EFFECTS OF VOICE OUTPUT AND DOSE ON AUGMENTATIVE AND ALTERNATIVE COMMUNICATION TREATMENT FOR PEOPLE WITH APHASIA

by

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Introduction: Aphasia frequently occurs after a stroke and may become a chronic communication/language disorder. Not all people with aphasia (PWA) fully recover to their premorbid language functioning. Many will face life-long communication difficulties impacting their quality of life. Despite Augmentative and Alternative Communication (AAC) intervention being used to improve the language and communication functioning for PWA, the effects of AAC intervention are obscured, because many variables, such as voice output and treatment dose, have not been investigated systematically.

Method: This dissertation includes a pair of studies that aim to determine the effects of two voice outputs (synthesized voice vs. human voice) and doses of computerized AAC training on naming performance with able-bodied individuals and PWA. The dissertation uses a single-subject combined 2 by 2 factorial design to investigate the impact of the two variables. A mixed model trajectory analysis (MMTA) is used to evaluate how single variables affect the treatment outcomes. Pre-and-Post standardized assessments are used for evaluating the outcomes.

Results: The results indicate that both able-bodied people and PWA learned to name words under the synthesized and human voice conditions using an AAC system. Overall, people learned better with human voice than synthesized voice. Both groups learned to name pictures by exposure only.

The results also show that adding one self-paced practice in the same session did not facilitate improvement of able-bodied individuals' performance. Additionally, the results show the performance of PWA is varied both within participant and across participants. All participants were satisfied with the training program.

Conclusion: This dissertation is the first study to test voice output and treatment dose as AAC intervention variables for PWA. Evidence supporting the value of voice output features in AAC intervention was found that may facilitate the naming skills of PWA. It also demonstrates MMTA, as an innovative way to evaluate the effects of an individual variable at the personal-level and group-level in AAC aphasia intervention. Future AAC studies can draw upon the findings to systematically investigate the numerous variables of AAC technology and treatment that are effective in improving language and communication performance.

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PREFACE

This PhD dissertation is the culmination of a life-long interest in communication and aphasia. It is also my personal journey in overcoming the communication difficulties from my language barriers. Many people over the years have helped me get here, and I would like to thank them. Firstly, I would like to thank my supervisor, Dr. Katya Hill for her support, encouragement and advice throughout this dissertation. I would like to thank Dr. Malcolm McNeil for his unlimited questions that force me to think all the time. I would like to thank Dr. Ty Ridenour for teaching me an innovative methodology for clinical studies with small samples. I would like to thank Dr. Katherine Seelman and Dr. Travis Threats for valuable insights into disabilities studies, and policies. I would also like to thank my mentors, Francois-Xavier Brajot, Ming-Chung Chen, and Michal Biel for interesting discussions that help me to build the study. I would like to extend my gratitude to Barry Romich, and AAC Institute for funding this study through the AAC Institute student scholarship. Without the funding, I would not have the opportunity to complete the dissertation and the program.

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1.0 INTRODUCTION

Each year, more than 795,000 people experience a new or recurrent stroke in the United States (Center of Disease Control and Prevention, n.d.). Twenty-one to thirty-eight percent of acute stroke patients have aphasia (Brust, Shafer, Richter, & Bruun, 1976; Paolucci et al., 1996; Pedersen, Jørgensen, Nakayama, Raaschou, & Olsen, 1995; Wade, Hewer, David, & Enderby, 1986). Aphasia is a devastating acquired language/communication disorder that may occur after a stroke or other brain injury. The disorder is marked by language deficits across all language modalities. Aphasiologists agree that aphasia is not a loss but an impairment of the linguistic rules for constructing language (McNeil & Pratt, 2001). Only 21-24% of the people with aphasia (PWA) fully recovered to normal language function (Laska, Hellblom, Murray, Kahan, & Von Arbin, 2001). Those who never fully recover after a long-term rehabilitation process, and long-term disability experience depression, loneliness, and social isolation, which ultimately affects the quality of life (Simmons-Mackie, 2008; Worrall et al., 2011). Augmentative and Alternative Communication (AAC) intervention has been used to decrease the communication difficulties from aphasia and help to establish confidence and positive emotions during the rehabilitation process (Hux, Weissling, & Wallace, 2008; Simmons-Mackie, 2008).

Speech language pathologists use the International Classification of Functioning, Disability and Health (ICF)(World Health Organization, 2001) as a blueprint to guide the interventions of aphasia (Threats, 2006). Currently AAC seems to be the last resort after traditional treatment (treatment for body functions and structure) has been terminated. Meanwhile AAC is considered a functional treatment approach that matches the activity domain of the ICF framework (Van de Sandt-Koenderman, 2011). Nowadays high-performance computer-based AAC technology used in aphasia treatment is more widely available than in the past decade, because of the rapid improvement of mass-market technology and decreased cost. Several studies have reported that PWA may benefit from the voice output of an AAC device in terms of their communication and speech production (Koul, Corwin, & Hayes, 2005; Weinrich, Boser, McCall, & Bishop, 2001). However, the effectiveness of AAC intervention is obscured when AAC intervention for aphasia does not identify the multiple variables, such as the type of voice output, size of picture, and etc. that can be manipulated as part of the AAC system and also for clinical treatment. It is commonly assumed that voice output has a positive effect on PWA's language performance and overall communication. Consequently, clinicians have difficulty interpreting which component or variable of treatment affects the achieved performance and outcomes.

Several computer-based word retrieval treatments for PWA have similar features provided by high-technology AAC intervention (e.g., words, picture, voice output, etc.) and have shown positive effects in language functions (Fink, Brecher, Sobel, & Schwartz, 2005; Raymer, Kohen, & Saffell, 2006). Although researchers have stated that AAC may help to restore language function (Kraat, 1990; Weissling & Prentice, 2010), no studies have explored the effect of the single variables of an AAC system, such as the voice output. Contemporary technology, especially mobile technology, is becoming less expensive and easier to obtain than the traditional speech language pathology related technology over the past decade, and AAC apps are no exception. Clinicians need evidence-based strategies to demonstrate that PWA can be helped (Threats, 2009). Understanding what AAC systems' features make a significant difference in supporting the restoration of language functioning for PWA is important for evidence-based practice.

In addition to the issues of the components of AAC systems, intensity of treatment is an undeniable variable studied to determine the effect on treatment and recovery. Today, a tremendous gap exists between effective treatment intensity recommendations (Bhogal, Teasell, & Speechley, 2003; Robey, 1998) among clinicians and other stakeholders (i.e., Health reimbursement). Moreover, healthcare reimbursement is limited (Simmons-Mackie, 2008). These issues force speech language pathologists to reconsider the strategies that will provide effective and affordable services with reduced funding resources. Using technology can be a solution to this problem. However, no AAC aphasia studies have explored the issue of treatment intensity.

This dissertation thus is aimed at determining if exposure to the voice output of an integrated computer-based communication system will improve PWA's language performance and the patient-reported outcomes on communication. The secondary goal is to investigate whether the intensity of using a self-paced practice program will affect PWA's language performance. Furthermore, the dissertation demonstrates the use of the mixed model trajectory analysis to analyze small sample data to receive advanced results instead of traditional analysis for single subject designs. The practical significance of this study is to investigate whether AAC as a compensatory strategy can occur while conducting restorative therapy via AAC technology.

This dissertation includes five chapters. In chapter 2, I first review the characteristics of aphasia. Next, I review the components of the ICF framework, and the connection between traditional treatment and AAC intervention based on the ICF framework. Later, I review the previous studies of computerized aphasia treatment and AAC aphasia treatment. Then I review the factors that may contribute to changes after AAC intervention, such as multimodal stimuli, and intensity of treatment. In addition to the above perspectives, I also offer alternative analytic methods for small sample sizes in answering questions about AAC treatment effectiveness. Lastly, I conclude Chapter 2 with the research questions of this dissertation. Chapters 3 and 4 constitute a series of studies conducted to investigate the proposed research questions. Finally, in chapter 5, I conclude with a discussion combining the results from chapters 3 and 4.

2.0 LITERATURE REVIEW

2.1 APHASIA

According to the American Speech Language Hearing Association [ASHA](n.d.), Aphasia is "a disorder that results from damage to the part of the brain that contains language. Aphasia causes problems with any or all of the following: speaking, listening, reading, and writing." Peach & Shapiro (2012) stated that "aphasia is characterized by an impaired ability to produce and/or comprehend language in the spoken, signed or written modalities." Brookshire (2003; p. 1) wrote that "aphasia is characterized by impaired comprehension and production of language, usually caused by pathology affecting the language competent half of the brain." The multiple definitions of aphasia address the similar concept that people who have aphasia have language problems across all modalities. Aphasia is not a loss of language but some disturbance or impairment of language. Some researchers hold another view of aphasia that includes other cognitive domains (ex: attention and/or memory). McNeil (1982, p. 693) defined aphasia "as a multimodality physiology inefficiency with greater loss of verbal symbolic manipulations (ex: association, storage, retrieval, and rule implementation). In isolated form aphasia is caused by focal damage to cortical and/or subcortical structures of the hemispheres(s) dominant for such symbolic manipulations. Aphasia is affected by and affects other physiological information processes to the degree that they support, interact with or are supported by the symbolic deficits." From this view, researchers assume that the impairment to cognitive functions other than language may explain part of the mechanism of aphasia (McNeil, Hula, & Sung, 2010).

Following the definitions addressed above, aphasia rehabilitation spread widely after World War II and focused on the nature of impairment and treatment (Hinckley, 2002). The main focus of this approach is to restore the language insufficiency resulting from aphasia, such as naming and word-retrieval impairment (Boyle, 2004), auditory comprehension impairment (Schuell, Carroll, & Street, 1955) , and syntax impairment (Thompson, Shapiro, Kiran, & Sobecks, 2003; Thompson & Shapiro, 2005). However, after a long-term rehabilitation, numerous PWA still never entirely recover, and they face depression, loneliness, social isolation and a poor quality of life because of the disability (Simmons-Mackie, 2008; Worrall et al., 2011). Functional and social approaches were also used with PWA with poor prognosis to meet the ultimate goal of aphasia rehabilitation to optimize the communication and social participation of PWA (van de Sandt-Koenderman, 2011). AAC has been used as a functional treatment approach to provide maximum communication through different techniques and technology when an individual is lacking verbal communication skills due to various factors.

While AAC intervention involves high-technology devices, such as touchscreen computers, or mobile tablets, the impairment-oriented approach to aphasia has also started to use technology. Computerized naming/word retrieval treatment is one example. Traditional naming/word retrieval treatments usually include pictures, written words, and spoken words, (Boyle & Coelho, 1995; Boyle, 2004; Raymer & Kohen, 2006). These components were continually used in computerized naming/word retrieval treatment (Corwin, Wells, Koul, & Dembowski, 2014; Fink et al., 2005; Herbert, Webster, & Dyson, 2012; Raymer et al., 2006; Routhier, Bier, & Macoir, 2016). Those features and components (pictures/symbols, voice output, technology, etc.) in the computerized naming treatments are similar to AAC intervention in aphasia. Therefore, the results of naming treatment in aphasia may become a part of the theoretical foundation of AAC intervention in aphasia, because of the similarity in the components. Especially considering that most of the AAC studies related to aphasia are relatively empirical rather than based on theoretical supports. Functional approaches use individuals' residual skills as effectively as possible and/ or to use AAC strategies to compensate for language deficits, and focus on achieving communicative activities daily (Hux et al., 2008; van de Sandt-Koenderman, 2011). In summary, AAC intervention holds the potential as a treatment for restoring linguistic skills as well as improving functional communication abilities, which is a combination of impairment-oriented and functional-oriented interventions. However, the connection between the impairment-oriented approach (computerized naming treatment) and the functional/social approach (AAC intervention) must be reviewed first.

2.2 ICF FRAMEWORK

Before delving into a more detailed review of the impairment-oriented approach and the functional-oriented approach of aphasia intervention, an international rehabilitation framework is introduced to help to differentiate the goals of different interventions for aphasia. The International Classification of Functioning, Disability, and Health [ICF] (World Health Organization, WHO, 2001) is an integrative framework that combines the medical framework and the social framework of rehabilitation in order to include a broader range of knowledge of disability from medical professions to individual's experiences (Seelman, 2004). The ICF includes three domains: 1) body functions and structure, 2) activity and participation, and 3) contextual factors of personal factors and environmental factors. Disability is considered an umbrella term for impairment, activity limitation and participation restrictions. Functioning comprises body functions and structure, activities, and participation. Environmental and personal factors are included in the ICF framework to represent the interaction with other elements in the framework (WHO, 2002; see Figure 1).

The ICF can be used as a comprehensive blueprint to challenge speech language pathologists to consider the client-centered goals across all domains, and help to meet the ultimate goal of aphasia rehabilitation, to maximize the quality of life of PWA. (Simmons-Mackie & Kagan, 2007; Threats, 2013). In the blueprint, all components of ICF should interconnect with each other (Threats, 2013). Since the components interact, clinicians can use the ICF framework to monitor all angles of the interventions, the potential interaction between components for PWA, and ensure all interventions are progressing toward the ultimate goal of a higher quality of life.

Despite the ICF provides clinicians with a comprehensive and interactive picture of PWA's intervention, more frequently, clinicians still focus on one component in the intervention, such as body functions, and do not consider the interaction between different ICF components. For example, AAC intervention is commonly considered as functional or compensatory strategies for PWA (Beukelman, Hux, Dietz, Mckelvey, & Weissling, 2015; Dietz, 2006; Johnson, Hough, King, Vos, & Jeffs, 2008). Here, AAC is used for "Activity" and "Participation" in the ICF framework. Activity/participation is defined as "the executions of actions by individuals and these behaviors' relationship to their individual lives" (WHO, 2001, p. 10). The treatment goal is to achieve the optimal level of communication in daily activities. Activities can range from having a small talk with neighbors to attending a discussion on house renovation. The participation-oriented approach to assessment and intervention focuses on social participation. PWA are at high risk for social isolation, so this type of approach concentrates on the consequences of aphasia. Often, this type of approach targets other stakeholders, but not the PWA, to ensure the social systems are supportive. When social systems are not supportive, PWA's psychosocial well-being and quality of life are easily diminished (Simmons-Mackie, 2008; van de Sandt-Koenderman, 2011). The outcome measures of activity/participation are usually activity/participation scales or patient-reported outcomes (Threats, 2013). The outcomes of AAC intervention often do not include the outcomes of "body functions" in the ICF framework.

On the other hand, PWA intervention can focus on body functions and structure mainly. By definitions of the ICF, body functions are "the physiological functions of body systems including psychological functions," whereas, body structures "are anatomical parts of the body such as organs, limbs, and their components" (WHO, 2001, p.10). Since aphasia is caused by brain functions, most traditional aphasia assessments and interventions fall under this section, also known as disorder-oriented approaches/impairment-oriented approaches (Cruice, 2008; Simmons-Mackie & Kagan, 2007; van de Sandt-Koenderman, 2011). These type of aphasia treatments targeted on the domain of body functions usually aim to restore language processing (van de Sandt-Koenderman, 2011). The outcomes of this type of approach usually are from measures of language and speech components (ex: semantics, syntax, phonology), but not the usage of those components in daily communication. For example, a PWA may receive a computerized naming training to name 10 target words spontaneously. However, we do not know if the PWA would use those words in daily communication even if he/she can name all of those words without any difficulties.

The paragraphs above indicate the current PWA interventions tend to focus on one domain of ICF. While ICF delineates that "body function and structures", activity, and participation interact with each other (see Figure 1), real practice does not consider them together. It is commonly seen that PWA received a naming treatment (impairment-oriented), where the outcomes focus on the target words but not the daily communication, whereas AAC intervention oftentimes focuses on the functional communication, but not the recovery of naming performance. Like section 2.1 addresses, when technology is involved both in computerized naming treatment (impairment-oriented) and AAC intervention (functional/social-oriented), they share many features (see Figure 2). Clinicians/researchers should start to measure outcomes across different components/domains of ICF no matter what interventions they use, and consider interconnection between components in their PWA intervention. Through the process, clinicians/researchers can understand how certain types of PWA interventions affects different domains, and how to modify the intervention, so it can not only affect one domain but also other domains.

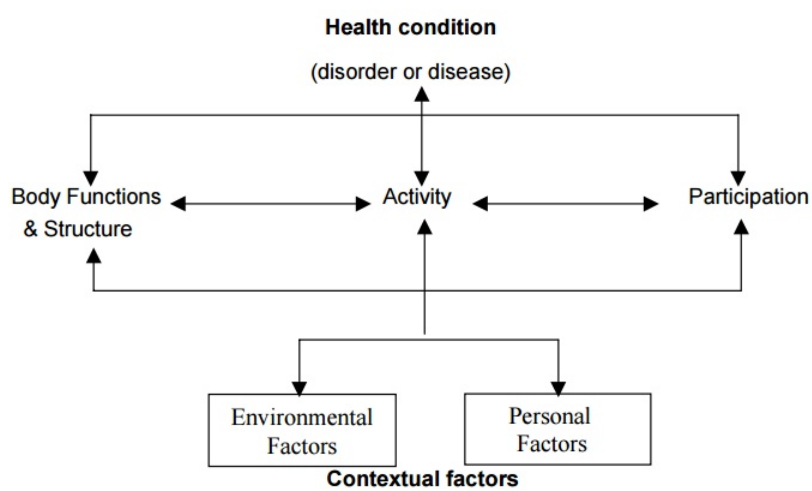


Figure 1 Overview of the ICF Framework.

Reprinted from Towards a common language for functioning, disability and health ICF (WHO, 2012).

http://www.who.int/classifications/icf/training/icfbeginnersguide.pdf.

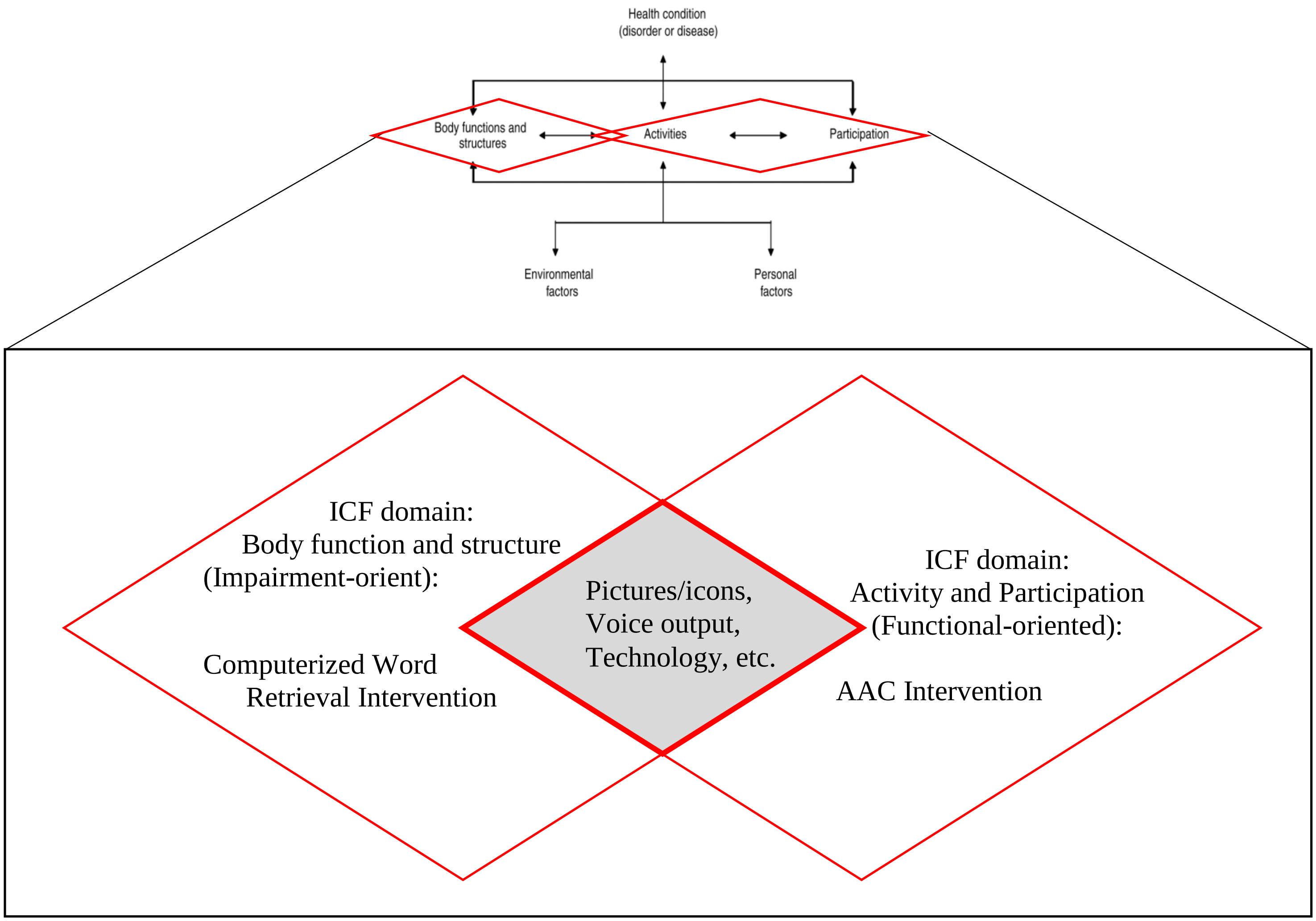


Figure 2 Overlap features between computerized naming/word retrieval intervention and AAC intervention

2.3 IMPAIRMENT-ORIENTED APHASIA THERAPY: WORD RETRIEVAL THERAPY

Word retrieval deficits are common deficits observed in PWAs. Raymer and Gonzalez Rothi (2002) illustrated a model of lexical processing to explain a strategic theoretical rationale for clinical decision-making in the assessment and intervention of naming deficits. Overall, the model is based on the models of normal lexical-semantic processing and production such as Levelt, Roelofs, & Meyers's model (1999) and Hillis & Caramazz's model (1994). The model posited the semantic system interconnected with semantic and phonological lexicons for inputs and outputs. In general, the word-retrieval treatments for aphasia have focused on either semantic or phonologic processing (Nickels, 2002). Several key tasks that can be done by using semantic and phonologic stimuli include oral picture naming, written picture naming, oral naming to spoken definitions, oral word reading, writing to dictation, auditory word to picture matching or verification, and written word to picture matching or verification. Those tasks are cross-modalities and used for facilitating word-retrieval processing (Raymer et al., 2002).

The treatments that focus on semantic processing include semantic comprehension tasks like picture-to-written word matching for enhancing semantic comprehension (Marshall, Pound, White-Thompson, & Pring, 1990). Semantic distinction is another treatment. Clinicians provided semantic information of a target picture that a client could not name, and contracted those semantic features to related words (Ochipa, Maher, & Raymer, 1998) The clinicians provided the semantic features surrounding the target picture in the center for the semantic feature analysis (Boyle &

Coelho, 1995). The treatments focused on phonologic processing in reading and repetition (e.g., asking patients to read or repeat words), phonological cueing hierarchy; (e.g., giving the initial phoneme as a phonologic cue), and phonological judgment treatment (e.g., judging the phonological information of a target word, like the number of syllables). Those treatments incorporated phonologic information in an attempt to restore naming abilities in persons with word retrieval deficits (Raymer et al., 2002). Some studies combined any semantic and phonological tasks together (Wisenburn & Mahoney, 2009).

Computerized word retrieval programs with clinician presence or with self-administration have been available and are more and more common due to the improvement in technology. For example, MossTalk Words (Fink, Brecher, Montgonery, & Schwartz, 2001) includes multi-mode matching tasks, which showed treatment effects in trained words (Fink et al., 2005; Raymer et al., 2006). Current computerized word retrieval training using tablets as the main tool also showed similar outcomes with different types of tasks, such as word association, matching tasks, and sentence completion. Participants in these studies were asked and/or encouraged to produce the target words during the tasks (Corwin et al., 2014; Routhier et al., 2016). Overall, PWA who attended these computerized word retrieval programs were satisfied with the results of the computer training (Corwin et al., 2014; Palmer et al., 2012; Raymer et al., 2006; Routhier et al., 2016). This result provided personal evidence from PWA's perspective for applying technology in aphasia rehabilitation. Participants seemed to have a high acceptance of the computerized training program.

Overall, previous studies have shown word retrieval treatments to be effective. Commonly, treatment effects of the word retrieval treatment tend to be larger for trained words than untrained words (Nickels, 2002; Routhier et al., 2016; Wisenburn & Mahoney, 2009), While little or unclear generalization was observed for untrained-unexposed words, connected speech, and functional communication (Boyle & Coelho, 1995; Routhier et al., 2016; Thompson, Kearns, & Edmonds, 2006; Wisenburn & Mahoney, 2009), some studies have still shown the potential of computerized word retrieval training generalized to untrained words, and connected speech (Corwin et al., 2014; Raymer, Simone, Kenagy, & Smith, 2013). The potential matches the ultimate goal of PWA: using their natural speech as much as possible.

Although the treatment effects of word retrieval intervention on connected speech and/or daily conversation are uncertain, we know integrating the semantic and phonological information can improve PWA's word retrieval skill. These task components included picture, spoken words, written words, and computers that are similar components in high-technology AAC interventions. Consequently, similar tasks can be done on a high-technology AAC system. The positive evidence of word retrieval treatments leads to the possibility that the use of high-technology AAC intervention with PWA may result in similar treatment effects.

2.4 FUNCTIONAL AND SOCIAL APPROACHES OF APHASIA THERAPY

Unlike the impairment-oriented approaches focusing on reducing language impairments, the goals of functional approaches are to achieve communicative functions in daily life (Van de Sandt-Koenderman, 2011). Functional approaches use individuals' residual skills as effectively as possible (Holland & Hinckley, 2002; Rautakoski, 2012) and/or use AAC strategies to compensate for language deficits (Hux et al., 2008; van de Sandt-Koenderman, 2011). In the 1970s, Holland

and her colleagues introduced the concepts of “Functional Communication”. The concept turned the treatment direction from the impairment aspect to the social aspect. Researchers proposed that the outcomes of treatment should be “functional” in PWAs daily life, and not only focus on reducing language impairments. Several interventions trained PWA in specific tasks or topics, so they could increase participation in their daily life. The outcomes were positive, but only in the trained contexts (Bellaire, Georges, & Thompson, 1991; Fox, Sohlberg, & Fried-Oken, 2001).

Social approaches in aphasia adopted the philosophies of a social model. The model suggests communication is a social activity. Following that, social approaches focus not only on communication and life participation, but also on the environments in which PWAs live (communicative, physical, social, and emotional; Simmons-Mackie, 2008). According to Simmons-Mackie (2008), the two goals of target communication are to enhance natural communication and to increase successful participation in authentic events. For example, conversational therapy focuses on information exchange and appropriate social communication skills for different contexts by using compensatory strategies like drawing or gesturing. However, some factors may create a barrier to communication, such as when the communication partners do not understanding the drawing or gesture, or a time constraint when applying the strategies. The situation shows that a social approach also has limitations while it focuses on PWA’s residual skills. In the meantime, it raises another question, which is: can effective communication be accomplished without language skills?

Before reviewing AAC and AAC aphasia intervention in the following sections, one functional communication treatment is reviewed. Besides AAC, conversational script training is another functional communication treatment. Clinicians help PWA to identify scenarios, and help the PWA develop the scripts for those selected scenarios (Cherney, Halper, Holland, & Cole, 2008;

Fox et al., 2001; Goldberg, Haley, & Jacks, 2012). Cherney et al. (2008) reported that participants had improvement in the script-related content, grammatical productivity and production rate. The scores of the WAB for two of three participants were improved. Moreover, participants and/or their spouses reported their confidence in communication and the ease of communication was improved. However, there was no significant improvement in the Quality of Communication Life scale (Paul et al., 2004) and the Communication Activities of Daily Living (Holland, Frattali, & Fromm, 1999) Following Cherney et al. (2008), Goldberg et al. (2012) reported that generalization of the script training was shown in less structured contexts. Participants could use the lines from the trained scripts with a novel communication partner. However, those conversations with a novel communication partner were still tied to the trained scripts. Although these studies showed the positive outcomes of the script training, still no clear generalization from the trained contents to untrained contents has been reported.

These social approaches do not consider reducing the language impairments, in other words, recover language functions. The intention of social approaches may be explained by Lapointe (2008; p.91) who stated “The precise nature of how much linguistic competence may be only marginally relevant if we find ways to intervene and improve life quality by increased activities and participation in the ambient world. Many.” However, language is still the essential element in communication. While much of the work in functional communication has focused on multi-modality resources (including gestures and facial expression), linguistic resources also need to be further explored if these two are to be maximally employed in aphasia therapy from a functional perspective (Armstrong & Ferguson, 2010). Impairment-oriented approaches and social approaches should not conflict with each other.

2.5 AUGMENTATIVE AND ALTERNATIVE COMMUNICATION (AAC)

The origin of "Augmentative" is "augment." According to the Merriam-Webster dictionary, "augment" means "to make greater, more numerous, larger, or more." "Alternative" is defined as "different from the usual or conventional." The definitions of these words provide a general concept of AAC; AAC is some type of communication. AAC can enhance communication, and it can be different from conventional communication.

The ASHA (2004a) stated:

> *"AAC involves attempts to study and, when necessary, temporarily or permanently compensate for the impairments, activity limitations, and participation restrictions of individuals with severe disorders of speech-language production and/or comprehension. These may include spoken and written modes of communication"*

AAC can be temporarily or permanently based on the severity of the speech language impairments. AAC is appropriate as an intervention when an individual's natural speech does not meet their daily communication needs. AAC can be the supplemental communication methods or strategies for enhancing the existing communication strategies (Romski & Sevcik, 1996). Conversely, AAC may be an alternative communication for some individuals, and become their primary means of communication (ASHA, 2004a). AAC interventions range from the low-end to high-end which depend on the level of technology involvement. The proposed study focuses on a high-technology AAC intervention that includes computerized systems, ex: synthesized voice output devices (ASHA, 2004a; K. Hill, 2010; Lloyd, Fuller, & Arvidson, 1997).

Several models of AAC assessment/intervention have been established. The participation model is considered a comprehensive framework for identifying the barriers of using AAC during assessments and interventions. This model focuses on comparing the functional participation requirements of similar populations (same age, same peers, same educational background, etc.) without disabilities to potential AAC users (ASHA, 2004a; Beukelman & Mirenda, 2013). The difference between the two may help clinicians to assess potential users' opportunity barriers and access barriers. The model also emphasizes the importance of the role of communication partners. Communication partners can have positive resources or negative impacts. The participation model focuses on identifying participation patterns, communication difficulties and communication needs (Garrett, 2005). The model rarely mentions language functions and performance.

Meanwhile, the language-based model focuses on variables that influence effective communication competence (Hill, 2004, 2006) Those variables include language components such as language forms and language content that a potential AAC speaker uses but are rarely discussed in AAC studies, especially in aphasia. Following Hill's language-based model, AAC assessments/intervention should not only focus on the barriers around the ambient world but also the clients' internal language performance and how language is represented and generated using an AAC system. Language performance is also important to address in AAC assessments and intervention (Hill, 2004, 2006). From the technology perspective, A Matching Personal and Technology Model (MPT) by Hill & Schere (2008) in AAC practice also emphasizes the functions and features of the most preferred and appropriate technology is one of key factors of successful AAC intervention. In summary, AAC assessment and intervention should include language performance and features of the technology supporting AAC. Such features are the variables that will be addressed in the proposed study.

2.6 AAC INTERVENTION IN APHASIA

Oftentimes, AAC is used as the last solution for PWA facing the chronic language disorder. Garrett & Lasker (2013) claimed that AAC can serve several functions for PWA that include: 1) enhancing the auditory comprehension of PWA; 2) providing means of expressing needs, preferences, or basic personal information; 3) serving as a word or phrase bank for more elaborate topics; 4) serving as a comprehensive communication tool to generate both spoken and written language; or 5) offering a specific technique to enable some individuals to participate, with more independence, in an important life activity. Most of the listed functions of AAC for PWA cover the activities and participation within the ICF. The only one that related to the body functions (internal language competence impairment by the brain damage) is the function of enhancing auditory comprehension, which may relate more to language competence. However, how AAC interventions can enhance auditory comprehension is still unknown.

Garret and Lasker (2013) stated "PWA must refer to informational supports that are outside of their heads-that is, not part of the automatized network of memories, association, and language that allowed them to communicate with minimal effort before the onset of aphasia" (p. 406). By this assumption, AAC strategies should focus on external representations of meaning. However, the authors did not define the external representations of meanings and how to test if the meaning is internal (inside the brain) or external (outside of the brain). Especially when aphasiologists have a general agreement, aphasia is not a loss of language (see section 2.1). The claim, "PWA *must* refer to informational support [emphasis added]", seems assertive. If the assumption of the "external representations" means pictures, icons, written words, auditory words, or even videos. Then, do all "external representations" have the same effects?

Hux et al. (2008) used McNeil (1988)'s definition and addressed that PWA have had difficulty processing all types of symbols. That means PWAs would not benefit from using an icon symbol (non-verbal symbol) to replace a written word (verbal symbol). To review the previous papers from McNeil (1982, 1983), the focus was on verbal symbols rather than non-verbal symbols. There was no clear explanation to address if PWA could or could not process non-verbal symbols mentioned in the two articles. In addition, the nonverbal disturbance of the PWA was inconsistent (Chertkow, Bub, Deaudon, & Whitehead, 1997). Some PWA's performance was not affected by non-verbal interference (icons). Research also showed that PWA had a similar ability in iconic (non-verbal symbols) tasks compared to the normal population (Thorburn, Newhoff, & Rubin, 1995). The above results showed PWA could still process non-verbal symbols. Therefore, the interpretation from Hux et al. (2008) seems in conflict with McNeil's (1982; 1983) papers. Moreover, if the processing damage is across all types of symbols, that means the results of most AAC studies might be questionable, because most AAC intervention consist of one or more types of non-verbal symbols (ex: photos, pictures, visually scenes and etc.). Another concern is the cognitive abilities of PWA. Hux et al. (2008) suggested using memory to help PWA. However, many studies have shown that PWA have memory issues (McNeil et al., 2010) How to use memory to help PWA in AAC intervention is another question.

AAC interventions for PWA traditionally include multimodal communication strategies (Beukelman & Mirenda, 2013; Lasker & Garrett, 2006). PWA are encouraged to use any strategies ranging from no technology (ex: speech, gesture, facial expression) to high technology (ex: voice output device). In order to facilitate the intervention selection, a classification system was introduced for categorizing PWA into two general groups: partner-dependent communicators and independent communicators, because some PWA may not be independent communicators longitudinally, and would always need a communication partner to initiate a response or provide support for communication (Garrett & Beukelman, 1992; Garrett & Lasker, 2013). In this approach, the training of communication partners becomes one of the key components of AAC intervention in PWA (Beukelman & Mirenda, 2013; Koul, 2011). No doubt communication partners are important when PWA cannot communicate independently, and need extra help. However, putting the energy of intervention on communication partners, because a PWA is partner-dependent, is not convincing. Overall, independent communication is still the ultimate goal. In order to use independent and functional communication, enhancing language skills in all modalities is important and should not be ignored (Armstrong & Ferguson, 2010). That a PWA is partner-dependent now does not mean he/she cannot be partner-independent later. Many studies showed that people with chronic aphasia can still benefit from aphasia treatments (Meinzer et al., 2004; Robey, 1998). Unfortunately, many AAC studies seem to focus on functional communication only.

High-performance computer-based AAC technology is more widely available now than in the past decade because of the rapid improvement of mass-market technology and the decreased cost. Although many aphasia studies involved from traditional PC (Cherney et al., 2008; Raymer et al., 2006) to mobile technology currently (Corwin et al., 2014; Kurland, Wilkins, & Stokes, 2014; Routhier et al., 2016), none of studies included aphasia AAC using mobile technology up to this point. Before mobile technology is blooming, computer-based AAC studies have been showed some positive outcomes previously. The following paragraphs will review two most common AAC aphasia system, In other words, the most common AAC displays that were used with PWA.

One type of computer-based AAC system usually uses a grid format with symbols/icons/pictures, which allows PWA to use icon symbols to generate short utterances (e.g., Computerized Visual Input Communication; CIV-C, Steele, Kleczewska, Carlson, & Weinrich, 1992; Johnson, Hough, King, Vos, & Jeffs, 2008; Koul et al., 2005; see Figure 3). Although the outcomes of this type of AAC system were shown that PWA was able to combine different icons using the AAC systems (Koul et al., 2005; Steele et al., 1992), and some of PWA showed improvement in pre-and post-treatment tests (Johnson et al., 2008), the outcomes of this type computer-based AAC studies were mixed across PWAs. The results also suggested that outcomes were affected by the severity of aphasia often.

Figure 3 Example of grid-format AAC display. From PIXON® Project Kit, Semantic Compaction® Systems, Inc. Reprinted with permission.

Another type of AAC aphasia approach is the Visual Scene Display (VSD, see Figure 4) (Beukelman et al., 2015; Dietz, 2006; Hux, Buechter, Wallace, & Weissling, 2010; McKelvey & Dietz, 2007). Researchers manipulated the user interface using personalized and contextualized pictures with the intent to improve PWA's communication. Studies on VSD (Hux et al., 2010; McKelvey & Dietz, 2007) referred to the definition from McNeil (1982, 1983), that PWA have symbolic processing problems, so the VSD with such information can decrease the load for processing. VSD experts also stated that grid type of AAC display will not only increase the processing load and overwhelm PWA’s working memory (Beukelman et al., 2015). However, the first conflict is that a VSD contains symbols also. In fact, VSD has multiple symbols within an environment or context (ex: pictures, written words, icons). In this case, the assumption was questionable. Another concern is the complicated display. How the display affects attention is unsure, especially when PWA have attention deficit caused by aphasia. A complicated display like VSD with many different stimuli may be worse rather than better.

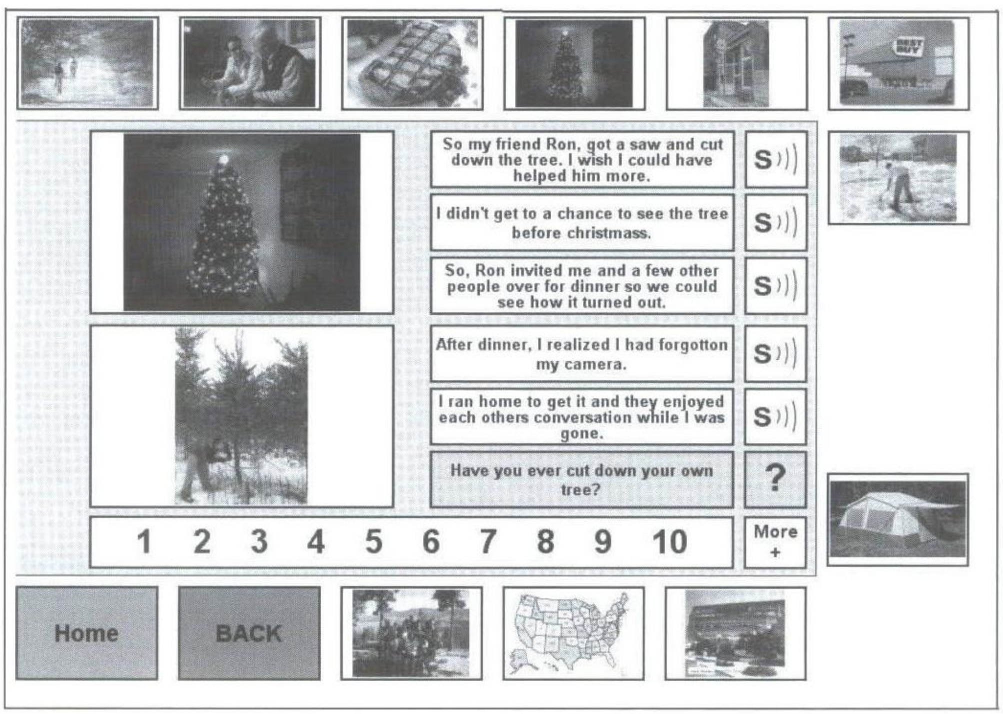


Figure 4 Example of visual scene display. From McKelvey, M. L., Dietz, A. R., Hux, K., Weissling, K., & Beukelman, D. R. (2007). Performance of a person with chronic aphasia using personal and contextual pictures in a visual scene display prototype. Journal of Medical Speech-Language Pathology, 15(3), 305-317. Reprinted with permission.

Although the two type of AAC aphasia systems (displays) showed positive treatment effects in communication effectiveness (McKelvey & Dietz, 2007; McKelvey, Hux, Dietz, & Beukelman, 2010), and proved that PWA navigate, manipulate and combine icons (Johnson et al., 2008; Koul et al., 2005), it is still not clear how these systems and outcomes related to language recovery. In the meantime, some claims that PWA may benefit from the voice output of an AAC device in terms of their communication and speech production (Koul et al., 2005; Weinrich et al., 2001). However, the effectiveness of AAC intervention is obscured when AAC intervention for aphasia does not identify the multiple variables that can be manipulated as part of the AAC system and also manipulated as part of clinical treatment. For example, participants were asked to repeat the voice output verbally (Weinrich et al., 2001). The repetition behavior prevented us from confirming if the treatment effect was truly from using the AAC system, because the outcomes of spontaneous speech might be caused by the verbal practice, which were also commonly shown in the computerized word retrieval treatments (Corwin et al., 2014; Routhier et al., 2016). In the past, some pediatric studies in AAC for participants with autism and/or intellectual impairment, have shown that high-technology AAC interventions had a positive effect in the facilitation of expressive language/verbal speech (Olive, Lang, & Davis, 2008; Romski & Sevcik, 1996). More recently, a study used behavioral measure (language sample analysis) and neuroimaging analyses (FMRI) to show improvement from few PWA (Dietz et al., 2014). That evidence may support the assumption that PWA may benefit from the voice output of high-performance AAC systems. From the literature review process, no study has focused on how AAC intervention with voice output can affect PWA's language performance.

2.7 IMPLICIT LEARNING/INCIDENTAL LEARNING

According to Ellis (2015, p.2), "Implicit learning is acquisition of knowledge about the underlying structure of a complex stimulus environment by a process which takes place naturally, simply and without conscious operations. Explicit learning is a more conscious operation where the individual makes and tests hypotheses in a search for structure." In other words, implicit learning is considered a learning process without consciousness. Meanwhile another term "incidental learning" is commonly used in vocabulary learning (Perruchet & Pacton, 2006; Saffran, Newport, Aslin, Tunick, & Barrueco, 1997; Seipel, 2011) . The general definition of incidental learning is the "learning of vocabulary as the by-product of any activity not explicitly geared to vocabulary learning" and is contrasted with intentional vocabulary learning, defined as "any activity geared at committing lexical information to memory" (Hulstijn, 2001, p.271). The definition of implicit learning refers to "without teaching", and incidental learning refers to "without intentional" (Rieder, 2003). These definitions are very similar, and frequently are used interchangeably. Basically, both terms imply that no matter whether people use implicit learning or incidental learning, they will pick up some knowledge outside of the target learning tasks.

Many studies have shown children, adults, and PWA could learn new words, foreign words, and novel words by exposure incidentally (Breitenstein et al., 2007; Breitenstein, Kamping, Jansen, Schomacher, & Knecht, 2004; Seipel, 2011). Not only can people learn by exposure without instruction, they also can learn to recognize unknown natural foreign words in a very short period of time (Gullberg, Roberts, Dimroth, Veroude, & Indefrey, 2010). Meanwhile, PWAs also have shown their implicit learning to auditory sequences (Schuchard & Thompson, 2014). All the evidence above suggests that both adults and PWAs are able to learn words by exposure and without feedback or instruction. This evidence may support the assumption of using high-technology AAC device with voice output to help PWAs "pick up" or learn words, because they are exposed to the voice output overtime. Every time they press a button on the AAC display, the voice output is presented simultaneously. However, up to this point, no AAC aphasia studies have investigated the effect of implicit learning when using AAC devices in PWAs.

2.8 MULTIMODAL STIMULI AND CUES

One advantage that technology can serve is to provide multimodal stimuli to PWA during intervention. Some studies reported that multiple stimuli (visual and auditory) may help PWA's auditory comprehension on repeated programs (Culton & Perguson, 1979) and naming (Johnson et al., 2008; Raymer et al., 2006). Controversially, Choe, Azuma, & Mathy (2010) tested if three adults with non-fluent aphasia and apraxia of speech could improve their speech production independently, practicing at home with a high-technology AAC system. The results showed using a high-technology AAC system for independent practice did not yield statistically significant results, but qualitative gains in performance were observed. In addition, the individuals with non-fluent aphasia and verbal apraxia, and their family members consistently rated verbal modeling (i.e., say the correct word after a clinician says it) as the most useful cue rather than semantic (i.e., "meows" for the word "cat") and phonemic cues (i.e., the /k/ sound for the word "cat") (Choe et al., 2010).

Evidence from studies of adult language learning may be used to support the concepts of multimodal stimuli in high-technology AAC-aphasia interventions. According to a generative theory of multimedia learning (Mayer, 1997), learners select and connect the most important visual and verbal information, organize that information, and integrate the new information with existing knowledge. The multiple modes of delivery (written words, icons, audio, etc.) affect the level at which learners employ cognitive processes to acquire knowledge. Khalid & Al-Seghayer (2001) found that providing texts and video simultaneously had better results for language learning than providing texts and pictures. Multimedia learners can integrate words and pictures more easily when the words are presented auditorily rather than visually (Mayer & Moreno, 1998). Plass, Chun, Mayer, and Leutner (1998) presented the results of English speakers learning German. Even though learning styles were different across all participants, all participants still benefited from verbal and visual stimuli together. Tight (2010) reported that mix-modality instructions stimulated the greatest learning and the best retention. Matching learning style and input is better than when these are mismatched, and utilizing mixed stimuli (auditory and visual) can lead to even greater gains. People also showed better performance on foreign word recall tasks when using auditory +written + pictorial stimuli (Bisson, van Heuven, Conklin, & Tunney, 2015). These results all support the assumption that PWA may benefit from the multimodal stimuli in high-technology AAC systems.

While several studies showed supportive results, Mayer, Heiser, & Lonn (2001) offer counter evidence. Their study compared the performance between viewing an animation with concurrent auditory narration explaining the formation, and the same condition plus on-screen text. The students who received an animation with concurrent auditory narration had better performance than the students who received extra information (on-screen text). This result suggested that more (multimodal stimuli) does not necessarily mean better outcomes. Mayer, Heiser, & Lonn, (2001) stated, when added, on-screen text can overload the visual information-processing channel, causing learners to split their visual attention between 2 sources (animation and on-screen text). Following this result, PWA may have similar disadvantage when receiving too many stimuli.

Although there is a concern that multimodal stimuli may increase people's load of processing during language learning, most of the reviewed studies above suggest that multimodal stimuli (cues) can improve adult language learning. In the meantime, previous studies also showed that able-bodied adults and PWA can learn words by exposure (see Section 2.7). Again, this evidence provides a certain level of confidence that the learning process of PWA and able-bodied participants are similar. Now, when thinking back to the process of high-technology AAC aphasia intervention, the process usually includes multimodal stimuli on a high-performance AAC device. Additionally, AAC speakers are exposed to visual and auditory stimuli repeatedly when they use the device. This process is similar to the adult language learning using multimodal stimuli. With this similarity, it is possible to say that high-technology AAC intervention may be able to mimic the positive effects of adult language learning studies for PWA's language performance.

2.9 INTENSITY OF TREATMENT

The intensity of aphasia therapy needed to improve communication skills has been an on-going clinical debate. The intensive treatment is generally considered as more than usual (Hinckley & Craig, 1998). Up to now, no clear definition of intensive treatment in aphasia rehabilitation has been confirmed with evidence (Baker, 2012; Cherney, 2013; Warren, Fey, & Yoder, 2007). Based on the framework from (Warren et al., 2007), many intensity variables can affect the outcomes of an intervention: dose (the number of teaching episodes or active ingredients in one session), dose form (the type of treatment activity), dose frequency (the number of a dose of intervnetion per time unit: day or week), total intervention duration (the total period of time of an intervention), and cumulative intervention intensity (dose x dose frequecny x total intervention duration).

The intensity of therapy affects the cost-effectiveness of treatment. In 2016 Medicare coverage (Centers for Medicare & Medicaid Services, n.d.), if an individual only has the original Medicare, the maximum reimbursement of the outpatient therapy services of Medicare is $3,700 for physical therapy and speech language therapy combined. That means only $ 1850 for SLP services each year if physical therapy is not given a higher percentage. This amount would only cover 26 1 hour sessions per year; 26 hours of treatment if the sessions are not terminated after the 31 minutes required for full reimbursement. The number is far less than the common number of sessions in a clinical setting. . One full hour session per week would total 52 sessions or 52 hours of therapy per year, nearly twice the amount that Medicare covers. Because of the gap in the amount of treatment between the professional recommendation and the real situation, determining a minimum number of treatment sessions that can achieve treatment effects is important, especially, when the shortage of funding for healthcare is a serious issue today and will be into the future.

Although the intuitive assumption would be high intensity of treatment is better than low intensity of treatment, the effect of intensity/dose of treatment actually is equivocal (Cherney, Patterson, & Raymer, 2011). Common intensity of treatment is 1-2 hours per week in regular outpatient services. The intensive treatment that was defined by studies was from 4-5 hours (Bakheit et al., 2007; Denes, Perazzolo, Piani, & Piccione, 1996; Robey, 1998) to 25 hours per weeks (Hinckley & Craig, 1998), and the duration of treatment delivered ranged from ten days (Pulvermüller et al., 2001) to 24 weeks (Bakheit et al., 2007). Non-intensive treatment is considered 1-2 hours per week (Robey, 1998) to five hours per week (Hinckley & Craig, 1998), and the duration of treatment was from six weeks (Denes et al., 1996) to 24 weeks (Hinckley & Craig, 1998). The cut-off point is unclear between intensive and non-intensive treatments. However, given these data, most PWA receive a non-intensive treatment regimen given healthcare reimbursement limitations.

Evidence suggests that more intense treatment leads to better outcomes on word retrieval measures (Bhogal et al., 2003; Hinckley & Craig, 1998). In the meta-analysis, Robey (1998) reported that even moderate intensity of treatment (i.e., 2-3 hours per week) can be associated with a large effect size when treatment begins in the "acute" phase of aphasia recovery. All participants had large effect sizes for trained words when trained 4-5 times/week, compared to only two participants when trained 1-2 time/week (Raymer et al., 2006). PWA with chronic aphasia (> 12 months post onset) could also benefit from intensive treatment (3hours/day over 2 weeks) in brain activities and language functions (Meinzer et al., 2004). Poslawsky, Schuurmans, Lindeman, and Hafsteinsdóttir (2010) reviewed the studies of aphasia rehabilitation which related to the nursing care, and determined what effective speech language treatments were appropriate in nursing practice. The study concluded the intensive treatment initiated in the early stage of aphasia had the best outcomes. However, many of the studies compared intensive treatment either to different treatments (Pulvermüller et al., 2001) or to no treatment at all (Mazzoni, Vista, Geri, & Avila, 1995). In the meantime, the results of the studies that compared the intensity of treatment with the same intervention were ambiguous. Some studies showed significant outcomes for intensive treatment (Denes et al., 1996; Hinckley & Craig, 1998), and some showed no significant difference between intensive treatment and non-intensive treatment (Bakheit et al., 2007; Hinckley & Carr, 2005). However, one important finding should be acknowledged. That is, most participants who were assigned to the intensive group did not reach the criterion for the amount of treatment. Therefore the conclusion was obscured. A possible factor that might cause the difference in the outcomes is the total amount of treatment. Basso's review (2005) supported the number of treatment sessions as an important factor in aphasia recovery. Additionally, PWA showed obvious improvements when they received treatment from 2 to 4 hours daily. Sage, Snell, Lambon Ralph (2011) investigated the intensity of treatment with a controlled total amount of hours. Participants reviewed two courses of treatments. Ten sessions were completed in either 2 weeks or 5 weeks. The results showed the majority of participants had improvement resulting from both intensive and non-intensive word retrieval treatment. The follow-up indicated better retention in the non-intensive treatment than the intensive treatment. Although some assumed that PWA may benefit from an intensive AAC intervention (Johnson et al., 2008), None of the reviewed studies addressed the intensity of treatment in AAC approaches. In summary, the evidence supports that having treatment is better than no treatment. When the intensity is extremely high (ex: 25 hours), the outcomes are clear. However, the minimum number of treatment sessions needed to demonstrate treatment effects has yet to be determined.

2.10 MIXED MODEL ANALYSIS

Evidence-based practice (EBP) has been an expectation of the field of AAC since the start of the century (ASHA, 2004; Hill & Romich, 2001; Hill, 2004). EBP emphasizes that when implementing an intervention/treatment, clinicians should appraise an intervention based on strong empirical, clinical and personal evidence. EBP requires attention to both external (previous literature and/or empirical data) and internal evidence (clinical practice and/or clinical data) (Dollaghan, 2012). Given the heterogeneity of PWA who may benefit from AAC, use of single-subject data collection and analysis methods may provide the best external evidence for clinicians to use to guide decision-making. Single-subject designs are commonly used to investigate the treatment effect based on single-subject data. The traditional data analysis of single subject designs is the visual inspection analysis. The strength of this analysis lies in its simplicity and practicality, but various studies have demonstrated low interrater agreement in interpreting graphed data, and a lack of guidelines (Harbst, Ottenbacher, & Harris, 1991; Ottenbacher, 1986). Another current criticism of visual inspection is that it is lacks formal inferential evidence such as autocorrelation, data cyclicity, and preexisting linear trend (Brossart, Parker, Olson, & Mahadevan, 2006). These disadvantages also lead to type I errors, and omissions of valuable information (Franklin, Gorman, Beasley, & Allison, 1997; Smith, 2012). Although several sophisticated analytic methods exist that have been traditionally used for single-subject design experiments (e.g., ANOVA/ANCOVA/MANOVA), those methods frequently fail to meet statistical assumptions (e.g., due to unplanned patterns of missing data or error covariance structure) or cannot accommodate both fixed-effects and time-varying covariates (Hedeker & Gibbons, 2006).

Mixed Model Trajectory analysis (MMTA) acts as an alternative to traditional single-subject data analysis procedures. As a statistical method, MMTA provides: 1) statistical power for small sample size, 2) robustness to missing data and outliers, 3) an account for autocorrelation, and 4) simple, yet robust, results (e.g., means, slopes) compared to time series analysis (Ridenour, Pineo, Maldonado Molina, & Hassmiller Lich, 2013). Recently, Chen et al (2015) used the method to demonstrate the potential of using speech generating devices to increase gains in speech and language development for Chinese-speaking children with autism. The results on treatment effectiveness were strengthen by using MMTA as a data analysis method. With additional supporting evidence such as from the study, hopefully increased use of MMTA by researchers and clinicians will help to build stronger external and internal evidence to guide AAC aphasia treatment decisions.

2.11 RESEARCH QUESTIONS AND HYPOTHESES

The aim of reviewing the studies summarized above has been to demonstrate the potential of using computerized AAC intervention to facilitate PWAs' spoken word performance. The Phase I study includes two experiments using the same experimental design based on guidelines proposed by Robey & Schultz (1998). In a Phase I study, the intervention and its hypothesized effects are identified. The study has a small sample size, and has initial approximations of candidacy criteria. The experiments differed from related research in its focus on comparing the effect of different types of voice feedback that can be used during AAC intervention. The experiments also examined the effect of intensity of treatment. This series of experiments started with normal control (NP) first, than the PWAs. The Institutional Review Board of the University of Pittsburgh approved the study for the protection of human subjects who were recruited in the study.

2.11.1 Experiment one

The experiment one aimed at answering the following three research questions:

1. Is there a significant difference in number of words acquired using an integrated computerized AAC training with synthesized voice output compared to the integrated computerized AAC training with human voice output in NP and PWA?

2. Is there a significant difference in number of words acquired using an integrated computerized AAC training combined with self-paced practice compared to the regular integrated computerized AAC training only in NP?

3. Is there a significant interaction between adding self-practice and adding voice output in an integrated computerized AAC training protocol in NP?

In order to answer those questions, the following specific aims and hypotheses are presented. The impact of the voice output feature for training vocabulary learning in NP was the first step toward testing the hypotheses with PWA.

The Specific aims for the experiment one with NP were:

Specific Aim#1: To validate the effect of vocabulary learning with synthesized voice output and with human voice output provided by an integrated AAC system.

- **Hypothesis:** NP who receive an integrated AAC computerized intervention with synthesized voice output will experience no significant different gains in confrontation naming in a novel foreign language words (Mandarin Chinese, MC) compare to NP who received a parallel treatment with Human voice output feedback.

Specific Aim#2: To investigate which intensity/dose of treatment leads the improved confrontation naming in NP.

- **Hypothesis:** NP with a treatment protocol that includes self-paced practice will have better gains in naming than NP with no self-paced practice included in the treatment protocol.

2.11.2 Experiment two

The Specific aims for the experiment two with PWA are were:

Specific Aim#1: To validate the effect of vocabulary learning with synthesized voice output and with human voice output provided by an integrated AAC system.

- **Hypothesis:** PWA receive an integrated AAC computerized intervention with synthesized voice output will experience no significant different gains in confrontation naming compare to receive a parallel treatment with Human voice output feedback.

Specific Aim#2: To investigate the effect of auditory exposure leads the improved confrontation naming in PWA.

- **Hypothesis:** PWA will experience no significant different gains in confrontation naming between trained words and exposed words.

3.0 EXPERIMENT ONE

3.1 METHODS

3.1.1 Participants

Eight monolingual English speakers were recruited from Pittsburgh metro area for this study with the Institutional Review Board (IRB) approval from University of Pittsburgh. All participants were between 20 to 55 years old, with no self-reported history in premorbid communication, neurologic or psychiatric disorders. They were able to point using one or more fingers and had a corrected visual acuity of at least 20/40 as determined by a Rosenbaum eye test. All participants passed a pure-tone hearing screening with a minimum 20dB HL bilaterally, at 500, 1000, 2000 and 4000 Hz, and the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) with a score greater than 26. All participants had a verbal fluency test (name as many words start with F as participants can in 1 minute) (M = 14.4, SD =4.5)(Tombaugh, Kozak, & Rees, 1999).No participants had Mandarin Chinese training or any other second language training while they participate in this study.

Table 1 Demographic data

Participants	Gender	Age	Education
P11	M	23	College
P12	M	22	College
P21	F	24	Graduate
P22	F	55	Graduate
P31	F	26	Graduate
P32	F	24	College
P41	F	20	College
P42	M	41	Associate degree
Overall		29.37	

3.1.2 Experimental stimuli

The experimental stimuli were 120 words chosen based on high frequency occurrence from the Mandarin Chinese conversational corpuses database (Chen, Hill, & Chen, 2009, 2010; Chui & Lai, 2009; Tseng, 2013) and nouns that commonly appear on high-technology AAC devices identified by experienced speech language pathologists. These words included pronouns, verbs, adjectives, adverbs, and nouns (appendix B). High frequency vocabulary a.k.a core vocabulary referred to words that are most commonly used across individuals and contexts (Beukelman & Mirenda, 2013; Hill, Baker, & Romich, 2007). Including high frequency vocabulary in an AAC application and devices is a usual clinical strategies for timing enhancement, message acceleration, and fatigue reduction (Beukelman & Mirenda, 2013).

The 120 words were split to two 60-word lists. Each 60-word list was separated into three twenty-word sets: the trained set, the exposed set, and the untrained set, as the experimental stimuli for the study. These 20 words were chosen based on random selection of the words into each word set, with ensurance that each word set included two pronouns so the participants could potentially generate short utterances (see Figure 5). The participants had a training on the trained words in the treatment phase. Participants were exposed to the exposed words during the treatment phase one time each session, but received no training on these words. The untrained words serve as controls. The untrained words were neither trained nor exposed during the treatment phase.

Participants started the training with the 60-word list. When participants reached the outcome criterion of 90% but still had not completed the assigned number of sessions, participants received continuous training on the other 60-word list to complete the assigned sessions.

Figure 5 Overview of the experimental stimuli

3.1.3 **Materials and equipment**

Each participant completed a self-report survey (Appendix A) to collect demographic information. The MoCA (Nasreddine et al., 2005) was used for to screen participants' cognitive abilities. A survey of participation satisfaction was used to understand participants' perceptions of the training protocol and the user abilities of the training program.

The AAC hardware was a 10.1 inches android tablet with a 32 location capacitive touchscreen display with an integrated AAC system (EuTalk; Chen & Wang, 2013; Wang & Chen, 2013). and with a female synthesized voice. The voice output was delivered to the participants through internal speakers of the tablet at the maximum level at 70 dB SPL. The user interface had the symbols organized based on a semantic syntactic grid display (Beukelman & Mirenda, 2013; Koul, 2011; see Figure 6). The participants used direct selection by fingers of choice. All experimental stimuli were color single meaning pictures from the Pixon Project Kit (Prentke Romich Company, 2009). Each word was presented with a picture, and the written word was on top of the picture.

The program had an automatic Language Activity Monitoring system (LAM; Hill & Romich, 2001). LAM is a data logging feature to collect actuation data during periods of training and practice. The data helped the investigator monitor participants' performance in the practice in terms of the accuracy of tasks, timing, and type of prompting. A Cannon FS 200 Camcorder and an Olympus WS-331M digital recorder were used to record the training sessions for treatment reliability and fidelity analysis. SAS software v. 9.4, and Microsoft Excel 2013 were used to complete the data analysis.

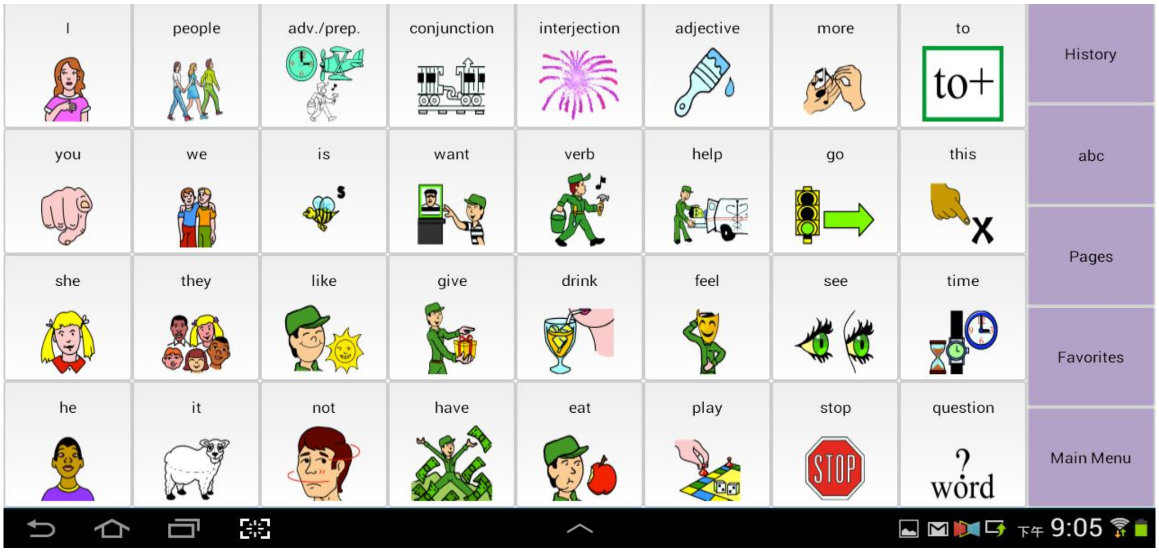


Figure 6 The sample display

3.1.4 **Experiment design**

The study used a within subject, across subjects at 2 x 2 factorial combining intervention design to investigate if exposure to different types of voice output when using an integrated AAC system would affect normal participants learning a Mandarin Chinese (MC) vocabulary. The investigator also wanted to explore whether increasing intensity/dose of using a self-paced practice program would affect normal participants learning of the selected MC vocabulary.

In the nature of single-subject design, investigators collect data on the target behaviors and the relevant behaviors as well in the baseline phase. Investigators test the outcome of experiments based on the effect observed. That is, how level and trends of the targeted behaviors change between study phases. The design is also appropriate for investigating generalization of an intervention (Thompson et al., 2006). Single-subject designs are cost-effective methods for testing hypotheses of treatment effectiveness or for piloting larger group studies (Levine & Downey-

Lamb, 2002). A 2 by 2 factorial design allows investigators to test the differential effect of two independent variables, and the interaction between them (Portney & Watkins, 2009). Since it is hard to use single subject design to explore the potential interaction between variables, combing the two designs could overcome this limit.

The two two-level independent variables were the types of voice (synthesized voice vs. human voice) and the intensity of treatment (regular training vs regular practice + self-paced practice) (see Table2). The two dependent variables are accuracy of naming of the trained words, and exposed words. Both dependent variables were measured at the end of a session in trained and exposed word. ($\frac{\#\ of\ corrected\ named\ items}{Total\ \#\ of\ words\ (40)} \times 100$). The accuracy score is the number correct named items divided by the total number possible (40) of each type of words (___/ 40). The total number (40) did not include the untrained words.

Table 2 The definitions of variables

Variables	Definition
Independent	
Types of voice	
Synthesized voice	Participant received a Mandarin synthesized voice output when pressing the icons in the AAC training program.
Human voice	Participant received a Mandarin live voice as a feedback from the investigator when pressing the icons in the AAC training program. The voice output in the program was turned off.
Intensity of treatment	
RT + SP	Participant received a regular training, and did a self-paced practice, three times per week.
RT	Participant received a regular training only, three times per week.
Dependent	
Accuracy of naming of trained words	$\frac{\#\ of\ corrected\ named\ items}{Total\ \#\ of\ words(40)} \times 100$
Accuracy of naming of trained words	$\frac{\#\ of\ corrected\ matched\ items}{Total\ \#\ of\ words(40)} \times 100$

Note: RT=Regular training. SP=Self-paced practice

Using a 2 x 2 factorial design, eight participants was randomly assigned to one of four groups, receiving a combination of regular training or regular training + self-paced practice when having synthesized voice output or human voice output (see Table 1). Here are the formula of the four groups:

- $\text{Group1} = (\text{Synthesized voice} \times \text{Regular training}) + (\text{Self paced practice}) = (S \times R) + S$
- $\text{Group 2} = (\text{Synthesized voice} \times \text{Regular training}) = (S \times R)$
- $\text{Group 3} = (\text{ Human voice} \times \text{Regular training}) + (\text{ Self paced practice}) = (H \times R) + S$
- $\text{Group 4} = (\text{Human voice} \times \text{Regular training}) = (H \times R)$

Here to note that the participant received a self-paced practice without any voice output in the group 3. Each participant will receive three sessions based on the assigned condition per week for a total of 24 sessions in 8 weeks.

Table 3 2 by 2 factorial design

		Types of Voice		
		Synthesized voice output (n)	**Human voice output (n)**	
Self-practice	**Regular training+ Self-paced practice**	Group 1 (2)	Group 3 (2)	**4**
	Regular training	Group 2 (2)	Group 4 (2)	**4**
	Total	4	4	**8**

3.1.5 Training modules

Module 1: Find the trained words only

Participants followed the direction from the investigator to access the computerized training program using the test device and direct selection to navigate the picture symbols. Participants received a written instruction and a verbal prompt on the screen via the program. Only one trained word was on the display each time. Other locations of the display were hidden, so the participants only saw blank locations on the display (see Figure 7). Each word appeared once. Some of the trained words were on the main display, and some of them were on the second level of the display.

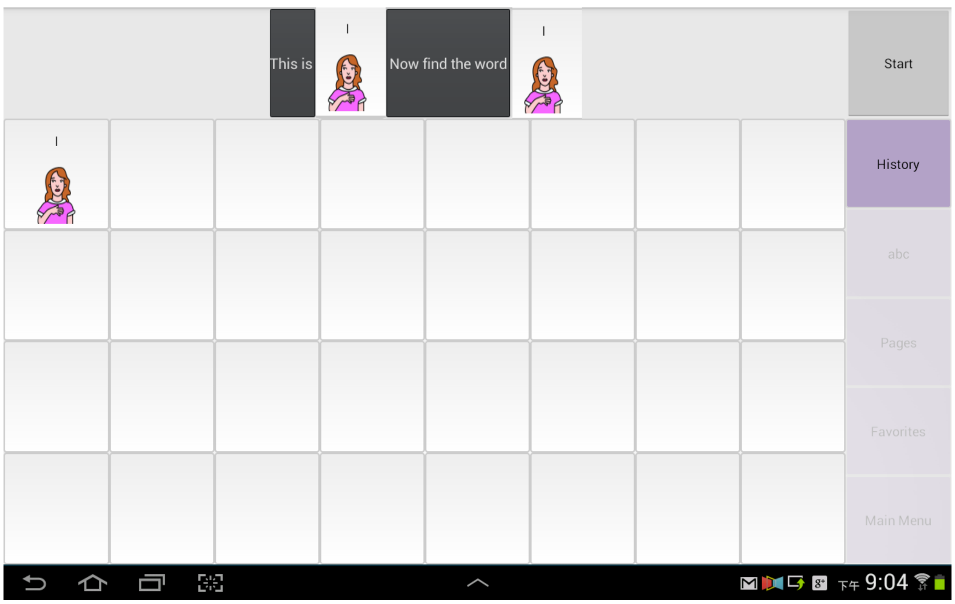


Figure 7 an example display of module 1

Module 2: Find the trained words on the full display

Participants received the same instructions as in module 1. One trained word each time, but the word was on the full display. That is, all picture symbols on the main display were shown. The participants saw all picture symbols on the display. Each word appeared once (see Figure 8).

Figure 8 an example display of module 2

3.1.6 Procedures

Screening

The investigator collected the performance of confrontation naming and the picture symbol-to-spoken word matching for all experimental stimuli (120 words) before the training started. The investigator asked each participant to name each picture symbol in Mandarin Chinese. They must show that they could not name all the words. For the picture symbol to spoken words matching task, the investigator presented a spoken word with 5 different picture symbols. Participants needed to point to the picture symbol that matched the presented spoken word. The accuracy of the picture symbol to spoken word matching screening must be less than 20% of accuracy. Participants did not receive any feedback during this phase.

Treatment

Treatment was administered in a quiet room with the investigator (See the script: Appendix C).

First, the investigator presented the exposed set one time in the beginning of a training session. The investigator would say "Now I want to show you some pictures on the device. I will point to the picture. You just look at those pictures. Let's start." The investigator presented the exposed words to a participant with synthesized voice output or her own voice which depends on the assigned condition using the computerized training program. No feedback or extra information was provided.

Second, the investigator started to train the participant using the trained set via a computerized AAC training program following the training modules with the 20 trained words. The investigator would say "Now let's start with the training program, I want you to find some words on the device. You will hear a command from the device (group 1 and group 2) or from me (group 3 and group 4). When you find the word, you will hear the device says the word. The investigator would guide the participant to complete the two training modules in 30 minutes. The investigator followed a structured training program based on the identified prompting hierarchy. For example, in module 1, for the first trained word "I", a participant first received the verbal prompt with a picture symbol of "I" (This is "I". Now find the word "I"). If the participant produced either no response or provides a wrong response in 5 seconds, then a repeated verbal prompt was given. If the participant produced either no response or provided a wrong response in 5 seconds following the prompt, a verbal prompt plus visual cue (highlighted the target word) was given. If the participant did not provide a correct response in 5 seconds, then the investigator provided a verbal prompt and the target word would be flash. If the participant does not provide a correct response in 5 seconds, then the investigator direct the participant to press the target word, then the participant will move to the next word. The same steps were repeated until the participant completed a module and then moved to the next module. If the participant was in the condition with human voice, the investigator said the commands and the verbal prompts aloud, and a participant completed the tasks. If a participant select the correct icon, the investigator would read the word again.

Participants in group 1 (Synthesized voice output + self-paced practice) and group 3 (Human voice + self-paced practice) completed an extra self-paced practice of the two training modules after the regular training. When completing the self-paced practice, participants in group 1 continued to receive the synthesized voice output from the device, and the participants in the group 3 did not receive any voice output or feedback under the investigator's observation.

After the training was completed based on the assigned condition, the investigator randomly picked two shapes (see appendix D) to avoid the primary memory effect. The participants were asked to draw two shapes following the dashed line. After the drawing task, the investigator asked the participant to name the trained words and the exposed words. When participants produced a guessable, but not intelligible word, the PI would say the correct word. Any word that could not be identified would not be verbalized by the PI.

A probe of untrained words was administered in the last session of each condition. Treatment continued on the trained set until 45% accuracy is reached (20 trained words). When participants reached the criterion and did not complete the 24 sessions, the participants started the second word set with the same procedures until 24 sessions were completed in 8 weeks.

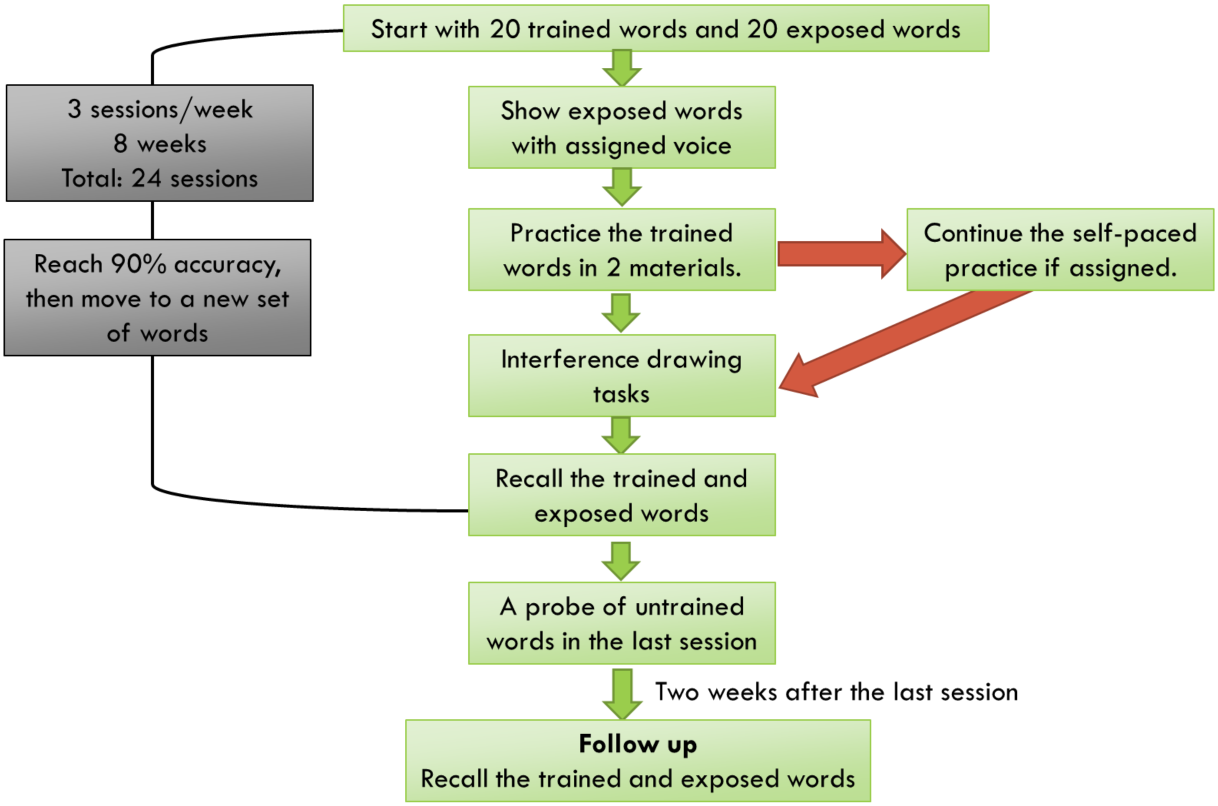


Figure 9 Treatment procedures

3.1.7 Data collection and analysis

Visual analysis was used to determine whether the intervention changed the participant's performance. Data were examined for level and the trend (Kazdin, 2011). While the visual analysis is the standard for evaluating the effectiveness of an intervention, more and more researchers have recommended using statistical measures as supplements to avoid bias and ensure objectivity (Barnett et al., 2012; Perdices & Tate, 2009).

The performance outcomes were analyzed using mixed model trajectory analysis (Ridenour, Hall, & Bost, 2009; Ridenour et al., 2013). Differences in the trajectories of the participant's performance was tested, as well as across participants. Analyses modeled the improvement rate of naming and interaction with the AAC device. Computing models of two variables: voice output and self-paced practice consisted of either of these fixed effects: sessions (each session by time order), voice output, self-paced practice, interaction between voice output and self-paced practice, or a model including all of these predictors. Four covariance structures were tested to account for serial dependence: compound symmetry (correlations between observations are equivalent regardless of lag time), the autoregressive (lag 1) structures toeplitz, and the autoregressive–moving-average (1, 1). The toeplitz structure was used for the analysis, because it had the best account for serial dependency based on statistical fit and parsimony. How well predictors fit to the data were tested using the following fit statistics: Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC) and -2 log likelihood. The likelihood-ratio chi-square test was used to determine the best fit models for trained words and exposed words. The Kenward-Roger test was used to control for Type I error in analyses of small samples. The Maximum Likelihood (ML) estimator was used to the fit of models, and to identify the best model, and the Restricted Maximum Likelihood (REML) was used to attain the estimates of parameters for the best model.

3.1.8 **Reliability and fidelity**

The point by point agreement and the Cohen's Kappa (Cohen, 1960) was calculated with 15% of the all sessions. An English-Chinese-speaking graduate student who was not familiar with the study served as the second rater for the treatment reliability using the audio recordings. Inter-rater reliability was checked for comprehensibility of participants' spoken words. An agreement was scored if the PI and the second rater recorded the same score of words that produced by participants. A disagreement was scored when two raters scored the same spoken words differently. The point by point agreement was 91.3 % for the trained words and exposed words. The Cohen's Kappa was 0.68. Both results suggests the results of the spoken words was highly reliable (Stemler, 2004). Treatment fidelity was controlled by the computerized training program, and the programmed prompting hierarchy. In other words, participants received the same amount of trainings and prompting hierarchy each sessions. The program control ensured that the training protocol had high fidelity. Procedure was self-monitored by the PI with a checklist (see Appendix F) to ensure the PI maintained the procedure fidelity.

3.1.9 **Participant satisfaction**

After completing the last session, all participants completed a nine-item survey regarding the satisfaction of the intervention with questions geared to capture their impressions of the effectiveness of the intervention and user-satisfaction with the device and treatment. All items were modified by previous studies that focused on the user satisfaction of human computer interface (Koester, 2004; Lewis, 1995; Lund, 2001). Each item was a statement, and participants rated their agreement with the statement on a scale of 1 to 5, with 1 =strongly disagree, and 5 = strongly agree. For example, item 1 read, "I feel it is easy to learn to operate this training program." (see Appendix E)

3.2 RESULTS

3.2.1 Individual visual inspection analysis

The results are first presented as individual levels on trained words and exposed words. The participant ID was coded as (group # participant#). For example, ID 11= group 1, participant 1, ID 12= group 1, participant 2. The coding rule was applied to four groups (see Table 4). Participant 12, and 41 (P12 and P41) completed the entire program in 18 sessions, and others completed the training program in 24 sessions. Figure 10 present the observed data for trained words and exposed words across the eight participants. All participants had declines in their follow-up session.

Table 4 Participant ID Chart

Group	1: (S×R+S)		~2: (S×R).		3: (H×R+S)		4: (H×R)	
Participant ID	11	12	21	22	31	32	41	42

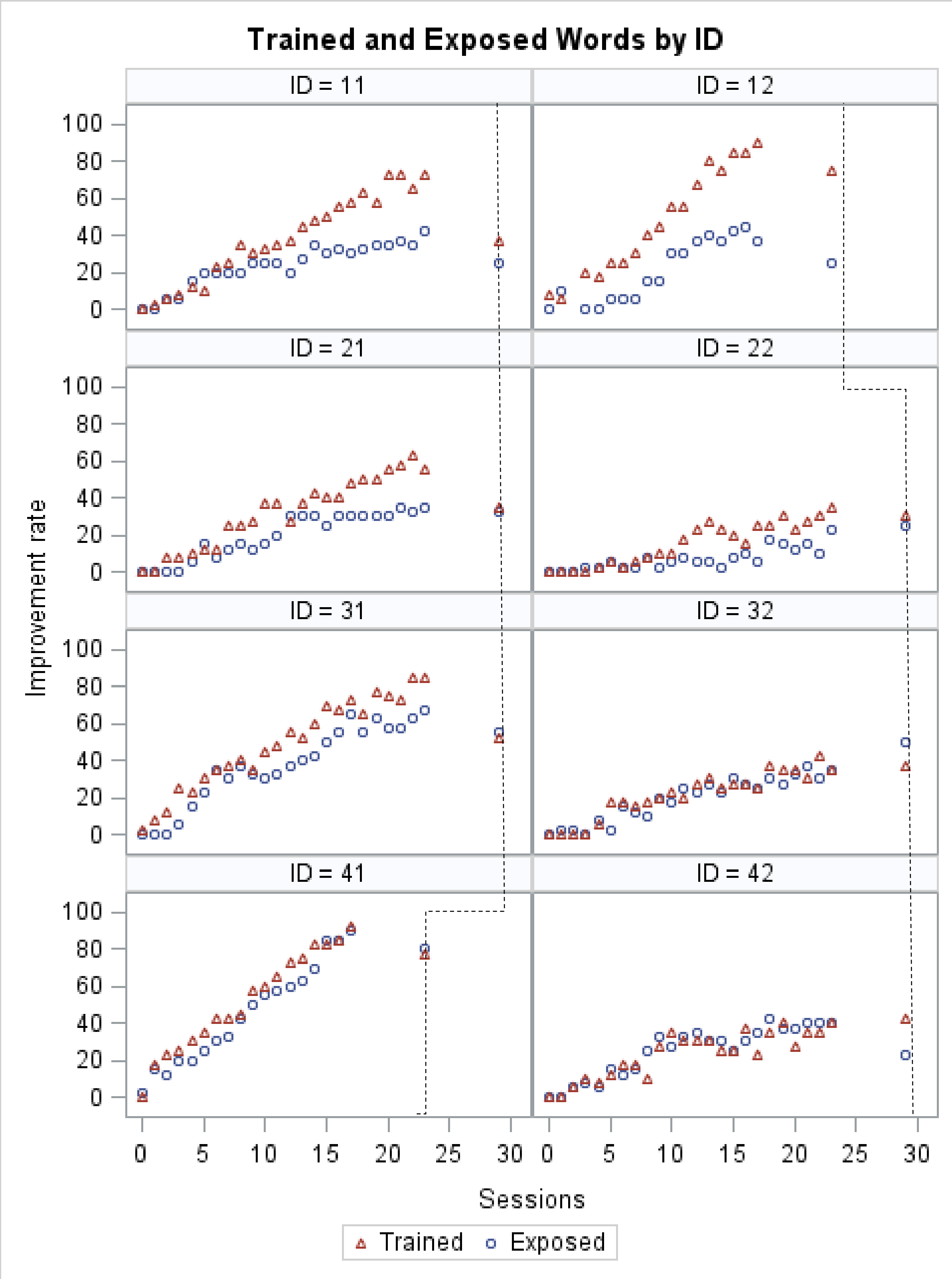


Figure 10 Raw data by individuals

3.2.2 Description of results at the group level

The range of mean of the trained words across the four groups were from 24% to 42% during the training period (see Table5). The order of the means across the four groups are group 1 (C×R+S) > group 4 (H×R)> group 3 (H×R+S) > group 2 (C×R). A gradually accelerating increase in four groups was observed. The range of mean of the exposed words across four groups were from 13% to 34% during the training period (see Table5). The order of the means across the four groups are group 4 (H×R) > group 3 (H×R+S) > group 1 (C×R+S) > group 2 (C×R). A gradually accelerating increase in four groups was observed, but the slopes of exposed words in four groups appeared smaller than the slopes of trained words based on the visual graph.

Table 5 Mean of trained word and exposed word in each group

Group	**1: (S×R+S)**		**~2: (S×R).**		**3: (H×R+S)**		**4: (H×R)**	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Trained (%)	41.95	26.07	23.54	17.86	35.21	23.89	35.42	24.42
Exposed (%)	22.62	14.16	13.23	11.62	28.23	19.46	33.69	22.68

Note. (S×R)+S = (Synthesized voice ×Regular training) + (Self paced practice);
(S×R) = (Synthesized voice ×Regular training);
(H×R)+S = (Human voice ×Regular training) + (Self paced practice);
(H×R) = (Human voice ×Regular training)

Each group included two participants. Group 1 (S×R+S): Figure 10 compared the observed data across the two participants in the group1. Participant 11 had a slower improvement rate than participant 12 on trained words. Participant 12 completed two 60-words in 18 sessions. Although participant 12 had a slower improvement rate in the first 9 sessions on exposed words, the improvement was over participant 11's after the first 9 sessions. The linear trend lines were generated based on the observed data of both participants. Figure 11 showed both the trained words and exposed words improved. The exposed words had slower gains than trained words.

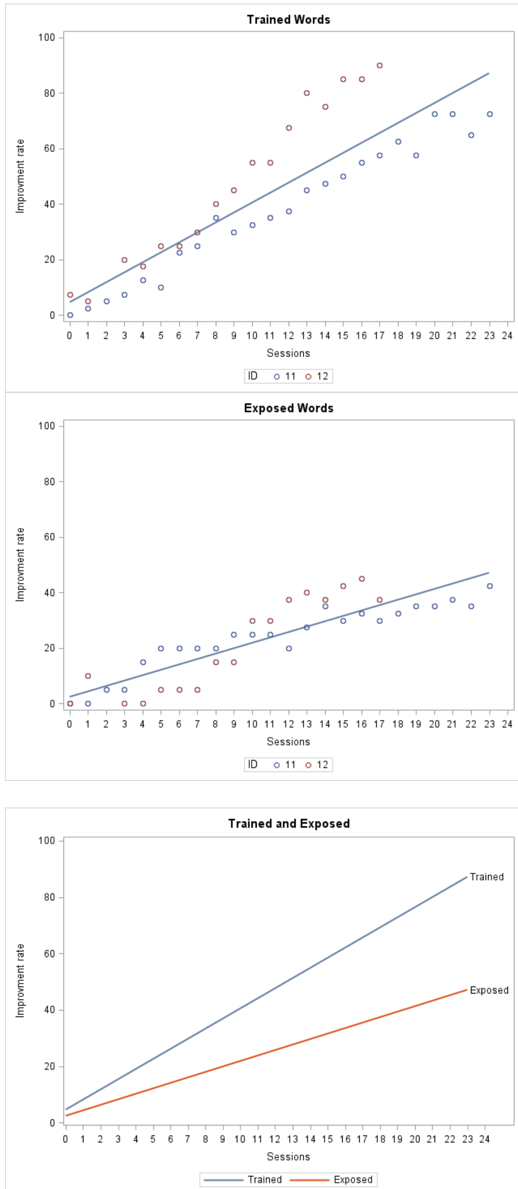


Figure 11 Raw data and trend lines in group 1

In group 2 (S×R), overall participant 21 had faster improvement rate than participant 22 on trained words and exposed words. Figure 12 shows that both of trained words and exposed words improved. The exposed words had slower gains than trained words.

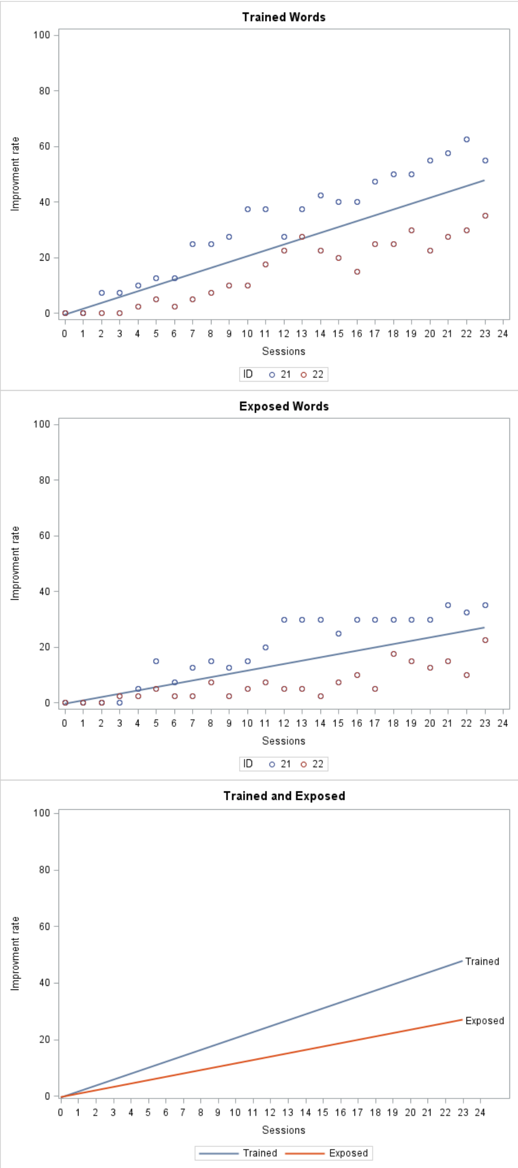


Figure 12 Raw data and trend lines in group 2

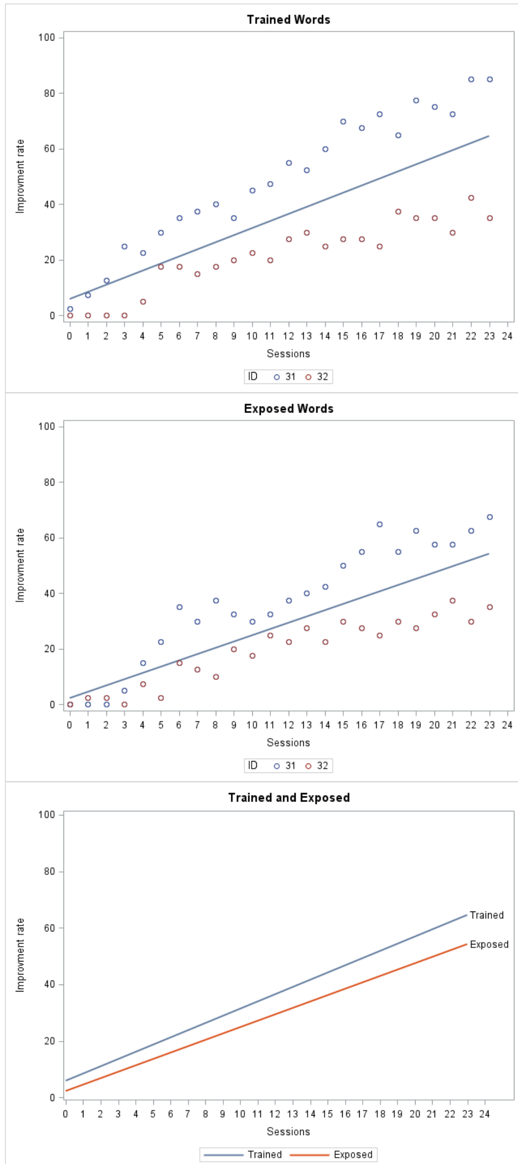


Figure 13 Raw data and trend lines in group 3

In group 3 (H×R) + S, overall participant 31 had faster improvement rate than participant 32 on trained words and exposed words. Figure 13 showed that both the trained words and exposed words improved. The exposed words had slower gains than trained words.

In group 4 (H×R) + S, overall participant 41 had a faster improvement rate than participant 42 on trained words and exposed words. Participant 41 also completed two 60-word sets in 18 sessions. Figure 14 showed that both of trained words and exposed words improved. The exposed words had slower gains than trained words.

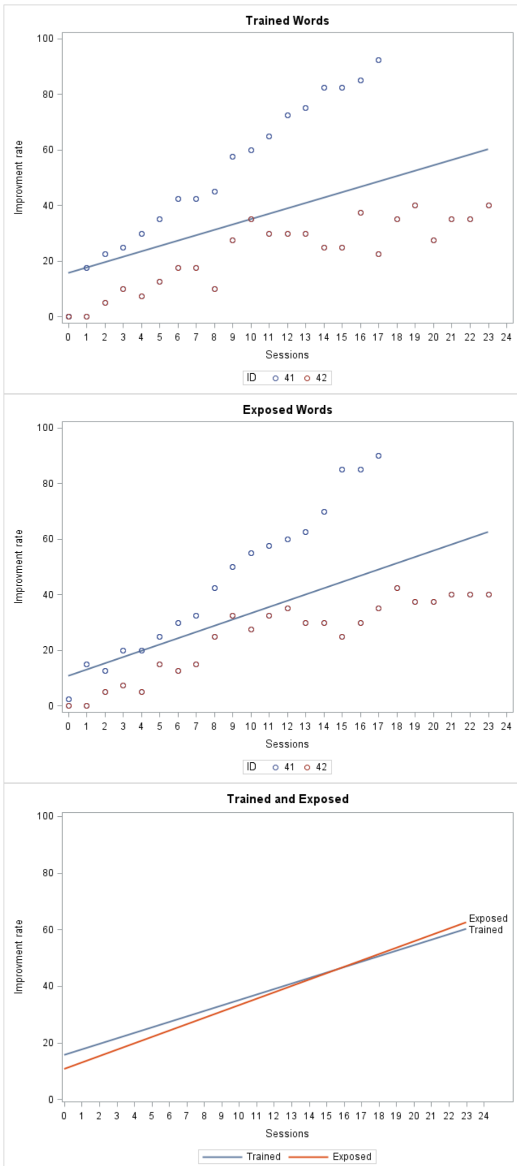


Figure 14 Raw data and trend lines in group 4

When comparing trained and exposed words by group, all four groups follow a similar pattern in that the trained words improved faster than the exposed words. However, groups 1 and 2 who had synthesized voice output had a bigger difference between the trend lines of the trained words and the exposed words than the groups with human voice output (3, 4). The trend lines in the group 4 crossed. The group 2 (S × R) had slowest improvement (see Figure 15).

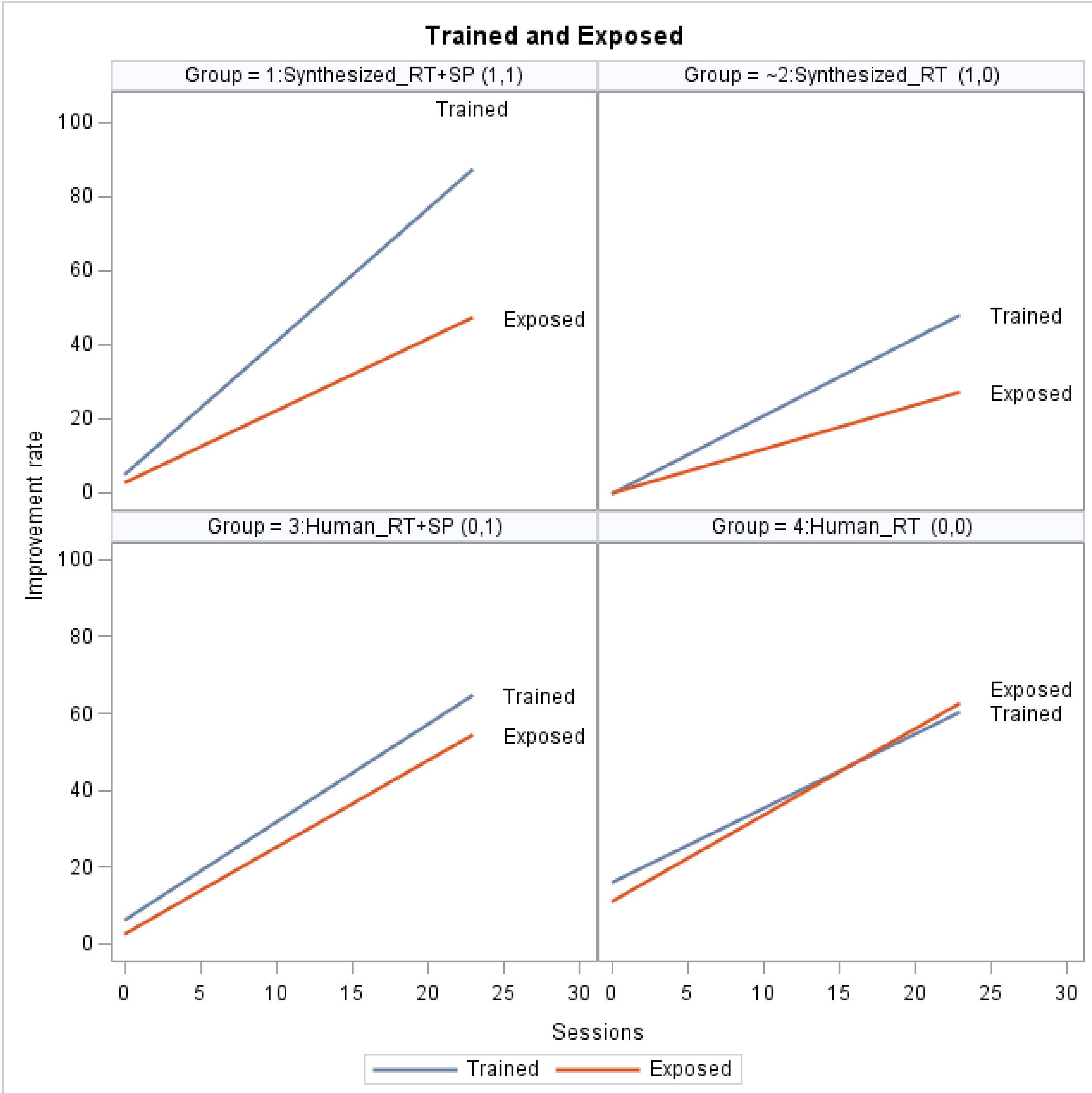


Figure 15 Comparing trend lines of 4 groups on both trained and exposed words.

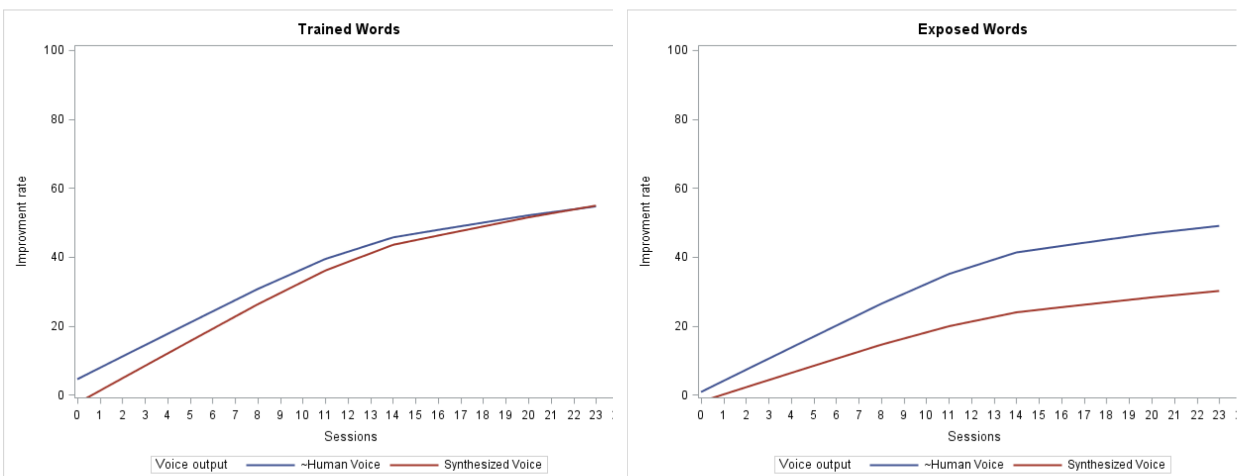
Group1=(Synthesized voice ×Regular training)+(Self paced practice); Group 2=(Synthesized voice ×Regular training);

Group 3=(Human voice ×Regular training) +(Self paced practice); Group 4=(Human voice ×Regular training)=(H×R)

3.2.3 Mixed model trajectory analysis

The above section showed the improvement across four groups using descriptive results and graphs. This next section reports the MMTA used to test each of the following parameters: number of session (time), voice output, and treatment intensity. MMTA was used to determine if these parameters served as statistically significant factors for the improvement rate on trained words and exposed words. The MMTA results indicated the best fitting model for naming improvement in trained words and exposed words involves the variables maturation (time=number of sessions) and voice output. That means, the improvement of the trained words and exposed words were not only contributed by the maturation (time), but also improved due to voice output. Additionally, improvement rates, as indicated by slope, showed that participants learned better under the human voice condition than under the synthesized voice. In terms of intensity of treatment, the MMTA results suggest adding a self-paced practice does not accelerate the learning trajectory.

To statistically test whether outcomes associated with intervention could be explained by different factors such as the type of voice output, and the intensity of training, all data were further analyzed using mixed model analysis. Table 6 and Table 7 presents fit statistics for competing models of the trained words and the exposed words. The results indicated a significant difference between the types of voice output. There was a significant relationship between the type of voice output and the naming improvement. Human voice output was associated with higher naming improvement on both trained and exposed words. Additionally, the results indicated that the naming performance was significantly different when the interaction between time and the type of voice output was considered. For trained words, the best fitting model consisted of (a) sessions, sessions * sessions, voice output, and the interaction of voice output and sessions, and (b) the sessions and intercept as a random effect (i.e. the size of the effect varies among participants). The aggregate model parameters of the trained words are Yij = 3.54+3.76×sessions-0.04×sessions×sessions-6.85×voice output+1.12×voice output×sessions (see Figure 16a). The best fitting model of the exposed words consisted of the same parameters as the trained word's model. The aggregate model parameters of the exposed words are Yij =-0.06+3.67×sessions-0.04×sessions×sessions-2.79×voice output-1.13×voice output×sessions (see Figure 16b). The best fitting model for the dependent variable provided evidence over and above the statistical tests of the robustness of the effect of the type of voice output. The test also demonstrated no significant difference between the types of training (see Table 7, model 10, Table 8, model 10) ($p<0.05$).



(a) Trained words **(b) Exposed words**

Figure 16 Predicted Aggregated Models of Synthesized voice output and Human voice output.

Table 6 Fit to the Data of the Full Hypothesized Model and Deterioration of Fit per Model Predictor for the outcome of trained word

#				Fixed				Random		-2Log	AIC	BIC	# of Parameters	LR $\chi 2$	
1	**Full Model**	s1	s2	v	P	v*p	v*s1	int	s	1073.5	1093.5	1094.9	17	**1 vs #**	**df**
2	**Full Model 2**	s1	s2	v	P	v*p	v*s2	int	s	1161.3	1167.3	1167.5	17	87.8	0
3	**Reduce vs1**	s1	s2	v	P	v*p		int	s	1152.9	1170.9	1171.9	16	-79.41**	1
4	**Reduce v*p**	s1	s2	v	P		v*s1	int	s	1073.6	1091.6	1092.6	13	-0.1	4
5	**Reduce p**	s1	s2	v		v*p	v*s1	int	s	1073.5	1093.5	1094.9	15	0	2
6	**Reduce v**	s1	s2		P	v*p	v*s1	int	s	1073.5	1093.5	1094.9	15	0	2
7	**Reduce s2**	s1		v	P	v*p	v*s1	int	s	1096.9	1114.9	1116	16	-23.4**	1
8	**Reduce s1**		s2	v	P	v*p	v*s1	int	s	1087.1	1105.1	1106.1	16	-13.6**	1
														4 vs #	**df**
9	**Reduce v**	s1	s2		P		v*s1	int	s	1088.8	1104.8	1105.7	11	-15.2**	2
10	**Reduce p,**	s1	s2	v			v*s1	int	s	1075	1091	1091.8	11	-1.4	2
11	**Reduce vs1**	s1	s2	v	P			int	s	1153.4	1169.4	1170.2	12	-79.8**	1

Note. Theoretical model includes all predictors, both as fixed and random effects. Each subsequent model tests whether fit to the data significantly worsens by dropping the listed term. s1 = sessions; s2= sessions*sessions; v=voice output; p=practice; Int. = Intercept; AIC= Akaike's Information Criterion; BIC = Bayesian Information Criterion; (-2) log = likelihood; df = degrees of freedom; Better fit to the data is indicated by smaller value of AIC, BIC, and -2 log likelihood.

***p<.05*, suggesting that this term cannot be dropped from the theoretical model, because the subsequent model fitted to the data significantly worsens than the theoretical model.

Table 7 Fit to the Data of the Full Hypothesized Model and Deterioration of Fit per Model Predictor for the outcome of exposed words

		Fixed						Random		-2	AIC	BIC	# of Parameters	LR χ2	
1	**Full Model**	s1	s2	v	P	v*p	v*s1	int	s	1096.7	1116.7	1117.4	17	**1 vs # (-2log)**	**df**
2	**Full Model 2**	s1	s2	v	P	v*p	v*s2	int	s	1191.2	1191.2	1192	17	-94.5	**0**
3	**Reduce vs1**	s1	s2	v	P	v*p		int	s	1171.4	1189.4	1190.1	16	-74.7*	**1**
4	**Reduce v*p**	s1	s2	v	P		v*s1	int	s	1098.4	1116.4	1117.1	13	-1.7	**4**
5	**Reduce p**	s1	s2	v		v*p	v*s1	int	s	1096.7	1116.7	1117.4	15	0	**2**
6	**Reduce v**	s1	s2		P	v*p	v*s1	int	s	1096.7	1116.7	1117.4	15	0	**2**
7	**Reduce s2**	s1		v	P	v*p	v*s1	int	s	1117	1135	1135.7	16	-20.3*	**1**
8	**Reduce s1**		s2	v	P	v*p	v*s1	int	s	1112.6	1130.6	1131.3	16	-15.9*	**1**
														4 vs # (-2log)	**df**
9	**Reduce v**	s1	s2		P		v*s 1	int	s	1101.6	1117.6	1118.2	11	-3.2	2
10	**Reduce p,**	s1	s2	v			v*s 1	int	s	1098.4	1114.4	1115	11	0	2
11	**Reduce vs1**	s1	s2	v	P			int	s	1174.4	1190.4	1191	12	-76*	1

Note. Theoretical model includes all predictors, both as fixed and random effects. Each subsequent model tests whether fit to the data significantly worsens by dropping the listed term. S1 = sessions; S2= sessions*sessions; v=voice output; p=practice; Int. = Intercept; AIC= Akaike's Information Criterion; BIC = Bayesian Information Criterion; (-2) log = likelihood; df= degrees of freedom; Better fit to the data is indicated by smaller value of AIC, BIC, and -2 log likelihood.

***p<.05*, suggesting that this term cannot be dropped from the theoretical model, because the subsequent model fitted to the data significantly worsens than the theoretical model.

3.2.4 **Participant satisfaction**

All eight participants completed a 5-point Likert scale satisfaction survey (1= strongly disagree to 5= strongly agree). Overall, the participants' ratings of their satisfaction with the training were positive. The mean score of the overall satisfaction of training was 4.13 (Item 9). 7 of 8 participants agreed it was easy to learn and operate the training program (mean score: 4.13,Item 1). All participants reported that their naming and speech was improved (mean score=4.69, item 3; mean score=4.13, item 4). Two participants reported that they were not in favor of this type of training. Four participants felt frustrated when using the training. Six participants reported that they would recommend others using the training (mean score= 4.00, item 8)

Table 8 Participant satisfaction results

Items	P11	P12	P21	P22	P31	P32	P41	P42	**Overall**
1. I feel it is easy to learn to operate this training program	5	4	4	4	3	4	5	4	4.13
2. I can complete the self-practice by myself easily.	5	4	n/a	n/a	5	3	n/a	n/a	4.25
3. I feel that my naming is improved.	5	5	4	5	4	5	4.5	5	4.69
4. I feel that my speech is improved after the training	5	4	4	3	4	5	3	5	4.13
5. I like this type of training	5	2	4	1	3	4	5	5	3.63
6. Using the training program can be a frustrating experience.	2	4	1	4	5	3	3	5	3.38
7. I would like to continue the similar training after the study.	4	3	4	2	3	4	2	5	3.38
8. I will recommend others to use this training program.	4	4	5	2	3	5	5	5	4.13
9. Overall, I am satisfied with the training.	5	4	5	2	4	4	5	5	4.25

3.3 DISCUSSION

In this study, I investigated whether synthesized voice output and human voice output play a similar role in the effect of foreign vocabulary learning using an integrated AAC system with NP. I also investigated whether NP would have better gains in naming with a treatment protocol that includes self-paced practice than NP with no self-practice included in the treatment protocol. This discussion is mainly based on the MMTA results. The results suggest that: (a) participants show improvement in naming with both human voice and synthesized voice across four groups; (b) participants show better improvement with human voice than synthesized voice; (c) participants not only show an improvement in trained words, but also exposed words; (d) participants who received extra self-paced practice do not show significant improvement compared to participants who did not receive extra self-paced practice. In addition, overall, all participants were satisfied with the training. What follows is a discussion of as well as alternative explanations for each finding.

3.3.1 Improvement with both human voice and synthesized voice

The first finding shows that all participants learned several foreign words no matter which type of voice output they were assigned. In other words, participants were able to learn foreign words as long as they were presented with voice output even though the learning effect varied in the four conditions. The finding supports previous research demonstrating people can learn foreign vocabulary not only via exposure to a human voice but also exposure to synthesized voice output (Gullberg et al., 2010; Shahrokni, 2009). The uniqueness of the finding is that it provides evidence to support that NP can learn foreign words by using an integrated AAC system with embedded training and synthesized voice output. The finding also provides the confidence to investigate the effect of the treatment protocol with people with communication disorders later. The result further supports the proposed assumptions that learning to use AAC may be similar to learning a foreign language.

3.3.2 Improvement of trained and exposed words

The second finding shows that participants receiving human voice output had significantly higher naming improvement than the participants receiving synthesized voice output only. This finding suggests that participants learned better when receiving the live human voice from the investigator than interacting with the AAC integrated training only. This result supports previous studies that people had better perception with a human voice than a synthesized voice in word identification, and recall tasks (Hardee & Mayhorn, 2007; Roring, Hines, & Charness, 2007; Srinivasan, 2010). Although the data indicates that participants made greater gains on naming with human voice output overall, the trajectory shows that participants assigned to the synthesized voice output started to catch up to their human voice counterparts over the course of treatment over time (Figure 16a). The finding suggests that participants may gain similar outcomes of human voice output and synthesized voice output after long-term usage. In other words, participants may have a similar learning outcome when using an AAC integrated training continuously. This result suggests that using synthesized voice output (as in AAC-based training) may be a solution to fill in the gap occurring with limited billing for treatment sessions.

The third finding suggests that participants learned not only the trained words, but also the exposed words with both a human voice and a synthesized voice. This result means that first, participants were able to learn foreign words using the integrated AAC training. This result is consistent with previous studies showing that people are able to learn words using a computerized training program. It also reflects the common assumption about practice. That is, practice can help people learn better. Secondly, this result demonstrates that participants were able to learn words by exposure to words with voice output and without practice, even though they learned fewer exposed words than trained words. This result supports previous studies' suggestion that people can learn words by auditory exposure (Breitenstein et al., 2004; Gullberg et al., 2010).

Like the second finding addressed, participants learned from human voice condition better than under the synthesized voice condition. The phenomenon was observed both in trained words and exposed words. The difference between trained words and exposed words is that even though participants learned trained words better when presented with a human voice, the gap between to two conditions of voice output decreased over time (Figure 16a). However, in exposed words, participants consistently learned better with a human voice than with the synthesized voice over time. Furthermore, the gap of improvement trajectories between human voice and synthesized voice gradually increased (Figure 16b). Nevertheless, the result suggests that participants can learn words by synthesized voice exposure. The limitation of the exposure is the improvement rate is slower than by human voice exposure over time. This result provides the foundation to apply the proposed protocol to PWA. It also supports the assumption that PWA may benefit from using an AAC system with synthesized voice output over time, and listen to the voice output exposure for relearning/regaining their spoken word production (Kertesz, 2014; Koul et al., 2005). Even though the improvement rate is slower than with human voice exposure, this condition is still a possible solution to help PWA gain desired language outcomes gradually as long as they continue to use the AAC system and practice frequently.

3.3.3 **Improvement with different dose of treatment**

Interestingly, increasing the intensity of treatment by adding an extra dose of self-paced practice did not impact the improvement rate across the eight participants in the study, which does not support the original hypothesis. In other words, more practice did not increase the improvement significantly. Similar results have been reported in previous studies with PWA (Raymer et al., 2006; Sage et al., 2011). That is, the results were either in favor of the non-intensive therapy (Sage et al., 2011), or both non-intensive and intensive therapy showed a positive treatment effect (Raymer et al., 2006). Although the current finding is similar to the two studies, one fundamental difference, the different definition of intensity, must be addressed here. Using the concepts from Warren et al (2007), the two studies manipulated the intensity by dose frequency (i.e., the number of doses of intervention per time unit: day or week. The two studies used per week), whereas the current study manipulated the intensity by dose size (i.e., the number of teaching episodes or active ingredients in one session). This difference makes the comparison impossible. Like other researchers stated, it is hard to conclude if intensive treatment is better than non-intensive treatments, because of the various definitions of intensity used in studies (Baker, 2012; Cherney et al., 2011; Warren et al., 2007). Here one can only make a temporary summary based on the current result. One possible explanation is adding one self-paced practice (dose) in the same session may not have reached the threshold necessary to accerelate the learning outcomes. Furthermore, it is possible that even though the quantity of practice doubles, the quality of the practice was actually different. When particiapants were assigned into the group with an extra self-practice, participants first completed a practice with the PI, then completed the second practice alone. Can the PI (clinician) involvement be a possible factor? In other words, is it possible that the practice effect of one self-paced practice is not as much as the practice effect of one practice with the PI? Previous studies suggested that when investigating the intesntiy of treatment, also need to consider the active ingredient in the treament (Baker, 2012; Cherney, 2013; Warren et al., 2007). Following the suggestion, it is important to identify the active ingredients, which may not only be the materials, but also the clinician involvement. Therefore the result can be used to modify the intensity of treatment in future SLP service. Another explanation for the finding is due to the small sample size. Because of the small number of participants in each group, the result could be influenced by some well-performed participants, such as P12 and P41, who completed the protocol with less sessions than others.

Since the current study acts as a preliminary investigation for future AAC intervention for PWAs, it is worth taking time to note that the dose of frequency was three sessions per week in the current study's training.This scheduling relatively higher than common out-patient SLP service. When high treatment frenquency usually reflects extra resource expenses (time, budget, and etc.), investigating a proper dose per session with lower dose freqency in one session can be essential to reducing those burdens from PWAs.

Before moving into the discussion of participants' satisfaction with regards to the training protocol, it is important to mention the value of using the MMTA in the study. Using the data on Table 5 as an example, the mean of group 1 (41.95%) is much higher than the mean of group 2

(23.54%). If we only use this result, we can interpret that the participants in the group with extra self-paced practice learned better than participants who received regular training only. However, when using the MMTA, the result suggests that adding a self-paced practice does not improve the learning trajectory in both trained words, and exposed words (see Table 7 and Table 8). Furthermore, the MMTA also provides the predictive models for the trajectories between different types of voice output. Thus we can use the results to predict the future learning trajectories (see Figure 16). These examples not only demonstrate the discrepancy between the descriptive analysis and the statistical analysis, but also show the advantage of MMTA. That is, providing detailed information for each of the predictors.

3.3.4 **Participant satisfaction**

Overall, the participant satisfaction scores had high values of satisfaction. Satisfaction was operationalized by a measure designed to assess subjective feelings of satisfaction to yield socially valid indices that can be used as a basis for further training efforts. The possible range of scores for items was between 1 and 5. Overall, participants are satisfied with the training (Item 9). Participants' responses indicate that all participants rated highly the training effect of naming and speech (Item 3 and Item 4), and the usability of the training (Item 1, Item 2). Since the training focused on word naming only, the two responses directed to the same outcome (naming) were considered together.

These results show that the training protocol worked as predicted, and provided the desirable outcome. That is, participants learned to say the foreign words. In the meantime, the result also shows that participant could operate the program. This positive outcome is important, because the ease of use is always one of the keystones to avoid high abandonment rates of AAC and AT technology (Baxter, Enderby, Evans, & Judge, 2012; Johnson, Inglebret, Jones, & Ray, 2006; Phillips & Zhao, 1993; Riemer-Reiss & Wacker, 2000). Six of eight participants reported that they would recommend the training to others, suggesting they feel positive and trust the training, so as to recommend it to others (Korneta, 2014).

Although participants reported that they were satisfied with the training and the naming outcome, there were three participants that reported using the training program could be a frustrating experience. Since the participants reported that the program was easy to operate, the assumption for this frustrating feeling was that it related to the training protocol, not the training system. Participants needed to continue the same training materials until they met the criteria. In the meantime, the participants did not receive immediate feedback on their speech, which might have increased their anxiety and impatience because of the uncertainty in their speech production. These factors might have resulted in two of the participants responding that they were not in favor of the training, and two participants reporting they would not continue a similar program.

It is worth mentioning that one participant (P22) scored the training program lower than other participants. She also performed worse than the other participants. She was assigned to group 2 (C x S + S). She received the synthesized voice output from the training program, and also did the self-paced practice with synthesized voice output. During the training, the participant reported that she mainly relied on the PI's feedback and instruction when she was examined for the learning outcome each session. She felt that she understood the human voice better than the synthesized voice output. She was the only participant that specifically addressed the difficulty of learning from the synthesized voice output. Her feedback not only reflects the result that participants learned better with a human voice, but also raises another curiosity. This participant was older than the other participants. One hypothesis is that adults may perceive synthesized voice differently based on age. Several studies have suggested that older adults had more difficulty perceiving and/or performing tasks with synthesized speech than younger adults (Hardee & Mayhorn, 2007; Roring et al., 2007; Sinatra, Sims, Bailey, & Najle, 2013). Although Wolters, Johnson, Campbell, DePlacido, & McKinstry (2014) indicated when presenting short information, such as the name of a medication, a high-quality synthetic voice worked liked a human voice, they also found that when the information was long and unknown by older participants, participants could not recall the information well regardless of the type of voice. Even though the current study only recruited one participant who was relatively older than the other participants and used foreign words as the experimental stimuli, which differs from previous studies, the current result tends to support the previous studies. This evidence also reminds us that when using synthesized speech for speech language pathology intervention, we should ensure that the synthesized speech is adjusted well to meet an older adults' needs.

3.4 LIMITATION

The first limitation to consider is that the study uses foreign words (Chinese words) as the experimental stimuli, which may influence the phonological memory of the participants, because of the different phonological structures between Mandarin Chinese and English. The difference is likely to have underestimated the effect of the training as compared to the learning that used pseudowords with the phonological structure of English, the participants' native language. Therefore, the results probably inform the process of learning a natural language phonologically different from the native language of participants more than they inform the learning of the native language. A second limitation is that it is hard to exclude the impact of the PI's demonstration and the variation of the demonstration and instruction during the testing process in each session. In other words, the training effect may not come from the synthesized voice output alone. That also means, the positive training effect from the synthesized voice may be overestimated. It is possible that when people only receive synthesized voice, the learning trajectory will be slower than what is presented in the study. The third limitation is the small sample size of the study. The results could have been affected by the outliers.

3.5 SUMMARY

This study is the first study to test the training effect of a tablet-based AAC integrated system, and its feasibility. The findings suggest that participants could learn trained and foreign words not only by human voice, but also by synthesized voice exposure. Participants learned better under the human voice condition than with synthesized voice output from the AAC system. The participants learned more trained word than exposed words. These findings provide the evidence to support the potential to develop AAC training using computerized-assisted methods with high-technology computer-based voice output. In the meantime, the finding reports that increasing the treatment dose in each session did not accelerate the learning trajectory across the four tested conditions. This finding raises further research questions related to AAC computerized training. That is, to test the different treatment intensity variables to determine the reasonable treatment intensity. Regardless of the research limitations, future research should focus on manipulating the clinician involvement, dose of treatment in each session, and also increase the sample size to identify the training effect of this type of training. Ultimately, the findings can be applied to PWAs' AAC intervention.

4.0 EXPERIMENT TWO

4.1 METHOD

4.1.1 Participants

Four monolingual English speakers with aphasia were recruited for this study with the IRB approval from University of Pittsburgh. All participants were between 36 years of age to 75 years of age, and reported no premorbid communication, neurologic or psychiatric disorder. All participants had a diagnosis of stroke. Participants had time of post onset between 5 months to 120 monthes after the first stroke without a history of recurrent neurological involvement. They were able to point using one or more fingers and had a corrected visual acuity of at least 20/40 as determined by the Rosenbaum card. All participants passed a pure-tone hearing screening with a minimum 35dB HL in at least one ear, at 500, 1000, 2000 and 4000 Hz. All participants passed the star cancellation test to show no visual neglect. All participants passed the Apraxia Screen of TULIA (AST) (Vanbellingen et al., 2011) with a score greater than 5 in the imitation part only to show no evidence of the upper limb apraxia. All participants had a history of speech language treatment poststroke, however, they received no other speech language training while they participated in this study. Three of the four participants did not have any AAC experience, and one participant had tried an AAC device briefly from previous treatment, but did not own one. Table 9 shows the participant demographic data. Individuals who passed all inclusion criteria were able to participate on assigned days and times.

Table 9 Participant demographic data

Participants	Gender	Age	Education	Post onset time	WAB-R Aphasia Quotient	Severity of aphasia
1	M	75	College	5 months	86.2	Mild
2	M	60	College	120 months	80.8	Mild
3	M	36	College	24 months	82.4	Mild
4	M	57	High school	23 months	32.9	Severe

4.1.2 Experimental stimuli

The experimental stimuli included four 30-word lists selected from Appendix B. These words are the same as the experimental stimuli in experiment one. Each word list included 10 trained, 10 exposed, and 10 untrained words (30words/list). Words were chosen based on the words that were randomly selected for each word set. This ensured that each word set included one pronoun so the participants potentially could generate short utterances.The participants had training on the trained words in the treatment phase. They were exposed to the exposed words during the treatment phase one time each session, but with no training on these words. The untrained words served as controls. These words were neither trained nor exposed during the treatment phase (see Figure 17).

Participants first started the training with one of 30-word lists . When participants reached the criterion outcome, but still had not completed the assigned number of sessions, paticipants received continuous training with another 30-word list to complete the assigned number of sessions.

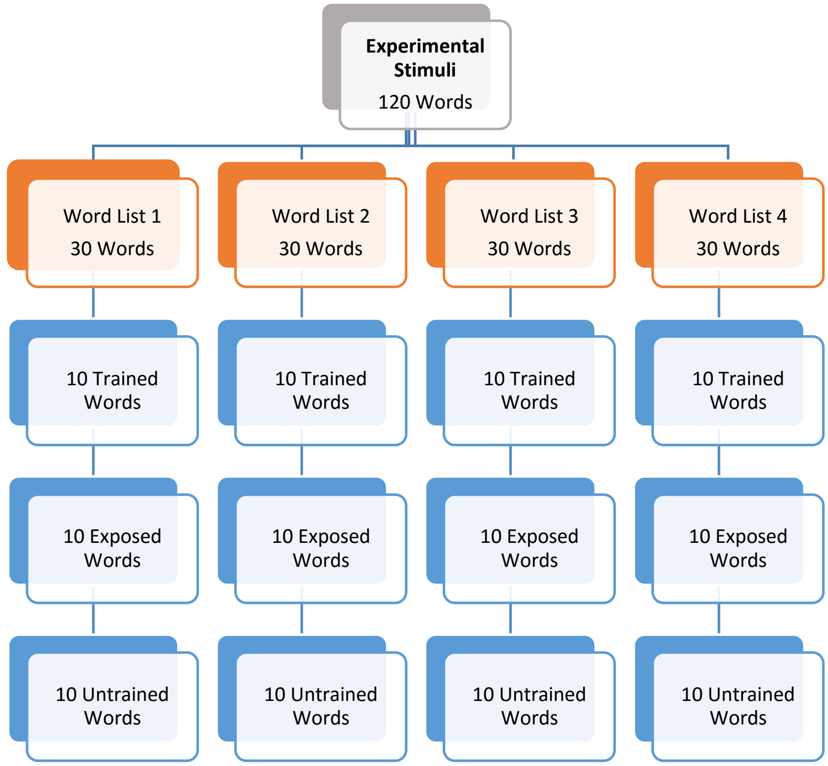


Figure 17 Overview of the experimental stimuli

4.1.3 Materials and equipment

A self-report survey was used to collect demographic information on the participants.The MoCA (Nasreddine et al., 2005) was used for to screen participants' cognitive abilities. The Apraxia Screen of TULIA (AST) (AST; Vanbellingen et al., 2011) was used to screen if participants had upper-limb apraxia that might affect their access to the tablet. The Star cancellation (Halligan, Wilson, & Cockburn, 1990) was used to screen if participants had visual neglect deficit that might affect their ability to see the display on the tablet. The apraxia screen and the start cancellation test were used to make the enrollment decisions. The Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006) was administrated. Only those subtests comprising the Aphasia Quotient (AQ) were administered. The AQ was used to evaluate participants overall langauge performance, and severity. The Computerized Revised Token Test-Listening (CRTT-L; McNeil et al., 2015) was used for assessing participants' auditory processing performance. The story retelling Procedure (SRP, Doyles, McNeil, & Spencer, 1998; McNeil, Doyle, Park, Fossett, & Brodsky, 2002) was used for evaluating participants' spoken language production. The WAB-R, CRTT-L, and SRP were administred in pre- and post treatment. A survey of participation satisfaction was used for understand participants' perceptions of the training protocol and the user abilities of the training program. The equipments used in experiment # 1 was used also in experiment two (see Section 2.1.3)

4.1.4 **Experiment design**

The study used a single-subject experimental design consisting of an alternating treatment design within participants to investigate if exposure to voice output from an integrated computerized AAC program would affect confrontation naming, overall language functions, and story retelling performance.

The treatment process consisted of two treatment conditions:

- **Condition 1:** Participants received the same integrated computerized language training as the experiment 1 . Instead of the synthesized voice output, participants received human voice directly from the investigator.
- **Condition 2:** Participants received an integrated computerized language training with synthesized voice output. That is, participants received human voice output as feedback using the computerized language training program when pressing the icons on the tablet.

Each participant was given one condition in one treatment session. The dependent variables were:

a. Accuracy of naming picture symbols for trained words and exposed words.
    a. The accuracy was measured in the end of each training session. The accuracy score is the number correct named items.
b. The post test results on WAB-R, CRTT-L, and SRP.

The first participant was randomly assigned to condition 1 or condition 2 using a "fair coin" (e.g., head = condition 1, tails = condition 2), and the second participant started with the other condition first. The same procedures were repeated for participant 3 and participant 4. Each participant received three sessions per week for a total of 24 sessions in 8 week.

4.1.5 Training modules

The training modules of experiment one were used with experiment two (see Section 3.1.5).

4.1.6 Procedures

Screening

Participants who responded to the recruitment notice and met the inclusion criteria were screened to confirm that they could participate in this study. The participants who met the criteria on the screening also completed the picture symbol-to-spoken word matching across the three word sets for describing the types of naming difficulty patterns (phonemic or semantics, or both) for each individual.

Treatment

Treatment was administered in a quiet room with the investigator (See the script: Appendix C).

First, the investigator presented the exposed word set one time at the beginning of a training session. The investigator would say "Now I want to show you some pictures on the device. I will point to the picture. You just look at those pictures. Let's start." The investigator presented the exposed words to a participant with synthesized voice output or her own voice depending on the assigned condition using the computerized training program. No feedback or extra information was provided.

Second, the investigator started training with the participant using the trained word set via the experimental computerized AAC training program following the training modules with the 10 target trained words from set 1. The investigator would say "Now let's start with the training program, I want you to find some words on the device. You will hear a command from the device (condition 1) or from me (condition 2). I want you to find words on the device based on the commands. When you find the word, you will hear the device says the word." The investigator would guide the participant to complete the two training modules in 30 minutes. The investigator followed the structured training program based on the identified prompting hierarchy. For example, in module 1, for the first trained word "I", a participant first received the verbal prompt with a picture symbol of "I" (This is "I". Now find the word "I"). If the participant produced either no response or gave a wrong response in 5 seconds, a repeated verbal prompt was given. If the participant produced either no response or provided a wrong response in 5 seconds following the prompt, a verbal prompt plus visual cue (highlighted the target word) was given. If the participant did not give a correct response in 5 seconds, then the investigator provided a verbal prompt and the target word would flash. If the participant did not give a correct response in 5 seconds, then the investigator directed the participant to press the target word and the participant moved to the next word. The same steps were repeated until the participant completed a module and then moved to the next module. If the participant was in the condition with human voice, the investigator said the commands and the verbal prompts aloud, and a participant completed the tasks. If a participant selected the correct icon, the investigator would read the word again.

Third, after completed two training modules with the investigator, the participant was asked to complete a self-paced practice without any instruction from the investigator. The content of the self-paced practice was the same training module from the face-to-face session. Participants in condition 1 did not receive any voice output or feedback during the self-paced training time with the investigator observing. Participants in condition 2 continued to receive the synthesized voice output from the device with the investigator observing their practice.

After the training was completed based on the assigned condition, the investigator randomly picked two shapes (see appendix D) to avoid the primary memory effect. The participants were asked to draw two shapes following the dashed line. After the drawing task, the investigator asked the participant to name the trained words and the exposed words.

A probe of untrained words was administered in the last session of each condition. Treatment continued on the trained set until 9 words were accurately identified. If participants reached the accuracy criterion before completing the 24 sessions, the participants started the second word set with the same procedures for 24 sessions or for 8 weeks of treatment which ever came first.

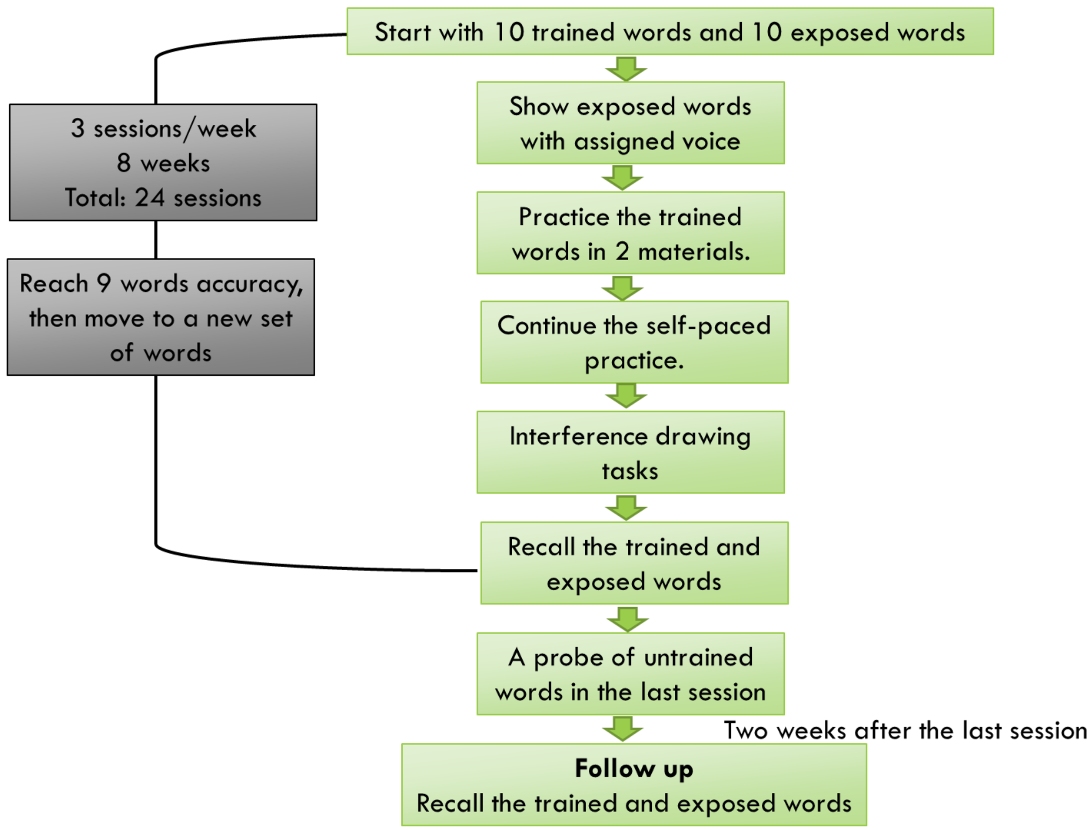


Figure 18 Treatment process

Post-treatment

All participants completed, the WAB, the CRTT-L, and the SRP after they completed all the sessions. The participants completed all the post-treatment tasks within 7 days.

Follow-up

All participants had a follow-up session 2 weeks after the last session. The participants completed a confrontation naming task for all 120 words.

4.1.7 Data collection and analysis

Visual inspection was used to present the accuracy of naming across the three word sets after each session. The mixed model trajectory analysis was used to determine the effectiveness of the different training conditions. The pre-and-post results of the WAB, the CRTT-L, and the SPR were collected to determine any changes after the intervention.

Besides the visual inspection for visualizing the growth, the performance outcomes were analyzed using mixed model trajectory analysis (MMTA) (Ridenour, et al., 2009; Ridenour et al., 2013). MMTA was used because it could test time variable, outcome variables, and predictor variables objectively. Differences in the trajectories of each participant's performance was tested individually. Analyses modeled the gains in improvement of number of named words and interaction with different voice outputs. Computing models of two variables: voice output and number of sessions with two types of voice output (v_sessions) consisted of either of these fixed effects: sessions (each session by time order), voice output, and interaction between voice output and sessions. Four covariance structures were tested to account for serial dependence: compound symmetry, the autoregressive (lag 1) structure, toeplitz, and the variance components. The variance components structure was used for the analysis, because it had the best account for serial dependency based on statistical fit and parsimony. How well predictors fit to the data were tested using the following fit statistics: Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC) and -2 log likelihood. The likelihood-ratio chi-square test was used to determine the best fit models for trained words and exposed words. The Kenward-Roger test was used to control for Type I error in analyses of small samples. The Maximum Likelihood (ML) estimator was used to the fit of models, and identify the best model, and the Restricted Maximum Likelihood (REML) was used to attain the estimates of parameters for the best model.

4.1.8 **Reliability and fidelity**

The point by point agreement and the Cohen's Kappa (Cohen, 1960) was calculated with 10 % of the all sessions. An English-Chinese-speaking graduate student who was not familiar with the study served as the second rater for the treatment reliability using the audio recordings. Inter-rater reliability was checked for comprehensibility of participants' spoken words. An agreement was scored if the PI and the second rater recorded the same score of words that produced by participants. A disagreement was scored when two raters scored the same spoken words differently. The point by point agreement was 95 % for the trained words and exposed words. The Cohen's Kappa was .89. Both results suggests the results of the spoken words was highly reliable (Stemler, 2004). Treatment fidelity was controlled by the computerized training program, and the programmed prompting hierarchy. In other words, participants received the same amount of trainings and prompting hierarchy each sessions. The program control is ensured the training protocol was with high fidelity. Procedure was self-monitored by the PI with a checklist (see Appendix F) to ensure the PI maintained the procedure fidelity.

4.1.9 **Participant satisfaction**

After completing the last session, all participants completed a nine-item survey regarding satisfaction with the intervention. Questions were geared to capture their impressions of the effectiveness of the intervention and user-satisfaction with the experimental device and treatment. All items were based on previous studies that focused on user satisfaction of human computer interfaces (Koester, 2004; Lewis, 1995; Lund, 2001}. Each item was a statement, and participants rated their agreement with the statement on a scale of 1 to 5, with 1 =strongly disagree, and 5 = strongly agree. For example, item 1 read, “I feel it is easy to learn to operate this training program.” (Appendix E)

4.2 RESULTS

4.2.1 Individual visual inspection analysis

Performance accuracy on the naming of trained and exposed words for every session by each participant is illustrated in Figures 19, 20, 21, 22. Three participants (P1, P2, and P3) received treatment in two treatment conditions (synthesized voice vs human voice). One participant (P4) received treatment in one treatment condition (Synthesized voice).

Figure 19 depicts the performance by P1 for trained and exposed words across the two treatment conditions (Human voice and Synthesized voice). P1 started with human voice then switched to synthesized voice. P1 completed the first treatment phase with human voice in 12 sessions, and completed the second treatment phases with synthesized voice in 10 sessions. Figure 16 shows P1 achieved criterion sooner with synthesized voice than with human voice.

Figure 20 depicts the performance by P2 for trained and exposed words across the two treatment conditions (Human voice and Synthesized voice). P2 started with synthesized voice then switched to human voice. P2 completed the first treatment phase with human voice in 8 sessions, and completed the second treatment phase with synthesized voice in 10 sessions. Figure 17 shows P2 also achieved criterion sooner with synthesized voice than with human voice.

Figure 21 depicts the performance by P3 for trained and exposed words across the two treatment conditions (Human voice and Synthesized voice). P3 started with human voice then switched to synthesized voice. P3 completed the first treatment phase with human voice in 7 sessions, and completed the second treatment phase with synthesized voice in 18 sessions. He had some difficulty with the second phase (Synthesized voice). Figure 18 shows P3 achieved criterion sooner with human voice than with synthesized voice, which is the opposite result achieved by P1 and P2.

Figure 22 depicts the performance by P4 for trained and exposed words in the computer condition only, because P4 did not achieve the criterion for switching to the other treatment condition. P4 completed 24 sessions with synthesized voice. Overall, P1, P2, and P3 met the criterion in the trained words in both treatment conditions. They also showed improvement with the exposed words in both treatment conditions. P4 did not show obvious improvement for either trained or exposed words in the synthesized voice condition.

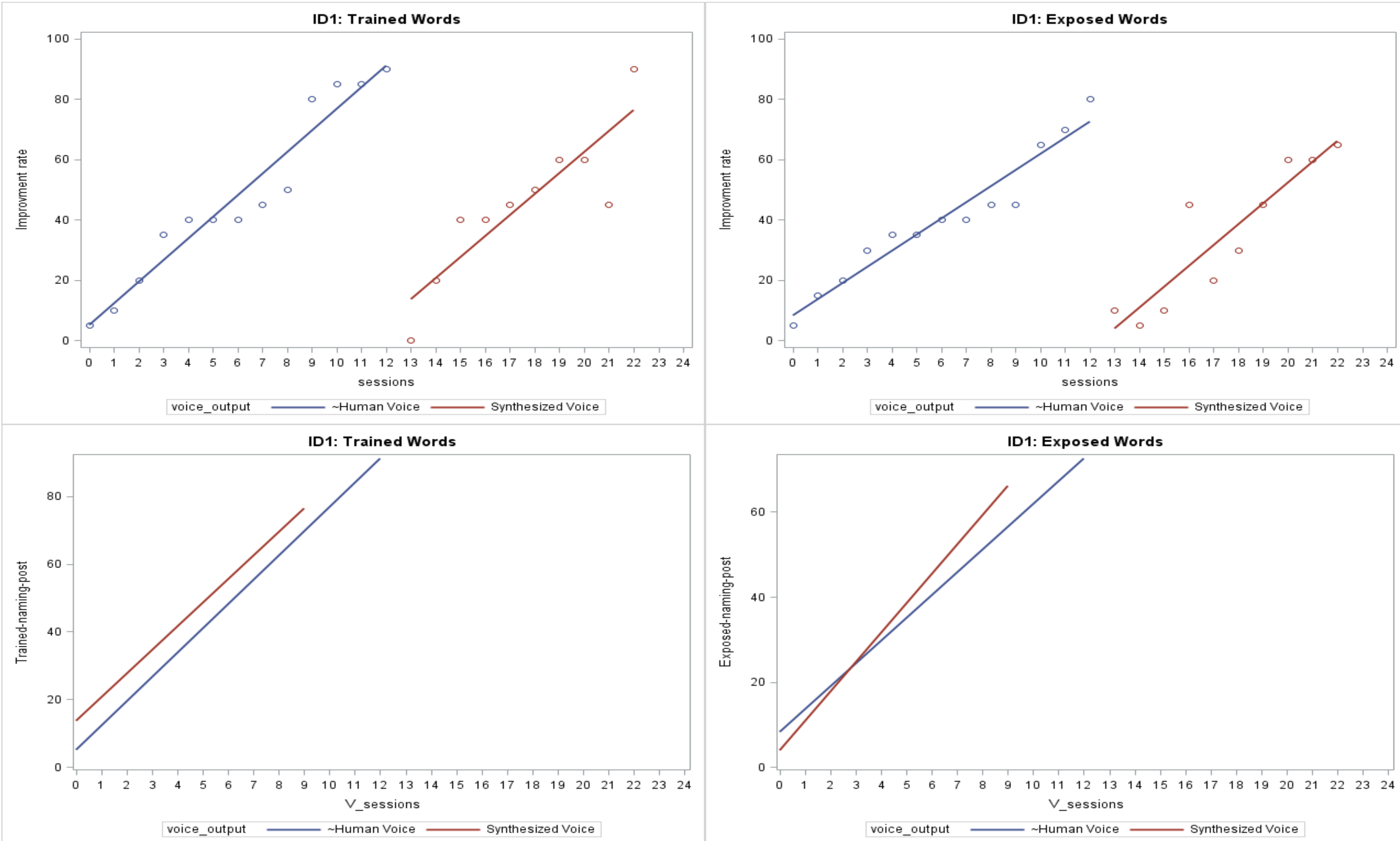


Figure 19 Number of named word in each sessions across two treatment conditions for ID 1

Note. The top row of graphs showed the raw data and trend lines by the order of the implantation of treatment conditions. The bottom raw of graphs showed the centered trend line of two treatment condition for comparing the slopes of two treatment conditions in trained words and exposed words. V_sessions=number of session by the type of voice output.

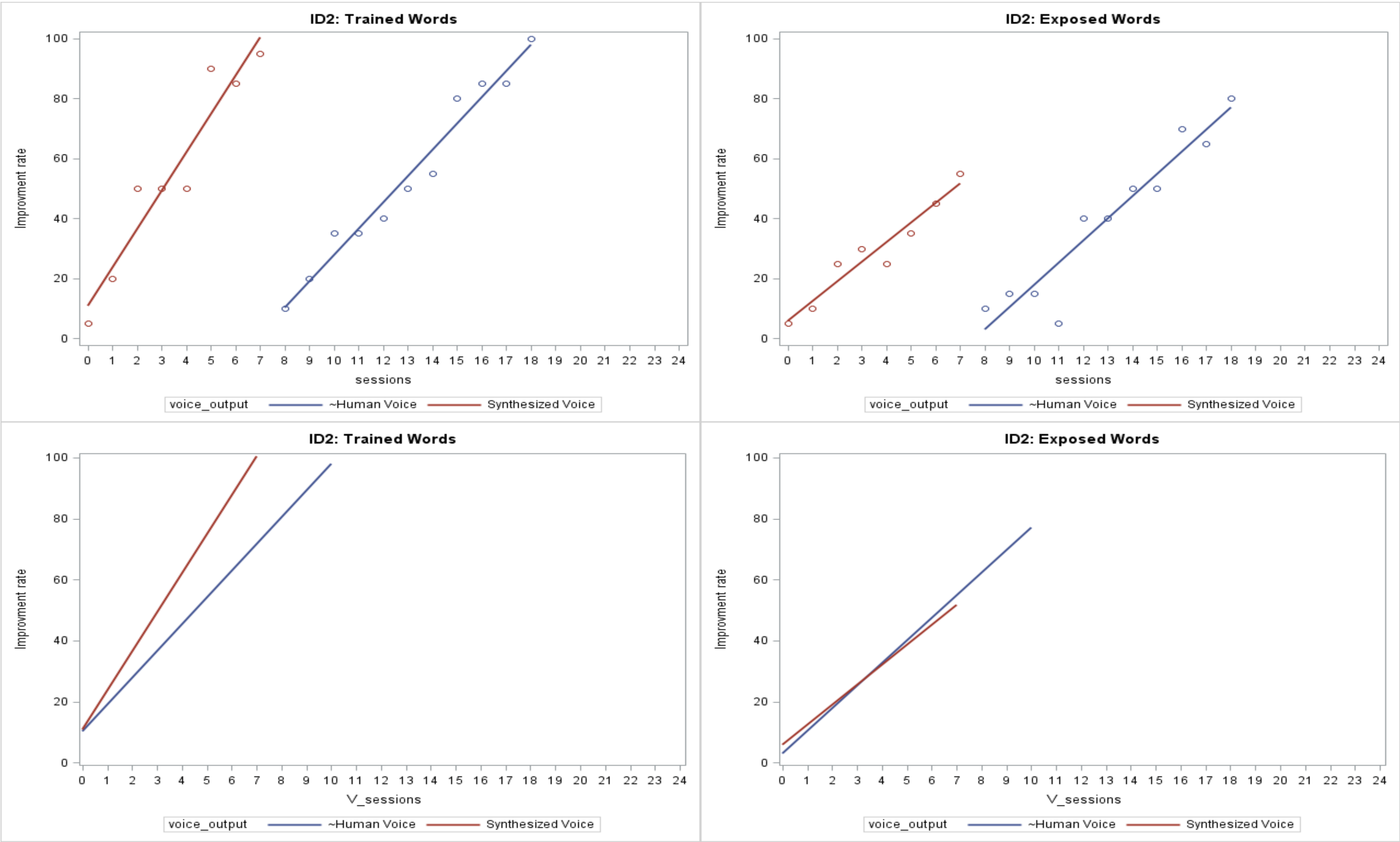


Figure 20 Number of named word in each sessions across two treatment conditions for ID 2

Note. The top row of graphs showed the raw data and trend lines by the order of the implantation of treatment conditions. The bottom raw of graphs showed the centered trend line of two treatment condition for comparing the slopes of two treatment conditions in trained words and exposed words. V_sessions=number of session by the type of voice output.

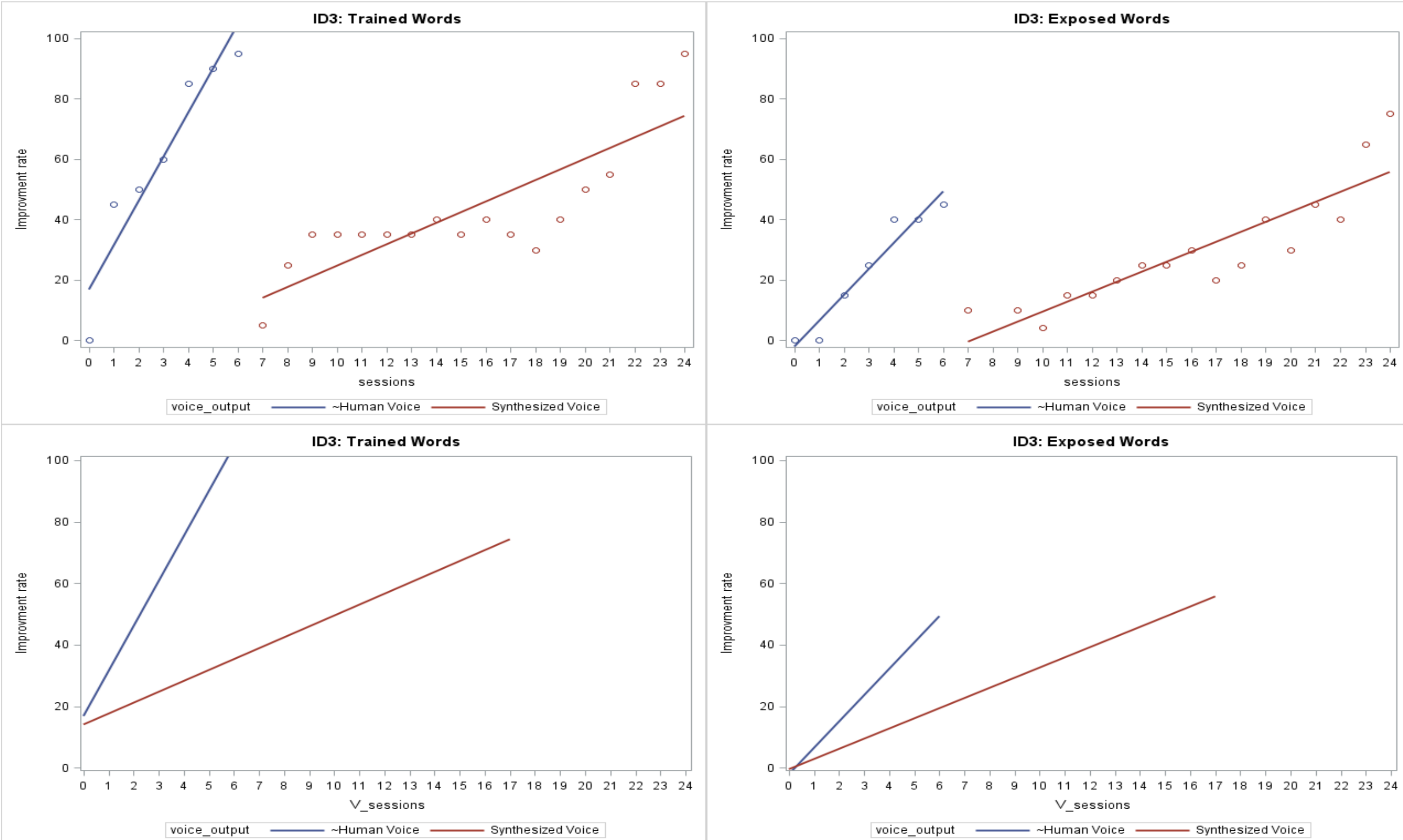


Figure 21 Number of named word in each sessions across two treatment conditions for ID 3

Note. The top row of graphs showed the raw data and trend lines by the order of the implantation of treatment conditions. The bottom raw of graphs showed the centered trend line of two treatment condition for comparing the slopes of two treatment conditions in trained words and exposed words. V_sessions=number of session by the type of voice output.

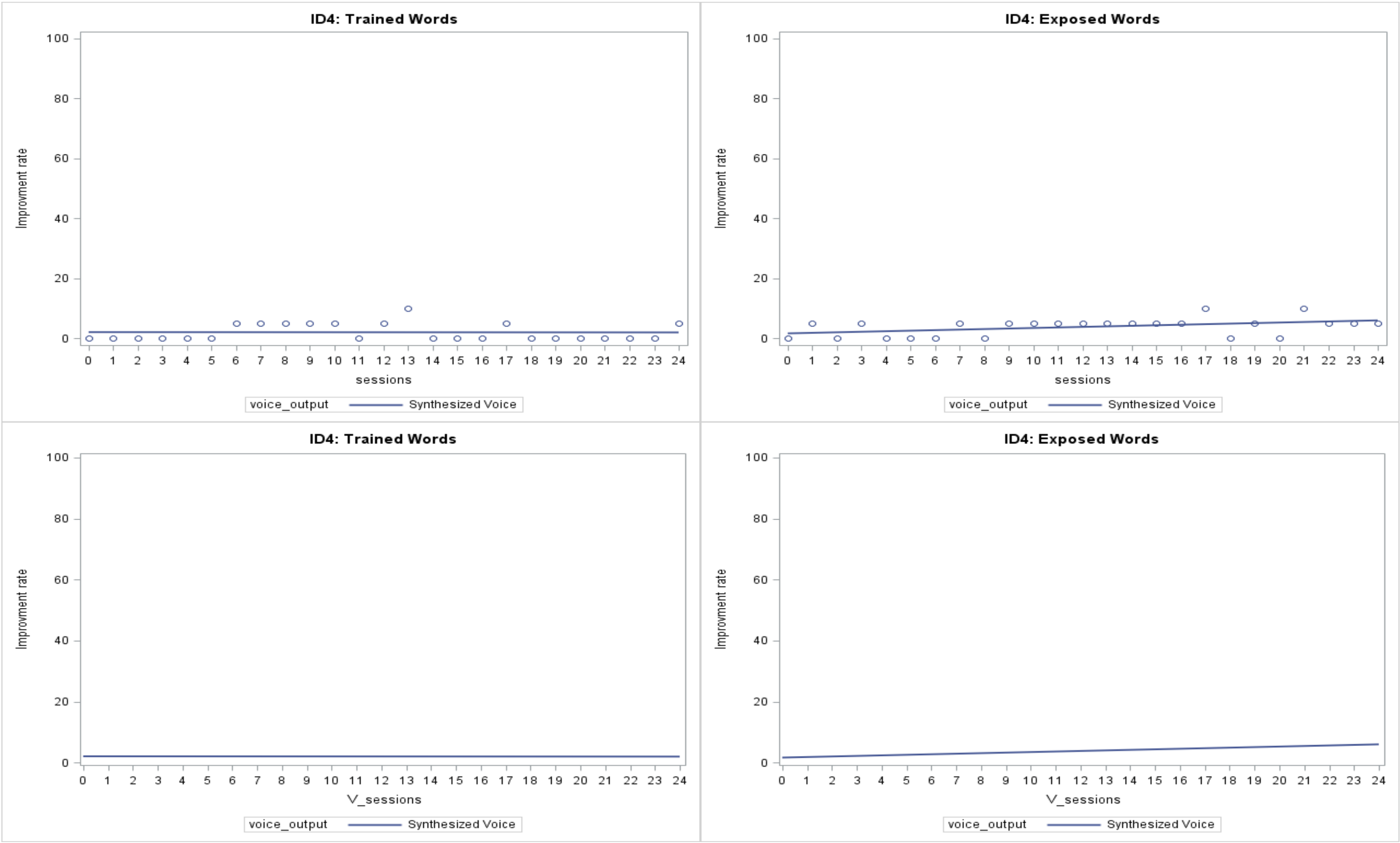


Figure 22 Number of named word in each sessions across two treatment conditions for ID 4

Note. The top row of graphs showed the raw data and trend lines by the order of the implantation of treatment conditions. The bottom raw of graphs showed the centered trend line of two treatment condition for comparing the slopes of two treatment conditions in trained words and exposed words. V_sessions=number of session by the type of voice output.

4.2.2 **Improvement in the trained and exposed words**

The difference in improvement for the trained and exposed words in the two different treatment conditions are presented for the four participants on Table 10. P1 had a higher mean of the number of named words in trained words than the exposed words. The phenomenon was observed both in synthesized voice and human voice conditions. The difference between trained words and exposed words in human voice is smaller than in synthesized voice. A similar pattern is shown in P2's results. While P3 also has higher mean for number of named words for the trained words than the exposed words, different to P1 and P2, P3 had a bigger difference between the trained words and the exposed words in human voice than in synthesized voice. P4 is the only participant that has a lower mean number of named words for the trained words than the exposed words in the computer condition. Figure 23 presents the trend lines to compare trained words and exposed words. A gradually accelerating increase is seen in participants 1, 2, 3, but the slopes of exposed words were judged to be smaller than the slopes of trained words based on the visual graph. Participant 4 did not show accelerating increase both in the trained words and the exposed words with synthesized voice output.

Table 10 Mean of performance in trained and exposed words

Participant	voice_output	# of observation	Variable	Mean	Diff.	Sd.
1	~Human Voice	13	Trained word	10.08	1.46	6.44
			Exposed word	8.62		5.08
	Synthesized voice	10	Trained word	10.50	2.7	6.11
			Exposed word	7.80		5.49
2	~Human Voice	11	Trained word	10.82	2.82	5.91
			Exposed word	8.00		5.18
	Synthesized voice	8	Trained word	11.13	5.38	6.56
			Exposed word	5.75		3.33
3	~Human Voice	7	Trained word	12.14	7.43	6.67
			Exposed word	4.71		3.82
	Synthesized voice	18	Trained word	8.83	3.02	4.55
			Exposed word	5.81		3.83
4	Synthesized voice	25	Trained word	0.40	-0.4	0.58
			Exposed word	0.76		0.60

Note. Diff=Difference

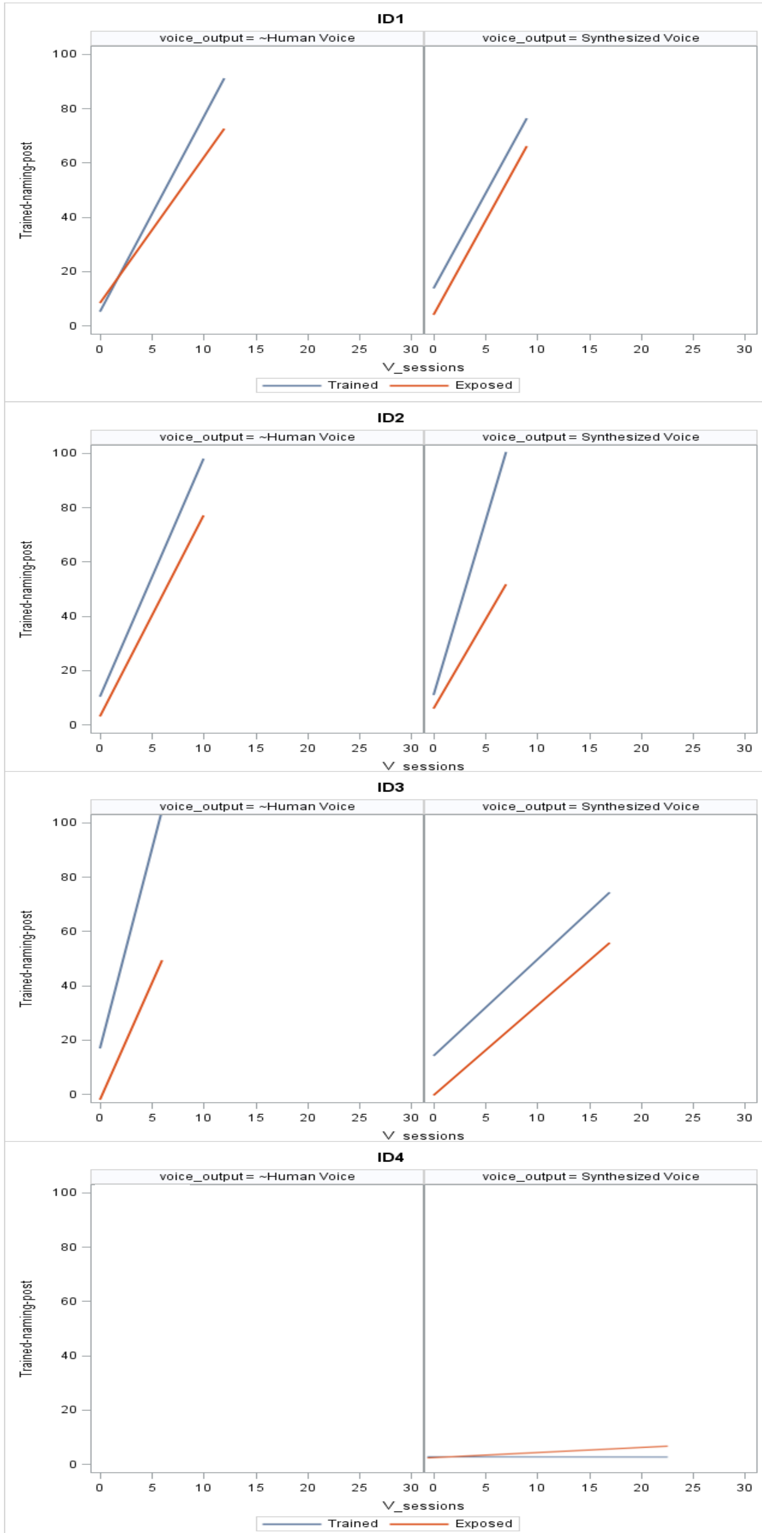


Figure 23 compare trained words and exposed words by ID

Note. V_sessions=number of session by the type of voice output.

4.2.3 Mixed model trajectory analysis

The section above showed the performance improvement of the four participants as descriptive statistical results and graphs. This section presents the results using the MMTA to test each term: sessions, voice output, and interaction between the two terms. Applying MMTA will help to determine whether a statistical significance was found for improvement on trained and exposed words for the terms. MMTA was used to analyze P1, P2, and P3's data, because they completed the two treatment conditions.

4.2.3.1 Participant 1

The MMTA results indicated the best fitting model for naming improvement in trained words involves the variables of maturation (time) and voice output. The results suggest that the improvement of trained words was not only contributed by maturation (time), but also by the voice output. Additionally, improvement rates, as indicated by the slope, are similar for the two voice output conditions. Meanwhile, the best model for the exposed words involves only the variable of maturation with neither human nor synthesized voice output contributing to naming improvement.

Table 11 and Table 12 present fit statistics for competing models of the trained and exposed words for P1. By comparing chi-squire value, the Model 2 in Table 11 is the best model for the improvement of trained words. The model consisted of (a) v_sessions (number of sessions), and (b) voice_output. The predicted model parameters are Yij = -.165+ 1.707 (v_sessions) + 2.983 (voice output) (see Figure 24). Although voice output contributed to improvement in naming, the two types of voice resulted in similar rates of improvement.

The Model 1 in Table 12 is the best model for the improvement of exposed words. The model indicates that only v_sessions contributed to the improvement statistical significantly. The best fitting model consisted of (a) v_sessions. The predicted model parameters are Yij = 1.067 + 1.3452 (v_sessions) (see Figure 25). Figure 26 compares the predicted models of trained words and exposed words. The results show the improvement rates are similar (by slope) under synthesized voice and human voice across trained words and exposed words.

Table 11 The fit statistics for competing models of trained words by P1

Model	Term	Fixed					-2log	AIC	AICC	BIC	# of Parameters	χ^2(-2log)	df	sig.
0	**Intercept**						147.9	151.9	152.5	154.1	3			
												0 vs 1		
1	**add v_sessions**	v_s					101.4	107.4	108.7	110.8	4	46.5	1	**
												1 vs 2		
*2	**add voice**	v_s	v				88.3	96.3	98.6	100.9	6	59.6	2	**
												2 vs 3		
3	**add v*vs1**	v_s	v	v* v*s 1			85.1	95.1	98.6	100.8	7	3.2	1	
												3 vs 4		
4	**add v_s2**	v_s	v	v* v*s 1	v_s2		83.8	95.8	101.1	102.7	8	1.3	1	
												4 vs 5		
5	**add v*vs2**	v_s	v	v* v*s 1	v_s2	v* v*s 2	83.1	97.1	104.6	105.1	9	0.7	1	

Note. v_sessions(v_s)=number of session by the type of voice output. v=voice_output, v_s2=v_sessions*v_sessions, v*s1=voice output*v_sessions, v*s2=voice output*v_sessions*v_sessions.

**p<.05, suggesting that this term cannot be dropped from the theoretical model, because the subsequent model fitted to the data significantly worsens than the theoretical model.

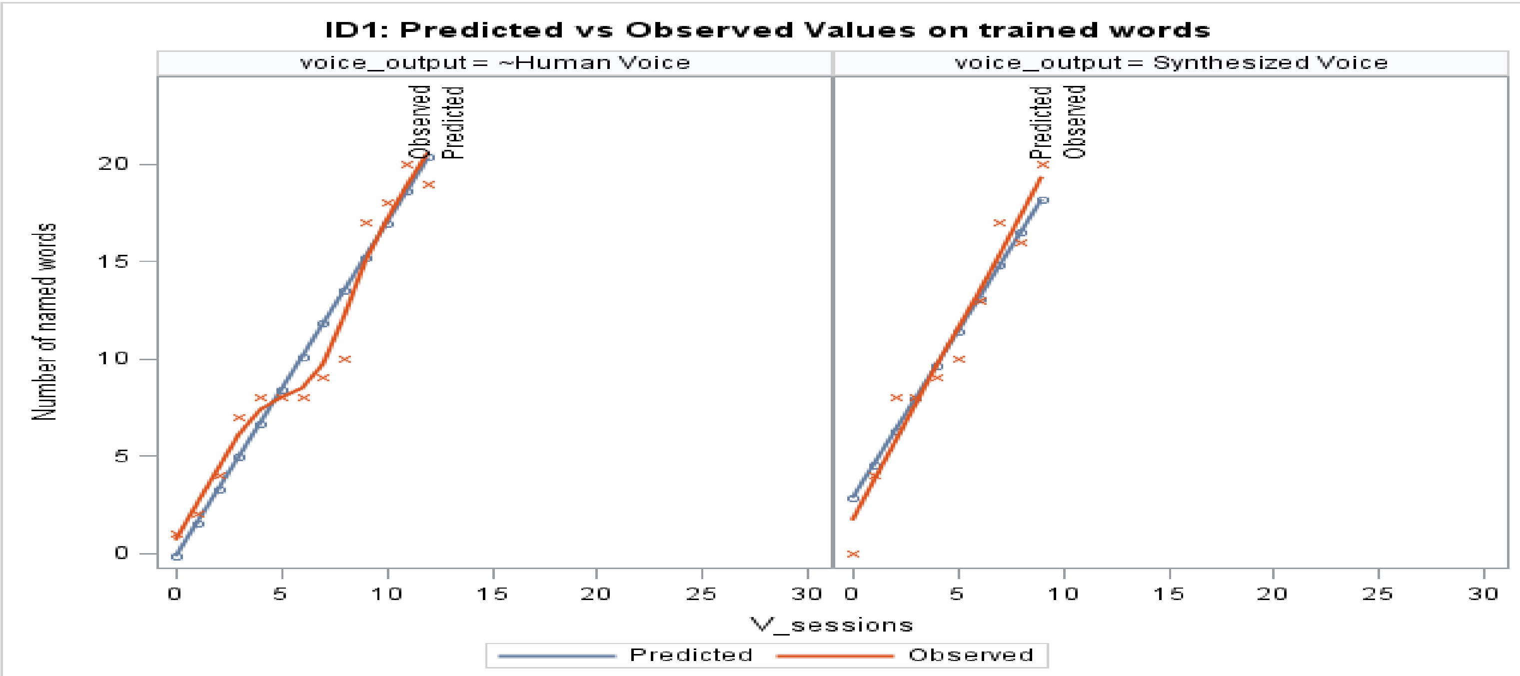


Figure 24 Trend lines of observed data and predicted model by P1-Trained words

Table 12 The fit statistics for competing models of exposed words by P1

Model	Term	Fixed					-2log	AIC	AICC	BIC	# of Parameters	Chi square(-2log)	df	sig.
0	**Intercept**						139.7	143.7	144.3	146	3			
												0 vs 1		
*1	**add v_sessions**	v_s					94.7	100.7	102	104.1	4	45	1	**
												1 vs 2		
2	**add voice**	v_s	v				92.2	100.2	102.4	104.8	6	2.5	2	
												2 vs 3		
3	**add v*vs1**	v_s	v	v*v*s1			88.9	98.9	102.4	104.6	7	3.3	1	
												3 vs 4		
4	**add v_s2**	v_s	v	v*v*s1	v_s2		85.5	97.5	102.7	104.3	8	3.4	1	
												4 vs 5		
5	**add v*vs2**	v_s	v	v*v*s1	v_s2	v*v*s2	85.5	99.5	106.9	107.4	9	0	1	

Note. v_sessions(v_s)=number of session by the type of voice output. v=voice_output, v_s2=v_sessions*v_sessions, v*s1=voice output*v_sessions, v*s2=voice output*v_sessions*v_sessions.

**$p<.05$, suggesting that this term cannot be dropped from the theoretical model, because the subsequent model fitted to the data significantly worsens than the theoretical model.

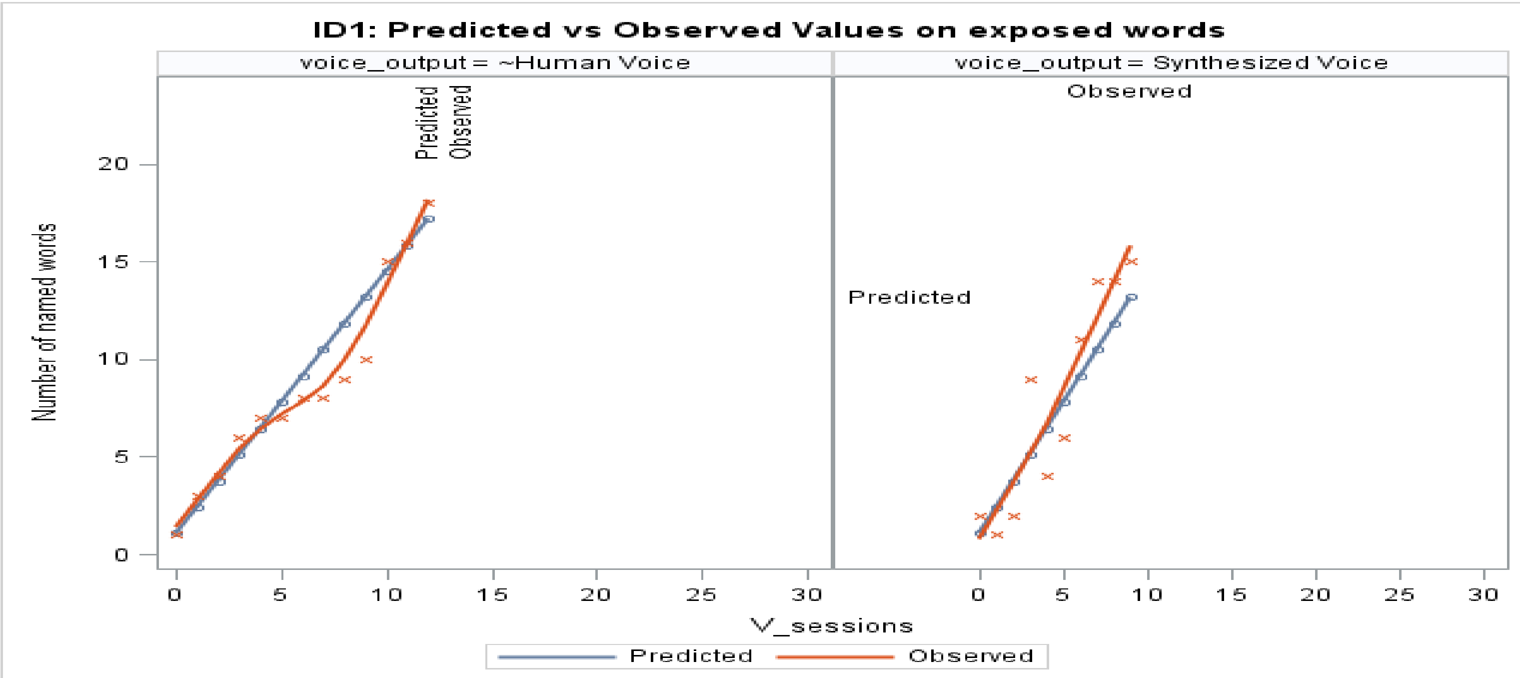


Figure 25 Trend lines of observed data and predicted model by P1-Exposed words

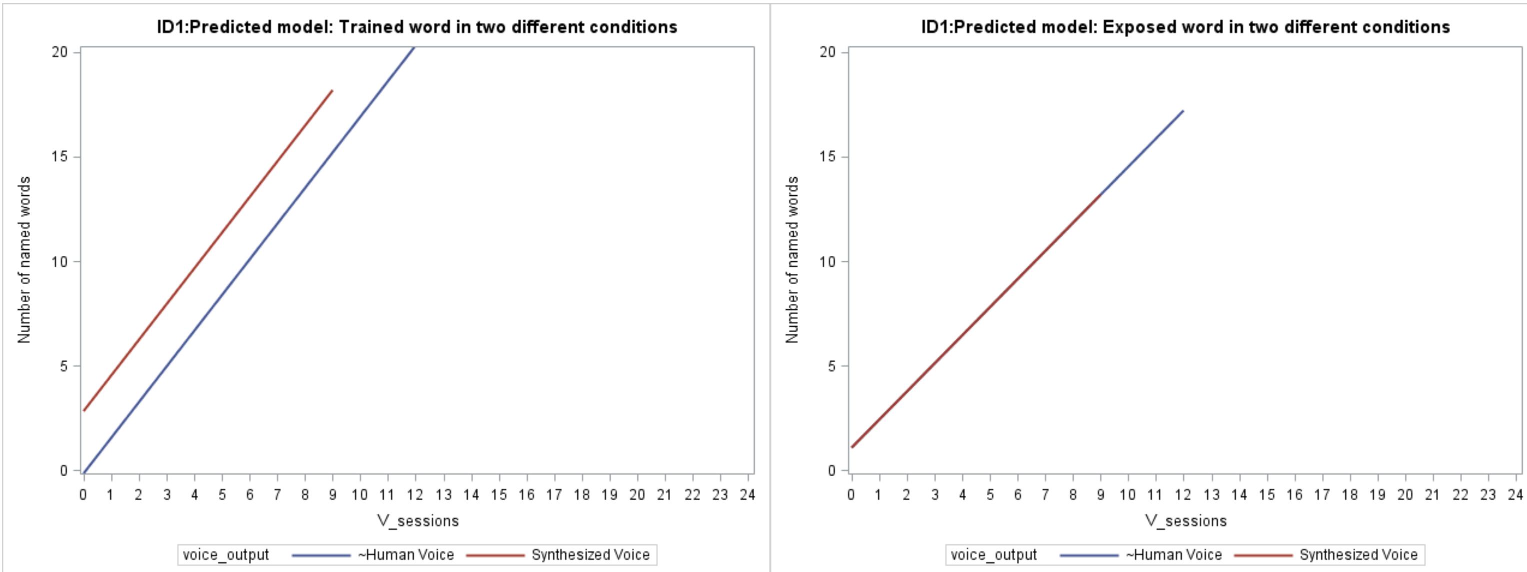


Figure 26 Compare the predict model between trained words and exposed words-P1

4.2.3.2 Participant 2

The MMTA results indicated the best fitting model for naming improvement in trained words involves the variables maturation (time) and voice output. The result suggested the improvement of the trained words was not only contributed by the maturation (time), but also the voice output, and the interaction between maturation (time) and voice output. Additionally, improvement rates, as indicated by slope, shows the P2 has faster improvement rate in synthesized voice output condition than in human voice condition. Meanwhile, the best model for exposed words involves only the variable of maturation with neither human nor synthesized voice output contributing to naming improvement.

Table 13 and Table 14 present fit statistics for competing models of the trained words, and the exposed words by P2. By comparing chi-squire value, Model 3 in Table 13 is the best model for the improvement of trained words. The best fitting model consisted of (a) v_sessions (number of sessions), (b) voice_output, and (c) v_sessions*voice output. The predicted model parameters are Y_{ij} = 2.0455+ 1.7545 (v_sessions) + 0.1212 (voice output) + 0.805 (v_sessions*voice output) (see Figure 27).

The Model 1 in Table 14 is the best model for the improvement of exposed words. The model indicates that only v_sessions contributed to the improvement statistical significantly. The best fitting model consisted of (a) v_sessions. The predicted model is Y_{ij} = 0.769 + 1.4384 (v_sessions) (see Figure 28). Figure 29 compares the predicted models of trained words and exposed words. The results show the improvement rates are similar (by slope) under synthesized voice and human voice across trained words and exposed words. The result shows the improvement rate of trained words under synthesized voice increases faster than the trained words under human voice. However, the improvement rate of exposed words are the same in both synthesized voice and human voice conditions.

Table 13 The fit statistics for competing models of trained words by P2

Model	Term	Fixed					-2log	AIC	AICC	BIC	# of Parameters	Chi square(-2log)	df	sig.
0	**Intercept**						121.1	125.1	125.8	127	3			
												0 vs 1		
1	**add v_sessions**	v_s					86.0	92	93.6	94.8	4	35.1	1	**
												1 vs 2		
2	**add voice**	v_s	v				74.6	82.6	85.5	86.4	6	11.4	2	**
												2 vs 3		
*3	**add v*vs1**	v_s	v	v*v*s1			66.4	76.4	81.1	81.2	7	8.2	1	**
												3 vs 4		
4	**add v_s2**	v_s	v	v*v*s1	v_s2		66.4	78.4	85.4	84.1	8	0	1	
												4 vs 5		
5	**add v*vs2**	v_s	v	v*v*s1	v_s2	v*v*s2	64.4	78.4	88.6	85	9	2	1	

Note. v_sessions(v_s)=number of session by the type of voice output. v=voice_output, v_s2=v_sessions*v_sessions, v*s1=voice output*v_sessions, v*s2=voice output*v_sessions*v_sessions.

**p<.05, suggesting that this term cannot be dropped from the theoretical model, because the subsequent model fitted to the data significantly worsens than the theoretical model.

Figure 27 Trend lines of observed data and predicted model by P2-Trained words

Table 14 The fit statistics for competing models of exposed words by P2

Model	Term	Fixed					-2log	AIC	AICC	BIC	# of Parameters	Chi square(-2log)	df	sig.
0	**Intercept**						110.3	114.3	115	116.2	3			
												0 vs 1		
*1	**add v_sessions**	v_s					64.3	70.3	71.9	73.2	4	46	1	
												1 vs 2		
2	**add voice**	v_s	v				64.3	72.3	75.2	76.1	6	0	2	
												2 vs 3		
3	**add vvs1**	v_s	v	v*v*s1			63.8	73.8	78.4	78.5	7	0.5	1	
												3 vs 4		
4	**add v_s2**	v_s	v	v*v*s1	v_s2		62.6	74.6	81.6	80.2	8	1.2	1	
												4 vs 5		
5	**add vvs2**	v_s	v	v*v*s1	v_s2	v*v*s2	62.5	76.5	86.7	83.1	9	0.1	1	

Note. v_sessions(v_s)=number of session by the type of voice output. v=voice_output, v_s2=v_sessions*v_sessions, v*s1=voice output*v_sessions, v*s2=voice output*v_sessions*v_sessions.

**p<.05, suggesting that this term cannot be dropped from the theoretical model, because the subsequent model fitted to the data significantly worsens than the theoretical model.

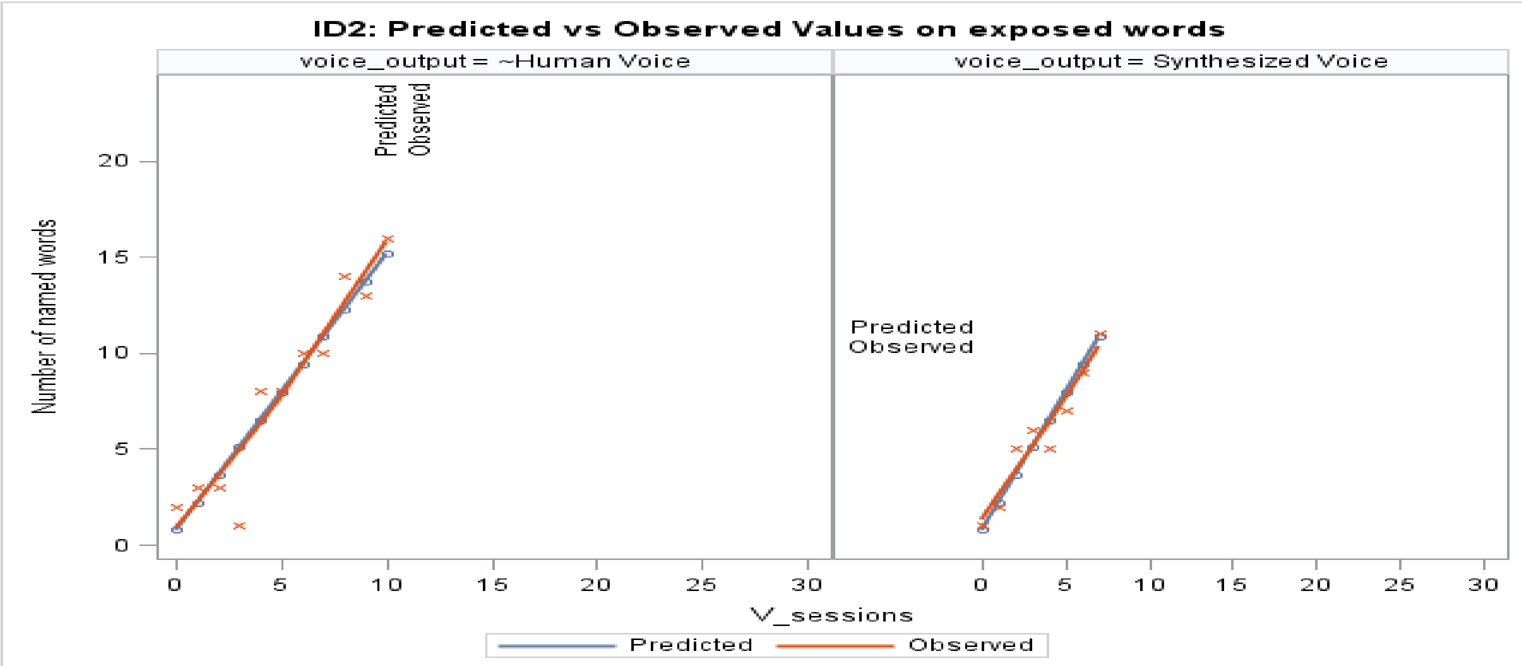


Figure 28 Trend lines of observed data and predicted model by P2-Exposed words

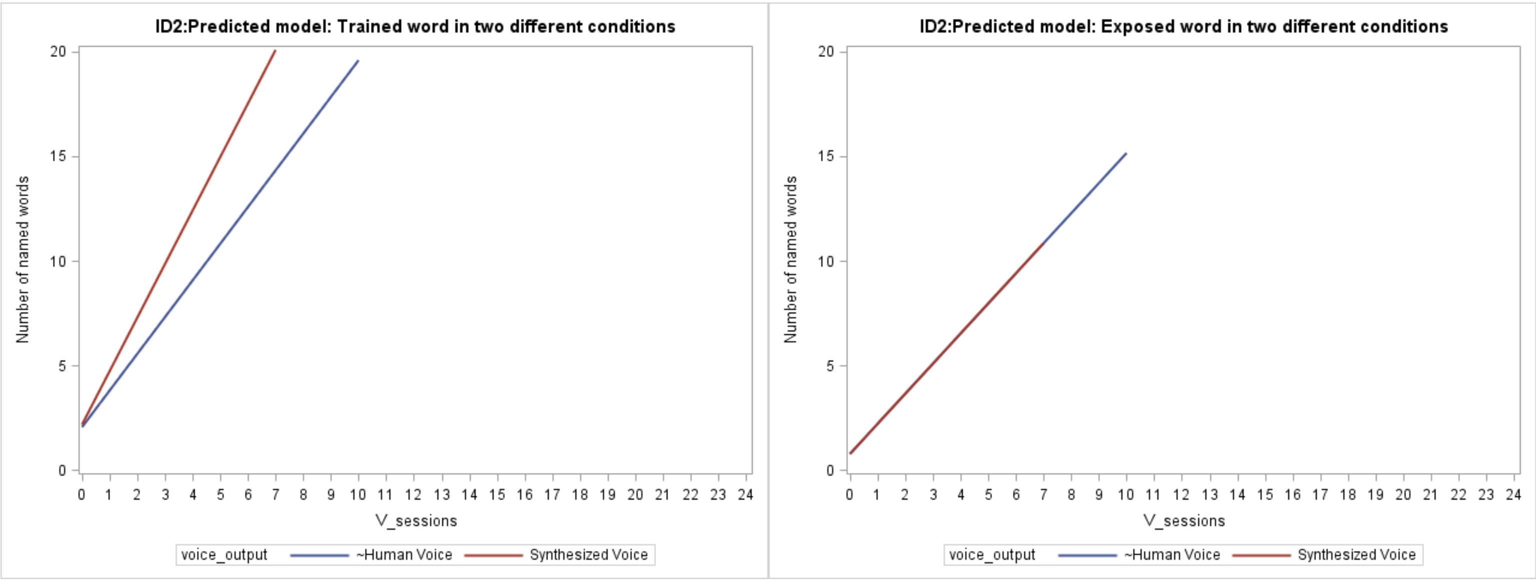


Figure 29 Compare the predict model between trained words and exposed words-P2

4.2.3.3 Participant 3

The MMTA results indicated the best fitting model for naming improvement in trained words and exposed words involves the variables maturation (time) and voice output. The result suggested the improvement of the trained words was not only contributed by the maturation (time), but also the voice output, and the interaction between maturation (time) and voice output. Additionally, improvement rates, as indicated by slope, shows the P3 has faster improvement rate in human voice output condition than in human voice condition in trained word and exposed words.

Table 15 and Table 16 present fit statistics for competing models of the trained words, and the exposed words by P3. By comparing chi-squire value, the Model 5 in Table 15 is the best model for the improvement of trained words. The best fitting model consisted of (a) v_sessions (number of sessions), (b) $v\_sessions^2$, (c) voice output, (d) v_sessions*voice output, (e) $v\_sessions^2$ *voice output. The predicted model parameters are Yij = 1.333 + 5.3571 (v_sessions) - 0.4048 ($v\_sessions^2$) + 4.1404(voice output) - 5.6482 (v_sessions*voice output) + 0.4636 ($v\_sessions^2$ *voice output) (see Figure 30).

Model 4 in Table 16 is the best model for the improvement of exposed words. The model indicates that v_sessions, $v\_sessions^2$, voice output, and the interaction terms contributed to the improvement statistical significantly. The best fitting model consisted of (a) v_sessions, (b) $v\_sessions^2$, (c) voice output, and (d) v_sessions*voice output. The predicted model parameters are Yij = -0.1885 + 1.4262 (v_sessions) + 0.048 ($v\_sessions^2$) + 3.1703 (voice output) – 1.6521 (v_sessions*voice output) (see Figure 31). Figure 32 compares the predicted models of trained words and exposed words. The result shows the improvement rate under human voice increases faster than under synthesized voice output for both trained and exposed words.

Table 15 The fit statistics for competing models of trained words by P3

Model	Term	Fixed	-2log	AIC	AICC	BIC	# of Parameters	Chi square(-2log)	df	sig.
0	**Intercept**		153.3	157.3	157.9	159.8	3			
								0 vs 1		
1	**add v_sessions**	v_s	146.2	152.2	153.3	155.8	4	7.1	1	
								1 vs 2		
2	**add voice**	v_s v	130.1	138.1	140.1	142.9	6	16.1	2	**
								2 vs 3		
3	**add v*vs1**	v_s v v*v*s1	113.2	123.2	126.4	129.3	7	16.8	1	**
								3 vs 4		
4	**add v_s2**	v_s v v*v*s1 v_s2	106.6	118.6	123.3	125.9	8	6	1	**
								4 vs 5		
*5	**add v*vs2**	v_s v v*v*s1 v_s2 v*v*s2	101.9	115.9	122.5	124.4	9	4.7	1	**

Note. v_sessions(v_s)=number of session by the type of voice output. v=voice_output, v_s2=v_sessions*v_sessions, v*s1=voice output*v_sessions, v*s2=voice output*v_sessions*v_sessions.

**p<.05, suggesting that this term cannot be dropped from the theoretical model, because the subsequent model fitted to the data significantly worsens than the theoretical model.

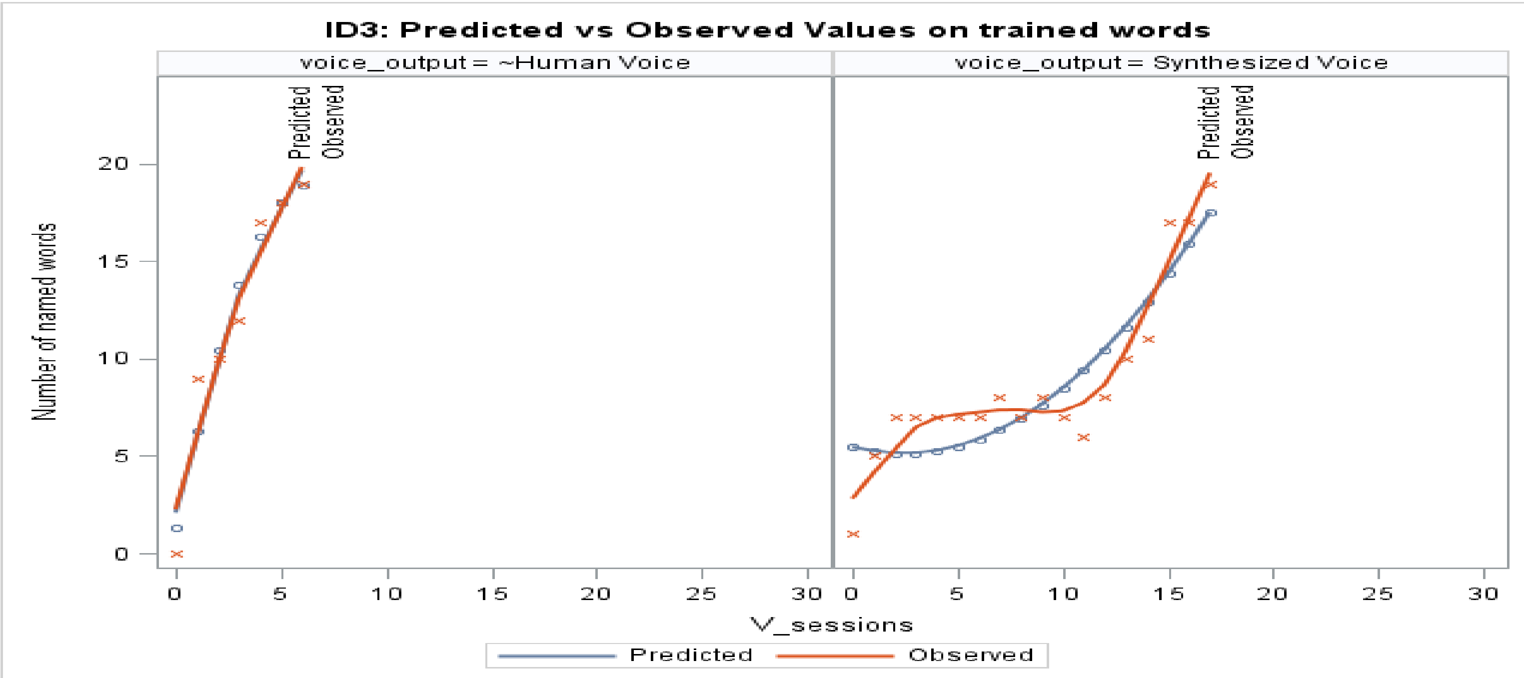


Figure 30 Trend lines of observed data and predicted model by P3-Trained words

Table 16 The fit statistics for competing models of exposed words by P3

Model	Term	Fixed	-2log	AIC	AICC	BIC	# of Parameters	Chi square(-2log)	df	sig.
0	**Intercept**		129.3	133.3	133.9	135.7	3			
1	**add v_sessions**	v_s	105.7	111.7	112.9	115.2	4	**0 vs 1** 23.6	1	**
2	**add voice**	v_s v	99.1	107.1	109.2	111.8	6	**1 vs 2** 6.6	2	**
3	**add v*vs1**	v_s v v*v*s1	88.3	98.3	101.6	104.2	7	**2 vs 3** 10.8	1	**
*4	**add v_s2**	v_s v v*v*s1 v_s2	76.5	88.5	93.4	95.5	8	**3 vs 4** 11.8	1	**
5	**add v*vs2**	v_s v v*v*s1 v_s2 v*v*s2	75.2	89.2	96.2	97.4	9	**4 vs 5** 1.3	1	

Note. v_sessions(v_s)=number of session by the type of voice output. v=voice_output, v_s2=v_sessions*v_sessions, v*s1=voice output*v_sessions, v*s2=voice output*v_sessions*v_sessions.

**p<.05, suggesting that this term cannot be dropped from the theoretical model, because the subsequent model fitted to the data significantly worsens than the theoretical model.

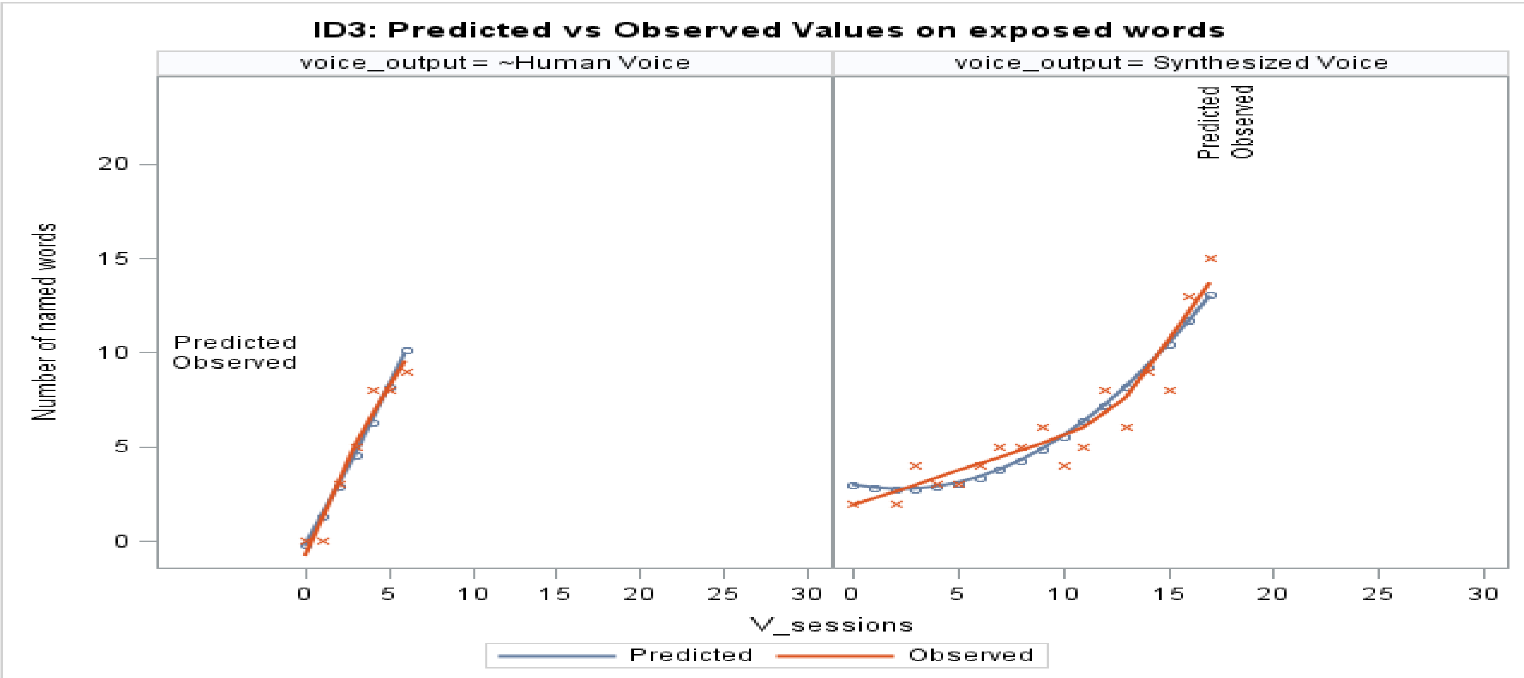


Figure 31 Trend lines of observed data and predicted model by P3-Exposed words

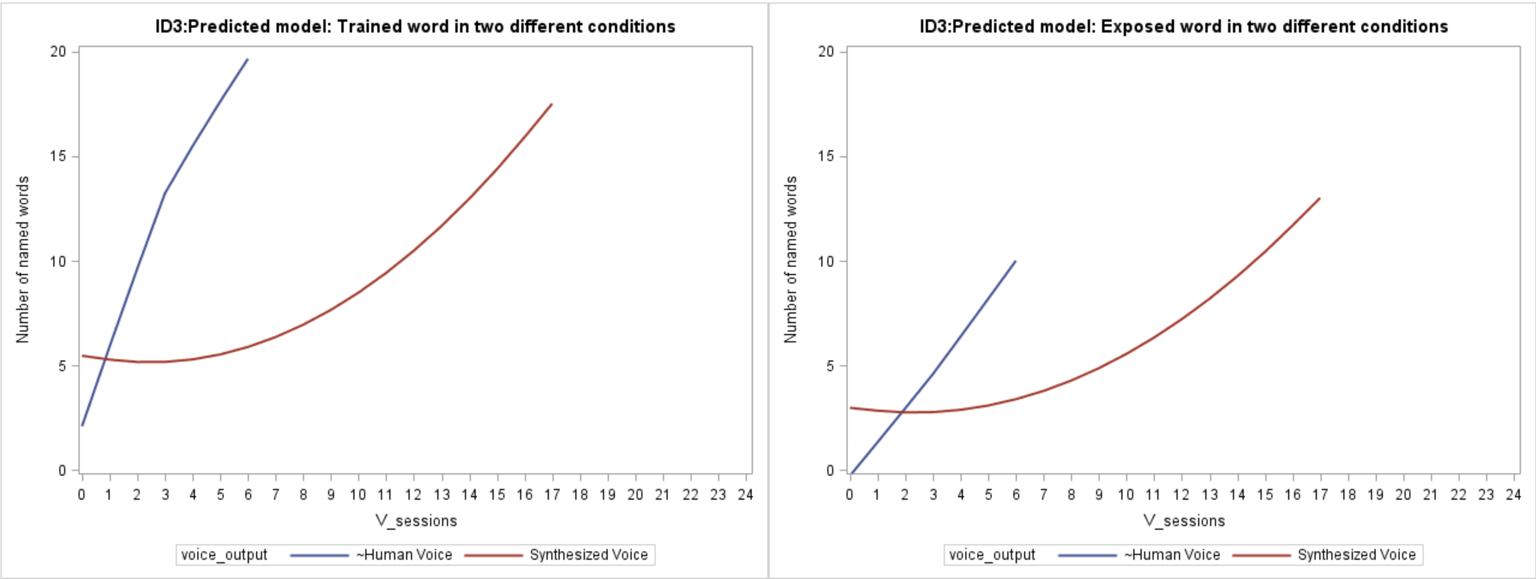


Figure 32 Compare the predict model between trained words and exposed words-P3

4.2.4 Pre- and post-tests

The difference in participants' pre and post treatment scores on the WAB, SRP, and CRTT-L are presented in Table 17. Standard error of measurement (SEM) was used for a notable change of the scores. All participants showed improvement in their Aphasia Quotient (AQ) descriptively. The improvement for P1 appears to be due to increased scores for all subtests but Auditory Verbal Comprehension. The improvement for P2 was on all subtests but primarily from Repetition. P3 had improvement on spontaneous speech, repetition, naming and word finding and had a decline on Auditory Verbal Comprehension. P4 improved mostly on Auditory Verbal Comprehension, then spontaneous speech and repetition, and declined slightly on naming. Interestingly, spontaneous speech and repetition for all participants increased. Using the SEM from Hula, Donovan, Kendall, & Gonzalez-Rothi (2010), P2 and P4 had over 1 SEM difference between pre- and post WAB-R AQ.

All participants improved at least 3 to 7 correct information units, which was equal to 1.85 to 4.35 Percent Information Unit (% IU) after the treatment. Using the SEM of % IU (Malcolm R McNeil et al., 2002), P2 and P3 had over 1 SEM difference between pre- and post- of SRP. The CRTT-L results represent participants' auditory comprehension. P1 and P2 showed a decrease in the overall mean score and the efficiency score. P3 had a slight improvement in the scores. P4 had the most improvement in the CRTT-L scores. Using the SEM of CRTT-L (Malcolm R McNeil et al., 2015), P2 and P4 had over 1 SEM difference between pre- and post- of CRTT-L.

Table 17 Pre and post treatment scores and difference (dif.)

Participant		WAB-Subtests: Spontaneous Speech Score	Auditory Verbal Comprehension Score	Repetition Score	Naming and Word Finding Score	Aphasia Quotient (AQ)	SRP: CIU	%IU	CRTT-L-Overall
P1	**Pre**	17	10	7.8	8.3	86.2	26	16.05	14.1
	Post	18	10	8	9	90	33	20.37	13.8
	Dif.	+1	0	+0.2	+0.7	+3.8	+7	+4.32*	-0.3
P2	**Pre**	16	8.5	7.4	8.5	80.8	11	6.79	13.4
	Post	19	9.1	7.0	9.3	88.8	16	9.88	12.41
	Dif.	+3	+0.6	-0.4	+0.8	+8.0*	+5	+3.09*	-0.99*
P3	**Pre**	16	9.8	7.8	7.6	82.4	25	15.43	12.55
	Post	17	9.45	8	8.2	85.3	28	17.28	12.85
	Dif.	+1	-0.35	+0.2	+0.6	+2.9	+3	+1.85	+0.3
P4	**Pre**	5	4.45	2.8	2.2	32.9	5	3.09	9.83
	Post	6	7.25	3.4	1.5	36.15	8	4.94	11.02
	Dif.	+1	+2.8	+0.6	-0.7	+3.25*	+3	+1.85	+1.19*

Note. WAB=Western Aphasia Battery; SRP = Story Retelling Procedure; CIU = Correct Information Unit; %IU = Percent Information Unit; CRTT-L = Computerized Revised Token Test-Listening

* >1 SEM difference between pro- and post- test.

4.2.5 Participant satisfaction

Participant satisfaction data were analyzed as the last post-assessment procedure. Table 18 provides the results for each participant and their overall scores. The average of overall satisfaction of all participants' rating was 4.04 on a scale of 1 to 5 (1 representing strongly disagree and 5 representing strongly agree). All participants reported that their speech and naming skills were improved. Two of four participants strongly agreed that they would participate in a similar training again. All participants stated that they would recommend others to use the training. All participants reported that the self-practice was easy to operate, and they did not feel frustrated using the training program.

Table 18 Results of participant satisfaction questionnaire

Items		Participant				Overall
		P1	P2	P3	P4	
1.	I feel it is easy to learn to operate this training program	5	5	4	3	4.3
2.	I can complete the self-practice by myself easily.	5	5	3	5	4.5
3.	I feel that my naming is improved.	4	5	4	4	4.3
4.	I feel that my speech is improved after the training	4	5	4	5	4.5
5.	I like this type of training	3	5	3	5	4
6.	Using the training program can be a frustrating experience.	1	1	3	3	2
7.	I would like to continue the similar training after the study.	3	5	3	5	4
8.	I will recommend others to use this training program.	5	5	4	5	4.8
9.	Overall, I am satisfied with the training.	4	5	3	5	4

4.3 DISCUSSION

This study investigated whether synthesized voice output and human voice output play a similar role in the effect of vocabulary learning using an integrated AAC system with PWA. This discussion covers the MMTA results of P1, P2, and P3, and descriptive data of P4. Results suggest that: (a) three of the four participants showed improvement in naming with both human voice and synthesized voice; (b) three of the four participants showed improvement not only with the trained words, but also with the exposed words; (c) the effects of the two types of voice output are varied by person; (d) Participants showed different improvements on the WAB and the story retelling procedures; (e) Overall, the participants were satisfied and/or highly satisfied with the training.

4.3.1 Improvement with both human voice and synthesized voice

Improvement in naming skills under both the human voice and synthesized voice conditions provides support that synthesized voice output as a feature of an AAC system may facilitate gains in PWA's naming ability. This finding provides some evidence to support previous research and clinical assumptions. That is, PWA might be able to improve confrontational naming skills using their natural speech with therapy using a high-performance AAC system treatment (Koul et al., 2005; Weinrich et al., 2001). Previous study included a procedure of asking PWA to repeat the target words on the AAC device after selected (Weinrich et al., 2001). The action explain the reason for the improvement in naming. In the current study, the participants were not asked to repeat any words. The participants only listened to the exposed words and practiced the trained words. That difference helped the current study exclude the practice effect from verbally repeating the words, and strengthens the effect from the voice output itself. Thus the current study directly tested the effect of the voice output. From previous studies we know that although people with communication disorders perceived synthesized voice output poorer than normal controls of understand (Koul & Dembowski, 2010), people with communication disorders can still gain benefit from exposure to synthesized voice output over time (Breitenstein et al., 2004). Meanwhile, the multi modal stimuli of the training program may help people to learn naming more effectively. This assumption is supported by previous studies in normal control (Plass et al., 1998; Tight, 2010) and PWA (Johnson et al., 2008).

Although three participants learned fewer exposed words than trained words, this finding still suggests that PWA's word naming skills can benefit by exposure to words without direct training. The result supports the common assumption that people can learn a first or second language by exposure (Ellis, 2015; Seipel, 2011). This assumption may not only be true for language learning by people without acquired communication disorders, but also for PWA. While previous AAC studies hypothesized the possibility of improvement based on exposure to words without direct training, this study provides clear evidence supporting this idea. That is, by listening to AAC voice output, PWA benefit from exposure as a clinical strategy. Consequently, though the exposed words available on an AAC system may not be the target words in the treatment sessions, the individual may experience benefits from hearing the words spoken when accessed. The finding indicates that PWA should use AAC systems with voice output as much as possible to increase the dose of exposure. As long as PWA continue to use or practice accessing words on the AAC system and listen to the voice output, they can be stimulated and may show gains later as a functional outcome.

4.3.2 Individual difference between the improvements with different type of voice output.

Although the study results suggest that most of the participants first were able to learn words from not only a human voice, but also a synthesized voice, participants' reactions to the two types of voice output differ. Based on the results of the mixed model analysis, the voice output played a significant role in P1's performance on the trained words. The improvement rate (slope) of the human voice and the synthesized voice were similar for both trained and exposed words. In the meantime, voice output did not affect the improvement of the exposed words either in the human voice condition or the synthesized voice condition. The improvement of exposed words was affected by the number of sessions only. This means that P1 learned naming by time, and no matter the type of voice exposure. P2's improvement of trained words, on the other hand, was affected by the voice condition. In addition to that, P2 had a better improvement rate when exposed to the synthesized voice than when exposed to the human voice. Similar to P1, P2's improvement of exposed words was affected by time only. Voice output also plays a significant role in P3's naming performance on the trained words and exposed words. The results show P3 had better naming performance of trained words when exposed under the human voice condition. A similar pattern is found in the naming performance of the exposed words. These three participants present the three possible outcome comparisons between human voice and synthesized voice in the trained words (Human voice > Synthesized voice; Human voice = Synthesized voice; Human voice < Synthesized voice). This result indicates that PWA may react differently when exposed to different types of voice output and is similar to previous studies showing the outcomes of naming were mixed (Wisenburn & Mahoney, 2009). For exposed words, even though two of three participants (P1, P2) had the same improvement rate when exposed to the human voice or the synthesized voice, P3 determined the human voice better than the synthesized voice. It is too dangerous to say that the effect of human voice and synthesized voice are the same, because the sample size is too small. However, one thing is certain based on the data: participants improved their naming skill of trained words under both human and synthesized voice exposure.

It is worth mentioning that a specific difference in the current study is the data analysis methods. Previous studies in PWA for AAC and naming commonly use single subject design, and the outcomes are usually presented with visual inspection analysis and effect size. Such analyses may be used to measure the treatment effect, but cannot test each dependent variable independently. Secondly, these standard methods cannot provide a predicted model to predict the future progress. Regarding the effect size, the Cohen's d which is commonly used in studies only is discussed. Although this statistical method can provide us with the magnitude of the treatment effect, Cohen's d cannot provide us with the details about what variables contribute to and to what degree in the treatment effect. Having the mixed model analysis allows for confidence in the results. Using the descriptive data of P1 as an example, the trend lines of trained words when implemented under computer and human voice conditions showed that the synthesized voice has a better outcome. When comparing the means, the synthesized voice also had a better outcome than the human voice in the trained words. The exposed words had the opposite results; that is, the synthesized voice exhibited a worse outcome than the human voice. The results were the opposite between the trend lines and the means in the exposed words. Based on mixed model analysis, it can be asserted that P1 had a similar improvement rate across both conditions of the voice types and both types of words. Since the mixed model analysis has been approved and had the statistical power, I chose to use the results of the MMTA method to present the final outcomes.

Methodologically, the current study used both visual inspection analysis and the MMTA to support the results on improved naming across the four participants. Improvement was not only due to maturation (time), but statistical analysis revealed that gains were associated with the two voice variables (computerized and human speech) for P1, P2, and P3. The results provide empirical data that AAC treatment is beneficial for supporting gains in naming skills for PWA under the conditions of direct word training and exposure to words, although direct training is more effective in improving performance. It also demonstrates the advantages of the MMTA in providing detailed information for each of the predictors.

4.3.3 **Pre-post tests**

Changes in the pre- and post-treatment WAB-R AQ scores, SRP, and CRTT-L suggest that all participants had some improvement in overall language and cognitive function. Although a five-point increase on the AQ seems to be used as the benchmark indicating clinical significance (Shewan & Kertesz, 1980), results of the Rasch analysis suggested a variable standard error of measurement (SEM) according to aphasia severity (> 2 points for AQs 28-68 ranging to > 6 points for AQs < 20 and > 90) (Hula et al., 2010). Based on the SEM reported in the study, two of the four (P2 and P4) participants were considered to have a noticeable improvement in the AQ scores.

The individual patterns of the AQ scores for the participants is worth a more thorough examination. Overall, P1 had a slight improvement on each subtest except auditory comprehension. However, he reached the ceiling on the auditory comprehension test at the pre-test, so this subtest was not sensitive enough to measure possible gains. P2 had the most improvement in the spontaneous speech subtest, followed by naming, and then auditory and verbal comprehension, with a slight decrease in the repetition score. Although P2 was functional, he tired easily which resulted in fluctuation of speech performance among the sessions. Sometimes he forgot something we were talking about right away, and sometimes he was fine. P2's increase in the spontaneous speech subtest score may have been in part due to his feeling particularly good that day. P3 showed a little decline in auditory comprehension. Since the decline was small, his performance could have been due to poor attention after the other subtests. P4 showed an increase in the scores on spontaneous speech, auditory verbal comprehension, and repetition, but a slight decrease in naming and word finding. Overall all participants showed improvement in their AQ score, which suggests they may have benefited from the intervention. For the two participants who did not have the change over 1 SEM, the possibility is that they could benefit from a different intervention schedule or different training materials to facilitate their improvement.

P1 and P2 had a decrease in the CRTT-L overall scores. P3 and P4 had an improvement in the scores. P4 had the most improvement in the CRTT-L, and the positive change was over 1 SEM (1 SEM=0.30; McNeil et al., 2015). Meanwhile, P2 had a negative change over 1 SEM which suggests that first, P4 had a noticeably positive improvement in auditory comprehension, but P2 had a noticeably negative change. Moreover, P1 and P3 had no significant change in the CRTT-L. Like the description before, P2 tired easily and his change might be due to his overall poor wellness and attention.

P4 was the only individual who did not present a distinct improvement in either the trained or exposed words under the synthesized voice condition. However he did show improvement on all the posttreatment tests with a slight decline in the naming subtest in the WAB-R. However, P4 had the most severe aphasia of the participants. He frequently used gestures to support his communication attempts. He represented a client most likely to be recommended an AAC system to improve functional communication. Although he did not show improvement on the dependent variables, and he was only exposed to the synthesized voice condition, his improvement on the WAB-R provides positive evidence to support the purpose of the current study. That is, by exposure and practice with an AAC system, PWA may gain some language skills and also speech. The result is interesting and also is supported by previous studies showing PWA could learn new word/non-words by auditory exposure (Breitenstein et al., 2004; Kelly & Armstrong, 2009).

Multimodal stimuli in the training and the exposure may have contributed to increasing in overall language skills. Similar results were also shown in Johnson et al (2008). The results are also supported by adult language learning; that is, multimodal stimuli can help people learning languages (Plass et al., 1998; Tight, 2010). Since the current study focuses on the naming skills, the naming score in the WAB is reviewed specifically. Most of the participants improved their naming scores slightly, except for P4. However, all participants showed some improvement in other speech related sub-tests: spontaneous speech and repetition. Some of them also showed some improvement in the auditory comprehension subtest. Attributing the results to the voice output, the picture, or both cannot be determined, but use of picture symbols with voice output in the study seemed to facilitate improvement.

The improvement observed in the SRP is further evidence showing that participants' overall language skills improved. Specifically, expressive language improved which was a focus of the study. The SRP is commonly used to evaluate overall language abilities, language comprehension and expression. The positive outcome from the post-tests across the four participants suggests PWA can benefit from treatment involving synthetic speech, graphic symbols and touch screen technology. P1 and P2 had the most notable changes over 1 SEM (McNeil et al., 2002) related to expressive language.

Most of the high-technology AAC systems for PWA include these components. The results demonstrate that clinicians working with PWA can be more confident in integrating AAC systems as part of treatment. The uniqueness of the current study is to try to demonstrate the possible overlap between AAC aphasia intervention and improvement-oriented computerized aphasia training. Furthermore, the results of the present study are similar to the findings reported for computerized aphasia training that indicates people can learn from technology.

Although P4 did not show improved naming with the training, his pre- and post- treatment scores on the WAB-R and SRP suggest he made improvements in his language and cognitive functioning. These results indicate that using this type of training with synthesized voice output only may have some effect on the underlying language processing or mechanism. Interestingly, P4's wife and daughter both reported that they thought P4's speech was clearer than before the start of the study. They reported that P4 spoke more than previously too. Their positive feedback encouraged us to continue the study. This feedback suggested that even if a person did not have improvement on the target words, this type of approach may facilitate the underlying mechanism

The difference between the current study and the previous studies is the inclusion of a measurement of speech performance, which is the most desired outcome that PWA want to see. Most previous aphasia AAC studies have focused on communication or functional communication, while previous studies have commonly provided results of functional communication or standardized assessments (Johnson et al., 2008; McKelvey & Dietz, 2007). Those results from previous studies are important. However, as researchers, we should seek the possibility of using AAC systems with similar types of the training to improve people's most desired or preferred outcomes. Last, the changes of pre- and post- tests across four participants are varied, and some of the participants had more noticeable changes than others in different domains. These phenomena suggest that four participants react differently to the intervention. Further investigation will be needed to determine the factors that affect different outcomes.

4.3.4 **Participant satisfaction**

The participant satisfaction was with higher values indicating higher degrees of satisfaction. The possible range of scores by item was between 1 and 5. Satisfaction was operationalized by a measure designed to assess subjective feelings of satisfaction to yield socially valid indices that could be used as a basis for further training efforts. Overall, participants were satisfied with the training (item 9). Participants' responses indicate that all participants highly rated the training effect of the naming, and speech (item 3 and item 4), and the usability of the training (item 1, item 2). These results show firstly that the treatment protocol worked as hypothesized, and provided a desired or expected outcome which is the improvement of speech. In the meantime, the result also passed the operational obstacle commonly seen when implementing AAC/AT technology (Phillips & Zhao, 1993). Furthermore, the ease of use is always one of the cornerstones to avoiding a high abandonment rate of AAC and AT technology (Baxter et al., 2012; Johnson et al., 2006; Phillips & Zhao, 1993; Riemer-Reiss & Wacker, 2000). 50% of participants indicated that they would continue with similar training, and 50% of participants maintained a neutral attitude. It is possible that the content and the treatment protocol were too repetitive during the treatment period, so that two participants rated it neutrally. All participants reported that they would recommend the training to others suggesting that they feel positive about and trust the training (Korneta, 2014).

4.3.5 Alternatives

Variables other than the training using the voice output AAC system may have resulted in some of the improvement documented. It is possible that any individual with aphasia receiving treatment like the study would improve simply because of the amount of social interaction with a SLP, and because of the intensity. P3 and P4 might have been impacted due to the social interaction more, because both of them did not work during the time and only interacted with family members most of time. Previous studies have shown that those PWA showing more improvement were those who had more social interaction (Johnson et al., 2008; Simmons-Mackie, 2008a). Intensity of treatment has been shown as a key treatment outcome factor (Cherney et al., 2011; Robey, 1998). The treatment protocol provided an increased amount over regular outpatient clinic-based services (one or two sessions per week). P4's results of naming skills have reflected his severity of aphasia, because he demonstrated the lowest changes on trained words and exposed words, and had lowest pre-treatment scores.

Another variable that could have contributed to the results of the study was the commitment and engagement. All participants volunteered and did not have access to speech language services during the research period. They were eager to improve their speech performance when they participated to the study. This suggests that the participants may have been more highly committed and engaged than might be expected in a general treatment population.

One person with aphasia is one person with aphasia. PWA commonly react different to the same intervention, and that each of participant's performance was influenced by their health, emotion, and pressures in their lives. The most salient case is P3. P3 had much slower improvement with the synthesized voice output than the improvement rate in the human voice output condition. Actually, he was sick often during the time of the treatment, and had low energy during the sessions.

4.3.6 Clinical relevance of the findings.

Although there are many studies working on auditory input, and exposure on vocabulary learning in PWA, the current study is the first study trying to integrate high technology AAC intervention to simulate the possible effect of different voice output condition for a speech related outcome, naming for PWA. The results provide empirical evidence rather than anecdote comments about whether PWA can improve their speech using an AAC system with synthesized voice output exposure over time. The finding also supports the assumption of continuity in using an AAC system overtime, even without specific practice. PWA can benefit from using device high technology AAC system, and may possibly improve their speech. Furthermore, the current study included the self-paced practice in the treatment protocol, and this showed a positive outcome. The findings provide evidence to support the potential of using self-paced practice as part of AAC treatment. The preferred protocol would be to provide the AAC self-paced practice as an adjunct with the clinician's face-to-face intervention. This approach may be a solution for increasing the amount of therapy sessions without necessarily significantly increasing direct therapy costs or passing along the financial burden to PWA and their families. Lastly, although, the original intention of the study was to investigate whether people with moderate to severe aphasia could improve their naming skills, the current study also indicates people with mild to moderate aphasia can also benefit from treatment for improving their naming. Thus, people with mild to moderate aphasia with initial guidance from an SLP, could practice as much as they prefer at home, and continue to improve their naming skills even after they are discharged.

4.4 LIMITATION

A primary limitation of the study is that the intensity of the treatment may not be feasible in real practice. The study adds evidence to guide clinical AAC decision making for PWA. However, many PWA may not have the opportunity to receive the dosage of sessions required to demonstrate the results obtained from this study. Thus the results point to a double-edge sword, increase dosage improves results, but many PWA may not the opportunity to receive the dosage needed to demonstrate desired outcomes. A second limitation is the extent to which the findings cannot be generalized to other adults with chronic and moderate-to-severe aphasia. The study highlights the heterogeneous nature of aphasia, especially noting the difference in outcomes achieved by the participants under the various treatment variables. This limitation can be overcome in future studies by increasing the number of participants for group 4, which can allow PI to explore the difference in change not only in the individual level, but also the group level; Furthermore, using mixed model analysis to test the generalization of treatment. However, unique patterns of performance gains may still be observed regardless of increasing participants. The results imply the importance of individualizing a client's treatment variables to maximize the effectiveness of treatment. Another limitation is that data were not collected from the participants using the AAC system outside the laboratory environment or in daily communication. Thus the study did not provide the opportunity to investigate generalization of the target words to daily communication.

Although the study collected some outcomes that related to speech performance from the customer satisfaction survey, it did not collect the outcomes of different perspectives of functional communication to understand the effect of the treatment in functional communication purpose. A final last limitation is that the limited number of baseline data may limit the conclusion about the treatment effect of different voice outputs. Thus this study should be considered as a phase I study for efficacy-based practice (Robey & Schultz, 1998), which suggests future recruitment of more participants to replicate the results.

4.5 SUMMARY

The treatment protocol with both the human voice and synthesized voice conditions appeared to improve naming for 3 of 4 participants. In the meantime, the three participants all improved their naming not only in trained words, but also exposed words. All four participants improved in their overall language functioning. The evidence first supports the potential of concurrent synthesized voice output from an AAC system for improving PWAs verbal skills. All participants were satisfied with the treatment protocol and were willing to recommend others to using the approach. All participants reported that self-paced practice was easy to use. The study provides some evidence for using self-paced practice to train participants using AAC. Future studies will focus on first, recruiting participants in both conditions to test the generalization of the current protocol. Second, having participants use both the practice and the AAC system in daily activities to investigate the generation from self-paced study practice to real verbal and communication usage.

Since participants valued self-paced practice integrating this strategy as routine for PWA therapy, gives opportunities to overcome several identified limitations.

5.0 CONCLUSION

This dissertation started from the question about whether the voice output of an integrated computer-based communication system can affect PWA's naming performance and the patient-reported outcomes. Later, the treatment dose was added to one session to test if using a self-paced practice program can affect PWA's naming. In additional to the aims, the dissertation also demonstrated the use of an alternative analytic method (MMTA) to analyze the data of the current single-subject design study to build a rigorous pilot study for this topic.

The results of the series of studies suggests that both NP and PWA can learn to name trained words under both voice conditions – human and computerized. However, the learning effect is different between the two groups. Overall NP showed that they learned better with human voice and synthesized voice both for trained words and exposed words, whereas the PWA had mixed results between participants. In other words, although PWA learned to name words by human voice and synthesized voice, individuals reacted differently with the type of voice output in trained words and exposed words. Additionally, the results indicate that NP can learn to name words by exposure to both variable conditions, whereas PWA performed differently on exposed words depending on whether they received human or synthesized voice output. The findings from the study strong support the idea that PWA may use a high-technology AAC system not only for activity/participation (functional/social-oriented) outcomes, but also for gains in body functions and structure (impairment-oriented) during rehabilitation.

Although using the self-paced practice to add the treatment dose in one section did not accelerate the improvement rate, the series of studies demonstrate the feasibility of computerized self-paced AAC training based on the positive feedback from both NP and PWA. The feedback also provides a direction to improve this type of AAC intervention. Hopefully, it can be used in daily practice to increase the accessibility of AAC intervention for PWA. Another significance that the dissertation provides is to demonstrate the value of MMTA with single-subject design studies. MMTA provides not only overall treatment effect data, but details information of the possible factors that contributed to the outcome. The move toward using MMTA is important, especially when most AAC aphasia studies have small sample sizes, and commonly are criticized because of the study size. This method allows researchers to evaluate AAC aphasia studies with a small sample thoroughly. Thus, researchers can identify how possible factors are weighted in the treatment outcomes, and build strong evidence-based approaches for the PWA population.

Besides the research results, the dissertation demonstrated the core value of the ICF framework. That is, the components/domain of ICF are interconnected, and the outcomes of different components should be considered. The PWA used a computerized AAC training including high frequency words that are commonly used in daily life. The target words were selected for PWA who had the opportunity to use what they learned from the training in their daily communication. Encouragingly, most PWA participants reported that not only their naming skill improved, but also their overall speech. Some family members even reported improvement in daily communication. This outcome demonstrates how a computerized AAC training could generate the interaction between body functions and structures, and activity and participation in the ICF. Moreover, the study also shows the evidence of how personal factors (ex: wellness) could influence the outcomes. Overall the study echoes to the ICF's concept of all components being counted. It also provides some thoughts for applying the ICF in clinical practice in the future.

Future research will focus on manipulating the clinician-related variables and different types of treatment intensity variables to further investigate the treatment effect of the protocol. It will also increase the sample size both for NP and PWA to identify the training effect of the protocol. Another direction of future research is to have PWA using both the practice and the AAC system in daily activities to investigate the generation from self-paced study practice to real verbal and communication usage.

Today technology penetrates into almost every aspect of people's daily life.. We cannot avoid technology involvement in AAC aphasia intervention. In contrast, we must investigate components systematically and methodically. Then, we, as not only researchers, but also clinicians, have evidence-based approaches to select for our clients. This dissertation is the first in a series of studies that intends to demystify the technological components of AAC intervention for PWA. Hopefully, the results of the dissertation can open additional avenues to evaluate AAC aphasia intervention. Ultimately, the efforts can make AAC aphasia intervention achieve the most effective communication possible for PWA for an improved quality of life.

Appendix A

SUBJECT HISTORY

Subject # ______________ Date of Birth: ____________
Gender:_____________ Age : ___________
Highest Education level:____________ Time of post onset:________________

1. Yes No: Do you understand any Mandarin Chinese? **(only for Experiment 1)**
2. Yes No: Did you have any brain damage, cognitive or psychiatric disorders before? If yes, explain and stop here:______________
3. Yes No: Have you ever had any kind of speech, language or learning problem before? If yes, explain and you may stop here:___________________
4. Yes No: Did you ever have treatment for a speech or language impairment before? If yes, explain and stop here:____________
5. Yes No: Do you have any vision deficits that might affect your participation in this study? If yes, explain:___________
6. Yes No: Do you need glasses to participate the study?
7. Yes No: Do you have difficulty hearing? If yes, do you wear a hearing aid? Bilateral/ Right / Left / NA
8. Which hand is used to write and eat? Right Left either hands equally

Appendix B

120 WORDS STIMULI

I	You	My	Me	Your	We
He	She	They	Her	Him	Them
Have	Do	Get	Can	Like	Go
Want	Take	Please	Know	See	Think
Need	Say	Use	Help	Walk	Play
Buy	Ask	Feel	Eat	Give	Turn
Call	Guess	Come	Quit	Listen	Change
Learn	Put	Read	Sit	Make	Write
Bring	Drink	Stop	To	It	On
That	Not	But	Some	This	So
More	When	Up	At	Always	Because
From	Many	Out	In	About	Only
Inside	Outside	Good	Bad	Happy	Sad
Hot	Cold	Bored	Sick	Open	Close
Sure	Tv	Music	Dad	Mom	Friends
Doctor	Computer	Cellphone	Thing	Rest	Today
Time	Tomorrow	What	School	Eye	Shower
Juice	Breakfast	Apple	Home	Bedroom	Book
Newspaper	Wait	Long	Short	Sorry	Lunch
Ice Cream	Exercise	Back	Mad	Here	There

Appendix C

PROCEDURE INSTRUCTIONS AND SCRIPTS
Experiment 1

Screening

The investigator will collect the performance of confrontation naming and the picture symbol-to-spoken word matching for all experimental stimuli (120 words) before the training starts. The picture symbols will be individually presented in random order.

The investigator will first start the naming screen. The investigator will say:

"I am going to show you 120 pictures. I will show one picture each time. I would like you to name them in Mandarin Chinese. If you don't know, just say I don't know"

The investigator will collect data on a checklist with √ = correct; x = incorrect.
After the screening, the investigator will start the picture symbol to spoken words matching task the investigator will say:
"Next, you will listen to 120 words in Mandarin Chinese. I will present one word each time. I would like you to point the picture that matches the spoken word. If you don't know, just say I don't know.

The investigator will present a spoken word with 5 different picture symbols. Participants need to point the picture symbol that matches the presented spoken word. The investigator will collect data on a checklist with √ = correct; x = incorrect.

Treatment

Turn off the speaker when the assigned condition is without voice output

When the treatment starts, the investigator will follow the script below:
"Now, we are going to start our Chinese word training. After the training, I will ask you to draw two shapes following the dashed line. Then, I will ask you to name words. In addition, I will ask you to listen to words and find the picture which matches each word. Do you have any questions before we start?"

Answer participants' questions or start Step 1.

Step 1:
The investigator will present the 20 exposed set one time in the beginning of a training session. The investigator will say:

"Now I want to show you some pictures on the tablet. I will touch the picture. You only need to look at those pictures. Let's start."

The investigator will present the exposed words to a participant with or without the voice output which depends on the assigned condition using the computerized training program. No feedback or extra information will be provided.

Step 2:
The investigator will start to train the participant using the trained set via a computerized AAC training program following the training modules with the 20 trained words. The investigator will say:

For condition with voice output: **"Now let's start the next task. I want you to learn some words on the device. You will hear a command from the tablet. When you find the word, I want you to touch the picture. Then, you will hear the tablet says the word."**

For condition without voice output: **"Now let's start the next task. I want you to learn some words on the device. You will hear a command from the tablet. When you find the word, I want you to touch the picture. Then, you will hear the tablet says the word."**

When Participant completes first module, the investigator will say"
"Let's start the next practice. It is more difficult than the first one. Again, I want you follow commands and find the words"

**** If a participant is assigned for another 30-minute self-paced training after the training, go to the Step 3. Otherwise, go to the step 4****

Step 3:
The investigator will say:
"Next, I would like you to do a practice by yourself. You will practice with the same materials that we have completed together. This time, I will not give you any feedback or help during the practice. When you are ready, let me know, I will turn on the training program for you. While you are practicing, I will sit in front of you. When you complete the training, let me know."
When a participant is ready, the investigator will set up the module 1 for the participant.
Step 4:

When a participant completes the assigned training, the investigator will randomly pick two shapes from the appendix D and say:

"Now, I would like you to draw these two shapes (show the paper to the participant) following the dashed line. When you are done, please let me know."

Step 5:
The investigator will say:
"This time I will first show you some pictures and I would like you to name those pictures. You just try your best to name them."
After the participant completes the naming task of the trained and exposed words, the investigator will say:
"Here is the last part of today. Now you will listen to some words. I will play a word each time. Please point the picture that matches the word you hear."
After the participant completes the naming task of the trained and exposed words, the investigator will say:

"Ok! We are done for today. Thank you!"

Step 6: (implement in the beginning of a new session after the 1st session)
The investigator will say:
"Before we start the training today. I will like to show you the pictures we have worked in last session and I would like you to name those pictures. You just try your best to name them."

After the participant completes the naming task of the trained and exposed words, the investigator will say:
"Now you will listen to some words. I will play a word each time. Please point the picture that matches the word you hear."

After the participant completes the naming task of the trained and exposed words, the investigator will say:
"Ok! Now let's start our training today."

Start from Step 1.

Experiment 2

Screening
The investigator will collect the performance of confrontation naming and the picture symbol-to-spoken word matching for all experimental stimuli (120 words) before the training starts. The picture symbols will be individually presented in random order. The screening tests should be with results of less than 20% accuracy across all 120 words.

The investigator will first start the naming screen. The investigator will say:

“I am going to show you 120 pictures. I will show one picture each time. I would like you to name them. You just try your best to name them.”

The investigator will collect data on a checklist with √ = correct; x = incorrect. Each picture will be showed 5 seconds, and then go to next word.

After the naming screen, the investigator will start the picture symbol to spoken words matching task the investigator will say:

“Next, you will listen to 120 words. I will present one word each time. I would like you to point the picture that matches the spoken word. If you don’t know, just say I don’t know.

The investigator will present a spoken word with 5 different picture symbols. Participants need to point the picture symbol that matches the presented spoken word. The investigator will collect data on a checklist with √ = correct; x = incorrect.

Treatment

*****Turn off the speaker when the assigned condition is without voice output*****

When the treatment starts, the investigator will follow the script below.
“Now, we are going to start our Chinese word training. After the training, I will ask you to draw two shapes following the dashed line. Then, I will ask you to name words. In addition, I will ask you to listen to words and find the picture which matches each word. Do you have any questions before we start?”

Answer participants’ questions or start Step 1.

Step 1:
The investigator will present the 20 exposed set one time in the beginning of a training session. The investigator will say:

”Now I want to show you some pictures on the tablet. I will touch the picture. You only need to look at those pictures. Let’s start.”

The investigator will present the exposed words to a participant with or without the voice output which depends on the assigned condition using the computerized training program. No feedback or extra information will be provided.

Step 2:

The investigator will start to train the participant using the trained set via a computerized AAC training program following the training modules with the 20 trained words. The investigator will say:

For condition with voice output: **"Now let's start the next task. I want you to learn some words on the device. You will hear a command from the tablet. When you find the word, I want you to touch the picture. Then, you will hear the tablet says the word."**

For condition without voice output: **"Now let's start the next task. I want you to learn some words on the device. You will hear a command from the tablet. When you find the word, I want you to touch the picture. Then, you will hear the tablet says the word."**

When Participant completes the module 1, the investigator will say

"Let's start the next practice. It is more difficult than the first one. Again, I want you follow commands and find the words"

Then, the investigator will turn on the module 2.

Step 3:

When Participant completes the two modules, the investigator will say"

"Before we start the next practice, do you need a 5-minute break?"

The self-paced training will start after a short break if the participant asks for it or the next module will start immediately. The investigator will say:

The investigator will say:

"Next, I would like you to do a practice by yourself. You will practice with the same materials that we have completed together. This time, I will not give you any feedback or help during the practice. When you are ready, let me know, I will turn on the training program for you. While you are practicing I will sit in front of you. When you complete the training, let me know."

When a participant is ready, the investigator will set up the module 1 for the participant.

Step 4:
When a participant completes the assigned training, the investigator will randomly pick two shapes from the appendix D and say:

"Now, I would like you to draw these two shapes (show the paper to the participant) following the dashed line. When you are done, please let me know."

Step 5:
The investigator will say:
"This time I will first show you some pictures and I would like you to name those pictures. You just try your best to name them."
After the participant completes the naming task of the trained and exposed words, the investigator will say:
"Here is the last part of today. Now you will listen to some words. I will play a word each time. Please point the picture that matches the word you hear."
After the participant completes the naming task of the trained and exposed words, the investigator will say:
"Ok! We are done for today. Thank you!"

Step 6: (implement in the beginning of a new session after the 1st session)
The investigator will say:
"Before we start the training today. I will like to show you the pictures we have worked in last session and I would like you to name those pictures. You just try your best to name them."

After the participant completes the naming task of the trained and exposed words, the investigator will say:
"Now you will listen to some words. I will play a word each time. Please point the picture that matches the word you hear."

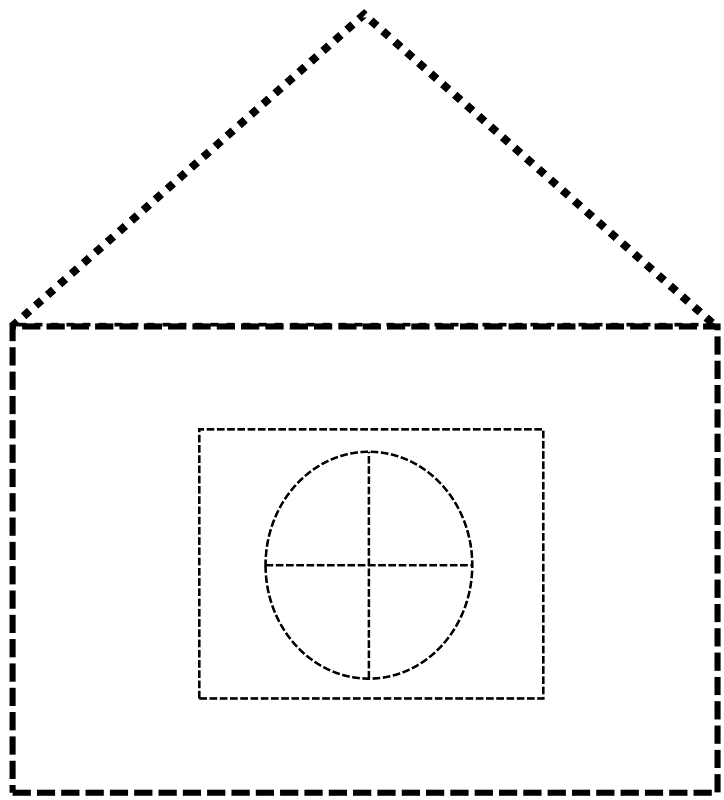
After the participant completes the naming task of the trained and exposed words, the investigator will say:
"Ok! Now let's start our training today."

Start from Step 1.

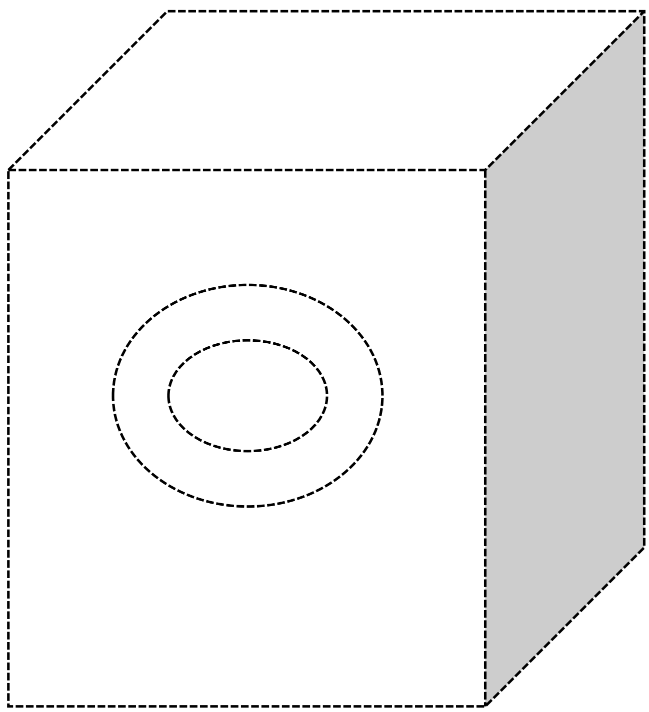
Appendix D

INTERFERENCE

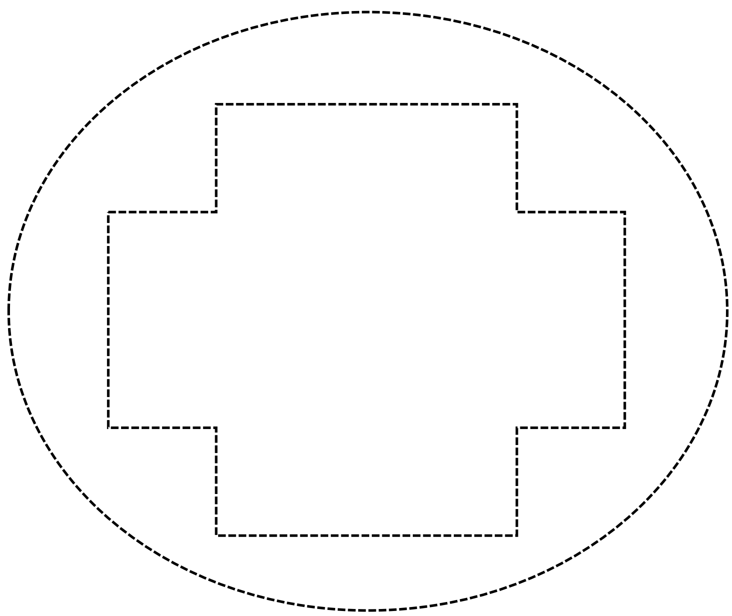
Interference 1



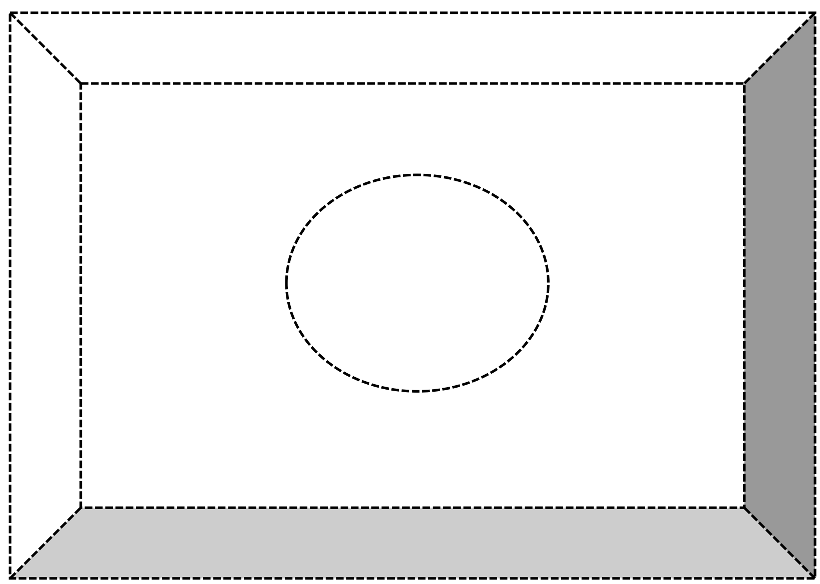
Interference 2



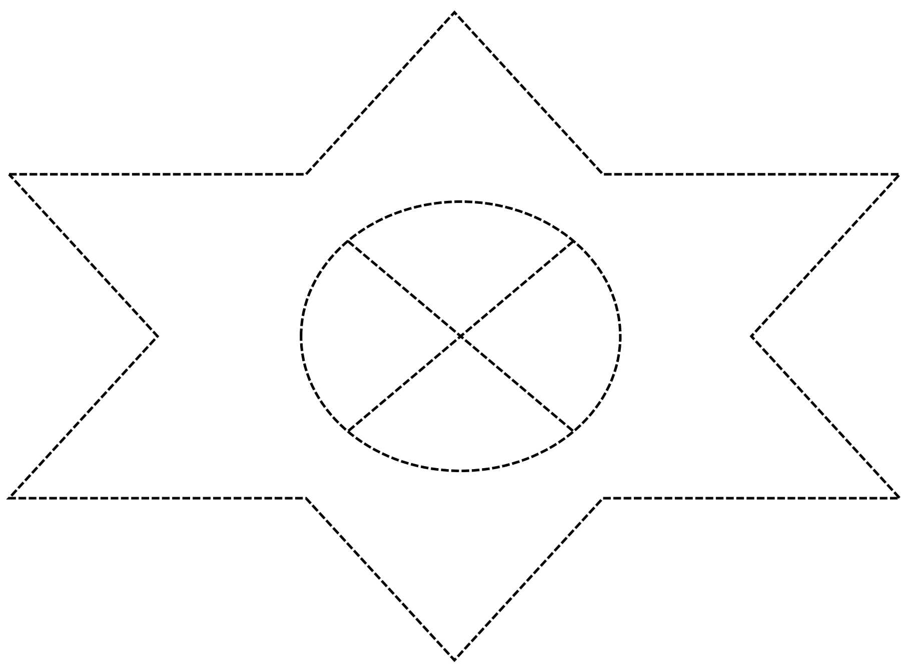
Interference 3



Interference 4



Interference 5



Appendix E

PARTICIPATION SATISFACTION SURVEY

Using the scale provided, please mark how much you agree or disagree with the following statements:

1	2	3	4	5
Strongly Disagree	Agree	Neutral	Disagree	Strongly Agree

1. I feel it is easy to learn to operate this training program	1 2 3 4 5
2. I can complete the self-practice by myself easily.	1 2 3 4 5
3. I feel that my naming is improved.	1 2 3 4 5
4. I feel that my speech is improved after the training	1 2 3 4 5
5. I like this type of training	1 2 3 4 5
6. Using the training program can be a frustrating experience.	1 2 3 4 5
7. I would like to continue the similar training after the study.	1 2 3 4 5
8. I will recommend others to use this training program.	1 2 3 4 5
9. Overall, I am satisfied with the training.	1 2 3 4 5

Appendix F

TREATMENT FIDELITY CHECKLIST

Direction: Mark x for items in which the condition was met.

Score	**Items**
	1. Participant was seated next to the SLP (investigator), with training program open in front of them.
	2. Investigator read all scripts of text.
	3. Investigator showed the exposed words to participant without any feedback.
	4. Investigator implemented the module 1
	5. Investigator followed prompting hierarchy
	6. Investigator implemented the module 2
	7. Investigator followed prompting hierarchy
	8. Investigator implemented the interference task
	9. Investigator implemented the tasks of naming and picture-to spoken word matching.

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