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Evaluation of an Augmentative and Alternative Communication Intervention for Individuals with Aphasia.

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Evaluation of an Augmentative and Alternative Communication Intervention for Individuals with Aphasia.

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By

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Abstract

The use of augmentative and alternative communication devices and programs has become more common in the field of speech therapy, especially with advances in technology. With a large population of people who suffer from aphasia, it is imperative that an effective form of therapy is utilized. The purpose of this study is to investigate the efficiency and effectiveness of augmentative and alternative communication programs, specifically iPad-based applications, in improving the communication needs and daily lives of individuals affected by aphasia.

Individuals (n = 20), ranging from ages 18 to 90, suffering from aphasia for 3 months or more were given six 1 hour therapy sessions with a certified speech and language pathologist, to work on their communicative abilities using the augmentative and alternative communication program. Participants were subjected to pre-evaluations prior to the intervention sessions and post-evaluations about a week following completion of the sessions. Evaluations included communication satisfaction and success assessment questionnaires, the Western Aphasia Battery (WAB), and probing tests, in which participants were to respond to the prompts given, with an EEG component to measure brain activity during these tests. Complications with the augmentative and alternative communication program resulted in setbacks, thus, to date, only preliminary data analyses were completed on three individuals. No significant changes were found in the participants' pre- and post- probing tests, with one performing worse (Wilcoxon Signed Ranks; $p = 1.000$), one remaining the same (Wilcoxon Signed Ranks; $p = 0.687$), and the other increasing his score (Wilcoxon Signed Ranks; $p = 0.125$). Although every individual improved on their post- Western Aphasia Battery score, the increases were not statistically significant (Wilcoxon Signed Ranks; $p = 0.109$). Average

scores on both questionnaires generally increased but not significantly. Despite this, on a clinical level these improvements were considered noteworthy. The fact that speech and language pathologists have seen a clinical significance and more data collection is still to be completed, the use of augmentative and alternative communication has an optimistic potential as a beneficial form of therapy, in regards to people's communicative functions and daily life, if not just a reliable, additional support system. From the EEG data of one subject's eyes closed test, the delta and theta bands had the highest mean power spectral densities in both the frontal and parietal lobes before and after therapy, supporting the idea that impaired brain regions produce more low frequency brainwaves than high frequency waves. Moreover, the mean power spectral densities of the left frontal lobe demonstrated a statistically significant decrease from pre- to post-, which in the case of the delta and theta bands may indicate possible recovery (Wilcoxon Signed Ranks; $p = 0.028$). However, more research is necessary to substantiate these conclusions and to explore the use of EEG in mapping brain lesions and tracking the brain's activity and rehabilitation, as well as the benefits of augmentative and alternative communication supports.

1. Introduction

Knowledge of aphasia and other disabilities has existed for a very long time. As society continually advances in the medical and technological fields, our ability to help and rehabilitate those with disabilities, both physical and mental, increases. It is undeniable that therapy has a huge impact on those with disabilities, whether it is helping them to achieve a complete recovery or marginally improving their quality of life. As people become more knowledgeable regarding brain disorders, especially aphasia, different forms of therapy or many forms integrated together are being developed in order to benefit each person’s unique case. Augmentative and alternative communication comprises methods intended to support or substitute one’s communication in all aspects, such as oral language, thoughts, needs, and opinions. Participants in this research study will be receiving therapy in the form of hourly sessions with a clinician using an augmentative and alternative communication program, as well as attempting to incorporate it into their daily life. In this study, an iPad-based augmentative and alternative communication program, GoTalk Now, is put to trial to determine if it was efficient and effective in improving an individual’s communication abilities and life, which are hindered due to aphasia post brain damage.

Aphasia is a communication and language disorder resulting from brain damage, typically cerebrovascular accidents or traumatic brain injuries. Depending on the size and depth of the brain lesion, the path to rehabilitation will vary for every person. Often, people will experience spontaneous recoveries within the first few months to a year post onset. To further encourage the brain’s recovery, people often attend therapy with speech and language pathologists. Regardless of the form of therapy, rehabilitation over time has been shown to typically result in improvements. After strokes and brain damage, many nerve cell connections are damaged and dysfunctional. Similar to how developing babies and adolescents solidify brain cell connections from constant use or weaken them from lack of use; the nerve connections for language lost due to brain damage must also be put to use to rebuild and strengthen them. Typically, patients suffering from aphasia will avoid words and phrases they have problems with, which will further deteriorate the already weak nerve connections responsible for verbal communication (Pulvermüller and Bertheir, 2008). During intensive therapy, in which patients are challenged beyond their limits, patients have been able to reactivate and reinforce nerve cell connections and thus improve their communication capabilities (Pulvermüller and Berthier, 2008). In fact, functional magnetic resonance imaging of the brain indicates increased speed in word finding and retrieval after rehabilitation (Peck *et al.*, 2004). Thus, it is probable that therapy sessions using this iPad-based application will bring about an improvement in the ability to retrieve words for individuals with aphasia. Specific training and therapy also improves one's auditory comprehension through the brain reorganization prompted by the rehabilitation (Musso *et al.*, 1999). Whether this training and practice is administered and supervised by a professionally trained therapist or a volunteer, patients will likely still improve in their communication from the constant support and encouragement (David *et al.*, 1982). This suggests that a key to progress and recovery, in which the brain will likely adjust in a positive way, is consistent practice and time, something that GoTalk Now can offer.

As technology advances, augmentative and alternative communication devices are becoming more common in aiding people with disabilities amd generating marked improvements. In a study to observe the influence of visuographic aids on aphasic patients, impaired individuals who had highly contextualized photos to refer to were consistently answering more accurately as well as feeling more capable in their reading comprehension versus those with low context graphics (Dietz *et al.*, 2009). Furthermore, people have been able to maintain their progress on learned words as well as learn new ones in the course of an iPad-based treatment program (Kurland *et al.*, 2014). Many of the augmentative and alternative communication programs offer interactive, detailed graphics and photos, which are essential in assisting individuals. Patients have expressed more ease with reading comprehension which they attributed to the highly contextualized visual scenes (Fried-Oken *et al.*, 2011). The application GoTalk Now boasts several features that make it a powerful communication device, yet it is still easy to navigate. This is especially important since the majority of the aphasia population is normally elderly, like our participants, who may be less technologically experienced. One beneficial feature is its customizable options, which offer patients the ability to personalize the application. The ability to have personal pictures or highly contextualized photos has been shown to result in patients executing matching spoken word to a visual more accurately (Fried-Oken *et al.*, 2011). Furthermore, mass practice of language use while accompanied by action has shown to be effective in improving one's communication capabilities with aphasia (Pulvermüller and Berthier, 2008). Thus, participants of this study will not only be using GoTalk Now during therapy sessions but also on their own in their daily lives with family members or their caretaker, which may produce a beneficial effect. In many cases, patients have continued with integrating the use of iPad programs in their day to day lives, which suggests that these augmentative and alternative communication aids are not only helpful but also feasible and a factor in improving their quality of life (Hoover and Carney, 2014).

The use of electroencephalogram (EEG) recordings to track the signals and activities of the brain has been relatively uncommon in the study of aphasia, although it could provide more insight to the individual's particular impairments. The power spectral density of certain bands could suggest which regions of the brain are more active during certain functions. It has been seen that there is a greater activity of the slow waves, delta and theta, produced in the locality of the lesion in aphasic patients, which is correlated to their relative cognitive impairment and suggests change in the brain's functioning capabilities (Hensel *et al.*, 2004; Spironelli and Angrilli, 2009). Furthermore, looking at these frequency bands, specifically high beta bands, may give indication to areas in which loss of connectivity were acquired and in which regions reorganization of the brain connections occurred (Spironelli *et al.*, 2013).

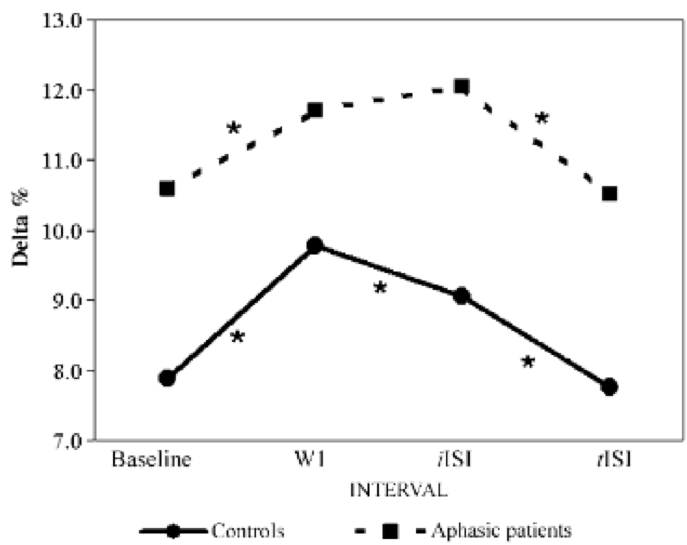
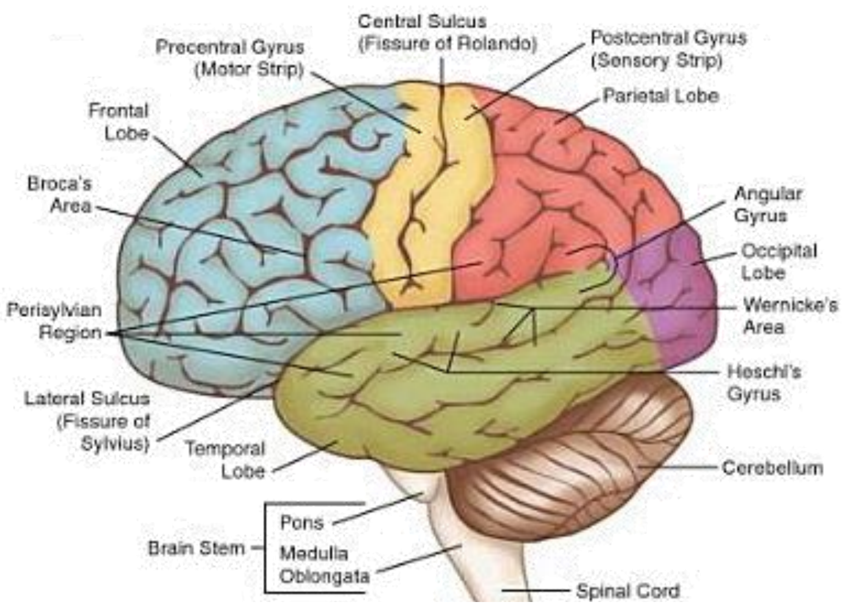


Figure 1. A Delta band analysis of the control group (solid line) versus aphasic individuals (dotted line) at different intervals (Spironelli and Angrilli, 2009).

The aim of this study was to test the efficacy of an augmentative and alternative communication aid on aphasic individuals. With the features the GoTalk Now application offers and previous evidence, it is believed that participants will develop improvements in their communication and comprehension abilities. Moreover, it is possible that their satisfaction in their abilities will potentially improve, which consequently may lead to a better quality of life. With the additional EEG measurements, it is hoped that EEGs will have clinical usefulness by possibly being a feasible instrument to track brain activity that can correlate with different impaired brain regions and language functions and note the progress in rehabilitation. It is expected that similar patterns, such as high delta and theta frequency band activity in damaged regions, will be seen in the subjects' EEG recordings.

2. Historical Background

Aphasia is a language disorder affecting an individual's ability to communicate. This creates difficulties in speaking and understanding speech, as well as reading and writing. Aphasia is a neurological disorder and is not a sign of lesser intelligence or a mental illness. It is most commonly the result of a stroke in an elderly person, but it is not restricted to the elderly population only. Similarly, strokes are not the only cause of aphasia. It can also result from certain brain lesions, due to head trauma, tumors, or infections. The severity of aphasic symptoms varies in several ways and often depends on the site of the brain lesion. There are typical patterns of language impairment and preservation, as well as other aspects such as articulation and word retrieval that are used to classify the different types of aphasia (Goodglass, 1993).



www.amyspeechlanguagetherapy.com/aphasia.html

Figure 1. The left hemisphere of the brain responsible for language functions.

2.1. Aphasia Types

2.1.1. Broca's Aphasia

Broca's aphasia (Table 1), also known as motor aphasia, efferent motor aphasia, and verbal aphasia, is characterized by a decrease or suppression of speech output with auditory comprehension still moderately maintained. Though phrases are normally limited to one to three word clusters, a lot of effort is needed to produce and articulate them. Each person's ability to articulate specific words varies depending on their familiarity with the word, and may be as extreme as complete incapability to minor awkwardness. Broca's aphasia is often, but not always, accompanied with agrammatism, which is the inability to speak in grammatically correct phrases. In addition, one word auditory comprehension is usually retained but more complicated phrases can be difficult for an individual with aphasia to understand. Reading comprehension is maintained, but their capability to write is limited in a similar fashion to how well the individual speaks. These impairments are due to a lesion surrounding the pars opercularis and pars triangularis of the left frontal lobe, known as the Broca's area, and extending posteriorly to the motor strip. However, lesions that do not penetrate deep enough into the periventricular white matter of the brain result in only temporary effects (Goodglass, 1993).

2.1.2. Wernicke's Aphasia

Wernicke's aphasia (Table 1) is also commonly referred to as sensory aphasia, temporal-acoustic and acoustic-mnestic aphasia, and syntactic aphasia. It is caused by lesions in the Wernicke's area, the posterior portion of the first temporal gyrus. Individuals with this form of aphasia normally form poorly structured sentences with incorrect syntax, or grammar, and often ill-chosen words (Jenkins *et al.*, 1975). Their auditory comprehension is extremely impaired, with very little capability of understanding sentences, let alone simple one word object names. Their speech output is often restricted due to difficulty finding words as well as unreasonably rapid and filled with errors they are unaware of. It is also common for their speech to be filled with newly created words or vocabulary unrelated to the topic and inappropriately used (Goodglass, 1993). The usage of incorrect words and syntax leads to incomprehensible speech, thus this is sometimes referred to as jargon aphasia (Reinvang, 1985). The degree to which the individual's reading and writing is affected is dependent on the depth and size of the lesion, but often, complete agraphia, the loss of writing ability, is present in Wernicke's aphasia. Lesions must encompass the region of the angular gyrus in order to result in reading and writing disorders (Goodglass, 1993).

2.1.3. Conduction Aphasia

Conduction aphasia (Table 1), commonly caused by a lesion in the supramarginal gyrus, is also known as afferent motor aphasia or central aphasia. Injuries that lead to this form of aphasia however are not restricted only to the supramarginal gyrus. Damage along the border of the Sylvian fissure will also result in conduction aphasia. Furthermore, lesions that reach posteriorly enough in the Sylvian zone will cause behaviors found in Wernicke's aphasia. Generally, people with conduction aphasia maintain articulation, rate of speech, and correct grammar, but their dialogue is marked with distinct characteristic errors (Goodglass, 1993). One main feature is a stutter like behavior called phonemic paraphasias (Jenkins *et al.*, 1975). Individuals also have periodic difficulties with word production, rearranging order of sounds, and replacing or inserting extra phonemes. Individuals may also have behaviors that resemble and border on those of Wernicke's, such as disorganized speech. What distinguishes conduction aphasia from Wernicke's is that the individual will likely recognize and continually attempt to correct mistakes. Another marked characteristic of this aphasia is difficulty repeating words or sentences, although they have relatively intact, but not perfect, auditory comprehension. Reading and writing abilities usually parallel auditory and speaking capabilities respectively. However, individuals may have more problems reading aloud due to difficulties in sequencing phonetics (Goodglass, 1993).

2.1.4. Transcortical Motor Aphasia

Transcortical motor aphasia (Table 1) or frontal dynamic aphasia, severely affects a person's ability to create spontaneous speech, limiting them to near normal ability for repetition (Goodglass, 1993). When properly tested, auditory comprehension is clearly impaired, but it remains fairly unaffected during simple conversations (Sarno, 1991). Individuals are usually able to form single word factual answers; however when encountering questions that require organization of thoughts, opinions, and words for an answer, they are not able to do so. Yet, if given the first sounds of a specific word, individuals are able to recognize and retrieve the appropriate word. There are times when people may make a breakthrough and form a normally structured sentence during conversation, which makes it difficult to classify this form of aphasia as fluent or non-fluent. One surprisingly distinct feature of transcortical motor aphasia is the high level of preservation of one's memorized material prior to the brain damage and onset of the disability. Lesions, often smaller than those of Broca's or Wernicke's, are found in the subcortical area of the anterior frontal zone creating a link between the motor speech region and the supplementary motor area and limbic structures, which are necessary for speech initiation. Brain injury to the cortical surface, part of the Broca's area, may also result in this disorder, although it has yet to be confirmed (Goodglass, 1993).

2.1.5. Transcortical Sensory Aphasia

Transcortical sensory aphasia (Table 1) behaviors are also similar those to of Wernicke's aphasia. This disorder is marked by impaired comprehension and well-maintained repetition capabilities; individuals can be described as fluent but paraphasic (Sarno, 1991). Though it resembles Wernicke's aphasia there are distinct characteristics that differentiate types. One's auditory comprehension is impaired and they are often oblivious of their language difficulties. Patients are often alexic (unable to comprehend written language) and agraphic (unable to produce written language) (Goodglass, 1993). Individuals with this form of aphasia have an astounding capability for repetition, even for long sentences (Reinvang, 1985). Moreover, they are able to incorporate some words their converser used to formulate their own answers to questions. Although, there are some cases in which the individual will echo or repeat words and phrases without comprehending the meaning. This form of aphasia is the outcome of a lesion deep in the region inferior to the angular gyrus and between the posterior end of the Sylvian fissure and the temporal-occipital (Goodglass, 1993).

2.1.6. Anomic Aphasia

Individuals with anomic aphasia (Table 1), also known as nominal aphasia or semantic aphasia are capable of fluent speech in regards to the syntax, articulation, and speed (Sarno, 1991). However, there are instances in which the patient is unable to produce the suitable word, usually nouns but also other syntactic words. Due to this difficulty, frequently, words or descriptions vaguely related to what they intended are substituted to preserve grammatical correctness. There are a number of possible lesion sites that will result in anomic aphasia, each presenting slightly different behaviors. Lesions in the angular gyrus region will cause individuals to have occasions of “alienation of word meaning,” when they fail to find the right word and are unable to distinguish and recognize it even when presented by another person (Goodglass, 1993; 214). It is often accompanied with impairments in reading and writing as well. Frontal anomia are due to small lesions in the subcortical frontal region typically linked with transcortical motor aphasia. This is almost a purely anomic disorder with the ability to complete words from just the first sounds. Lesions in the inferior temporal gyrus cause serious difficulties in word recovery; however relatively fluent and grammatically correct speech and written language are maintained. There are instances when one has almost fully recovered to near normal communication capabilities, but there still are some residual behaviors of anomic aphasia (Goodglass, 1993; Reinvang, 1985).

2.1.7. Pure Modality-Specific Aphasias

Pure modality-specific aphasias include three different syndromes: pure word deafness, subcortical motor aphasia or aphemia, and pure word blindness. Pure word deafness is caused by lesions in the bilateral temporal lobe or the unilateral left temporal region and results in being unable to interpret sounds of words. Lesions deep in the lower area of the motor strip cause subcortical motor aphasia, in which only speech articulation is impaired. Pure word blindness, also coined as “letter-by-letter reading,” is described as the loss of one’s ability to read (Goodglass, 1993; 216). Some will be able to recognize letters, but words will be constructed letter by letter through soundless spelling. This syndrome is the consequence of damage to the left visual cortex and the posterior corpus callosum (Goodglass, 1993).

Table 1. The types of aphasias with their alternative names, location of the lesion(s), and the typical language behaviors.

Aphasia Type	Alternative Names	Lesion Location	Communicative Behaviors
Broca's Aphasia	Motor Aphasia, Efferent Motor Aphasia, Verbal Aphasia	Pars opercularis and pars triangularis of frontal lobe, extending into the motor strip	Speech output: 1-3 word phrases Auditory comprehension: moderately maintained Reading and Writing: reading comprehension is kept, writing is similar to speech Other: agrammatism
Wernicke's Aphasia	Sensory Aphasia, Temporal-acoustic & acoustic-mnestic aphasia, Syntactic aphasia	Posterior portion of first temporal gyrus	Speech output: difficulty finding words, filled with mistakes Auditory comprehension: extremely impaired
Conduction Aphasia	Motor aphasia, Central aphasia	Supramarginal gyrus, Sylvian fissure and sometimes the Sylvian zone	Speech output: stutters, impaired word production, disorganized Auditory comprehension: fairly intact Reading and Writing: parallel auditory and speaking abilities
Transcortical Motor Aphasia	Frontal dynamic aphasia	Subcortical area of anterior frontal zone	Speech output: spontaneous speech severely lacking, limited to repetition Auditory Comprehension: fairly intact
Transcortical Sensory Aphasia	N/A	Deep and inferior to angular gyrus, between posterior end of Sylvian fissure and tempro-occipital	Similar to Wernicke's Speech output: oblivious to language difficulties, superb repetition Auditory comprehension: impaired Other: alexic, agraphic
Anomic Aphasia	Nominal aphasia	Angular gyrus, subcortical frontal region, inferior temporal gyrus	Speech output: fluent articulation, rate, and syntax, sometimes produce unsuitable words
Pure Modality-Specific Aphasias	N/A	Bilateral temporal lobe or unilateral left temporal, lower motor strip, left visual cortex and posterior corpus callosum	Pure word deafness: unable to interpret word sounds Subcortical motor aphasia/aphemia: impaired speech articulation Pure word blindness: impaired reading ability

2.2. History of Aphasia

Human language has been in existence from the beginning of human presence; with medical recordings of speech loss of unknown causes dating back as early as 3500 BC in the Edwin Smith Surgical Papyrus (Goodglass, 1993). It was not until 400 BC that the causal relationship between brain injury and loss of speech was recognized. Speech disturbances were described in the Hippocratic writings as often following a fatal illness or injury; however because the terms a*phōnos*, or voiceless, and *anaudos*, or speechless, were given multiple connotations depending on their context, the exact speech loss patterns they were describing are not known (Sarno, 1991). During the age of the Romans, physicians and philosophers began attempting to identify specific cognitive roles in different areas of the brain. For example, perception thought to originate from the lateral ventricles, reasoning from the third, and memory was from the fourth ventricle (Sarno, 1991). Following the footsteps of those in the Roman ages, people of the Renaissance period began applying previous knowledge of brain ventricles in determining certain diagnoses and treatments. For instance, Antonio Guainerio attributed two patients' aphasic symptoms of paraphasic misnaming and minimal vocabulary to excessive phlegm in the fourth ventricle, which was believed to be for memory (Sarno, 1991).

Throughout the fifteenth to most of the eighteenth century, most of the different aphasic disorders were observed and recorded, though the cause of this phenomenon was still relatively unknown (Goodglass, 1993). In 1770, Johann Gesner wrote a chapter "Die Sprachamnesie" (Speech Amnesia) which played a major role in the perceptions of aphasia with its wealth of descriptions and analyses of language loss patterns but retained motor and articulatory functions (Goodglass, 1993). It is from this work that Gesner further developed the associationist theory of aphasia, in which aphasia was thought to be a disorder caused by the failure to associate a perception or idea with the right linguistic sign (Sarno, 1991). With more understanding of the disorder, the 1800s was a century full of advances in the clinical knowledge of aphasia. Jean-Baptiste Bouillaud had classified this language disorder into two types, articulatory and amnesic, and can be credited with the basis of classification for fluent or non-fluent aphasia we know of today. At this time, the idea of neuropathological basis, in which the brain was comprised of organs each specific to their own cognitive function or trait, was also first presented by Franz Joseph Gall (Sarno, 1991).

Beginning in 1861, aphasia became a significant indication of focal brain disease, in which one area is responsible for the abnormalities, from previously being just a minor curiosity. Paul Broca identified Broca's aphasia. His autopsy studies on several aphasic patients led him to announce that "we speak with the left hemisphere" from his findings, in which a significant number of patients had lesions in the left hemisphere (Sarno, 1991; 8). He made it clear however, that not all aphasia types were related to the left hemisphere, but at least the motoric type was. In 1874, Carl Wernicke described aphasia symptoms from a lesion in the first temporal gyrus of the left hemisphere as sensory aphasia, or what we now know as Wernicke's aphasia (Sarno, 1991). In addition, he constructed one of the first diagrammatic schemes using the knowledge he had of the motor and auditory regions of the brain and construed seven different types of aphasia. His work in diagrammatic schemes of aphasia manifested the beginning of the age of "diagram-makers" in studying the disorder (Osgood and Miron, 1963). This associationist, or localization theory, which was supported by both Broca and Wernicke, was subjected to heavy criticism by many. The theory postulated that people's brains had specialized regions for certain functions, in which the left hemisphere had different specialized areas and all necessities for language (Reinvang, 1985). It was also believed that there were interconnected cortical centers within the language regions that functioned as reservoirs for aural and visual memories of words as well as motor patterns of both spoken and written speech. With these assumptions, both Broca and Wernicke believed that aphasic disorders were not results of lower intellectual capability, but instead, of disturbances in the ability to associate proper verbal labels to ideas (Sarno, 1991). However, many people who believed in the cognitive model, in which it was believed that "intelligence is always lamed" in aphasia (Sarno, 1991; 10). Thus people with the disorder were described as "noetic," meaning their deficiency in language was interrelated to a diminished intellectual aptitude (Goodglass, 1993). Criticism stemmed from the idea that it was impossible and unacceptable to localize language in the brain and distinguish intelligence from aphasia (Reinvang, 1985).

This debate over the associationist and cognitive model continued through the early twentieth century. In 1935, the beginning of the modern period of aphasia, Weisenburg and McBride conducted experiments to test aphasic patients' degree of intellectual impairment on nonverbal tests. They established that aphasia was not necessarily linked to a lower cognitive capacity since many patients performed satisfactorily on the tests (Sarno, 1991). Today, it is accepted that aphasia and the many subtypes and disorders associated with it are consequences of brain damage to certain regions.

2.3. Electroencephalogram (EEG)

Especially in this day and age, our technology has allowed for the ability to map the brain's functions, thus supporting the associationist theory. With the technology of quantitative EEG, scientists have been able to more fully understand which regions of the brain are responsible for particular actions and functions. The EEG, through electrodes in contact with the surface of the scalp, records oscillations of the electrical potentials in the brain's activity. These oscillations are a result of the brain's activity during a resting state or from stimulations and can change in power due to the area of neurons stimulated or the desynchronization of the neurons in that particular population. The first EEG recording ever taken on a human subject was carried out in the 1920s by a German scientist named Hans Berger (Tong and Thakor, 2009). It was not until 1982 when the first EEG was recorded on an aphasic patient for a diagnostic assessment, in which it was found that there was a substantial association between slow wave activity and a brain region with a lesion (Nagata *et al.*, 1982).

The EEG is a valuable tool to monitor the brain's functions and responses to a global injury because it allows for a continuous measurement of neurological activity (Tong and Thakor, 2009). In fact, the diagnosis of many brain abnormalities and disorders are formed by inspecting the EEG signals produced by the brain (Sanei, 2013). The EEG usually records the output of five major brainwaves: delta, theta, alpha, beta, and gamma. Delta frequency bands are typically in the frequency range of 0.5 to 4 Hz and are normally related to an individual being in a state of deep sleep. Theta bands fall within 4 to 7.5 Hz and are appear to be associated with one's state of arousal and relative drowsiness. Alpha waves are normally the most prominent brainwave generated at 8 to 13 Hz and are the bridge between relaxation and awareness. They are related to one's ability to be conscious of the environment while still maintaining a calm composure. The higher frequency bands are often present when the brain is processing more complex stimuli. The beta waves range from 14 to 26 Hz and are connected to the brain's effort in thinking, focusing, and solving problems. The last major frequency band, gamma waves, is the least noticeable at above 30 Hz but usually no greater than 45 Hz, with a small amplitude. This brainwave is used to study and observe event related synchronization of the brain and an action, such as finger movement (Sanei, 2013). After damage to the brain caused by events such as a stroke or a traumatic brain injury, signals have a significant reduction in power and tend to be nonstationary, unpredictable in signal patterns, which includes "seizure activity, burst suppression patterns, nonreactive alpha or beta patterns and generalized suppression" (Tong and Thakor, 2009; 171). Thus, it is hoped that by incorporating the EEG in this study, patterns of brainwave production can be identified and correlated to the participants' aphasic symptoms and site of brain damage.

2.4. Prevalence and Impacts

Based on stroke data, about 0.1 to 0.4% of the population in the developed world suffers from aphasia (Code and Petheram, 2011). Currently, over one million people in the United States are affected by this disorder annually. In other words, 1 out of 250 people have aphasia, making it more common than Parkinson's disease, cerebral palsy or muscular dystrophy (National Aphasia Association, 2016). Approximately 180,000 Americans acquire this disorder each year and 80,000 of those individuals acquire it as a result of a stroke (National Aphasia Association, 2016; National Institute on Deafness and Other Communication Disorders, 2010). Of those who develop aphasia as a result of a stroke, 60% of those individual will have it become a chronic condition (Grawburg *et al.*, 2014). Anyone is susceptible to this disorder, although it is more prominent in the elderly population, with people who have suffered from a stroke. It has been found that 15% of individuals 65 years or younger are susceptible to it; however once they reach 85 years or older the likelihood of acquiring aphasia increases to 43% (Engelter *et al.*, 2006).

Aphasia has many lasting impacts that alter an individual's life. Even with therapy and support, a complete recovery is often unlikely as was discussed previously. The daily lives of people with aphasia will drastically change with this disability. Due to difficulty in communicating, patients often withdraw from society, choosing to avoid social interaction that proves to be challenging or uncomfortable for them (Vickers, 2008; Pulvermüller and Berthier, 2008). Moreover, the impairment of communication has caused many to experience difficulties in the work force. According to a National Aphasia Association survey, approximately 72% of aphasic patients were unable to return to their jobs after the onset of aphasia (Vickers, 2008). Furthermore, studies have shown that language and social interaction, or activities, directly affect an individual's growth, development, self-esteem, and acceptance (Cruice *et al.*, 2003). Thus, it is no surprise that depression is extremely common in the aphasic population, especially among those with chronic aphasia, when their impaired communication negatively affects their growth and acceptance. Patients who are affected by non-fluent aphasia are significantly more depressed, in both frequency and severity, compared to others in the aphasic population (Robinson and Benson, 1981). In addition, the depression aphasic patients suffer from and the negative attitudes towards their predicament may lower their motivation to rehabilitate, as well as their rate of recovery (Code *et al.*, 1999).

Aphasia not only affects the individual's livelihood, but it also affects those people around him or her. For families with an aphasic person, the original understood agreements about roles and responsibilities of the different family members no longer apply after the start of the disability (Zemva, 1999). Studies have shown that an individual's aphasia affects many aspects of family members' lives. This is known as a third party disability. In particular, family members expressed that they had to learn, consider and apply their knowledge of the individual's aphasia to their daily lives, and thus they noted changes in their general tasks and demands, communication, self-care, domestic life, interpersonal interactions and relationships, major life areas or necessities, and community, social, and civic life (Grawburg *et al.*, 2013; Le Dorze and Brassard, 1995). Moreover, studies have also shown that the family members themselves may develop depression or other minor psychiatric disorders (Grawburg *et al.*, 2013).

2.5. Treatments

Over the years, aphasia treatments have experienced little change, and although treatment approaches are relatively similar, each treatment plan is individualized for the patient's particular needs. Rehabilitation for patients with aphasia is often focused on reestablishing all or most of their impaired communication abilities, while also teaching and implementing tactics and supports to compensate for those difficulties. In order to further aid in the process of recovery, therapists will continually help to reinforce intact language modalities and behaviors. In addition and perhaps one of the most important goals of therapy is to educate the family and caregivers about the nature of aphasia as well as techniques and additional supports to maximize their proficiency in conversations (American Speech-Language-Hearing Association, 2016).

Hildred Schuell, who was very involved in the study of language and speech pathology in the mid-1900s, argues that treatment of aphasia does not involve teaching the patients words, but instead stimulating the language processes in the brain. Thus she relied heavily on the strategy of auditory stimulation. Auditory stimulations produced by a therapist during individual therapy can be controlled and manipulated in a way the patients can comprehend more (Sies, 1974). These stimulations consist of "meaningful language units" and "common words" of any length, spoken at a pace the patient can keep up with, without having the words becoming distorted (Sies, 1974: 139-140). During auditory stimulations, phrases and words will often be reinforced with multiple reiterations. One of the most important factors in intervention programs for patients with aphasia is working with the individual's personal abilities and type and severity of their aphasia (Sies, 1974).

Presently, two standard therapy types are typically implemented: impairment based and communication based. Impairment based therapies focus on tasks to help the individual improve in particular language modalities he or she struggle the most in. On the other hand, communication based treatments are oriented around aiding the individual to more easily convey their message and thoughts (National Aphasia Association, 2011). Group therapy, which is more communication based, is also a form of intervention utilized to help rehabilitate a patient's language deficits. In the past, this form of therapy usually provided more indirect stimulation from interaction in the group setting rather than direct stimulation. During group therapy the patients are all engaged in discussions with less particular direction or area of focus than that of individual therapy (Sarno, 1991). Although, group therapy sessions may be less focused on rehabilitating certain language modalities, they are still an effective form of therapy in which patients can improve their linguistic and communication abilities (Elman and Bernstein-Ellis, 1999).

Therapy approaches in the past and even in the present day have typically focused on the individual's rebuilding of speech production and comprehension. Thus, the progression of augmentative and alternative communication devices, which are used as enhancements or substitutions for those with speech disabilities, has been slow through the years even with our advances in technology. This is due to the fact that therapists and intervention programs have often been funded to only help patients improve their natural speech until it plateaus and not further. As a result, intervention strategies have tended to omit including augmentative and alternative communication devices to aid speech and focused on generating natural speech (Fried-Oken, *et al.*, 2011). The use of augmentative and alternative communication devices is still a work in progress that will hopefully expand in the upcoming years. As more of these supports are being developed, it will provide clinicians more opportunities to conduct research in this field and perhaps discover more evidence of its benefits and as a standard therapy strategy.

3. Material and Methods

3.1. Participants

In this study, which was approved by Casa Colina Hosptial's IRB, there were a total of 20 participants ranging from ages 18 to 90. Each individual was referred by Casa Colina Hospital and Centers for Healthcare staff or was recruited through flyers from aphasia conferences. Before these individuals were eligible to participate in the research study, they each had to go through screenings approved by clinicians. Specifically, they must be diagnosed with some form of aphasia and must not have any diagnosis of dementia. Furthermore, they must be 3 months or more post onset of aphasia, in order to control for spontaneous recovery which often occurs within the first few months after the onset. Participants and/or caretakers were also asked to describe what aspects of communicating they struggled with and if they have ever received therapy for these difficulties. Participants were also required to be physically and visually able to use an iPad comfortably.

The option to undergo electroencephalogram (EEG) recordings during the evaluations was offered to as many participants as possible, unless it hindered with timeline of the study. Subjects were more permitted to decline the use of the EEG. Participants with and without the EEG recordings underwent the same procedures, tests, and questionnaires.

3.2. Therapy/Intervention

Participants received six free 1 hour therapy sessions with Casa Colina Hospital speech and language pathologists. Therapies were catered to each individual's specific needs and areas of difficulties. Therapy sessions were conducted with the use of an iPad application called GoTalk Now. During the sessions, the clinicians focused mainly on teaching participants on how to properly use the program more adequately and how to integrate it into their daily lives. For example, over the course of 6 weeks, they concentrated mainly on teaching the individuals how to use the program with weekly checks. They also incorporated other activities towards the last few weeks that challenged and helped improve their communication, such as a personal narrative introduction communication with the therapist. These activities, such as the personal narrative, are important in order to help patients become and feel more comfortable and capable at interacting in the society. Furthermore, prior to the beginning of therapy, clinicians designed individualized curriculums for each person based on their pre-therapy evaluation. Participants were required to own an iPad or rent one from Casa Colina. Prior to the therapy, participants either attended a group training session on how to use GoTalk Now or were given some form of manual or tutorial to familiarize them with the application.

3.3. Pre- and Post-Therapy Evaluation

3.3.1. Probing Tests

Three tests were administered during the individual's pre- and post-therapy evaluation. During the eyes closed test, participants were asked to keep their eyes closed and stay as still they could for 5 minutes. The eyes open test, they were asked to focus on a fixation cross for another 5 minutes. The purpose of these tests was to collect resting state data. The probing test, or prompting and response, included a total of 30 prompts. Each prompt had a degree of randomness and varied from "feed the tire to the duck" to "make the shoe jump over the pig" to ensure that they were not tasks easily done in everyday life.

Overall, there were 30 different prompts, but each prompt was administered as one of the three variations: verbally, statically, and dynamically. For verbal prompts, only verbal directions were given, in which their language comprehension and memorization is put to the test. Static prompts also had a verbal prompt but were also accompanied with a picture of the final result of the action. Prompts given dynamically had the verbal component as well as a video of the action asked, that was on a loop throughout the entire response period. Both static and dynamic prompts are considered as scene cues, which have been suggested to be a useful mode of augmented input for the augmentative and alternative communication supports. Static cues are thought to activate more brain associations through the increase in information provided by the picture versus that of a stand alone command. On the other hand, dynamic cues further portray a more complete idea of the relationships in context (Schlosser *et al.*, 2013). These two prompt types will hopefully indicate if the augmentative and alternative communication program helped the participants' comprehension through picture associations. Participants were given a total of 50 seconds to listen to the prompt and to respond accordingly. Each prompt was stated twice before the participant was to respond. Before the start of probing tests, a teaching task was administered to ensure that the participants could differentiate the variety of objects used.

Post-evaluations were done within about a week following the last therapy session. The eyes open and closed tests remained the same. However, some prompts in the probing test were altered with new objects to avoid participants remembering and recognizing previous prompts.

Movements and deviations from the task, at their respective time, were noted during eyes closed and open tests. Responses to the probing test were recorded as correct or incorrect, with the time at which the action was completed.

3.3.2. Electroencephalogram (EEG)

The B-Alert X24 EEG system was utilized to record electrical activity of the brain during certain activities. This system is a wireless headset which transmits the signals to a laptop that was used during the evaluations. An impedance test was conducted once the headset was set up on the subject in order to ensure that the connection of the electrodes were strong enough. If not, electrodes were adjusted and more electrode lotion was applied, until a strong connection was achieved.

Brain activity was recorded from the beginning of the entire evaluation until the end. Electrical activity during the eyes open, eyes closed, and the probing tests (prompting and response) were analyzed. Time markers were placed during the start and end of the 5 minute eyes open and eyes closed tests. They were also placed at the beginning and end of the prompts and at the end of the allotted 50 seconds.

3.3.3. Standard Assessment: Western Aphasia Battery

The Western Aphasia Battery (WAB) is a test used to assess an individual's language function and capability. It was administered to participants by the clinicians during both their pre- and post-evaluations.

3.3.4. Communication Questionnaires

Two questionnaires were given to the participants by the therapists, prior to and after therapy: the Communication Satisfaction Questionnaire and the Communication Success Questionnaire. The caretakers of the individual were also required to fill out a Communication Success Questionnaire, made specifically for them, before and after the therapy. All questionnaires were created by the clinicians working on this study. The questionnaires were not only used as a personal measurement of the subjects' communicative skills but also as a reference to determine which areas were more important to focus on during therapy.

Questions for the Communication Satisfaction Questionnaire were as followed:

1. How satisfied are you with your ability to communicate your needs to your therapist?
2. How satisfied are you with your ability to communicate your needs to your physician?
3. How satisfied are you with your ability to communicate your needs to your family?
4. How satisfied are you with your ability to state your opinions?

Questions for the Communication Success Questionnaire were as followed:

1. How successful are you at communicating medical information?
2. How successful are you at communicating comments to family members?
3. How successful are you at following directions?
4. How successful are you at communicating basic wants and needs?
5. How successful are you at accessing resources in the community?

The possible responses to the questions on the Communication Satisfaction questionnaire were based on a Likert scale, in which 1 = Never, 2 = Almost Never, 3 = Sometimes, 4 = Almost Always, 5 = Always, and 6 = N/A. The Communication Success Questionnaire the Likert scale consisted as 1 = 0-25% of the time, 2 = 26-50% of the time, 3 = 51-75% of the time, 4 = 76-10% of the time, and N/A for not applicable.

3.4. Data Analysis

The effect of the augmentative and alternative communication intervention, GoTalk Now, was compared using the nonparametric tests, Wilcoxon Signed Rank test and the McNemar's test, due to the small sample size. The Spearman's Rank test was used to determine the degree of correlation between the Western Aphasia Battery and the probing test scores. The program IBM SPSS Statistics was utilized in conducting these statistical analyses, while Microsoft Excel was used to produce the graphs. Unexpected setbacks with the original augmentative and alternative application caused the study to be delayed for approximately a month and a half. The application underwent updates which led to malfunctions in its functions. Thus analyses were performed on a subset of only three individuals.

Recorded EEG data were checked for quality, converted into mean power spectral densities using the B-Alert Lab program. Only the eyes closed data for one subject were analyzed. The power spectral densities of different frequency bands were compared between the regions of the left and right hemispheres, as well as the left and right parietal regions using a Wilcoxon Signed Ranks test. An additional analysis utilizing the Wilcoxon Signed

Ranks test was completed between the power spectral densities of the left frontal and parietal regions pre- and post-therapy sessions.

4. Results

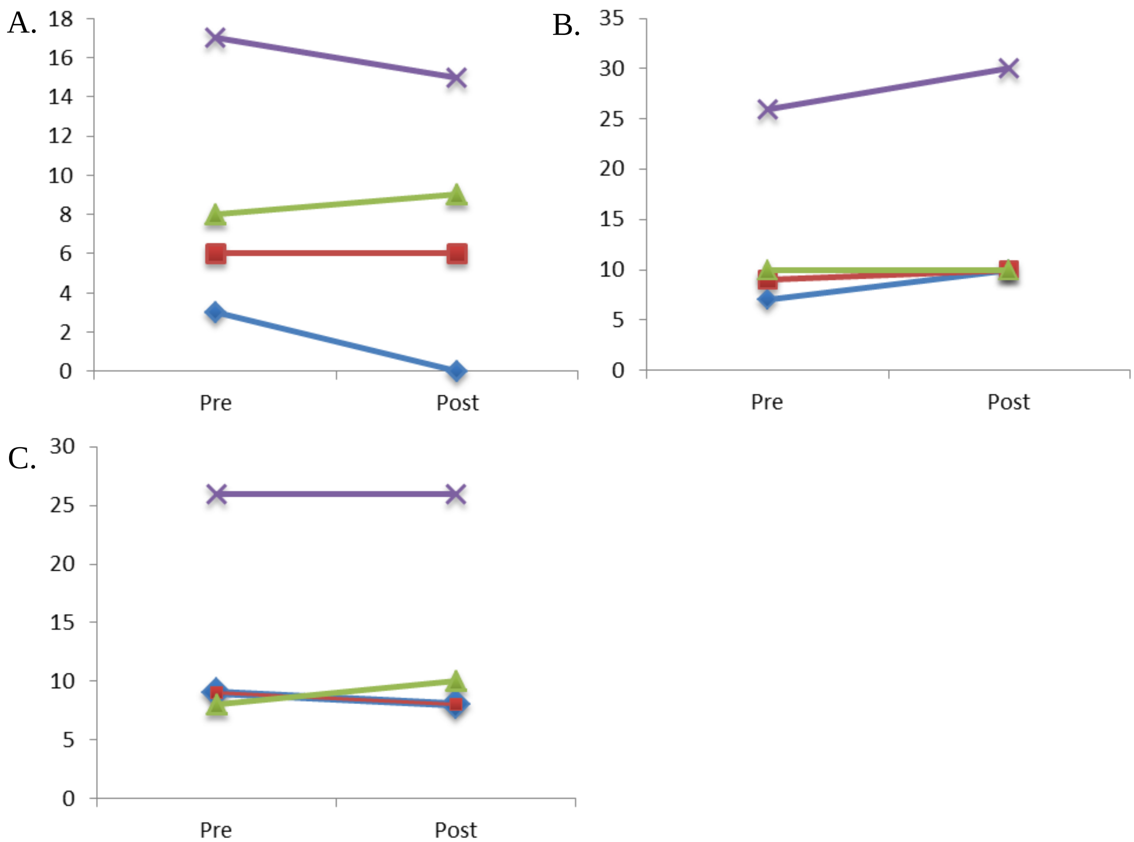


Figure 1. The individual subjects 3 (A), 5 (B) and 18's (C) pre- and post- prompting scores of the different prompt types: verbal cues (blue), static visuals with verbal cues (red), dynamic visuals with verbal cues (green) and all the prompts as a collective (purple).

Table 1. The individual subjects' p-values of the McNemar's test for each of the different prompt types and all the prompts together comparing pre- to post- (N = 3).

	Verbal Prompts	**Static Prompts**	**Dynamic Prompts**	**All Prompts**
Subject 3	0.250	1.000	1.000	1.000
Subject 5	0.250	1.000	N/A	0.125
Subject 18	1.000	1.000	0.500	0.687

Table 2. The average scores and standard deviations, pre- and post-, of the different prompt types and all the prompts as a collective (N = 3).

Prompt Type	Pre	Post
Verbal Prompt	6.333 ± 3.055	6.000 ± 5.292
Static Prompt	8.000 ± 1.732	8.000 ± 2.000
Dynamic Prompt	8.667 ± 1.154	9.667 ± 0.577
All Prompts	23.00 ± 5.196	23.37 ± 7.767

4.1. Probing Tests

Six 1 hour therapy sessions with the iPad application did not result in a significant difference in the patients' ability to respond correctly to the probing tests (Wilcoxon Signed Rank; $p = 0.655$). As a group, the average total scores on the probing test increased slightly from 23.00 to 23.37; however, the average verbal prompting scores decreased by 0.333 (Table 2). When looking at the patients individually however, they generally improved or remained the same on most of the post-prompting tests in relation to the pre-tests, only one patient performed worse in total on the post test (Figure 1, Figure 1.A). Although there were changes in the individuals' scores on the different prompt types, they were not significantly different (Table 1).

4.2. Standard Assessment: Western Aphasia Battery

The mean Western Aphasia Battery scores for all of the subjects were found to have improved following the six 1 hour therapy sessions with the application (Table 3). Every patient was able to improve on their Aphasia Quotient, which is the total Western Aphasia Battery score, post-therapy sessions (Figure 2). However, this increase as a group was not significant for any of the Western Aphasia Battery categories, as well as the entire test itself

(Wilcoxon Signed Rank; p = 0.109, p = 1.00, p = 0.109, p = 0.109, p= 0.109 for spontaneous speech, auditory verbal comprehension, repetition, naming and word finding, and aphasia quotient respectively).

Table 3. The mean scores, pre- and post-therapy session, of the different categories in the Western Aphasia Battery as well as the total score (N = 3).

	Pre	Post
Spontaneous Speech	6.667 ± 1.155	10.33 ± 3.215
Auditory Verbal Comprehension	7.233 ± 1.475	7.383 ± 2.023
Repetition Score	6.133 ± 2.194	7.200 ± 1.970
Naming and Word Finding	4.167 ± 2.757	5.000 ± 3.061
Aphasia Quotient	48.40 ± 14.79	59.83 ± 19.00

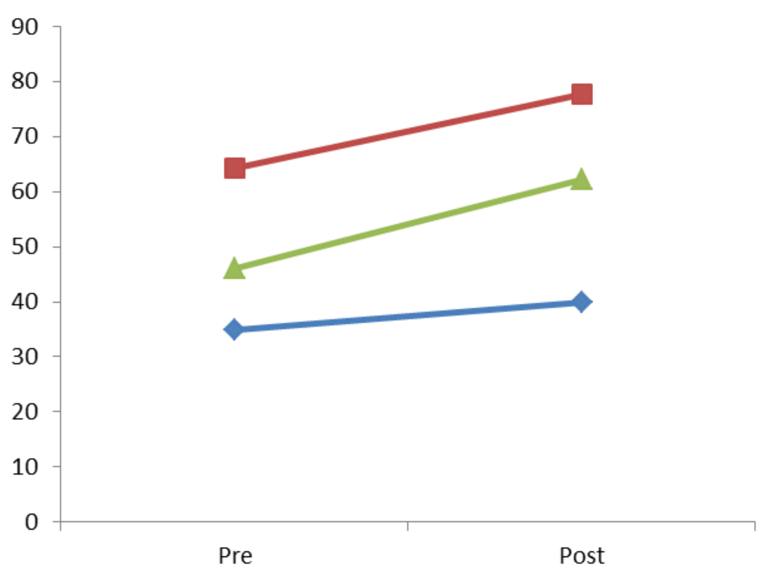


Figure 2. The Aphasia Quotient scores pre- and post-therapy session for subject 3 (blue), 5 (red), and 18 (green) (N = 3).

4.3. Correlation between the Western Aphasia Battery and the Probing Test

There was a significant positive correlation between the Western Aphasia Battery score and the probing test (Figure 3; Spearman's Rank; p = 0.021).

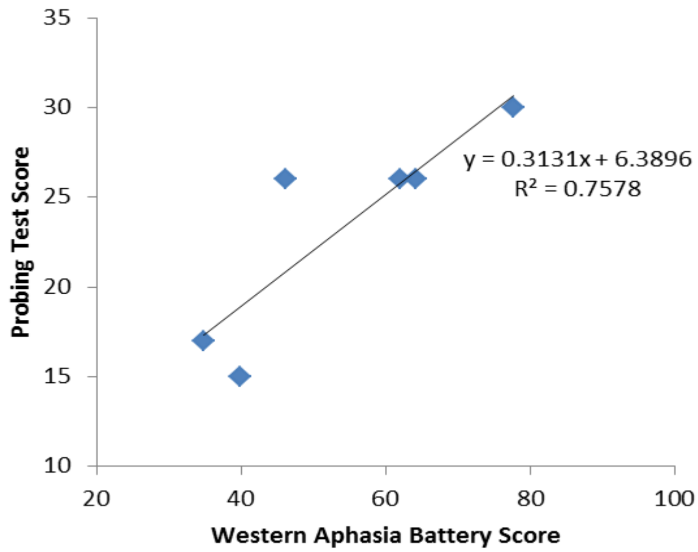


Figure 3. The relationship between the subjects' Western Aphasia Battery Score and their Probing Test Scores, pre- and post-intervention sessions (N = 6).

4.4. Communication Questionnaires

Most of the pre-therapy scores on the Communication Success questionnaires generally began in the lower end of the range, however the post-intervention sessions many of the scores increased (Figure 4). One person felt less successful in their ability to communicate, particularly in following directions, communicating basic needs and wants, and accessing resources in the community. On average, the reported scores for success in the particular areas of interest were higher or the same, following therapy with the iPad application (Figure 4F). Although subjects reported having more success in the different areas of communication, these differences were not significant for all (Wilcoxon Signed

Rank; p = 0.180, p = 0.109, p = 0.414, p = 1.000, p = 0.414 for questions 1, 2, 3, 4, and 5 respectively).

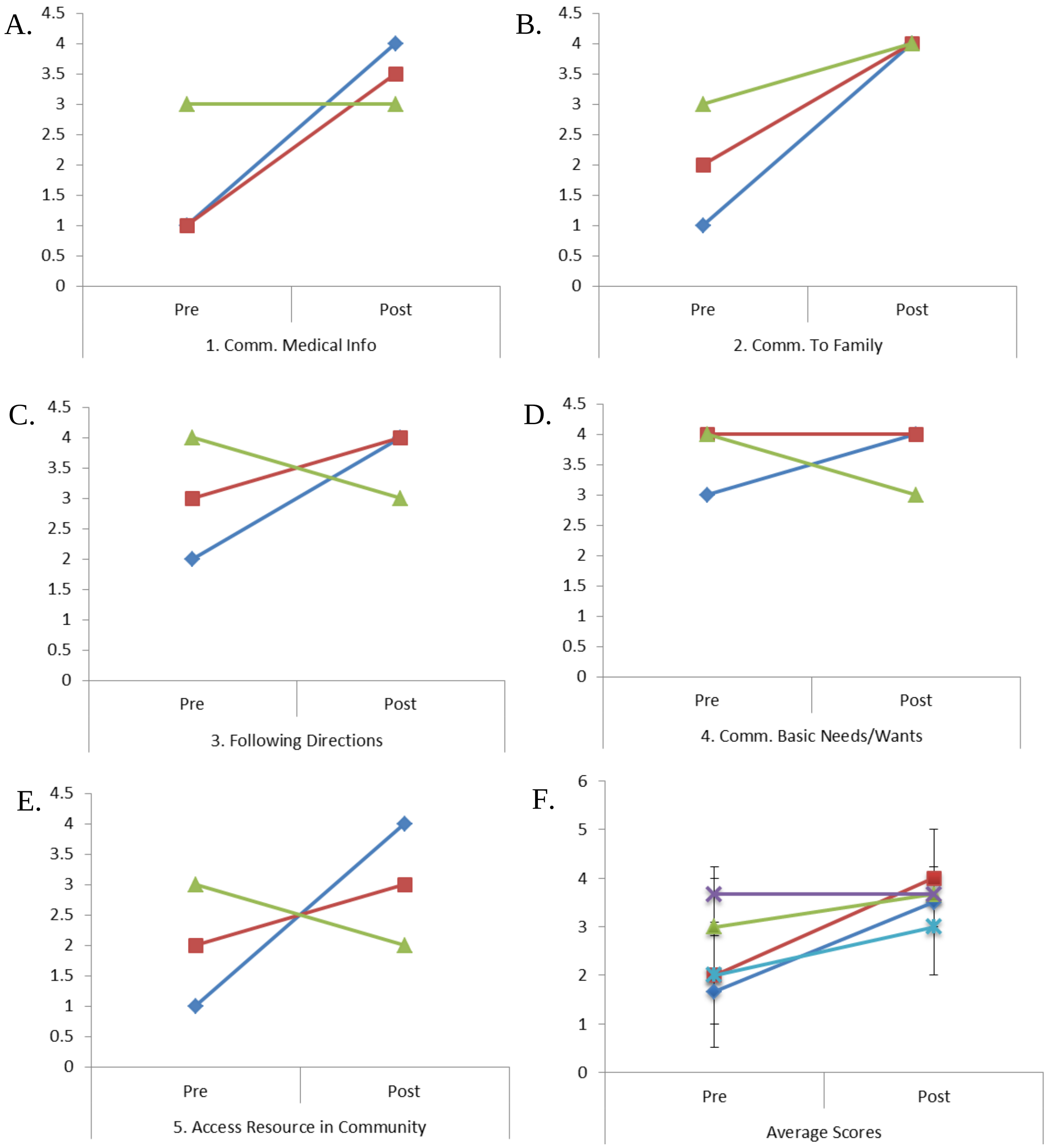


Figure 4. The pre- and post-scores of subject 3 (blue), 5 (red), and 18 (green) for the different questions of the Communication Success Questionnaire: Communicating medical information (A), Communicating to Family Members (B), Following directions (C), Communicating basic needs and wants (D), Accessing resources in the community (E). The average scores and standard deviations for questions 1 (blue), 2 (red), 3 (green), 4 (green), and 5 (bright blue) as a group (F).

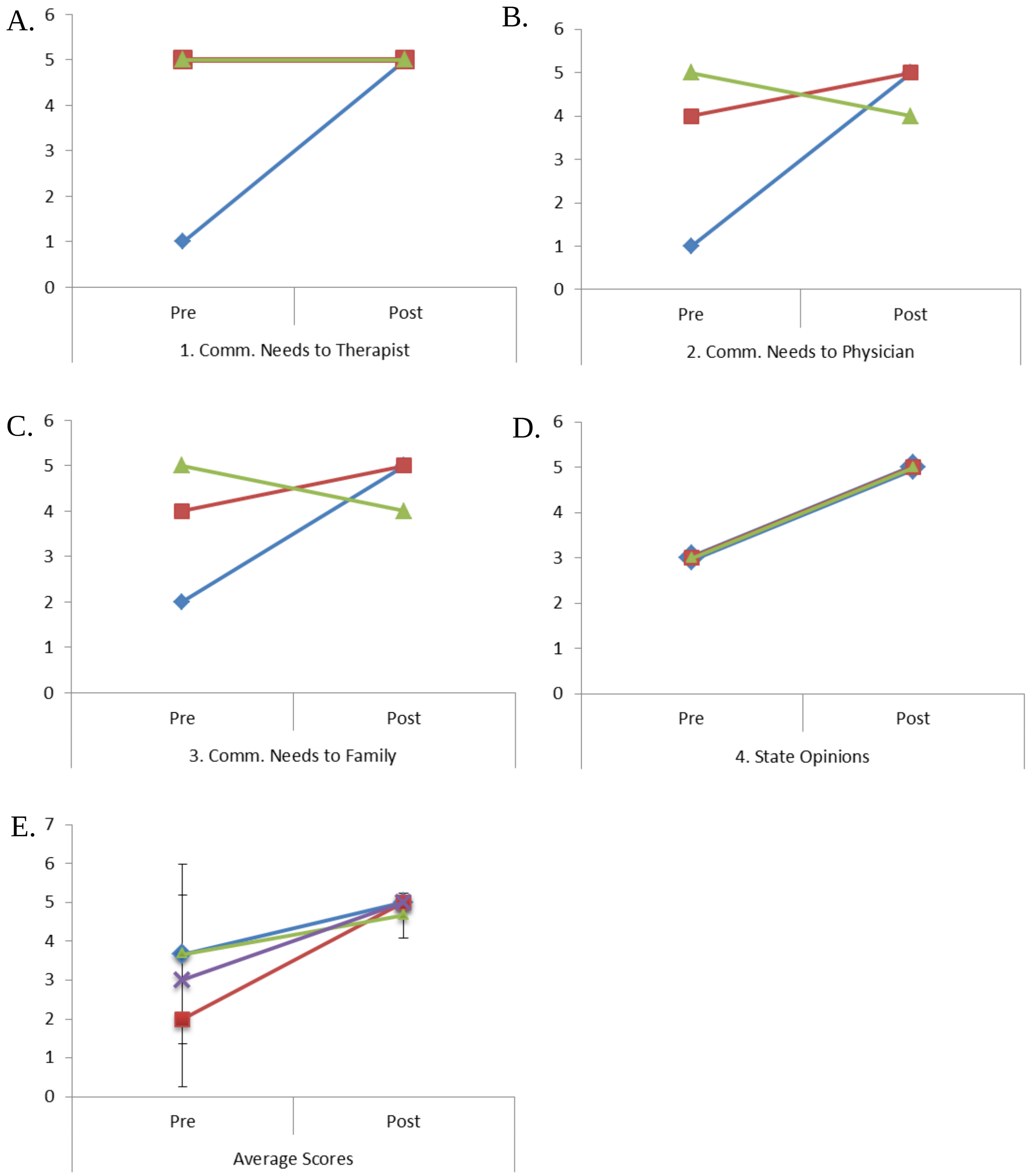
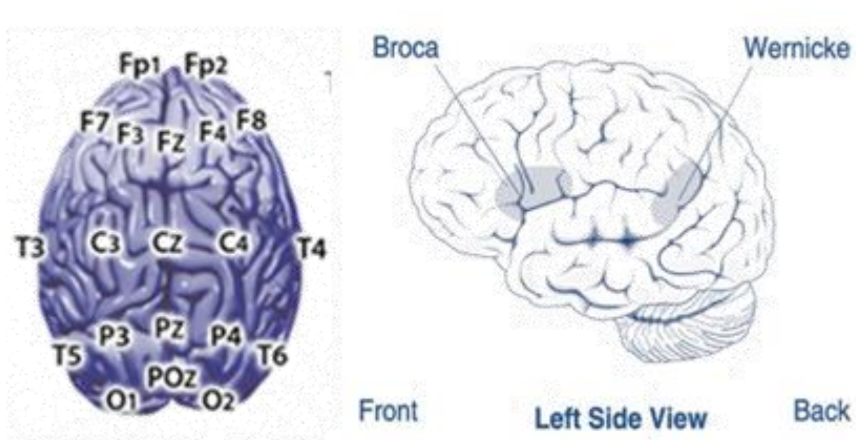


Figure 5. The pre- and post-scores of each subject 3 (blue), 5 (red), and 18 (green) for the different questions of the Communication Satisfaction Questionnaire: Communicating needs to a therapist (A), Communicating needs to a physician (B), Communicating needs to family members (C), Stating their opinions (D). The average scores and standard deviations for questions 1 (blue), 2 (red), 3 (green), and 4 (purple) as a group (E).

Likewise, on average the subjects rated their satisfaction in their communication in each particular area to have been better after beginning the use of the augmentative and alternative communication program than that of before (Figure 5E). Most of the patients reported more or equal satisfaction in each area of communication as compared to their satisfaction prior to the sessions; however one subject did report to feel less satisfaction in two areas (communicating their needs to a physician and to family members) (Figure 5). These reported differences for each question were not significant (Wilcoxon Signed Rank; p = 0.317, p = 0.102, p = 0.414, p = 0.083 for question 1, 2, 3, and 4 respectively).

4.5. EEG Case Study of Subject 18



www.advancedbrainmonitoring.com/xseries/x24/ and www.nidcd.nih.gov/health/aphasia

Figure 6. The positioning of the different channels on the B-Alert X24 wireless headset (A); and the Broca’s and Wernicke’s regions of the brain in the left hemisphere (B).

The EEG component of the assessments was taken in order to determine if there was any correlation between brain activities in certain regions to the patients’ aphasia symptoms. In this case we are specifically focusing on the resting state of the brain when the eyes are closed. Given twenty-four channels on this particular EEG headset the channel F7, localized in the left frontal lobe, was of interest because Broca's area is in this general vicinity and the subject was believed to have Broca's aphasia (Figure 6). Thus the activity of the parietal lobe, channel P3 and P4, was also analyzed to use as a comparison since there was no supposed damage to it

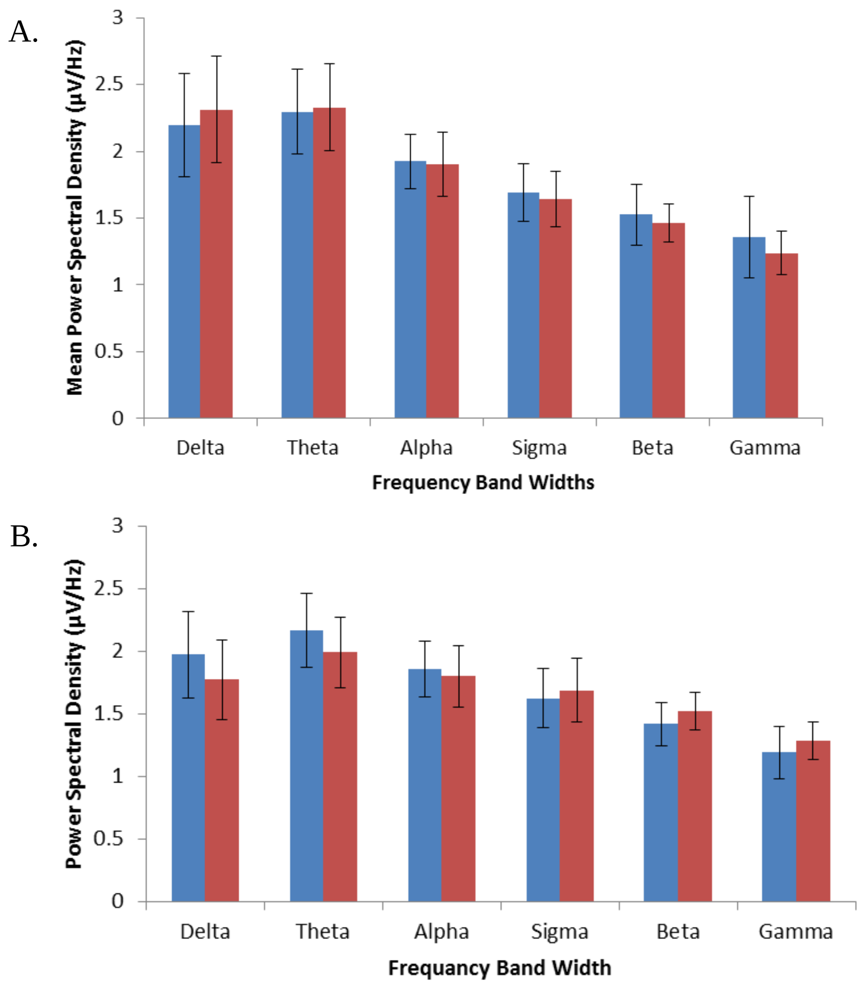


Figure 7. The comparison of left (blue) and right (red) hemispheres' mean power spectral densities of different frequency bands, with standard deviation, produced from Subject 18's frontal (A) and parietal (B) lobes during the pre-therapy eyes closed test.

When comparing the brain activity of Subject 18 prior to therapy in the frontal lobes of both hemispheres at channel F7 and F8, it was found that the power spectral densities of the different frequency bands were typically higher on the left side, except for the Delta and

Theta bands (Figure 7A). The mean power spectral densities of the bands produced from the right side versus the left however were not significantly different (Wilcoxon Signed Rank; p-value = 0.463). Comparing the activity produced from channel P3 of the parietal lobe in left hemisphere, to that of channel P4 in the right hemisphere, the Delta, Theta, and Alpha bands had higher activity (Figure 6, Figure 7B). Similar to the frontal lobe however, the mean power spectral densities of the bands in the different hemispheres did not have any statistically significant variance (Wilcoxon Signed Rank; p-value = 0.753).

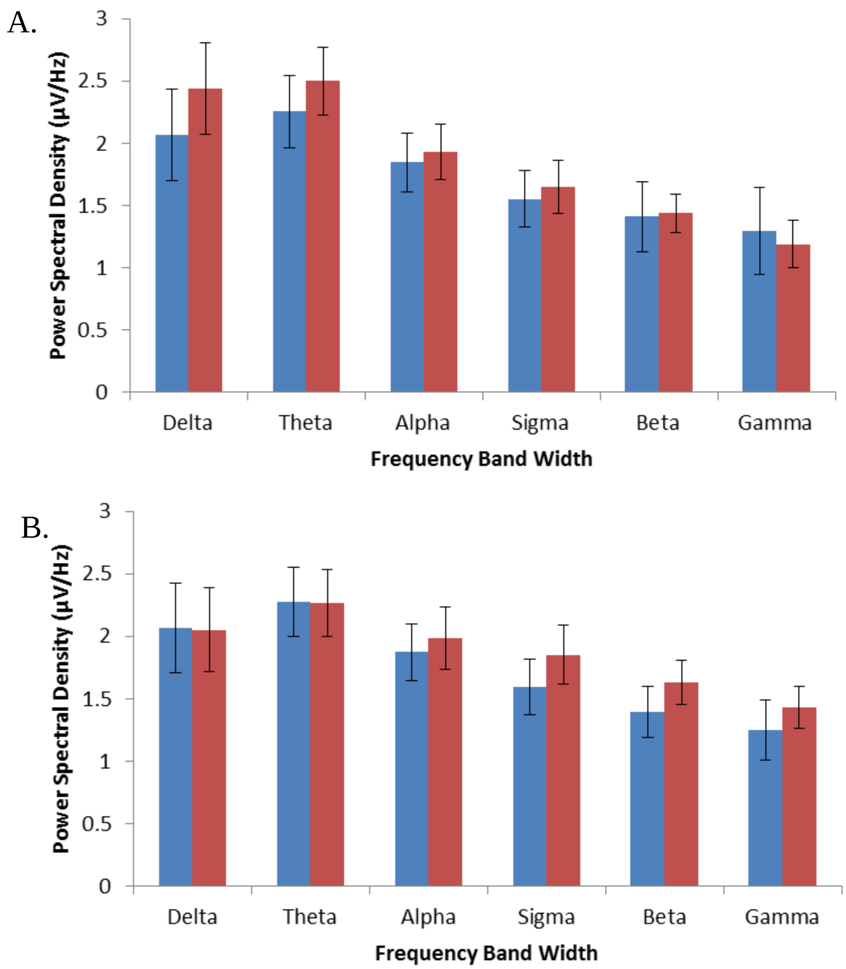
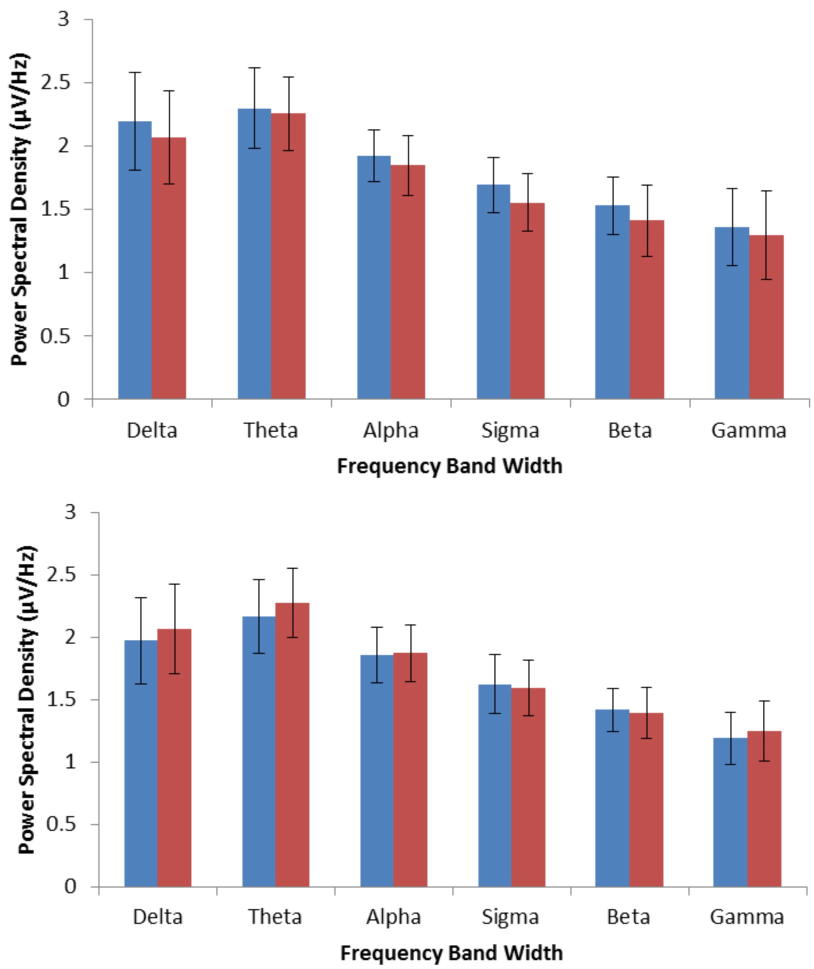


Figure 8. The comparison left (blue) and right (red) hemispheres' mean power spectral densities of different frequency bands, with standard deviation, produced from Subject 18's frontal (A) and parietal (B) lobes during the post-therapy eyes closed test.

The same comparisons were completed to analyze the mean power spectral densities of both hemispheres post- augmentative and alternative communication intervention. Many frequency bands in the left hemisphere post-therapy appeared to have smaller mean power spectral densities than the right hemisphere's (Figure 8). It was found that both lobes, frontal and parietal, did not differ significantly when comparing the left to the right hemisphere (Wilcoxon Signed Rank; p-value = 0.173, p-value = 0.116 for the frontal and parietal respectively).

A.



B.

Figure 9. The mean power spectral densities of different frequency bands, with standard deviation, produced from Subject 18's frontal (A) and parietal (B) lobes during the both pre- (blue) and post-therapy (red) eyes closed test.

To examine the possible effects of the augmentative and alternative communication intervention, the pre- and post-EEG's of the left frontal lobe at channel F7 were compared against each other and likewise for the left parietal lobe at channel P3. The activity in the frontal lobe post therapy was found to be significantly higher during the pre-therapy evaluation than during the post-therapy evaluation (Figure 9A; Wilcoxon Signed Ranks; p-value = 0.028). On the other hand, the mean power spectral densities varied across the frequency bands of the parietal lobe, with most proving to be greater after the 6 therapy sessions (Figure 9B). However, the changes in the brain activity during the pre- and post-therapy evaluation were not statistically significantly different (Wilcoxon Signed Ranks; p-value = 0.249).

5. Discussion

Due to a little over a month of setbacks, caused by updates and malfunctions with the original program Autismate 365 (now Oneder), we ultimately decided to switch to GoTalk Now. Thus, analyses were performed on an incomplete set of data of three out of twenty subjects, who had completed the intervention sessions with Autismate 365. However, in the meantime the preliminary data were analyzed using nonparametric tests to hopefully find trends in the data. In addition, more in depth analyses for each individual were completed to further examine the effects of using an augmentative and alternative communication device. All subjects improved on their Western Aphasia Battery score although probing tests varied for each participant. These preliminary results suggest that the use of augmentative and alternative communication devices in therapy or in daily life may, to some degree, improve the communicative capabilities of a patient with aphasia. However, there is still possibility of changes in the results, once all that data has been collected.

When looking at the subjects' scores on the Western Aphasia Battery and their probing test, we can make some assumptions as to the person's level of function. This is due to the fact that from the preliminary data, the relationship between the two scores had a positive significant correlation (Figure 3). Furthermore, high Western Aphasia Battery scores have been found to associate to good functional communication skills in acute aphasic patients, based on the Communicative Effectiveness Index (Bakheit *et al.*, 2005). Thus, it is possible to classify these subjects into low, medium, or high functional aphasic patients and to take into account these levels when making conclusions. With that said, it is likely that subject 5 and 18 are high functioning individuals, while subject 3 is low functioning.

Although the probing tests had no significant difference when comparing pre- to post-, there is still hope that the use of an iPad-based application may help these patients. One subject, in fact scored worse on the post-probing test, by incorrectly responding or not responding to all the verbal prompts when previously in the pre-therapy test he was able to correctly respond to three (Figure 1.A). This change in score could have been due to sheer luck or from paying more attention during the first test, which could have given us an inaccurate baseline to compare his post test score to, especially since his low score on the Western Aphasia Battery would indicate he is of low communicative function. Furthermore, it is possible that he was less familiar with the new objects utilized in the post tests even with the teaching task, and therefore it could have affected his ability to respond. Thus, his inability to answer more of the prompts during his post-evaluation does not necessarily indicate that the program had an adverse or no effect for him, because he was still able to answer one more static prompt than he had in the pre-test. However, there is a real possibility that this individual did just get the responses wrong due to his own inadequacies. In this case, follow ups in the future should be utilized to determine whether he failed to improve because of the short time frame of the study or if the additional support truly has no beneficial effect.

Another subject increased his score from a 26 to a perfect 30 during the post-test; however, this was not significant (Figure 1B, Table 2). Because he scored high on his Western Aphasia Battery and probing tests, we can likely classify this individual as high functioning. With this in mind, the subject might have had a ceiling effect and had very little room to show his maximum progress, with only four questions out of the thirty to further improve on in the post-evaluation. It is possible that with more prompts, there could have been a significant difference in his performance, which would provide more evidence that this iPad-based augmentative and alternative communication approach to therapy can result in improvements, if not just act as an additional communicative support.

The preliminary results of the Western Aphasia Battery scores, is what offers more optimism on the beneficial effects of GoTalk Now, over the results of the probing tests. All subjects improved their scores slightly or marginally. The fact that the Western Aphasia Battery is a standardized test, testing several aspects of language, compared to the probing tests, which were created by our research team, allows us to make more sound conclusions. Although the increases in scores did not prove to be statistically significant, it is notable that all subjects had in fact scored higher on their post therapy test (Figure 2, Table 3). With more data, it is possible that this difference would be significant, if there is still an increase in scores on average.

The questionnaires given to the patients before and after therapy also indicate that the use of an iPad-based augmentative and alternative communication program could be beneficial. Before administering the therapy sessions, many patients felt low success and satisfaction in most areas of the questionnaire. However, although not significant, which could be a result of the small sample size, on average many reported higher success and satisfaction in their communicative capabilities (Figure 4, Figure 5). Looking at the Communication Success questionnaire, there are two increases that are of importance. When it came to being able to communicate medical information to another person, the patients first felt that they were usually unsuccessful, but post therapy sessions they reported being more successful. The one person who felt that there was no change in his ability to communicate medical information was already relatively high on the scale. This is of utmost importance because one needs to be able to easily communicate any medical problems they are experiencing, especially at times when there is no family member or caregiver around to help them. Furthermore, all participants reported that they felt more successful in communicating with family members. This is extremely important due to the fact that many patients with aphasia and their families experience tension and misunderstandings due to the onset of the disability (Zemva, 1999). Thus, the fact that they feel more able to communicate with their family may lessen the adverse impacts on their loved ones and perhaps lead to a better quality of life in their home. The results of the Communication Questionnaires indicate that one participant had contradictory feelings when it came to his satisfaction in communicating his needs to family members versus his success. However this could be due to misunderstanding over the question and being unable to express what they feel, especially since this participant reported lower scores than previously in two areas. Furthermore, although he reported to have felt more success, it does not always translate into satisfaction because they could still feel unhappy even with their new abilities or feel more defeated and aware that they are still incapable of communicating at a higher level. People suffering from Broca's and Wernicke's aphasia may often react to testing failures with "catastrophic" emotions, thus it possible that these emotions caused by the disability are making him less satisfied (Sarno, 1991; 37). However, because on average the subjects did feel more satisfied with their abilities, it is likely that the therapy and application has had a beneficial effect on them and can improve their quality of life. Yet, because there was no control group to compare to, it is a likely possibility that these participants experienced a placebo effect and did not improve on their communicative abilities although they felt they had. Even if this were the case, it is still a good sign that participants felt more satisfied because this in itself it may have the capability of improving their happiness and self-esteem.

Even though none of the statistical tests proved to have any significance, in cases such as this study, the clinical significance can be more appropriate and practical to employ in analyzing the data for its implications. The speech and language pathologists involved in this study have reported seeing several improvements in their clients. One clinician in fact has noted, from his own opinion, that there has been a clinical significance, which came to a surprise to him given the fact that the therapy program lasted only 6 sessions. He explained that the familiarity of the personalized visual aids was hopefully triggering more cognitive connections to help with their aphasia. Thus, he attributes this improvement to the fact that the augmentative and alternative communication applications have targeted the patients' apraxia, which is a motor speech disorder, through the repetition and visual aids, which in turn also rehabilitates other language modalities as well.

During resting state, the brain is still outputting electrical signals. By looking at EEG recordings it is possible that correlations between brainwave activity and areas of brain damage can be made. In this EEG case study, one individual (subject 18) was diagnosed with aphasia and apraxia caused by a cerebrovascular accident. The clinician noted that, from the signs and patterns of his communicative abilities, subject 18 is suffering from Broca's aphasia. This means that the lesions and brain damage are likely to be in the frontal lobe of the right hemisphere, in the Broca's area. It is seen that the participant exhibited varied power spectral densities within the frontal and parietal lobes of the right and left hemispheres, both pre-and post-therapy, with no specific pattern or statistical difference (Wilcoxon Signed Ranks; $p = 0.463$, $p = 0.753$, $p = 0.173$, $p = 0.116$ for left and right frontal lobe pre-therapy, for left and right parietal lobe pre-therapy, for left and right frontal lobe post-therapy, for left and right parietal lobe post-therapy respectively). However, it was observed that all the Delta, Theta, and Alpha bands in the frontal and parietal lobes, before and after therapy, were typically higher than the rest of the frequency bands (Figure 7, Figure 8, Figure 9). This could be attributed to the fact that the EEG recording was taken during an eyes closed resting state; hence, there was a lower output of the higher frequency bands, since no complex brain functioning was taking place. Furthermore, a higher Beta power spectral density in the left frontal region, prior to therapy, could be explained by idea that the damage to the brain resulted in activation of previously dormant and concealed networks, similar to what has previously been observed (Angrilli *et al.*, 2003; Vitali *et al.*, 2007). As for the parietal lobe, because this individual was affected with Broca's aphasia it reasonable that there is no particular pattern or significance found, when comparing the right to the left hemisphere.

Previously, it has been found that areas of brain damage typically output stronger intensities of the low frequency Delta and Theta bands, because the damage restricts the brains ability to output signals of higher frequencies, which is exhibited across all the EEG results (Hensel *et al.*, 2004, Spironelli and Angrilli, 2009; Sprionelli *et al.*, 2013). In fact, the greater outputs of the low frequency bands could be linked to poor clinical outcome (Szelies *et al.*, 2002). Therefore, because we do see high power spectral densities for the delta and theta bands in the left frontal lobe pre- and post-therapy, it may indicate a site of a lesion, which is further supported by the fact that this person is suffering from Broca's aphasia. After completing the 6 sessions of therapy with the application, this patient's power spectral power densities for all different brain rhythms from the frontal lobe decreased, which was in fact found to be statistically significant (Figure 9A, Wilcoxon Signed Ranks; $p = 0.028$). In regards to the theta and Delta bands, it is probable that the greater power spectral densities of these two frequency bands are a result of brain damage. Thus, it is possible that the decrease in power spectral density for these two bands could indicate reorganization or recovery of the damaged area. The decreases seen across the frequency bands could have also been due to the subject's alertness and awareness on that particular day. For example, the participant may have been more aware of the noise occurring in the hallway outside the room, which could have been picked up by the auditory sensor region right next to Broca's area; thus, the EEG channel may have picked up higher intensity of signals. On the other hand, because the lesion is likely in the frontal lobe in the vicinity of Broca's area, it seems rational that there is no significant difference or pattern similar to when comparing the left and right parietal lobes (Wilcoxon Signed Ranks; $p = 0.249$). Thus far, from what has been exhibited in this individual's EEG data of the eyes closed resting state, it appears that it has further supported the results of previous studies. Thus it is feasible that utilizing EEG to track the brain's activity may be a viable technique in mapping sites of impairments caused by strokes or other injuries.

Due to the fact that this was a pilot study, there are several aspects which could be improved upon to ensure a more accurate and conclusive study. To begin, the sample of size was very low (N=20). Furthermore, the analyses were completed on an even smaller sample (N=3), which could have produced erroneous statistical findings. With the addition of more data sets for both the evaluation assessments and the EEG, it would have also further solidified or disproved previous studies. In particular, only implications and hypotheses could be made in regards to the EEG data, due to the fact that only one person's data set was analyzed. Furthermore, the population was not restricted to certain groups such as level of communicative function, age, gender, or type of aphasia. If more controls were utilized, it is probable that results could have been more conclusive in regards to whether use of the iPad-based application produced improvements and which groups respond most beneficially to the application. In addition, more controls in regards to the participant's type of aphasia could have also resulted in a more in depth and conclusive analysis, for both the effectiveness of the augmentative and alternative communication program and the feasibility of utilizing an EEG to track the patients' disabilities. Furthermore, because of a funding constraint, the study was unable to be conducted over a longer period of time with more participants. Therefore conclusions were based on a short term result which could change over an extended period of time. It cannot be conclusively determined whether their learning effects and thoughts about the program will be a short or long term effect, since it is possible they only temporarily remembered what they have learned and may forget in time. We hope to survey the participants 6 months after their therapy session to observe whether the use of augmentative and alternative communication device is still being used and if it does in fact have a long term effect on their ability to communicate.

Overall, the preliminary data give high hopes to the future of the augmentative and alternative communication industry as well the use of EEG to learn more about the individuals' impairments. Although the data were not significantly different, the optimistic testimonials of the therapists suggest that there is a degree of clinical significance in the participants' improvements. This not only provides support that GoTalk Now may be an effective language support, but also that in general, the use of augmentative and alternative communication devices and programs are most likely also helpful for people suffering from aphasia. In addition, this study has not only helped a few people of the aphasic population, and perhaps even more, but it has now provided therapists with more evidence of the beneficial effects and results of this form of intervention. Thus, it is hoped that through this study and many others, the augmentative and alternative communication industry will continue to progress and become a standard form of rehabilitation. Furthermore, because results of the EEG data on a single subject's eyes closed resting data have thus far supported previous studies, it also provides more positive evidence to continue exploring this aspect within the aphasia population and perhaps gaining more understanding of the brain itself. However, similar to that of the use of augmentative and alternative communication devices and programs, the use of EEG is still relatively new in terms of the aphasic population and must be further studied and observed.

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