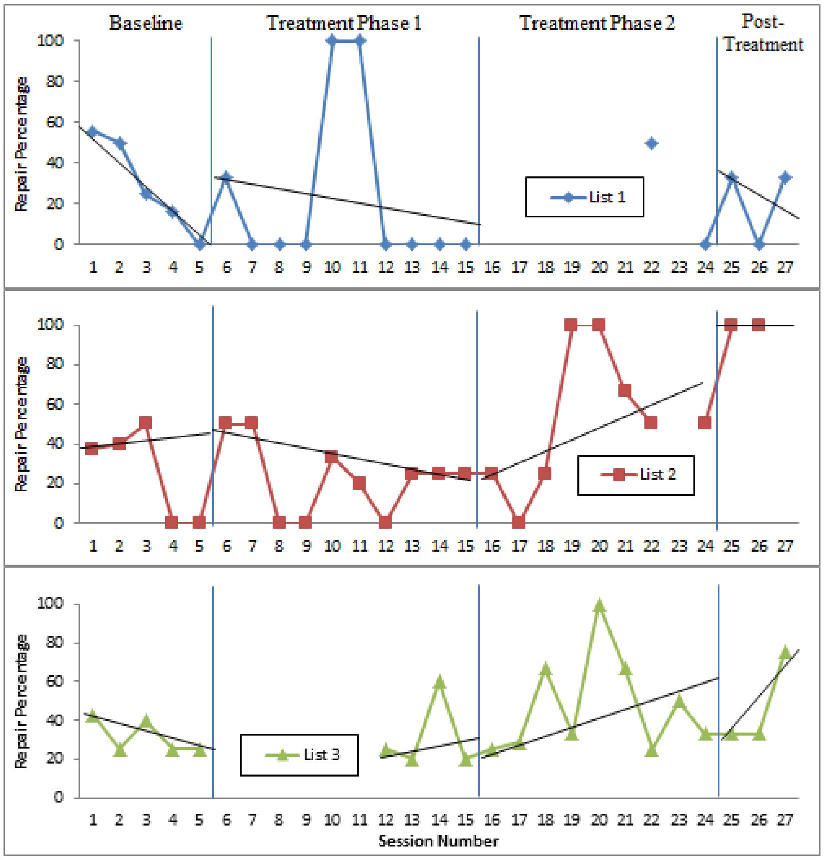
Level. Figure 37, below, displays participant 2's communicative repair score level analysis. For word list 1, participant 2's mean communicative repair score was 29.4% at baseline, 23.3% during treatment phase 1, 25% during treatment phase 2, and 22.2% post treatment indicating no effect on this list. On word list 2, his mean communicative repair score was 25.5 at baseline, 22.8 during treatment phase 1, 52.1 during treatment phase 2, and 100% (no failed communication repair attempts) post-treatment. This indicates a positive increase in participant 2's communicative repair score for word list 2 with each study phase. Word list 3 also showed some positive increases in level but not to the same degree as word list 2.

Figure 36. Participant 2 Communicative Repair Score- Level



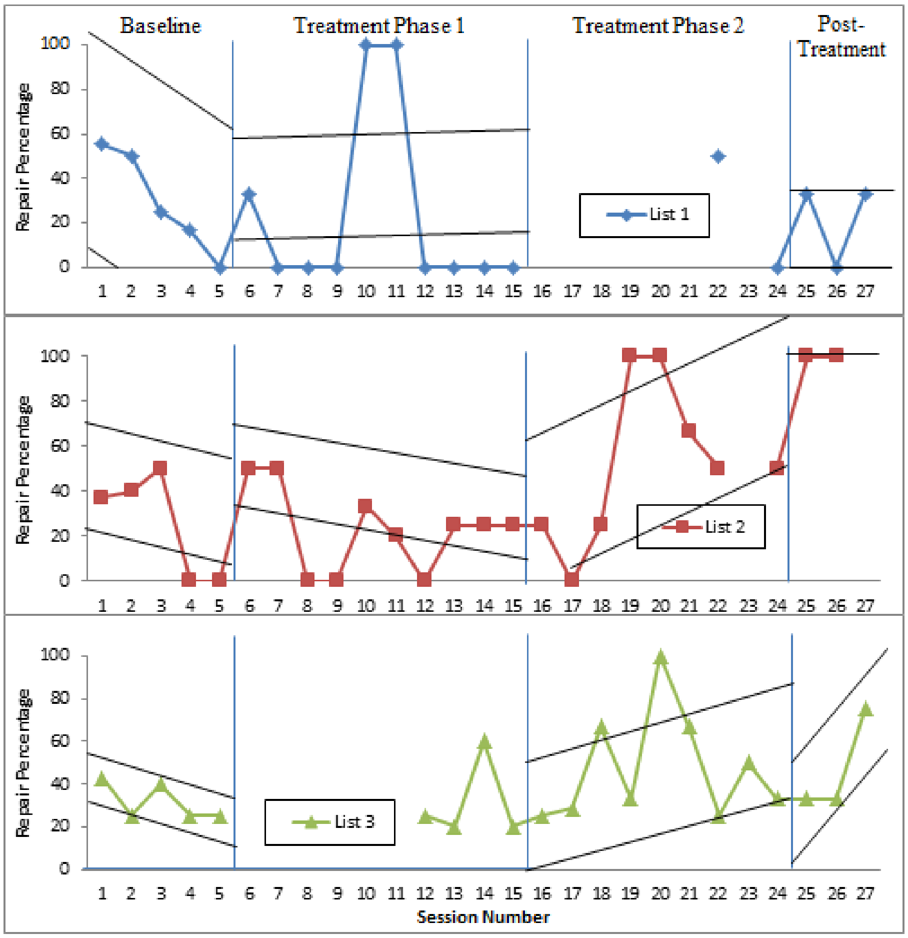
Trend. Trend was determined using the best fit line of data points for each phase and word list. A graph of the trend line for each word list for participant 2's communicative repair score is displayed, below, in Figure 38. Word list 1 showed negative trend lines across all phases of the study. Word list 2 showed a positive trend line at baseline, a negative trend line during treatment phase 1 and positive or stable trend lines for the remainder of the study. Word list 3 showed a negative trend line at baseline but positive trend lines through the remainder of study phases.

Figure 37. Participant 2 Communicative Repair Score- Trend



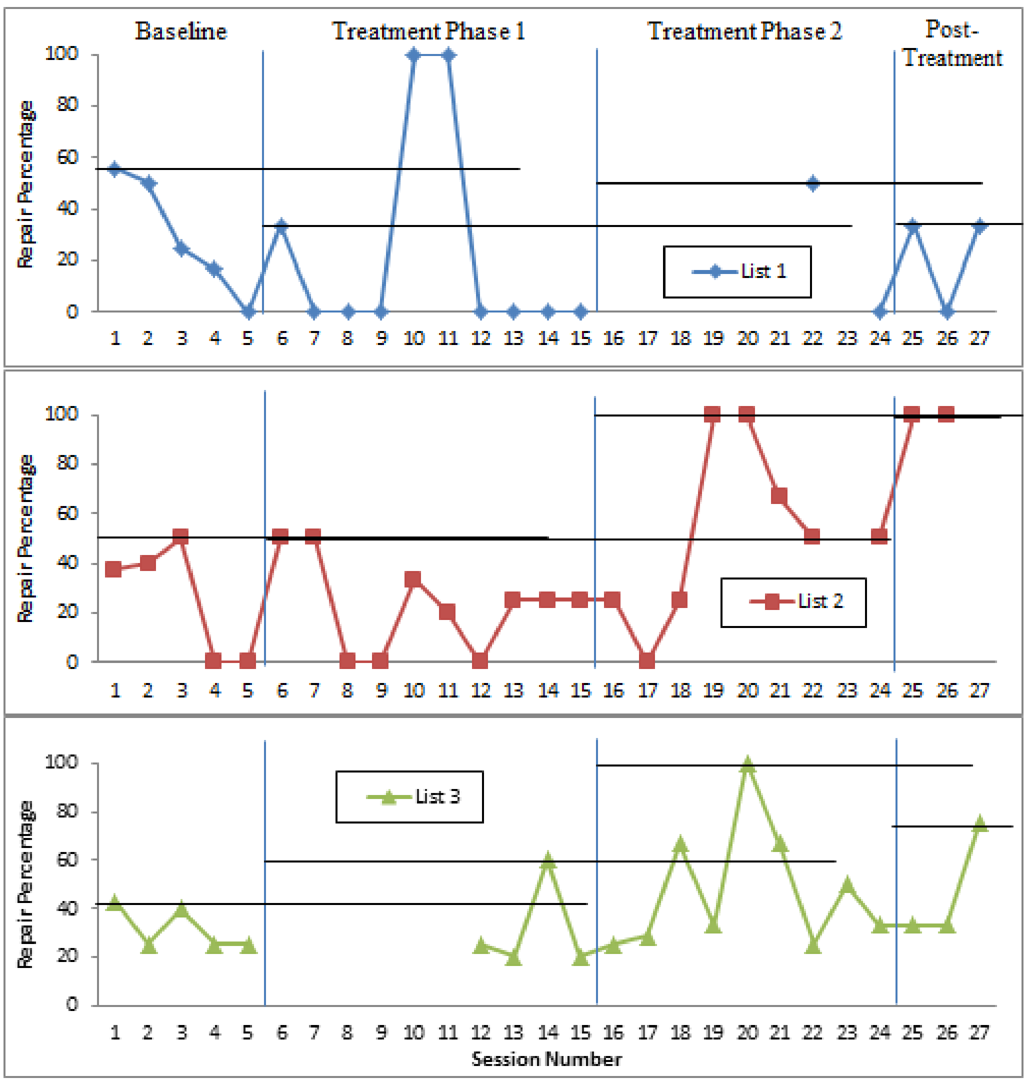
Variability. The variability is reported as the range of standard deviation above and below the trend line during each study phase. Figure 39, below, displays participant 2's variability for communicative repair score across each word list. Both treated word lists showed decreased variability post-treatment compared to baseline levels of variability. Word list 3 (untreated) remained highly variable throughout, increasing in variability as the study progressed.

Figure 38. Participant 2 Communicative Repair Score- Variability



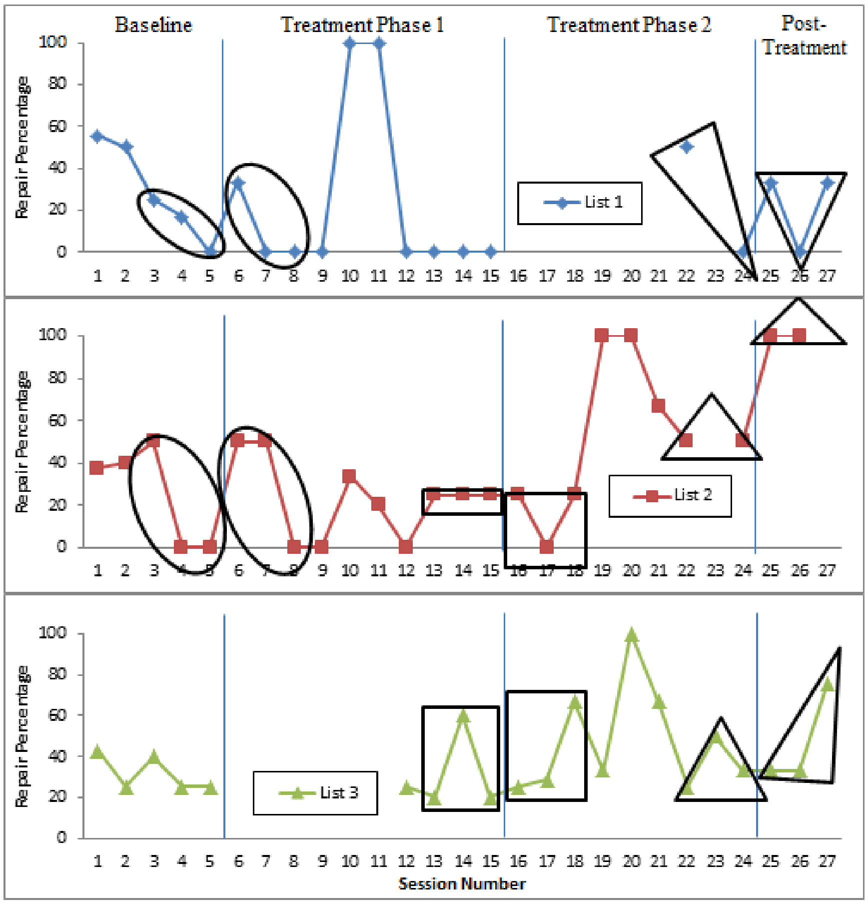
Degree of overlap between phases. The degree of overlap between phases was analyzed as the number of data points within a phase that overlapped with the highest point of data from the previous phase. The researcher examined the degree of overlap between adjacent study phases for each word list. Participant 2's communicative repair score and degree of overlap between phases is displayed below in Figure 40. Between baseline and treatment phase 1, word list 1 had 8 overlapping data points (80%), word list 2 had 10 (100%), and word list 3 had 3 (75%). Between treatment phase 1 and treatment phase 2, word list 1 had 1 overlapping data point (50%), word list 2 had 4 (57%), and word list 3 had 6 (67%). Between treatment phase 2 and post-treatment, all word lists had 2 to 3 overlapping data points (100% overlapping for each word list). Therefore, the least amount of overlapping data points for participant 2's communicative repair score occurred during treatment phase 2 suggesting an increased effect of treatment on breakdown resolution at this time.

Figure 39. Participant 2 Communicative Repair Score- Degree of Overlap



Immediacy of effect. Researchers visually compared the last three data points of one phase and the first three data points of the next phase using shapes (i.e., ovals, rectangles and triangles) to observe the immediacy of effect (Figure 41). No immediate effects of treatment on participant 2's communicative repair score were evident for word lists 1 and 3. Word list 2 showed no immediate effects until the transition from treatment phase 2 to post treatment.

Figure 40. Participant 2 Communicative Repair Score- Immediacy of Effect.



Participant 2 formal assessments. Participant 2 completed the nonverbal subtests of the CLQT and the CADL-2 during baseline and post-treatment sessions. Participant 2 was nonverbal and unable to complete the CLQT in its entirety as with participant 1. He displayed improvements in design memory, mazes, design generation, and clock drawing with an overall increase in his visuospatial domain skills. He also increased his raw score on the CADL-2 from 61 pre-treatment to 68 post-treatment. Participant 2's performance on formal assessments can be viewed below (Table 12).

Table 12. Participant 2 Formal Assessment Results

	Cognitive Linguistic Quick Test							CADL-2		
	Symbol Cancellation (12)	Symbol Trails (10)	Design Memory (6)	Mazes (8)	Design Generation (13)	Visuospatial Domain Skills (105)	Clock Drawing Domain (13)	Raw Score	Stanine Score	Percentile
Pre-Treatment	2	1	3	4	0	30 Severe	5 Severe	61	3.7	22.7
Post-Treatment	0	1	5	8	2	48 Moderate	4 Severe	68	4	35

Participant 2 also completed the CAT disability questionnaire at baseline and post-treatment. His responses before and after treatment were similar. However, he reported increased ease using writing to communicate at the word level (changing his score from a 3 pre-treatment to a 2 post-treatment). His ranking of worry over his communication scores changed from a 4 (0 = “no problem” to 4 = “major problem”) pre-treatment to a 2 post-treatment.

Chapter IV

Discussion

The findings suggest that a multimodal communication treatment, previously used with people with aphasia, may also benefit some individuals with low intelligibility following severe TBI. However, gains for people with TBI were less robust compared to findings for people with aphasia. First, the author will consider outcomes from the modality probe and RCT for both participants. Next, the participants' performance on formal assessments will be reviewed. Finally, information about limitations and future research appears.

Modality Probe

Participant 1 demonstrated significant improvement in production of the five communication modalities for word lists 1 and 3 during the modality probes. Most notable were his increases in accurate productions of gesturing, drawing, and text-to-speech (TTS). Immediate positive effects of treatment were evident as participant 1 had very few overlapping points between baseline and treatment phase 1. Due to severe memory deficits, his increases in TTS use were likely due to the use of special instructions provided during intervention sessions. Specifically, his performance improved as errorless learning was utilized to teach the steps to successfully communicate a message on the iPad application. Sohlberg and Mateer (2001) describe errorless learning as an instructional method used with individuals with memory deficits to reduce errors during the acquisition stage resulting in improved learning. Similarly, Wallace & Hux (2014) identified the benefits of using errorless learning to teach people with aphasia to use high tech AAC devices. Examination of the use of errorless learning for individuals with TBI who have memory impairments, particularly for AAC strategies that are unfamiliar (e.g., TTS), is warranted.

Participant 1's mean number of total modalities produced, as evident through visual analysis of level, increased throughout both treatment phases. He continued to improve on word list 1 beyond the first phase of treatment suggesting long-term benefit of treatment. Additionally, after learning the modalities for the treated words, participant 1 appeared to generalize his use of the five modalities to the untreated words as well but to a lesser degree than treated word lists. His improvements across word lists were so great that during later modality probe tasks, he used or attempted to use each possible modality for every target. This generalization and maintenance of skill may be due in part to his independent development of the strategy of counting the modalities he used on his hand to identify whether he missed any possible methods.

Participant 2 did not generalize as well as participant 1 to untreated targets. Specifically, participant 2 had significant improvements in his total production of modalities for the treated word lists (1 & 2) and no effect on the untreated word list. For the treated word lists, his average, as indicated by the visual analysis of level, improved over the progression of the study. Although his performance on word list 3 revealed slightly improved averages with each phase of treatment, the improvements were much slower and less extensive than for the treated word lists. These results suggest that participant 2 may have memorized modalities rather than learned the use of nonverbal modalities as a strategy. Additionally, participant 2's executive function impairments likely interfered with his generalization to untreated words. The gains on word list 3 were most evident toward the end of treatment suggesting that he required additional practice to begin to show generalization of strategies to untreated words. Although gains in accuracy were not overwhelming, participant 2 also displayed a decrease in variability post-treatment suggesting that the multimodal intervention improved his consistency in responses. Similar to participant 1, participant 2 most consistently used gesturing and drawing throughout treatment and demonstrated gains in his productions of these modalities.

Referential Communication Task

Both participants showed more notable gains during the modality probe task than during the RCT. Therefore, participants showed the capability to use the various modalities, however, the strategies were not always being used during structured functional tasks. These findings are similar to those reported by Wallace, Purdy, and Skidmore (2014) with people with aphasia. These researchers found that participants' showed greater improvements in the modality probe task compared to improvements in switching behavior. Specifically, one of the two participants made gains producing the individual communication modalities but did not use the strategies to effectively increase switching behavior during the RCT or formal testing during this similar study. The authors hypothesized that these results were due to his severe impairments in auditory comprehension and cognitive skills.

Participant 1 improved in his use of all communication strategies during the modality probe task, and therefore had the skills to produce targets in each modality. However, during the RCT, he did not display the same type or degree of modality use. He rarely utilized the TTS application during the interaction and mostly relied on gesturing and drawing (sometimes combined with speech). As memory was a substantial challenge for participant 1, he often forgot that he had access to other strategies, particularly during early treatment sessions. The strategy of counting the modalities produced that he employed during the modality probe was not helpful during the RCT. His performance might have improved had the researcher incorporated additional memory strategies into treatment activities. Sohlberg and Mateer (2001) discuss the use of external memory aids as a favorable means to compensate for difficulties with memory, attention, and executive functions. For example, the use of the modality chart as an external memory aid during all study tasks (probe tasks and treatment sessions) may result in improved performance and help to remind him of the strategies available to use during interactions.

As was true of his performance during the modality probe, Participant 2 was more variable in his use of modalities during the RCT than participant 1. Similarly, during the modality probe he used multiple type strategies (e.g., gestures, TTS, drawing, writing), but he typically only utilized gestures and some drawings to communicate during the RCT. Participant 2 displayed increased impulsivity and increased instances of perseveration of previous productions or targets. These behaviors, likely the result of his executive function impairments, interfered with his use of modalities during the RCT as well. Also, participant 2's tendency to fatigue and difficulty attending to study tasks at the start of the project may have impacted performance early on. However, his fatigue appeared to decrease overtime resulting in improved attention during probe tasks and treatment. It is possible, that treatment directly increased his stamina for communication activities.

Correct initial nonverbal attempts. Neither participant showed significant effect sizes relative to changes in correct initial nonverbal attempts. However, visual analysis and consideration of standard deviations may indicate that changes were occurring as a result of treatment. Using the visual analysis of level, it was evident that participant 1 increased his mean number of correct initial non-verbal attempts post-treatment for all word lists but mostly for trained word lists. Participant 1 also began to show evidence of positive trend lines and a decrease in variability during treatment phase 2. After treatment, his mean number continued to improve along with an increase in positive trend and variability effects. These effects were not as evident until treatment phase 2, suggesting again that he required additional practice sessions to use these strategies accurately on his first attempt. These results might indicate that as treatment progressed, participant 1 began to anticipate the need to use a nonverbal communication strategy (alone or combined with speech attempts) to have successful exchanges with communication partners.

Visual analysis of participant 2 revealed an increase in level, or mean number of correct initial nonverbal modalities produced (trained word lists), from baseline to post-treatment and a decrease in standard deviation for word list 1 post-treatment. Throughout the study, his positive trend lines for treated word lists suggest continued improvement across all phases. Prior to treatment, he would either not respond or appear to attempt verbal communication with unsuccessful attempts to vocalize. After treatment, he often used nonverbal communication modalities on his first attempt. This change suggests improved awareness of the need to use nonverbal modalities due to his nonverbal status. In contrast, his performance on word list 3 was unaffected by treatment suggesting minimal generalization in his ability to predict the need to use a nonverbal strategy.

Modality switching. Although neither participant had significant effect sizes for modality switching, both participants displayed changes including decreases in standard deviation and increased average number of modality switches after treatment. Participant 1 showed high levels of variability in his switching among communication modalities at baseline but appeared more consistent throughout treatment phases and into post-treatment. The evaluation of his performance may have been affected by the interconnectedness of the RCT variables. Specifically, as the number of successful initial non-verbal attempts increased, he had fewer opportunities to repair and switch modalities, potentially resulting in lower scores.

Although not reflected in analysis of effect sizes, participant 2 often displayed accurate switching after items on the probe tasks were completed. That is, after the completion of the probe, the participant would sometimes have a delayed switch. Similarly, he was highly successful at switching during treatment when provided with cues by the examiner. Without cues during the probe tasks, his executive function deficits caused him to perform poorly. Specifically, he demonstrated poor self-monitoring and recognition of errors. This behavior is consistent with Wallace and Kimbarrow (2016)'s discussion about poor awareness of deficits and impairments in theory of mind, and the negative impact these characteristics have on communication interactions. This may imply that multimodal interventions with individuals who present with similar deficits may have improved success by integrating strategies to increase self-monitoring and recognition of errors into the protocol.

Communicative repair score. Participant 1 developed a consistent pattern utilizing gesturing on first attempts followed by writing on second attempts possibly indicating the development of writing as a backup strategy when his preferred modality (i.e., gesture) was unsuccessful. Although participant 1's effect sizes were not significant due to variability at baseline, his average communicative repair score increased and his standard deviation, or visual analysis of variability, decreased for treated word lists post-treatment. The untrained word list (i.e., 3) also showed similar findings, suggesting generalization of his ability to repair, but his scores returned to his baseline performance level at the conclusion of treatment phase 2. His performance repairing breakdowns for word lists 1 and 2 remained stable at the conclusion of treatment. This finding suggests that more functional practice must be incorporated to create increased opportunities people with TBI to practice real-life skills. As previously mentioned, functional practice is important for promoting generalization in people with TBI (Hux, 2011). To improve the ability of people with TBI to effectively use strategies and repair communication breakdowns, clinicians may need to spend additional time encouraging functional practice of skills.

Participant 2 showed increased variability when compared to the performance of participant 1. Similar to participant 1, participant 2 relied mostly on gestures and drawings during the RCT. Although participant 2 did not demonstrate significant effect sizes for communicative repair score, his standard deviation decreased for word lists 1 and 2 (treated) and his mean communicative repair score increased for word list 2 post-treatment. Improvements were also noted for word list 3 but his variability on this untreated word list remained present post-treatment. This suggests that participant 2's gains were most evident during phase 2 suggesting that he also needed additional practice using strategies in an interactive way. Similarly, in a study combining semantic treatment with multimodal communication treatment, Carr (2013) found that treatment effects assessed using the RCT were delayed and the participant required a greater number of intervention sessions than expected to learn the behaviors. As with participants with TBI in this study, Carr (2013) found that changes were not evident until the end of treatment sessions and suggested increasing treatment dosage to determine whether increased change would be observed with time. Similarly, more training may be required to see increased treatment effects on strategy use with people with TBI as previously suggested for people with aphasia. Carr (2013) also only included instruction for 3 modalities compared to the 5 used in the current study. It is possible, that instruction in 5 modalities was a cognitive burden to the participants in the current study further explaining the delayed response during RCT probes.

Formal Assessments

Both participants showed some improvements on formal assessments post-treatment. Participants 1 and 2 showed gains in CADL-2 scores post-treatment suggesting improved communicative effectiveness using any modality. These findings provide some evidence for generalization not detected during the RCT. In addition, both participants made gains in visuospatial skills on the CLQT. This was an unexpected result that may be due to the visual stimulation provided during treatment tasks. Each of these findings should be examined in future studies.

Limitations

Due to the small sample size included in this treatment study (n=2), findings from this study cannot be generalized to other individuals with TBI. However, it provides an initial examination of multimodal interventions for the TBI population which may help determine best way to teach people with TBI to use communication strategies for breakdown resolution. The lack of significant effect sizes is likely due in part to the heterogenic nature of the TBI population and variability in performance and deficits that is common to TBI. Blake (2016) discusses that TBI may be described as follows: "'if you've seen one patient with TBI, you've simply seen one patient with TBI'- you should not expect them to be all that similar (p. 132). Relative to the wide range of cognitive and communication abilities of people with TBI, it is likely that treatments, such as the multimodal communication treatment used in this study, would need to be tailored to specific deficits (Sohlberg & Mateer, 2001). For example, incorporating external memory aids or rate control techniques for impulsivity and rapid responses may improve overall effects of the treatment.

Another limitation of this study was the limited number of opportunities for participants to repair failed first communication attempts as initial attempt success improved. For example, if the participants successfully gestured for 8 out of 10 targets on a word list, they only had two opportunities to repair breakdowns with the communication partner. This situation occurred for both participants in this study as they achieved up to100% accuracy on some first attempts once treatment began. In contrast, if they had only 4 successful first communication attempts out of 10, they had 6 opportunities to repair breakdowns with the communication partner. Thus, increased performance, decreased the number of opportunities the participants had to repair breakdowns. Unlike in previous studies conducted with people with aphasia, the researchers did not designate a number of attempts to be falsely misunderstood by communication partners to control for this factor (Carr, 2013; Purdy & Wallace, 2015; Yoshihata, Watamori, Chujo, & Masuyama, 1998).

This study did not aim to determine how participants function during natural interactions, but rather examined performance during structured communication tasks. Therefore, it is difficult to determine whether the participants demonstrated improvement outside of the structured study tasks in real-life situations. Participant 1's caregiver reported increased use of nonverbal strategies, particularly gesture, in the home environment. His caregiver also identified that he seemed to repair breakdowns more quickly as treatment progressed. Participant 2 had fewer communication partners and limited expectations to communicate at his residential facility. As generalization to real life activities is the ultimate goal of interventions, it is a limitation of this study that researchers did not conduct observations of real-life communication or consistently track caregiver reports of everyday communication. Additionally, the researcher did not control for potential practice or communication opportunities which differed across participants.

A final limitation of this study is that the researcher used guidelines for effect sizes that are meant to be used as benchmarks for people with aphasia and lexical retrieval (Robey & Beeson, 2005). As there are no established effect sizes to use for this intervention with people with TBI, the researcher had to borrow and use effect sizes for treatment studies with people with aphasia. People with TBI may present with levels of success different from those with aphasia and therefore transferring effect sizes from aphasia literature to TBI results may not yield as accurate results or appropriately reflect meaningful changes.

Future Research.

The lack of significant effect sizes and differences between the participants' performance may also suggest the need to modify the treatment for people with TBI and poor intelligibility. Future research may examine modified treatments tailored to the specific needs or cognitive profiles of people with TBI. For example, incorporating use of external memory aids for individuals with memory impairments, increasing the amount of treatment time allotted to functional practice, and incorporating treatment for rate control and self-monitoring strategies within the multimodal intervention. Use of external aids in future studies might benefit people with TBI similar to those in this study. As described in the discussion, a cue board of the potential communication strategies may be used as a reference by some individuals. As the participants did not consistently show effect of treatment immediately, at times not until treatment phase 2, future work might examine the amount of repetition people with memory impairments resulting from TBI need.

Additionally, modifying the methods of outcome measurement may allow researchers to better capture changes as a result of treatment. For example, conducting future research and establishing benchmarks for effect sizes more applicable to the TBI population may yield promising results and effect sizes more indicative of the individuals' performance. As people with TBI tend to have increased variability, this should be factored into the evaluation of results. Observations and evaluations of carry over to real-life situations, either through regular caregiver report or observations may also provide helpful information about generalization of strategies. Finally, as decreased opportunities to repair communication breakdowns interfered with measurement of some dependent variables, incorporating additional planned tasks to assess repair strategies may provide a more reliable measure of performance after treatment.

Conclusion

The primary aim of this study was to examine the efficacy of a multimodal communication treatment for people with severe traumatic brain injury and low intelligibility. The results of the study provide clinicians and researchers with valuable information for the design and treatment of a multimodal intervention for people with TBI. Although the researcher found mixed results, this multimodal intervention may be appropriate for some people with TBI. However, further investigation for treatment and outcome measurement changes are warranted.

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Appendix A. Modality Chart

Modality Chart

iPad

Write

Gesture

Draw

Speak

Appendix B. Demographic Form

TBI Participant Demographic Form Participant Code___________

These questions will be answered via interview with a member of the research team and, if permission is provided, collected from health services provider using HIPPA approved forms.

1. Age: ________________
2. Gender: MALE FEMALE
3. Date of birth:__________________
4. Primary language: _____________________________
5. Date of injury:______________________
6. Lesion location:_________________________
7. Length of post-traumatic amnesia:
   ___1 day or less
   ___Less than 1 week
   ___Over 1 Week
8. Length of loss of consciousness:
   ___ Less than 1 hour
   ___Less than 1 day
   ___Less than 1 week
   ___Greater than 1 week- how long?_______
9. Ranchos Los Amigos Scale of Cognitive Function Level:_______________
10. Handedness before brain injury: Right Handed Left Handed
11. Handedness after brain injury: Right Handed Left Handed
12. History of other strokes/ brain injury; describe:__________________________________
13. Racial / ethnic group:
    ___ American Indian / Alaskan Native
    ___ Asian
    ___ Native Hawaiian or other Pacific Islander
    ___ Black or African American
    ___ White (Caucasian)
    ___ Hispanic or Latino
14. Please mark the highest educational level completed:
    ___ Elementary or junior high school

___ Some high school
___ High school graduate or GED
___ Vocational or technical school
___ Some college
___ College graduate
___ Post-graduate (Master's; Ph.D.)

15. What is your occupation (or what was your occupation at the time you stopped working)?

____

16. With whom do you currently live?

___ I live alone
___ Family (spouse or domestic partner, children, parents, other relatives)
___ Friends / Roommate
___ Assisted Living or Adult Family Home
___ Other, Please describe: ____

17. Do you have any other physical conditions that, in your opinion, affect your participation in day to day activities?

___ No

___ Yes, Please describe: ____

18. Are you currently enrolled in Speech-Language Therapy (check all that apply):
no yes: individual yes: group

Duration of Speech Therapy: _____________

19. Current diagnosis of aphasia:________________

20. Current diagnosis of dysarthria or apraxia of speech:

___ No

___ Yes, Please describe: ____

21. Do you have a history of speech, language, or cognitive impairments prior to accident? If yes, please describe:

____

Appendix C. Vision screening

Jane Thomas Susan Sarah Mark Alice

Susan Frank Thomas Jane Richard

Molly Mary Sarah Susan Alice Thomas

Mark Susan Jane Thomas Susan Sarah

Holly Margaret Alice Lauren Gordon

Sarah Frank Susan Jane Alice Hannah

Elizabeth Susan Sarah Molly Mark Jane

Richard Alice Mary Lauren Sarah

Jane Sarah Elizabeth Marie Katherine

Thomas Anthony Margaret Elizabeth

Marie Jane Sarah Mary Gordon Frank