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Comparison of High-Tech Augmentative and Alternative Communication Interfaces: Do Age and Technology Experience Matter?

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COMPARISON OF HIGH-TECH AUGMENTATIVE AND ALTERNATIVE COMMUNICATION INTERFACES: DO AGE AND TECHNOLOGY EXPERIENCE MATTER?

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LIST OF ABBREVIATIONS

AAC = Augmentative and Alternative Communication

A-FROM = The Living with Aphasia: Framework for Outcome Measurement

ALPS = Aphasia Language Performance Scale

AOS = Apraxia of Speech

ASHA = American Speech-Hearing Association

AQ = Aphasia Quotient

BCI = Brain Computer Interface

CADL-2 = Communicative Activities of Daily Living-2

CETI = Communicative Effectiveness Index

CIAT = Constraint-Induced Treatment

CIU = Correct Information Unit

CIUs = Correct Information Units

ICF = International Classification of Functioning, Disability, and Health

MCT = Multimodal Communication Treatment

MCT+S = Multimodal Communication Treatment Plus Semantic Treatment

MDPQ-16 = Mobile Device Proficiency Questionnaire-16

M-MAT = Multimodality Aphasias Therapy

MoCA = The Montreal Cognitive Assessment

PCS = Picture Communication Symbols

PROSE = Predictive Retrieval of Story Extracts

PWA = People with Aphasia

SGDs = Speech Generating Devices

VSD = Visual Scene Display

VSDs = Visual Scene Displays

WAB = Western Aphasia Battery

WHO = World Health Organization

ABSTRACT

Previous research has demonstrated that individuals with stroke-induced aphasia can use augmentative and alternative communication (AAC) when they cannot meet their communication needs using spoken language (Dietz, Weissling, Griffith, McKelvey, & Macke, 2014; Purdy & Van Dyke, 2011). Of the various interfaces found in the different AAC systems, the grid display and the visual scene display (VSD) have been used by individuals with aphasia (Hough & Johnson, 2009; Dietz et al., 2018). However, there is a scarcity of research examining the comparative usefulness of these interfaces.

This prospective study attempted to understand how neurologically healthy individuals of different ages and varying levels of technology experience describe composite pictures using the grid and VSD interfaces presented on a high-tech AAC system.

The study included three groups: 18 young adults (18 to 39 years), 24 older adults with technology experience, and 20 older adults with limited technology experience. Both older adult groups were age ranged between 60 to 91 years. Participants described two composite pictures with each AAC interface presented on an iPad. They were allowed 4-minutes to describe each picture.

A mixed between and within-subject design was utilized to analyze three dependent variables: 1) the total number of correct information units (CIUs; Nicholas & Brookshire, 1993), 2) the percentage of CIUs, and 3) CIUs per minute.

The study results show a significant difference between each older adult group and the younger adult group for total CIUs ($p < .000$) and CIUs per minute ($p < .000$). There was no significant difference across the two older adult groups. Additionally, there was no significant difference in performance across the two interfaces for any of the groups.

The findings show that age does impact performance, with young adults producing more CIUs and more CIUs per minute than older adults. However, the difference in technology experience found in the older adult groups did not impact performance. Furthermore, both interfaces used in the current study were equally beneficial for describing pictures.

INTRODUCTION

Communication and Language

Communication is commonly defined as an exchange of information to meet various needs (Hedge, 2010) and is not a behavior that is unique to humans. It can be further defined as "a means by which individuals relate their wants, needs, thoughts, feelings, and knowledge to another person" (Fogle, 2019, p. 3). This act of communication encompasses different forms (e.g., a dog barking to indicate hunger, nodding one's head in acknowledgment, and writing a letter to a colleague), and language is one such form.

Language is a complex and uniquely human trait essential for communication (Fedurek & Slocombe, 2011). Furthermore, language involves using symbols and codes adhering to a set of rules in order to produce either oral or non-oral communication (Fogle, 2019; Hedge, 2010). Speech, also known as spoken language, is the most common form of oral communication produced by most individuals. In other words, individuals use speech (i.e., by the help of articulators) to deliver language. However, language can be manifested as a non-oral communication (i.e., without using articulators) as seen in sign language.

During our childhood, we develop our first language without any specific training. Consequently, we say that our first language is acquired rather than learned. For most of us with intact perceptual, cognitive, and motor skills, our first language is produced using speech, also known as the spoken language.

However, the effortless use of speech is not possible for all individuals (Beukelman & Ray, 2010). Due to various developmental and acquired speech and language disorders, some individuals struggle to meet their communication needs via natural speech. Of these individuals, some will require other language systems and methods to meet their communication needs.

Aphasia

Although aphasia is one of the most prevalent acquired language disorders, with more than 2 million individuals in the United States diagnosed (National Aphasia Association, 2018), it is not a condition familiar to the general public. Aphasia arises from damage to the language-specific regions of the brain (Papathanasiou & Coppens, 2017), and commonly occurs due to stroke, also known as cerebrovascular accident (Kelly, Brady & Enderby, 2010; Marshall et al., 2016). The language deficits that manifest with aphasia may affect all modalities, such as speaking, listening, reading, writing, and signing (Papathanasiou & Coppens, 2017). Aphasia may also affect various linguistic structures such as phonology, morphology, syntax, semantics, and pragmatics (Papathanasiou & Coppens, 2017). These linguistic deficits give rise to communication breakdown, which interferes with successful engagement in everyday activities, education, work, relationships, and participation in society.

The multifaceted nature of aphasia and its impact that goes beyond an individual's language and communication has been captured by the following definition:

> An acquired selective impairment of language modalities and functions resulting from a focal brain lesion in the language-dominant hemisphere that affects the person's communicative and social functioning, quality of life, and the quality of life of his or her relatives and caregivers. (Papathanasiou & Coppens, 2017, p. 4).

Of those diagnosed with aphasia, some may regain their language while close to 50% will continue to exhibit challenges when using their language for communication (Laska, Hellbolm, Murray, Kahan, & Von Arbin, 2001). The introduction of the International Classification of Functioning, Disability, and Health (ICF; WHO, 2001) has shifted the paradigm of treatment for health conditions from solely a medical approach to a biopsychosocial approach. Consequently, treatment is no longer restricted to the body function and structural deficits (i.e., an impairment-based treatment). Rather it is now recognized that researchers and clinicians must consider how aphasia impacts everyday life activities and an individual's participation in the social world. Furthermore, the ICF delineates the roles that the environment and an individual's personal characteristics play in functioning, disability, and health (WHO, 2001). The Living with Aphasia: Framework for Outcome Measurement (A-FROM; Kagan et al., 2008) was developed specifically for aphasia utilizing the ICF model (WHO, 2001). According to the A-FROM (Kagan et al., 2008), both traditional impairment-based treatment (e.g., training of grammatical structures, semantic feature analysis) and compensatory treatments (e.g., Augmentative and Alternative Communication) are encouraged. Additionally, caregiver training and environmental changes are also emphasized to improve the well-being of people with aphasia.

Defining Augmentative and Alternative Communication

When individuals cannot meet their communication needs with the use of a natural language such as speech, it becomes crucial to look for alternative methods of communication. The field of augmentative and alternative communication (AAC) emerged to meet the needs of the many individuals who do not have adequate speech for communication. AAC was defined by the special interest division of AAC of the American Speech-Language-Hearing Association (ASHA) as follows:

> An area of research, clinical, and education practice. AAC involves attempts to study and, when necessary, compensate for temporary or permanent impairments, activity limitations and participation restriction of individuals with severe disorders of speech-language production and/or comprehension, including spoken and written modes of communication. (The Special Interest Division of AAC, ASHA, 2005, p.1).

According to the above definition, AAC is not only considered as an alternative form of communication in the absence of speech but also a means of supplementing communication when spoken language is inadequate to meet a person's needs (Dietz et al., 2018; Moffat, Pourshahid, & Baecker, 2017). Additionally, AAC has been used to support the reading deficits in individuals with acquired language disorders (Dietz, Hux, McKelvey, Beukelman, & Weissling, 2009).

Classification of AAC Systems

There are various AAC tools and strategies to enhance communication in those with spoken language deficits. These tools and strategies are collectively known as AAC systems. Each AAC system has unique characteristics to support the needs of those with communication deficits.

Types of AAC Systems

AAC systems can be defined as 'unaided' or 'aided.' The unaided systems use one's own body to communicate (e.g., signs, gestures, and facial expressions). In contrast, the aided systems require the use of one's body combined with other materials and devices (e.g., communication books, pictures, paper and pencil, computer, or speech generating device/SGD) (Sigafoos & Drasgow, 2001; Smith & Connolly, 2008). Additionally, aided AAC systems can be further described as low-technology (low-tech) or high-technology (high-tech) (Baxter, Enderby, Evans, & Judge, 2012). The low-tech aided systems include writing, pointing to objects, pointing to pictures on a book (e.g., communication book), and pointing to images on a board (e.g., communication board).

High-tech aided systems use computer or mobile technology. Hence, high-tech systems can generate digitized speech output and are also known as speech-generating devices (SGDs). Some of these high-tech AAC systems can be defined as dedicated SGDs (e.g., Tobii Dyanavox, Lingraphica) because they are used exclusively for communication by those with speech and language deficits. High-tech AAC also includes AAC mobile software, also known as AAC apps (e.g., Proloquo2Go™, TouchChat™), designed for mobile or tablet devices. Historically, the most commonly used AAC systems were the unaided and low-tech systems. However, aided high-tech systems are becoming increasingly popular (Zangari, Lloyd & Vicker, 1994) o the dynamic storage options for vocabulary and the ability to generate speech output (Caron, Light, Davidoff, & Drager, 2017). All AAC systems have different symbol options and are organized in different layouts informed by clinical observations, research, and individual needs.

Types of Symbols and Interfaces

Our spoken language consists of symbols manifested as sounds and words. Similarly, AAC uses various symbols. There are two main categories of symbols used in AAC systems; these are known as unaided symbols and aided symbols (Beukelman & Mirenda, 2013; Smith & Connolly, 2008). Unaided symbols rely on one's own body and include gestures, facial expressions, vocalizations, and signs (Beukelman & Mirenda, 2013). On the contrary, aided symbols depend on an external item such as a real object, miniature object, pictorial symbol, or an orthographic symbol. The aided symbols have various characteristics that can be manipulated based on individual needs. Some of these symbol characteristics include realism, iconicity, ambiguity, complexity, figure-ground difference, acceptability, color, and size (Fuller, Lloyd & Stratton, 1997; Schlosser, 2003; Schlosser & Sigafoos, 2002).

Efficient communication requires easy access to these symbols during a conversation. To this end, researchers have attempted to identify different methods of organizing these symbols, also known as interfaces. The grid display is the most widely used interface. In the grid display, individual symbols are placed within separate spaces within a grid (Garrett & Huth, 2002; Ho, Weiss, Garrett, & Lloyd, 2005). See Figure 1 for an example of a grid display.

In high-tech grid displays, these symbols are organized hierarchically. Hence, the homepage (also known as Page 1 or Level 1) will have multiple folders that store words related to predetermined categories. For example, the homepage will include folders labeled with superordinate words (e.g., clothes, vehicles) to represent categories. When a superordinate category is selected, different pages with related subcategories (e.g., office wear, nightwear) will open further down the hierarchy until a specific item (e.g., trousers) is reached. Some grid displays may use phrases instead of single words.

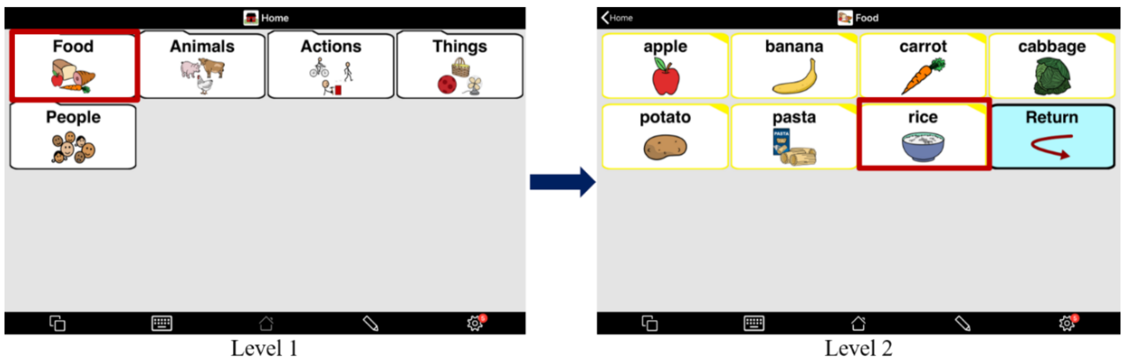


Figure 1. A High-Tech Grid Display Programmed Using Proloqu2Go App
Note. This depicts the hierarchical organization of a grid display with two pages, also known as levels. The image on the left is the homepage, which includes folders for various superordinate categories. The selection of the folder labeled as food on the left opens the second page on the right with specific food labels. These screenshots of Proloquo2Go pages have been customized for this study and used with permission.

Besides the grid display, the Visual Scene Display (VSD) is yet another interface used in aided AAC systems. See figure 2 for a snapshot of a VSD. The VSD consists of pictures and photographs that provide rich contextual information. In a VSD, the key concepts, such as people, actions, and objects related to the picture, are placed within the scene itself (Blackstone, 2004). For example, a picnic photograph will include all related concepts such as people, food, feelings, and various actions depicted in the scene. The Visual Scene Displays (VSDs) can take different formats. For example, the VSD can have written word labels within the picture or next to the picture. See figure 2 for an example of a VSD. In both grid and VSD interfaces, the symbol type and symbol interface can be further personalized to meet the user’s needs (Light, Wilkinson, Thiessen, Beukelman & Fager, 2019). For example, in a grid display, the symbols can be organized based on linguistic theories, motor learning theories, or a combination of these theories.

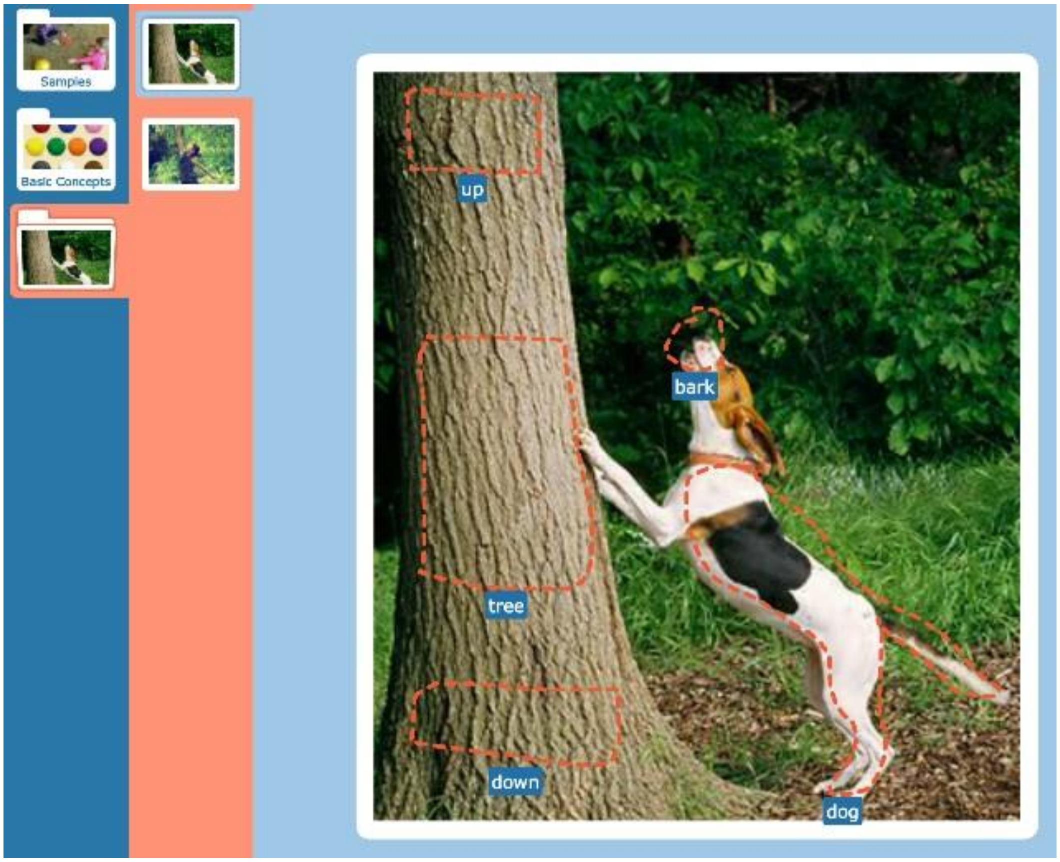


Figure 2. A High-Tech Visual Scene Display Programmed Using Snap Scenes App
Note. The image shows hotspots that are outlined with dotted lines and labeled using corresponding words. Touching a hotspot will result in the production of the word. This VSD interface has been adapted with permission from Tobii Dynavox, LLC. Copyright 2020 by Tobii Dynavox.

A grid display that uses a linguistic theory organizes symbols based on semantic categories in a hierarchical structure. Hence, semantically related items are grouped together. According to motor learning theories, repeated goal-directed movement results in the movement becoming automatic, thereby limiting cognitive resources needed to recall the steps for the targeted behavior (Keele, 1968; Schmidt & Lee, 2005). AAC systems have attempted to use strategies that enhance motor learning when organizing symbols. One strategy that enhances motor learning is using a fixed location for symbols with only one navigation sequence (Thistle & Wilkinson, 2013). Additionally, the image or the symbol type can be varied from photographs to line drawings on the grid display.

For the VSD interface, symbols can be created either using line drawings or photographs. Furthermore, VSD interfaces can be designed with or without written labels (Griffith, Dietz, & Weissling, 2014). According to Light et al. (2019), VSDs produced for individuals with developmental disorders included hotspots that produce separate words. However, VSDs for individuals with aphasia have used multiple written messages alongside the image instead of single words (Light et al., 2019).

Access Methods

In AAC, access methods indicate how a person interacts with an AAC interface. Direct access indicates that the user will select symbols with either touch, pointing, or eye gaze. For example, the individual using the AAC system will point to a picture on a communication book to express a target word. Indirect access methods are available for individuals who have impaired motor or perceptual skills. Some of the indirect access methods used in AAC include scanning and brain-computer interface (BCI) (Beukelman & Mirenda, 2013; Brumberg, Pitt, Manti-Kozlowski & Burnison, 2018).

Justification for the Study

All individuals diagnosed with aphasia will not recover their language skills to premorbid levels (Laska et al., 2001; Wade, Hewer, David, & Enderby, 1986). Furthermore, because aphasia is a heterogeneous condition, individuals may present with varying degrees of language deficits in different modalities.

Some individuals with aphasia may have severe language deficits that require AAC to meet their functional communication needs. According to the research literature, people with aphasia have benefited from numerous AAC systems, from low-tech to high-tech (Dietz, Weissling, Griffith, McKelvey & Macke, 2014; Knollman-Porter, Brown, Hux, Wallace, & Uchtman, 2016; Purdy & Van Dyke, 2011; Rao, 1995; Steele, Aftonomos & Koul, 2010; van de Sandt-Koenderman, 2004). Furthermore, individuals with aphasia have used AAC for different reasons. For some, AAC helped supplement language skills (Knollman-Porter et al., 2016; Rao, 1995; van de Sandt-Koenderman, 2004), while for others, it acted as an alternative means of communication due to limited or no useful verbal language skills (Steele et al., 2010). Additionally, there has been preliminary evidence to demonstrate that AAC may enhance spoken language skills (Albright & Purves, 2008; Dietz et al., 2018) and stimulate neurological changes (Dietz et al., 2018; Kleih, Gottschalt, Teichlein & Weilback, 2016). Furthermore, it was argued that AAC uses intact brain regions, thereby encouraging the brain's reorganization for positive communication outcomes (Dietz et al., 2018). Consequently, AAC appeared to have multiple uses for people with aphasia.

Examination of how people with aphasia use AAC indicates that early research encouraged the use of gestures, drawing, pointing to pictures on a communication book or board (Bellaire, Georges, & Thompson, 1991; Purdy, Duffy & Coelho, 1994; Rao, 1995; Sacchett, 2002). These low-tech AAC systems are continuously investigated as a treatment option for this population. For example, the Multimodal Communication Training (MCT; Purdy et al., 1994) encourages the use of any modality to compensate for spoken deficits. The MCT with individuals with chronic aphasia resulted in increased communication ability in structured settings (Purdy & Van Dyke, 2011; Purdy & Wallace, 2016; Wallace & Kayode, 2017).

The ability to store more extensive vocabulary and create personalized symbols makes high-tech AAC systems more advantageous than low-tech systems such as communication books and communication boards. Despite the usefulness of low-tech systems for this population, the research literature also gives evidence that some people with aphasia can adopt these high-tech AAC systems to support their communication needs during treatment (Johnson, Hough, King, Vos & Feffs, 2008; McKelvey, Dietz, Hux, Weissling, & Beukelman, 2007; Steele et al., 2010). There are different types of high-tech AAC systems used by this population. However, non-use of high-tech AAC systems may occur when the appearance of dedicated SGDs highlights communication deficits (Linebarger, Romania, Fink, Bartlett & Schwartz, 2008). On the contrary, AAC apps are relatively inexpensive compared to dedicated SGDs and considered socially more acceptable because they can be used on a tablet or a smartphone (McNaughton & Light, 2013). Hence, the use of AAC apps on a tablet device may increase use and acceptance by people with aphasia

Typically, aided high-tech AAC systems for people with aphasia organize symbols using two interfaces: grid display (Koul, Corwin, Nigam, & Oetzel, 2008; Johnson et al., 2008) and visual scene display (VSD) (Griffith et al., 2014). According to the research literature, people with aphasia were successfully trained on both the grid display (Hough & Johnson, 2009; Johnson et al., 2008; Koul et al., 2008) and the VSD (Dietz et al., 2018; Griffith et al., 2014; McKelvey et al., 2007). However, only one known study investigated the comparative effectiveness of these two interfaces (Brock, Koul, Corwin & Schlosser, 2017). According to Brock et al. (2017), the two people with aphasia who participated in their study took more turns when using the VSD. Furthermore, frustration was less during navigation with the VSD (Brock et al., 2017).

The scarcity of research comparing the grid display and VSD indicates the need for further investigation to understand users' comparative utility during various communication tasks. Additionally, most VSD interfaces for individuals with acquired communication disorders utilized preprogrammed complete utterances to reduce the demand on working memory (Light et al., 2019). However, there are no known studies that investigated the use of VSD interfaces with different design options for people with aphasia or neurologically-healthy adults. For example, there are no known studies on VSDs with hotspots that allow activation of a single word at a time in utterance formulation.

Furthermore, previous studies have used familiar high context images (e.g., personal photographs) or identical images related to the story that was narrated. In Brock et al. (2017) study, participants described episodes of a television program. Hence, the researchers took pictures from the television episodes and programmed them to the VSD interface. Including identical pictures restrict the VSD from being used with a different task or communicative situation. Hence caregivers and individuals involved in programming the AAC system would need to develop a new set of scenes for each communicative situation. Furthermore, using identical pictures make it difficult to know if the individual selected the word or message with meaning or it was a random act of matching. However, the AAC literature for people with aphasia or healthy adults has no evidence for using VSD interfaces with high context scenes that are different from the stimulus being described along with single word hotspots.

According to Light et al. (2019), to further advance the field of AAC, there is a need for future research that examines different AAC interface designs for various populations. Correspondingly, there is a need to investigate other design options within the grid and VSD interfaces for people with aphasia.

The evidence for people with aphasia using AAC should be viewed cautiously due to small sample sizes, the number of case studies reported, and lack of experimental control. In fact, we know very little about how neurologically intact adults interact with high-tech AAC systems. Spoken language involves the production and comprehension of speech; this is acquired effortlessly by most individuals with intact perceptual and cognitive skills during their early childhood. However, adopting AAC might be more challenging than a natural language such as spoken language for various reasons. For example, a spoken language learner has multiple opportunities to observe and imitate spoken language used by others (e.g., parents, siblings, and peers). On the contrary, because very few people use AAC, and because AAC systems are heterogeneous, it is more challenging to learn AAC through observation and interaction. Furthermore, the general public is unfamiliar with AAC systems, which further limits the number of communication partners for those who use AAC. In addition, AAC requires a different set of skills not needed for verbal language. Some of these skills include the ability to navigate an external device by becoming proficient in device operation, as well as learning the linguistic symbols used (Light, 1989).

Consequently, to use AAC competently, it is necessary to master motor and visual/auditory skills to operate the system, navigation through symbols, and linguistic skills associated with symbols found in their system. Before the onset of aphasia, individuals were competent communicators with a pre-established language system that involved a defined skill set. Hence, for individuals with aphasia who experience changes in information processing due to their neurological deficits, learning a new set of skills may be quite challenging. In fact, we know very little about how neurologically healthy adults with an established language learn an AAC system, which is different from spoken language. Thus, examining how neurologically intact adults with a pre-established linguistic system adopt AAC will provide useful information when introducing AAC systems to adults with neurological conditions such as aphasia.

Furthermore, different AAC design options require individuals to use AAC in different ways. For example, some systems require individuals to identify abstract symbols to represent a concept (Bartlett, Fink, Schwartz, & Linebarger, 2007; Linebarger et al., 2008). Hence, a new set of skills need to be learned based on the AAC system one chooses to use. Consequently, examining neurologically intact adults using different AAC displays may help understand the ease of use and skills needed for each unique interface. Additionally, due to language deficits, people with aphasia can struggle to self-report preferences for AAC systems and reasons for choices. However, by studying neurologically healthy adults, it is possible to gain answers to these questions, which in turn may help improve AAC designs for those with communication difficulties.

Stroke, also known as a cerebrovascular accident, is one of the leading causes of aphasia (Kelly et al., 2010; Marshall et al., 2016). As a result, older adults are at a higher risk of stroke-induced aphasia (Ellis & Urban, 2016). Furthermore, there is an increased likelihood that older adults have limited exposure to technology. Consequently, this may impact the use of high-tech AAC systems. Device features (Higginbotham & Caves, 2002; Meder & Wegner, 2015), ease of use (Bailey, Parette, Stoner, Angell & Carroll, 2006; Beukelman & Mirenda, 2013), and technology issues (Smith & Connolly, 2008) have played a role in adopting high-tech AAC systems in populations outside of aphasia. Similar challenges may be expected with people with aphasia and those who are older adults. In fact, studies of older adults and the use of technology suggest that older adults face challenges in adopting technology in the form of computers and smartphones (Chiu et al., 2016; Hale, Cotton, Drentea, & Goldner, 2010; Hwangbo, Yoon, Jin, Han, & Ji, 2013; Leung, McGrenere & Graf, 2011). However, the use of technology in the older adult population can vary based on exposure to technology, technology availability, attitudes, and skill (Broady, Can, Caputi, 2010; Schreurs, Quan-Haase, & Martin, 2017). Consequently, being advanced in age does not always suggest that an individual will most certainly struggle with technology. Although there is a higher likelihood of older individuals to demonstrate difficulties in using technology (Chiu et al., 2016; Hale et al., 2010; Hwangbo et al., 2013; Leung, McGrenere & Graf, 2011), it is not known how experience with technology can impact high-tech AAC use. Besides, there are no known studies that look at the role of technology experience and performance on high-tech AAC systems.

Additionally, healthy aging results in various neurological changes (Marques et al., 2016). Changes in visual perception (Anderson, 2012), executive function (Brennan, Welsh, & Fisher, 1997; MacPherson, Phillips, & Della Sala, 2002), attention (Tse, Balota, Yap, Duchek, & McCabe, 2010), speed of processing (Kennedy & Raz, 2009; Park & Reuter-Lorenz, 2009), and working memory (Kennedy & Raz, 2009) may impact high-tech AAC even in healthy older adults. Therefore, it is crucial to understand how healthy older adults use AAC and to understand if a particular AAC interface is more conducive based on age. However, no known studies have examined how neurologically healthy adults use different AAC interfaces. Likewise, there are no known studies that examine the comparative performance on different interfaces across age-groups and varying levels of technology experience.

Study Purpose

The purpose of this prospective study was to understand how neurologically healthy individuals of different ages (e.g., young adults and older adults), and varying levels of experience with technology describe composite pictures using two AAC interfaces: a grid display and VSD. The two interfaces were programed using commercially available AAC apps and presented via an iPad. Participants interacted with each interface using direct activation by pointing on the touchscreen iPad. The findings from this study will provide normative data on how neurologically healthy adults of different age groups perform on these interfaces with limited training. Furthermore, the study will help understand the role of technology experience in using high-tech AAC systems, especially in the older adult population. This study examined different design options for presenting symbols; therefore, it aligns with future AAC research needs required to move the AAC field forward (Light et al., 2019).

The participants' performance on the grid and VSD interfaces were measured based on 1) the number of Correct Information Units (CIUs: Nicholas & Brookshire, 1993), 2) the percentage of CIUs, and 3) CIUs per minute.

Research Questions and Hypotheses

1) Are there differences among young adults, older adults who have experience with technology, and older adults who have limited experience with technology when describing composite pictures using AAC interfaces as measured by the number of CIUs, percentage of CIUs, and CIUs per minute?

   Hypothesis: A statistically significant difference between groups was anticipated.

   The young adults were expected to outperform both older adult groups because young adults have increased exposure to technology during everyday life activities and may have started using technology at a younger age compared to older adults. According to research, older adults face more challenges when using technology (Chiu et al., 2016; Hale et al., 2010; Hwangbo et al., 2013; Leung et al., 2011), which may impact using AAC apps.

One of the older groups has relatively more experience using mobile technology. However, perceptual and attention deficits, along with slower reaction time, common in older adults, may affect their performance compared to the young adult group (Anderson, 2012, Brennan et al., 1997; Tse et al., 2010).

Furthermore, when comparing the two older adult groups, it may be expected that the older adult group with technology experience to outperform the older adult group with limited technology experience. This outcome was anticipated because increased technology experience may be advantageous in using high-tech AAC systems such as AAC apps. According to Chiu et al. (2016), older adults can learn to use technology successfully if they have had prior experience. In fact, lack of exposure can increase anxiety when using technology (Chiu et al., 2016), which may negatively affect an individual's performance. Consequently, older adults with limited technology experience may experience more challenges navigating the AAC apps.

2) Are there differences among young adults, older adults who have experience with technology, and older adults who have limited experience with technology when describing composite pictures using the grid display and VSD as measured by the number of CIUs, percentage of CIUs, and CIUs per minute?

Hypothesis: A statistically significant difference across the two interfaces was anticipated.

A higher number of CIUs, a percentage of CIUs, and CIUs per minute were anticipated when participants use the VSD compared to the grid display. Previoius studies have found that people with aphasia can attend more quickly and frequently to objects presented in task engaged photographs (Thiessen, Beukelman, Ulman & Longenecker, 2014). Similarly, because the VSDs use contextual images that are task engaged, It was expected for neurologically healthy adults to locate these target words easily and, in less time, compared with the grid display. In fact, according to Oliva and Torralba (2007), the processing of visual information occurs faster when presented in natural scenes. As VSDs are natural scenes, I expect the participant to navigate more quickly when using the VSD, resulting in better outcomes compared to the grid display.

3) Which AAC interface was preferred by young adults, older adults who have experience with technology, and older adults who have limited experience with technology and why?

It was hypothesized that all groups would prefer the VSD due to the use of photographs and ease of finding words. However, it was anticipated that some individuals within groups to prefer the grid display owing to individual differences.

LITERATURE REVIEW

Classification of Aphasia

Aphasia is a heterogeneous condition in which individuals present with varying language deficits. For that reason, aphasia classification systems have emerged to group individuals based on different language characteristics. One classification system groups people with aphasia based on verbal language output. According to this classification, individuals who produce connected verbal output in the absence of halting speech have fluent aphasia. On the contrary, those who have limited verbal output characterized by halting speech have non-fluent aphasia (Davis, 2007). Currently, the most common classification system of cortical aphasia is the neoassociationist model (Geschwind, 1967). According to the neoassoicationis model, lesion-specific language characteristics define the aphasia subtypes (Papathanasiou & Coppens, 2017). See Table 1 for the common characteristics associated with the various subtypes of aphasia.

Table 1. Characteristics of the Subtypes of Aphasia Based on Neoassociationist Classification

Types of Aphasia	Fluency	Comprehension	Repetition	Naming
Broca's	Non-fluent	Relatively intact	Poor	Poor
Wernicke's	Fluent	Relatively poor	Poor	Poor
Conduction	Fluent	Relatively intact	Poor	Poor
Transcortical motor	Non-fluent	Relatively intact	Intact	Poor
Transcortical sensory	Fluent	Relatively poor	Intact	Poor
Anomic	Fluent	Relatively intact	Intact	Poor
Global	Non-fluent	Relatively poor	Poor	Poor

Evolution of Aphasia Theories

To understand and describe aphasia, numerous theories and models emerged throughout history. These theories resulted from the wide-ranging characteristics of aphasia (McNeil & Copland, 2011) and the advancement in methods of inquiry to anatomy and the brain's function (Marebwa et al., 2017; Ulm, Copland, & Meinzer, 2018).

Localization View

According to this theory, researchers assumed specific areas of the brain to be specialized for specific tasks (Ardila, Bernal, & Rosselli, 2015). Consequently, specialized language centers were thought to be localized in the brain.

There were several influential findings related to this theory: Paul Broca's identification of the left hemisphere anterior brain region for language production, Carl Wernicke's posterior language area, and Litchtheim's model of language processing (Doody, 1993; Papathanasiou & Coppens, 2017; York III, 2009).

Connectivity View

The advancement of neuroimaging techniques led to the understanding that language processing to be associated with brain networks (Marebwa et al., 2017; Ulm et al., 2018) and not be limited to specific regions, as suggested by the localization view. Studies that demonstrated the activation of multiple brain areas during language processing provided evidence for this view (Ardila et al., 2015; Delshad, Nilipour, Barekatain & Oghabian, 2017).

Cognitive Neuropsychological Approach

According to McNeil & Copland (2011) and Papathanasiou & Coppens (2017), language processing consisted of various subcomponents or modules responsible for specific tasks. For example, a single word production may involve processing in multiple modules such as in the phonological input lexicon, semantic system, phonological output lexicon, and in the response buffer. Hence, based on this approach, processing in each module occurs independently from other modules (McNeil & Copland, 2011).

Accordingly, the language characteristics manifested in different types of aphasia were indicative of disruptions that occur in one or more of these modules. Several models have emerged for single word processing (Ellis & Young, 1988) as well as for sentence processing (Garrett, 1984) based on this cognitive neuropsychological approach.

Computational Connectionist Approach

This approach emerged due to the lack of clarity regarding the interaction between modules described in the cognitive neuropsychological approach (McNeil & Copland, 2011). In this approach, language processing moved away from solely independent modules to more interconnected processing. Consequently, a word production task may consist of multiple connections with other modules. Additionally, some connections were considered stronger, while others were weaker, allowing error monitoring and subsequently correct word production (Purdy & Van Dyke, 2011). The language characteristics seen in aphasia are thought to be the result of the destruction and/or weakening of these connections (McNeil & Copland, 2011). There are several models based on the computational approach (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Levelt, Roelofs, Meyer, 1999; Schwartz, Dell, Martin, Gahl, & Sobel, 2006).

The Biopsychosocial Approach to Aphasia

The language deficits in aphasia may affect many aspects of the individual's well-being as well as their family. The biopsychosocial approach to treatment emerged as a holistic method with an emphasis on increasing quality of life (Papathanasiou & Coppens, 2017). Treatment provided in this approach focuses on "biological impairment-based factors and the psycholinguistic and cognitive processes to language and communication within the social context of the person with aphasia" (Papathanasiou & Coppens, 2017, p. 116). In other words, the approach looks at how the physical, language, and cognitive factors impact the functioning in the social world. The Living with Aphasia: Framework for Outcome Measurement (A-FROM; Kagan et al., 2008) was explicitly developed for those with aphasia utilizing the biopsychosocial approach found in the International Classification of Functioning, Disability and Health (ICF; WHO, 2001).

The A-FROM (Kagan et al., 2008) consists of four overlapping domains that result in life with aphasia: language and related processing, environment, personal factors, and participation (Simmons-Mackie, King & Beukelman, 2013). The language and related processing domain represent subcategories related to processes for speaking, understanding, writing, and reading. The environment domain represents external factors that impact the communication of the person with aphasia. Subcategories within this domain include the knowledge and attitude of people in the environment, other people's skills to support communication, the physical environment, resources, and services, systems, and policies. The personal factors and identity domain represents factors internal to the person with aphasia; these include the person's identity, confidence, self-esteem, age, gender, and others. The participation domain emphasizes personally relevant life activities such as implementing roles and responsibilities, leisure and recreation, relationships, communication and conversation, and community involvement. Hence, targeting each domain in the biopsychosocial approach may lead to increased communicative participation and improved quality of life. See Figure 3 for A-FROM (Kagan et al., 2008).

The early approaches to aphasia treatment emphasized impairment-based (also known as linguistic-based) programs (i.e., training of grammatical structure, intensive auditory stimulation, semantic feature analysis) to remediate language deficits (Van de Sandt-Koenderman, 2004). However, within the A-FROM (Kagan et al., 2008), any treatment approach which includes both restorative and compensatory methods may be included with the ultimate goal to increase well-being. Various treatments that can be incorporated within this framework include; noninvasive brain stimulation (Hamilton, Chrysikou & Coslett, 2011; Lefaucheur et al., 2017), caregiver training (Arroyo, Goldfarb, & Sands, 2012; Kent-Walsh & McNaughton, 2005; Purdy & Hindenlang, 2005), and augmentative and alternative communication (AAC) methods and systems (Dietz et al., 2014; Knollman-Porter et al., 2016; Purdy & Van Dyke, 2011; Steele et al., 2010; van de Sandt-Koenderman, 2004).

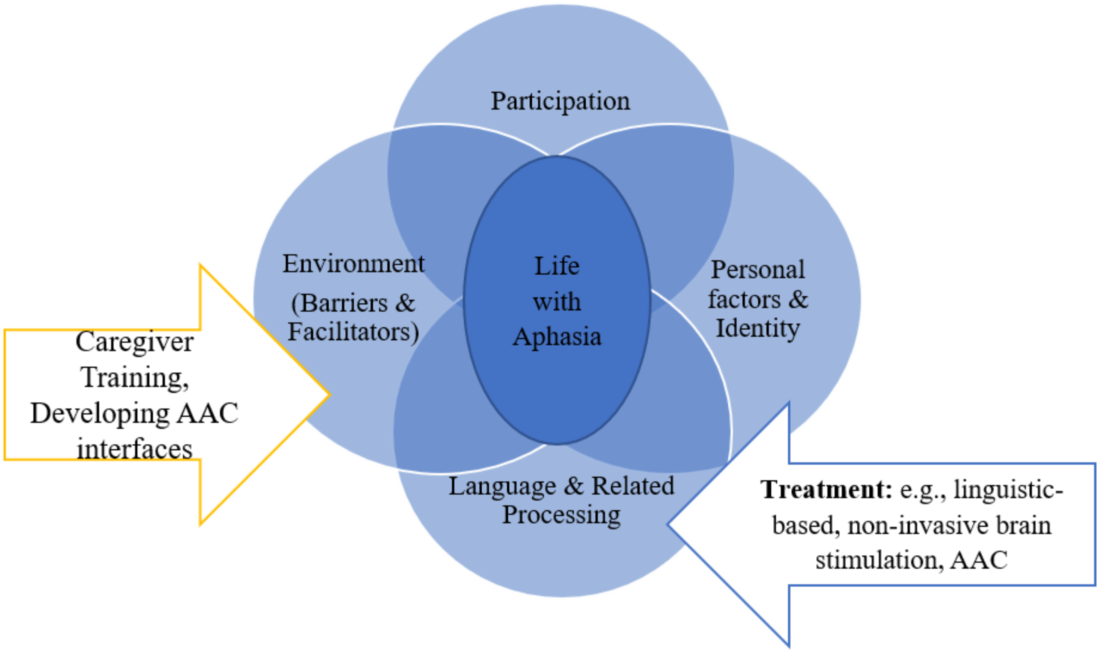


Figure 3. Living with Aphasia: Framework for Outcome Measurement (A-FROM) Adapted with permission from Kagan, A., Simmons-Mackie, N., Rowland, A., Huijbre, M., Shumway, E., McEwan, S.,…S. Sharp, 2008, *Aphasiology, 22,* p. 266. Copyright 2008 by Aphasia Institute.

The Use and Development of Augmentative and Alternative Communication

AAC consists of various techniques and systems that allow an individual with limited verbal language to meet his or her communication needs (Beukelman & Mirenda, 2013). AAC can be used with individuals who have developmental and acquired communication deficits (Garrett, Beukelman, & Low-Morrow, Mirenda, 2014; Purdy & Van Dyke, 2011; Rao, 1995; Romski et al., 2010; Wallace & Kayode, 2017). Historically, AAC was used by individuals with developmental disorders and with some individuals with acquired speech disorders.

A speech disorder occurs due to impairment in planning, programming, control, and execution of muscles needed for speech (Duffy, 2013). Consequently, an individual may not be able to adequately use oral muscles to produce speech that a listener understands. However, in a language disorder such as aphasia, deficits are linguistic (e.g., vocabulary, grammar, reading ability) with no oral motor muscle deficits. Individuals who have an isolated speech deficit may have intact language but may not be able to produce speech.

Currently, there has been a growth in the population of AAC users, including individuals with acquired speech deficits and language deficits (Estes & Bloom, 2011; Zangari et al., 1994). This growth in the number of consumers has occurred owing to the advancement in technology that has made AAC more accessible for individuals with varying communication deficits resulting from stroke, primary progressive aphasia, traumatic brain injury, and brainstem injury (Baxter et al., 2012; Beukelman, Fager, Ball, & Dietz, 2007; Dietz, Weissling, Griffith, McKelvey, & Macke, 2014). The availability of more socially acceptable communication applications via mobile technology has also increased AAC acceptance (McNaughton & Light, 2013). Furthermore, AAC acceptance has increased as the treatment philosophy changed from treatment solely looking at linguistic gains (e.g., number of words verbally produced, the accuracy of grammar) to improving language competence through any form of verbal or non-verbal means (Zangari et al., 1994).

Augmentative and Alternative Communication Practice Models

Throughout history, several models of practice have emerged to guide AAC assessments and interventions. The newer models replaced older models to adhere to best practices (Beukelman & Mirenda, 2013). One of the older models used was known as the candidacy model and emphasized eligibility. Therefore, individuals were excluded from AAC treatment if they had relatively better skills (i.e., an individual who was able to produce a few words intelligibly), did not have required prerequisites (i.e., an individual with hearing impairment), or because they did not have a needed skill (i.e., have significant cognitive deficits which were thought to interfere in adopting AAC) (Beukelman & Mirenda, 2013). Consequently, an individual with aphasia who can use a small number of spoken words meaningfully may not be eligible to receive AAC treatment based on this model. The candidacy model focused on the person with the communication deficit, but it did not consider how the external environment limited the person's ability to communicate. Hence, the individual with the communication deficit needed to be changed or fixed. The candidacy model has now been abandoned in most developed countries (Beukelman & Mirenda, 2013).

A more recent model that examines AAC assessments and interventions is the participation model (Beukelman & Mirenda, 2013). The participation model is a dynamic model that attempts to identify and remedy barriers while increasing the opportunity for users of AAC to engage in everyday life (Beukelman & Mirenda, 2013). Unlike previous models, the participation model takes a holistic view by looking at the user’s strengths and weaknesses and societal and environmental barriers. The participation model demonstrates the importance of considering individuals with communication deficits, other people in society, and the environment in which they interact. Additionally, the model is conducive to monitor the changing needs that occur with time for those who use AAC.

A successful assessment and an intervention plan with individuals with communication deficits must result in increasing their participation in everyday life activities. Consequently, the participation model aligns with demands established by the ICF (WHO, 2001), which aligns with the A-FROM (Kagan et al., 2008).

Efficacy of Low-tech AAC for People with Aphasia

Early on in aphasia treatment, researchers have used gestures and writing with individuals who have limited expressive language skills (Rao, 1995). Later, various treatments using non-verbal modalities that do not require any technology started to emerge. Multimodal communication training (MCT) encourages people with aphasia to use various modalities such as drawing, gesturing, writing, and pointing to pictures as a means of overcoming spoken language deficits. MCT research has demonstrated positive treatment outcomes for people with aphasia (Purdy & Van Dyke, 2011; Purdy & Wallace, 2016; Wallace & Kayode, 2017).

Rao (1995) presented a case study of a 67-year-old individual with aphasia two years post-stroke. According to the Western Aphasia Battery (WAB; Kertesz, 1980) scores, he presented with severe jargon aphasia, accompanied by severe auditory and reading comprehension deficits. The treatment program encouraged using different modalities in a sequence of gestural training, followed by drawing training in the clinic. Subsequently, a combined treatment of gestures and drawings was used during daily activities at home. The participant received treatment daily for 2-weeks as an impatient and 4-weeks as an outpatient. Additionally, the caregiver received training to encourage using multiple modalities at home. By the end of the treatment, the participant demonstrated increased functional communication by using 30 gestures and drawing for activities of daily living. Additionally, WAB scores improved for word reading (from 0% to 90%) and for yes/no questions (from 40% to 90%). Hence, based on this case study, it was apparent that people with aphasia may benefit from using alternative modalities to compensate for spoken language deficits and to increase functional communication. Although improved word reading may suggest that alternative modalities also improve language skills, we cannot confirm this hypothesis with a single case study.

Purdy & Van Dyke (2011) used an MCT protocol to train several modalities simultaneously (i.e., integrated training) rather than sequentially with two individuals with aphasia. The researchers anticipated better modality switching with an integrated MCT protocol (Purdy & Van Dyke, 2011). The MCT requires relatively intact semantic representation, which allows the user to select a target concept from any modality (Purdy & VanDyke, 2011). Consequently, the non-verbal semantic ability was examined using the pyramids and palm trees test (Howard & Patterson, 1992). This study was a single-subject AB design with two individuals with aphasia. One participant was diagnosed with Broca's aphasia and the other with Wernicke's aphasia. Participants were given three sets of 20 picture cards that corresponded with target words identified from the Communicative Activities of Daily Living-2 (CADL-2; Holland, Frattali, & Fromm, 1999). Participants received six to eight hours of training across eight sessions. During the training, participants named pictures using four different modalities: oral naming, writing, gesturing, and pointing.

At the end of treatment, the individual with Broca's aphasia who had an intact semantic representation increased naming via multiple modalities, and modality shifting on the CADL-2 compared to baseline performance. However, the individual with Wernicke's aphasia and impaired semantic representation continued to struggle with naming, while modality shifting increased a small amount. All in all, the limited number of participants makes it difficult to assert the effectiveness of integrated MCT. In fact, the variability in outcomes among participants could be due to differences in semantic ability, but this requires further investigation. However, according to Purdy & VanDyke (2011), the outcomes of the individuals with Broca's aphasia were much greater than those who received sequential MCT in a previous study (Purdy, Duffy, & Coelho, 1994). The findings suggest integrated MCT to be better than sequential MCT for modality switching. However, results must be interpreted with caution due to the number of participants and the heterogeneity of their aphasia. Besides the differences in semantic skills in participants, other characteristics specific to different types of aphasia may have impacted treatment outcomes. For example, the individual with Wernicke's aphasia may have had more significant comprehension deficits compared to the individual with Broca's aphasia. Consequently, the individual with Wernicke's aphasia may have faced more challenges following instructions during training. Thus, replication of this study with a larger sample may provide a better understanding of integrated MCT.

Purdy & Wallace (2016) used a single-subject, multiple baselines across stimuli design to examine the effect of intensive MCT during a referential communication task with three participants who had chronic Broca's aphasia. One participant presented with co-existing mild apraxia of speech (AOS) while the other had severe AOS. All participants received integrated MCT training 2-3 hours per day, five days a week, for a total of two weeks. The referential communication task entailed describing a picture using two nouns to an unfamiliar communication partner. According to post-treatment findings, two of the three participants increased naming via multiple modalities, while the third showed little change in the use of non-verbal modalities. Evidently, the findings were similar to non-intensive MCT treatment outcomes. Based on these findings, we might expect people with aphasia to benefit from either the non-intensive MCT or from the intensive MCT. One limitation of the study was the variation of treatment duration across participants. For example, the treatment hours per day varied based on the participant's rate of response. Additionally, the treatment duration gradually reduced when the participant became familiar with the task and improved performance. As a result, we cannot make generalizations about the impact of treatment duration on MCT.

Wallace and Kayode (2017) modified the MCT treatment by including a semantic treatment (S+MCT) component. The researchers used a single-subject, multiple baseline design across word lists to investigate the appropriateness of the treatment program. A single individual with severe, chronic aphasia who also presented with severe semantic deficits participated in the study. In addition to the usual MCT protocol used by Purdy & VanDyke (2011), the participant received treatment for non-verbal semantics to name target items using different modalities across 12 sessions. Post-treatment testing showed improvements in modality switching and non-verbal semantic skills. However, spoken language skills did not improve. According to researchers, positive changes in modality switching were observed in the later sessions, suggesting the need for multiple practice opportunities. Despite no improvements in verbal language skills, an increase in vocabulary by any modality should be perceived as a benefit for individuals with severe aphasia.

Yet another low-tech AAC method involves the use of picture books. An ABA and alternating treatment single-subject design was used with two individuals with global aphasia (Ho, Weiss, Garrett, & Lloyd, 2005). The study examined the use of two different types of picture books to interact with a familiar communication partner. Each participant received training once for a five a minute duration across five days with each picture book. The two different picture books consisted of the same content but contrasted by the type of symbols used (the effect of symbols on communication is discussed later on in this chapter). Based on the findings, the two individuals with global aphasia were more actively involved in the communication interaction in the presence of a picture book than without a picture book.

Bellaire et al. (1991) examined the use of picture communication boards in a multiple-baseline design across behaviors (e.g., baseline, treatment, generalization training I, generalization training II, maintenance) study by two individuals with chronic Broca's aphasia. The treatment involved encouraging social responses, requesting, and sharing personal information with communication boards. During the treatment phase, participants pointed to pictures in response to questions such as "show me how you would say…". Participants had to attain an 80 percent correct response rate in two of the three sessions or complete a maximum of 15 sessions during the treatment phase to move to the next stage. The participants completed 25 trials to elicit 15 target responses in each session. In the first generalization training stage, participants were involved in role-playing in the treatment room. They had to attain 80 percent correct responses in two of the three sessions or complete a maximum of 9 sessions to move forward. The second generalization training was completed in a natural setting; participants had to attain the same requirements as in the previous stage to move on to the next phase of maintenance. According to generalization probes, a minimum of 23 sessions were required for participants to use the communication board to share personal information. Researchers found that the participants in this study were able to generalize the use of the communication board above baseline performance only if training occurred within a natural setting (i.e., generalized training II). Furthermore, they observed that once an alternative method of expressing a particular word was established, then a different means was not adopted. For example, if head nodding was an established method for greetings, then the individual was not inclined to point to a picture found on the communication board to meet this need.

One study looked at the effect of low-tech visual scene display (VSD) interfaces on the communicative interaction with unfamiliar communication partners (Hux, Buechter, Wallace, & Weissling, 2010). The researchers used low-tech VSDs in three conditions: shared VSD, non-shared VSD, and no VSD to examine its impact on shared communication space between an individual with aphasia and nine communication partners. The low-tech VSD interfaces consisted of contextually rich pictures. The study required the individual with aphasia to engage in a conversation on a predetermined topic using the three conditions mentioned above. Consequently, the individual with aphasia engaged in a conversation with each communication partner for approximately four-and-half minutes in each condition. The participant in the study did not receive any training to use VSDs. However, the participant was familiar with using a communication book. Hence, the two VSDs that were created for the experimental task was included in this communication book. A shared VSD allowed the individual with aphasia and the communication partner to see and use the VSD interface. On the contrary, the non-shared VSD only allowed the individual with aphasia to view and use the interface. Findings show improvement in turn-taking and meaningful content production with the shared VSD interface compared to other conditions. Findings from this study highlighted the critical role communication partners play in creating a positive communication interaction. All in all, the quality of the communication interaction improved when both the user of the AAC system and the communication partner played an active role.

The research discussed so far indicates the benefit of low-tech AAC systems for people with aphasia. Similarly, high-tech AAC systems also have shown positive outcomes with this population.

Efficacy of High-tech AAC Treatment for People with Aphasia

Johnson et al. (2008) used a single-subject repeated measures design to examine the grid display with three individuals with chronic aphasia on the Dialect by Zygo™. All participants were diagnosed with non-fluent aphasia. Two of the three participants had Broca's aphasia while the other had Mixed aphasia, and aphasia severity ranged from moderate to severe. Each grid display used participant-specific symbols organized into a four-level hierarchy structure. Consequently, Level 1 consisted of a broader category (i.e., food), while Level 4 consisted of the most specific item (e.g., pineapple). All participants received treatment for 1 hour, three to four times per week, for three months.

Additionally, caregivers also received training on using the AAC system at home. The treatment involved responding to questions and structured statements with the interface (e.g., producing “I want apple” in response to the question “what would you like to eat?”). At the end of the treatment, WAB (Kertesz, 1982) Aphasia Quotient (AQ) scores improved for one participant; however, auditory comprehension on the WAB improved in all participants. In addition, there were positive changes in communication, as reported on the Communicative Effectiveness Index (CETI) (Lomas et al., 1989) by caregivers. Findings suggest that individuals with chronic non-fluent aphasia can use the grid display interface to respond to basic needs. A limitation of the study was restricting communication to a few functional tasks.

Furthermore, the lack of experimental control made it difficult to ensure these positive changes resulted from using AAC. In other words, it is difficult to justify that improvements in comprehension occurred with the use of AAC and not from a different treatment effect. However, the investigators reasoned that the increase in comprehension resulted from using an auditory modality to provide treatment instructions.

A replication of the above study was completed with an individual diagnosed with severe, chronic, non-fluent aphasia (Hough & Johnson, 2009). The participant successfully mastered navigation of the grid display interface by the end of a 40-session treatment period. Additionally, WAB (Kertesz, 1982) AQ scores improved throughout treatment with most gains observed on visual and auditory comprehension. According to both studies (Hough & Johnson, 2009; Johnson et al., 2008), people with aphasia demonstrated the ability to utilize the hierarchical structure found in the grid display to answer questions and make requests.

A single-subject multiple-baseline across behaviors was used with three individuals with chronic, severe Broca's aphasia to investigate the ability to combine graphic symbols when producing phrases and sentences of differing syntactic levels (Koul et al., 2008). The study used a dynamic grid display with four levels via DynaMyte 3100 to organize the graphic symbols, alongside written labels. The treatment led to increased sentence formulation; however, the degree of success varied across participants. The findings show that people with aphasia were able to use the grid display successfully to elicit utterances. However, the study did not investigate the generalizability of learned skills to natural everyday communication.

The VSD interface's usefulness with an individual with chronic Broca's aphasia and AOS was examined using a multiple-baseline across themes design (McKelvey et al., 2007). The VSD interface in this study was presented via Table XL from Dyanavox. The interfaces for the two themes were developed with the participants before treatment. Baseline data were obtained over a three-week period, which included six sessions. Each session involved a 15-minute conversation with a communication partner with the two themes that were developed. Subsequently, the participant received a 60-minute training twice a week for three weeks during treatment for the two themes. The interaction between the individual with aphasia and the communication partner was assessed using three dependent variables: talking about disability, talking about navigation/organization of the items on the device, and the percentage of inappropriate question and answer exchanges obtained during 15-minute interactions. The study findings demonstrated an increase in communicative interaction quality and a reduction in off-topic conversations. Despite the limited opportunities for individuals with chronic aphasia to receive adequate treatment (Katz et al., 2000; McKenzie et al., 1993), the findings demonstrated the positive benefits of providing training for AAC systems.

TalkBac is a text-based communication system developed for individuals with non-fluent aphasia. The TalkBac system stores written words and sentences in a hierarchical structure for later retrieval. Four participants with non-fluent aphasia with the ability to provide a consistent yes/no response were trained to use TalkBac (Waller, Dennis, Brodie, & Cairns, 1998). Each participant used a personalized TalkBac system and received training at home once a week for 1-1.5 hours over 3-months provided by the speech-language pathologist involved in the study. Additionally, caregivers also received training. After training, treatment was initiated and completed over nine months. During treatment, the researcher visited the participants weekly and was encouraged to use the TalkBac to communicate. At the end of treatment, conversation abilities were examined with and without the TalkBac system. Furthermore, language skills were tested by comparing pre-and-post training WAB (Kertesz, 1982) scores. Based on findings, two of the four participants improved their conversation abilities with the use of TalkBac. However, one participant was already proficient in using a non-verbal modality for communication and did not adopt TalkBac, while the other showed no improvements. Additionally, three participants improved on their post-WAB scores for written expression and comprehension. These results suggest that the TalkBac system may improve linguistic skills for some individuals. The results further revealed that individuals with previously established successful methods of communication (i.e., use of gestures or writings) might not adopt a high-tech AAC system as automatically as those who did not have a pre-established method.

SentenceShaper is a processing software that records words for later manipulation in sentence formation (Bartlett et al., 2007; Linebarger et al., 2008). The SentenceShaper stores the individual with aphasia's verbal productions as symbols for later access. A case study on a single individual with moderate, non-fluent aphasia showed that the use of the SentenceShaper increased the morphosyntactic complexity of narratives produced during aided and non-aided productions after a 12-week treatment (Albright & Purves, 2008). Results suggested that the use of AAC like SentenceShaper may improve language skills for some individuals with aphasia. However, these gains were only seen in structured treatment sessions with a single participant, and generalization to natural settings was not observed.

In another study, Fink, Bartlett, Lowery, Linebarger & Schwartz (2008) compared narratives produced by five individuals with mild to moderate non-fluent aphasia in three conditions: without SentenceShaper, with SentenceShaper, and unaided post SentenceShaper use. These narrative productions with SentenceShaper were elicited after 2-3 training sessions. The results showed an increase in the number of correct information units (CIUs; Nicholas & Brookshire, 1993) when participants used SentenceShaper. Consequently, the use of an AAC system provided access to more words increasing the number of CIUs. A common characteristic in aphasia is word-finding deficits, also known as anomia, which results in language absent of content words, which reduces the number of both CIUs and the meaning of the message. The findings from this study suggest that the SentenceShaper increased access to words resulting in a higher number of CIUs, which may improve the communication interaction.

Steele et al. (2010) examined if Lingraphica, a computer, and symbol-based SGD could improve outcomes on standardized assessments of 20 individuals with chronic Global aphasia. The AAC treatment entailed using Ligraphica during therapy twice a week for 1-hour in the clinic while also having access to the device at home. The number of weeks for the treatment varied for each participant and ranged from 10.4 to 45.9 weeks. At the group level, there were statistically significant gains for auditory verbal comprehension, naming, and AQ on the WAB (Kertesz, 1982). Additionally, the functional communication based on the CETI (Lomas et al., 1989) completed by caregivers also improved with treatment. However, due to the lack of experimental control, we cannot be confident that these positive changes were solely due to the use of Lingraphica.

Comparing Low-Tech and High-Tech Treatment for Aphasia

Waller and Newell (1997) used a case study design to examine a text-based, high-tech AAC system known as the Predictive Retrieval of Story Extracts (PROSE). The PROSE stores language produced by the individual with aphasia for later access. The researchers compared narratives produced by an individual with non-fluent aphasia using a low-tech storybook and the PROSE. Additionally, these productions were also compared to a narrative produced by a caregiver. Findings showed that the participant spent an extended time narrating with PROSE. Furthermore, there were more initiations and continuations than responses by the individual with aphasia with PROSE compared to the other two methods. The findings demonstrated that the individual with aphasia had more control over the conversation, as seen by the measurement variables with PROSE.

Comparing AAC Treatment with non-AAC Treatments for Aphasia

Treatment outcomes at the discourse level were examined by comparing the multi-modality aphasias therapy (M-MAT; Rose, 2013) and constraint-induced aphasia treatment (CIAT; Pulvermuller et al., 2001) (Rose, Mok, Carragher, Katthagen & Attard, 2016). As previously discussed, multimodality treatment encourages the use of any modality to meet communication needs. Within this study, M-MAT encouraged the use of gestures, drawing, writing, and reading. The purpose of CIAT is to provide intensive treatment that encourages the use of speech and discourages the use of other modalities. Thirteen individuals with different aphasia types (Broca's aphasia, anomic aphasia, and conduction aphasia) and severities were placed in two groups. Both groups received each treatment program counterbalanced. Treatment for each intervention was completed for 30 hours across 2-weeks. Participants received a one-week break between interventions. Study results demonstrated individual differences in treatment outcomes for participants. For example, individuals with mild aphasia had better outcomes post-CIAT, and individuals with moderate to severe had better outcomes post-M-MAT. Overall, both treatments were efficacious. The findings suggest that individuals with mild aphasia may not adopt low-tech AAC in the form of M-MAT because they may possess residual speech for communication. However, individuals with severe aphasia have limited ability to use spoken language; therefore, they may compensate spoken language deficits by successfully adopting AAC.

Research on Symbol Types in AAC

Ho and colleagues (2005) used remnant and pictographic books with two individuals with Global aphasia. The study used a combined ABA and alternating treatment single-subject design. The remnant books used in the study included actual objects and pictures, while pictographic books used colored Picture Communication Symbols (PCS; Mayer-Johnson, 1992). Participants received training on using each type of picture book during five sessions across five days. Baseline data were obtained during a 5-minute interaction in the absence of a communication book (i.e., no symbols). The nine communication partners received training to ask three open-ended questions and three comments. Subsequently, data were collected from a 5-minute interaction with a communication partner during the intervention. A two to 10-minute break was provided when transitioning between the books. The type of book used was counterbalanced across people with aphasia and communication partners. Study results showed an increase in initiation for both participants, and communication breakdowns were reduced with both types of symbol books compared to using no symbols. However, more pointing was seen with the remnant pictures. These findings suggest the importance of personalized materials for individuals with Global aphasia. Additionally, caregivers also found it easier to interact with personalized items. However, there were individual differences in performance, suggesting the need to understand personal preferences. In fact, it is crucial to investigate performance on different AAC symbols and systems before identifying a system that meets the individual needs of the person with aphasia.

The effect of different types of visual supports (e.g., personally relevant and line drawing) and linguistic supports (i.e., with and without text boxes) on perceived helpfulness were examined by Griffith et al. (2014). The study used a case-series approach with four individuals with chronic, moderate-severe Broca's aphasia. The symbols were presented as VSD interfaces on the DynaVox Vmax™. Prior to the experiment, a single session was completed to familiarize the participants with the AAC device and the VSD interfaces. Subsequently, the participants were involved in narrating stories with an unfamiliar communication partner. The study found that participants used expressive language more often to retell narratives with an increased dependence on the personally relevant over the line drawing. Furthermore, the availability of text was preferred over no-text.

A collective case study was completed with five people with aphasia to investigate the usefulness of personally relevant photographs and written texts provided as VSD interfaces (Dietz et al., 2014). The VSD interfaces were programed on the DynaVox Vmax™. Three participants were diagnosed with Broca's aphasia, one with transcortical motor aphasia, while the other presented with transcortical sensory aphasia. Participants were provided with four variants of the VSD interface: personally relevant pictures with written text, personally relevant pictures without written text, non-personally relevant pictures with written text, and non-personally relevant pictures without written text. Prior to the experimental task, participants had the opportunity to familiarize themselves with four practice VSDs. However, there was no predetermined criterion to achieve before moving onto the experimental task. Overall, participants found personalized photographs with written text to benefit narration with unfamiliar communication partners.

Dietz and colleagues (2018) used a pre- and post-treatment design with a control group to examine spoken language outcomes for a narrative treatment. The study further explored neurological reorganization due to the treatment with functional magnetic resonance imaging (fMRI). The treatment materials included personally relevant pictures presented using the VSD interface on the DynaVox Vmax^{TM}. The 12 study participants comprised of fluent and non-fluent aphasia. Six of the 12 received the AAC narrative treatment while the remaining acted as the control group. Individuals in the control group received treatment as usual. Both groups received treatment for a total of 12 hours. These 12 hours were spread across one-hour sessions that occurred three times weekly, across 4-weeks. When looking at standardized measures, more participants in the AAC group improved on their WAB (Kertesz, 1982) scores compared to the control group; this may suggest that AAC treatment may have a positive outcome to improve verbal language. A limitation of this study is using different treatment goals for the two groups and targeting narration skills as the behavioral outcome. Hence, findings should be interpreted with caution. Another significant result in this study is the increased leftward lateralization for both groups and greater activation in visual areas for the AAC group.

Research on the Number of Symbols and Location

A study compared the effect of the number of symbols used and the number of levels (also known as screens) on a grid display to produce words and sentences (Petroi, Koul & Corwin, 2014). The study included ten individuals with moderate to severe Broca's aphasia and ten neurologically healthy adults to examine between-group differences. Participants received verbal and written instructions on completing the task prior to initiating the experimental task. The number of symbols used per screen included four, eight, twelve, and sixteen; both groups identified words more accurately with four symbols per screen, followed by twelve symbols and eight symbols. Participants also identified more symbols in a shorter time when only four symbols were available per screen. Furthermore, participants in both groups accurately identified more symbols when navigating across fewer levels.

Comparing Different AAC Interfaces

Wallace & Hux (2014) compared two different types of grid display interfaces using a single-subject alternating treatment design. One interface used in the experimental study had a homepage layout, and the other had a navigation ring. To see superordinate categories available in the homepage layout, the user must use the homepage button or use the go-back button. On the contrary, with the navigation ring layout, the superordinate categories remain visible no matter across levels. In both interfaces, symbols were organized into 4-levels and were presented on the Maestro device by Dynavox. Two individuals with aphasia participated in this study; one was diagnosed with Broca's aphasia and the other with moderate Wernicke's aphasia. Neither participant had previously used AAC but had experience with computers. The treatment that involved training on navigation occurred for a maximum of 5 sessions, with each session lasting 30 minutes before moving to the next interface. The study found that both participants improved accuracy and efficiency in navigation with both displays. However, participants were more consistent and efficient when using the interface with the navigation ring.

Brock et al. (2017) presented a case study in which researchers compared the grid display interface with the VSD interface presented on the Dynavox Vmax. The study attempted to understand how communication interactions on an episode of a television program varied across interfaces. The amount of training received varied for participants. Participant one received training in 3 sessions for each interface before engaging in a conversation with a communication partner about a television episode. The second participant completed the experiment differently from participant one and received five training sessions with the grid display and seven sessions for the VSD. This second participant had an additional step where a second episode was asked to be described using each interface in the absence of training. This change with the second participant was included to investigate generalization. Descriptively, there was an increase in the number turns taken, and a decrease in frustration and navigation errors when using the VSD interface over the grid display. Additionally, based on the second experiment with the second participant, generalization was seen when using the VSD, but there was no generalization with the grid display. According to the researchers, this finding may suggest that VSD training resulted in faster generalization.

The Usefulness of AAC for People with Aphasia

Aphasia may affect different linguistic modalities at varying levels. Consequently, a more intact modality may be used in an AAC system to augment communication deficits (van de Sandt-Koenderman, 2004; Dietz et al., 2014). For example, isolated pantomimes have been used successfully by people with aphasia when speech could not be produced (van Nispen, van de Sandt-Koenderman & Krahmer, 2018). Additionally, studies on MCT use further demonstrate the usefulness of unaided AAC for people with aphasia (Purdy & Van Dyke, 2011; Purdy & Wallace, 2016; Rao, 1995; Wallace & Kayode, 2017). All these studies on non-verbal means of communication were forms of unaided AAC that benefited people with aphasia.

Research showed that individuals with severe aphasia often benefited from the information presented in multiple modalities (Purdy & Wallace, 2016; Rao, 1995; van de Sandt-Koenderman, 2004). For example, combining images and text was more beneficial than images alone for individuals with aphasia (Dietz et al., 2009; Dietz, McKelvey, & Beukelman, 2006). The various AAC systems have easily incorporated multiple modalities for their layouts.

Despite language deficits, people with aphasia may often easily recognize graphic symbols and photographs related to everyday tasks. (Koul & Lloyd, 1998; McKelvey, Hux, Dietz, & Beukelman, 2010). The various AAC systems have used this skill by including symbol-based interfaces that use pictographs or real-life photographs (Kelly, Brady & Enderby, 2010; Marshall et al., 2016). Furthermore, evidence suggests using graphics during conversations between PWA, and unfamiliar partners increased content and specificity, and reduced off-topic responses (Ulmer, Hux, Brown, Nelms, & Reeder, 2017). Thus, a more meaningful interaction may result with AAC; this may become more relevant with individuals with aphasia who have limited spoken language. In fact, the use of images may reduce the need for linguistic processing, which can be challenging for those with severe aphasia. Hence, if a participant could not produce language orally, read, or write, then a picture may be used and processed easily.

According to intersystemic reorganization theory, a weak system can be improved when paired with a stronger system (Luria, 1972). Consequently, an intact visual processing system in PWA might be used for language recovery (Dietz et al., 2018). Preliminary findings of leftward lateralization of language functions and increased visual area activation in PWA who use AAC may suggest that AAC may impact language recovery (Dietz et al., 2018). Furthermore, evidence of brain reorganization was seen when BCI was used with PWA (Kleih et al., 2016), where the greater amplitude of the P300 wave suggested improvement in neural activity.

Challenges of Using AAC with People with Aphasia

According to Fried-Oken, Beukelman, and Hux (2012) AAC was scarcely used as a treatment option for individuals with aphasia due to several reasons: unrealistic expectations (i.e., PWA and caregivers desire for complete recovery of spoken language), funding only available for restorative treatment, and the failure of AAC specialists to develop useful strategies for this population. The literature also discussed other factors that limit the use of AAC with this population. One factor that negatively impacts the adoption of AAC was the attitude of PWA and their communication partners. For example, using a high-tech AAC device highlighted the individual's communication deficits to the society, which may have led to the rejection of the device (Linebarger et al., 2008). Furthermore, many reject using AAC because they fear the loss of spoken language despite research evidence to show that AAC does not inhibit spoken language production (Franco, Carleto, Lamonica & Caldana, 2015; Rose, 2013). Additionally, the communication partners who are knowledgeable in communicating with those who use AAC are limited, resulting in communication breakdown and rejection of AAC (Wilkinson & Jagaroo, 2004). The attitude, fear of inhibiting spoken language, and lack of communication partners may limit AAC use to therapy settings or at home. This, in turn, reduces opportunities to practice AAC, resulting in reduced AAC competence.

Often AAC systems rely on visual symbols to present vocabulary; therefore, visual cognition, which is defined as "the study of visual-spatial functioning and its neurological functioning" (Wilkinson & Jagaroo, 2004, p. 124), must be considered when developing of AAC systems (Wilkinson & Jagaroo, 2004; Wilkinson, Light, & Drager, 2012). To this effect, studies have investigated visual cognition of people with aphasia in the hope of improving AAC systems (Thiessen et al., 2014; Thiessen, Beukelman, Hux & Longenecker, 2016). Thiessen and colleagues (2014) recognized that people with aphasia fixated quickly and often to human figures in both task-engaged and camera-engaged contextualized images. However, for objects, task-engaged contextualized images were better at gaining quick and frequent fixations when compared to camera-engaged images with individuals with aphasia and healthy adults (Fletcher-Watson, Findlay, Leekam, & Benson, 2008; Thiessen et al., 2014).

Executive functioning allows individuals to plan, monitor one's behavior, and switch behavior when needed. Some people with aphasia may present with deficits in executive functioning (Nicholas, Sinotte, & Helm-Estabrooks, 2011), and this may affect AAC use. For example, switching from spoken production to a different modality to compensate for a communication breakdown may be difficult for PWA (Purdy & Wallace, 2016). Additionally, executive functioning may impact the transfer of skills from a structured setting to a natural environment (van de Sandt-Koenderman, 2004). Consequently, the generalization of AAC to natural environments may become challenging and will require AAC to be practiced in real everyday activities for successful adoption.

The grid display interface requires learning various navigation steps, which can be challenging when executive functioning is impaired (Nicholas & Connor, 2017). Consequently, those with executive functioning difficulties may respond better to VSDs that eliminate the need to remember different navigations steps for words (Nicholas & Connor, 2017).

Some AAC systems demand both communication and navigation to coincide (Purdy & Dietz, 2010); this may be challenging for those with aphasia who have inadequate working memory (Brock et al., 2017). The VSD may require a limited number of navigation steps when compared to a grid display. Hence, once again, the VSD interface may reduce the demand for working memory.

Some individuals with aphasia may present with comprehension deficits. Hence, individuals may require a longer training period to adopt AAC use (Wallace, Purdy & Skidmore, 2014). This can be challenging, especially when individuals do not have access to adequate therapy (Katz et al., 2000; MacKenzie et al., 1993). Consequently, there is a need to develop AAC systems and training paradigms that are more intuitive to people with aphasia and can be easily learned.

Technology Skills of Older Adults

Technology may be defined as “any electronic or digital product or Service” (Mitzner et al., 2010, p. 2). Currently, there is increased usage of technology by individuals of varying ages for everyday activities. According to Ryan & Lewis (2017), in 2015, approximately 78% of the U.S. households had a desktop or laptop, and 77% had a handheld digital device. Technology use is not limited to younger populations. With the increased availability of smartphones, older adults are now exposed to technology that was previously unavailable to them. Consequently, there is an increase in the number of older adults who are technology consumers (Friemel, 2016; Pruchno, 2019).

According to the Pew Research Center, in 2012, approximately 53% of older adults were internet users (Smith, 2014). Age has been considered a critical factor that determines success in using technology. However, the literature on computer and technology use shows that older adults can learn to use technology just as younger adults with increased time for training and when a positive learning environment was created (Broady et al., 2010).

Broady et al. (2010) conducted a literature review to understand similarities and differences in attitude and experience in computer use and technology for young and older adults. The literature revealed that attitude did relate to age; therefore, older adults were more uncomfortable using technology. They also found that older adults were more concerned about performance accuracy over completing a computer task quickly. Furthermore, the literature indicated that prior experience with technology has a positive outcome for learning technology but less so with attitude. Overall, the researchers stated the importance of providing more time for learning and creating a positive learning environment for older adults to learn technology as efficiently as young adults.

A mixed-methods study was completed in Taiwan to understand the attitudes, impact, and learning needs of adults above 50 years when using mobile technology (Chiu et al., 2016). A total of 20 individuals completed an eight-week training, and 16 completed focus group interviews. The study found that these adults with limited exposure to technology can adopt technology when their anxiety was reduced through training. Additionally, several other factors were identified to increase technology use; these include perceived benefit, completed higher education, and had prior experience with technology. Furthermore, support from family members and friends also played a positive role in learning technology.

Leung and colleagues (2011) completed a mixed within-subject and between-subject design to investigate age-related differences in mobile icons' usability. A total of 36 participants divided between two groups completed the study. According to the study findings, the older adults (65 years and above) had more difficulty discerning mobile icons than the younger group (20 -39 years). This difference was more evident when icons were abstract. Based on these findings, we may expect older adults to be slower at recognizing the required icons on a mobile device. Hence, older adults may need more time to access the required apps and function on mobile devices when compared to young adults.

Czaja et al. (2006) examine factors that predict the use of technology. The study used data obtained from 1204 community-dwelling adults, which included young adults (18-39 years), middle-aged adults (40-59 years), and older adults (60-91 years). The researchers found age, education, race, fluid and crystallized intelligence, computer self-efficacy, and computer anxiety as predictive of technology use (Czaja et al., 2006).

Mitzner et al. (2010) conducted a qualitative study on technology use and attitudes towards technology by older adults. This study recruited 113 community-dwelling older adults to engage in focus group discussions. Findings indicated perceived usefulness and ease of use were essential factors that predict technology use. Additionally, most older adults in the study expressed positive attitudes regarding technology.

Teeken et al. (1996) looked at age effected discrete (single) and reciprocal (back-and-forth) pointing. A total of 141 participants between the ages of 25 years to 75 years participated in the study. They found discrete pointing to be progressively slow with the advancement of age compared to the reciprocal pointing. The reciprocal pointing did become slower with aging, but the change across age was not as large as with discrete pointing.

Hwangbo et al. (2013) examined the pointing behavior of older adults with smartphones. Twenty-two adults above the age of 65 participated in the study, which involved pointing to randomly organized targets of various sizes and various spacing between targets. The study found that older adults performed better when targets were larger in size and when space between targets was greater. However, if the targets were larger, then performance was not influenced by spacing.

Summary of the Literature

Overall, the AAC literature for people with aphasia is expanding gradually. Study findings confirm that both low-tech and high-tech AAC systems have benefitted people with various types of aphasia and severity levels. Most participants in the studies discussed presented with non-fluent kinds of aphasia, such as Broca's aphasia (e.g., Dietz et al., 2014). However, there is some evidence that individuals with fluent aphasia (i.e., Wernicke's aphasia) can also benefit from AAC (e.g., Wallace & Hux, 2014).

Communication encompasses multiple functions, such as greeting, naming, requesting, or narration. However, most early studies targeted structured tasks with limited functional use. The more recent studies have gradually shifted treatment outcomes to investigate functionally relevant tasks such as narration. According to research on the different interfaces, narratives were easily targeted using the VSD interface (e.g., Dietz et al., 2018), while single words and short utterance production with the grid display interface (e.g., Koul et al., 2008).

Most AAC studies were limited to observation/descriptive studies, case studies, and single-subject designs; therefore, they have limited experimental control. Furthermore, the number of participants in most studies was small. Although single-subject designs can be beneficial with a heterogeneous population like aphasia, there is a need to replicate these studies with multiple participants to understand the benefits for more individuals. Additionally, there is a need for replication in experimentally controlled group study designs to determine the generalizability of findings to a larger population.

According to the literature on older adults, it is apparent that this population may have more challenges using technology than younger adults who are more exposed and therefore more familiar with technology. However, there are no known studies investigating how older adults use high-tech AAC; consequently, this necessitates further investigations. Conducting quality research to address the many gaps in the literature can increase the efficacy of AAC treatment and improve clinical practice.

METHOD

Study Design

This prospective, repeated measures design with a mixed within-subject and between-subject analysis was used to understand if there was a difference across two different AAC interfaces and individuals of varying ages and technology experience.

Participants and Sampling

The study consisted of three participant groups: 1) young adults, 2) older adults with technology experience, and 3) older adults with limited technology experience. These groups were selected using convenience sampling. The study received approval from the institutional review board (IRB). See Appendix A for IRB.

The participants were recruited using flyers and word of mouth. The young adult group was between the ages of 18 to 39, and the older adult groups were between the ages of 60 to 91 years. The age ranges for each group were determined based on Czaja et al. (2006) study that predicted the use of technology by young, middle-aged, and older adults. The two older adult groups were mean age-matched using a t-test. Furthermore, a Chi-square test (McHugh, 2013) was used for gender matching of the older adult groups.

A total of 65 individuals volunteered to participate in the study. Three participants did not pass screening; therefore, they were excluded from the study. Consequently, 62 participants completed the experimental task. The young adult group comprised of 18 individuals with a mean age of 26.94 (SD = 6.13); seven were male and 11 females. The older group with technology experience consisted of 24 individuals with a mean age of 68.08 (SD = 6.66), five were male, and 19 were females. The older adult group with limited technology experience consisted of 20 individuals with a mean age of 70.65 (SD = 9.07), six were male, and 14 were females. There was no statistically significant difference in mean age for the two older adult groups, $t(42) = -1.098$, $p = .278$.

Similarly, the Chi-square analysis showed no significant relationship between gender and the two older adult groups, χ^2 (1, $N = 44$) = 0.489, $p = .484$. Participants in the study included individuals of different ethnic groups. See Table 3.1 for demographic information.

Table 2. Mean Age, Age Range, Gender and Ethnicity of All 62 Participants

	Young Adults (*n* = 18)	Older adults with technology experience (*n* = 24)	Older adults with limited technology experience (*n* = 20)
Mean Age	26.94 (*SD* = 6.13)	68.08 (*SD* = 6.66)	70.65 (*SD* = 9.07)
Age Range	18 - 38	61 - 83	61 - 91
Gender			
Male	7	5	6
Female	11	19	14
Ethnicity			
American Indian/Alaska Native	1	0	0
African American/Black	4	5	6
Hispanic/Latino	1	0	0
White	10	18	14
Mixed Ethnicity	2	0	0
Other	0	1	0

Note. *n* = number of participants; *SD* = Standard Deviation; Mixed ethnicity included: American Indian/Alaska Native and White (*n* =1), Hispanic/Latino and White (*n* =1)

Inclusion and Exclusion Criteria

All participants met the following inclusion criteria: 1) native English speakers, 2) no known neurological disorders, language disorders, or substance abuse per self-report, 3) adequate vision, 4) no color blindness, 5) adequate hearing, 6) no cognitive impairment, 7) adequate reading ability, and 8) not pregnant. To determine inclusion, the following screening tools with established validity and reliability, included:

- **Vision screening -** The Rosenbaum Vision Pocket Screener (Rosenbaum, 1982) was used to determine if participants have the required 20/100 vision corrected or uncorrected for the task. This screener uses letters and numbers presented on a card and held 14 inches away from the participant to assess visual acuity. Participants were requested to read out loud letters and numbers corresponding with 20/100 vision.

- **Color blindness screening -** The Ishihara test was utilized. The test involved participants naming numbers made of colored dots surrounded by different colored dots. According to this test, an individual who presents with color blindness will not be able to separate dots used for numbers from background dots making it challenging to name the numbers accurately. However, those with normal vision can distinguish different colors that allow the correct naming of numbers.
- **Hearing Screening -** The portable audiometer and a listening task were employed for hearing screening. Participants must pass a pure-tone air conduction hearing screener for either aided or unaided at 40dB SPL for 500, 1000, 2000, and 4000 Hz in at least one ear. Those who failed the pure tone had to listen and respond correctly to a verbal instruction ‘raise one finger’ to continue the study.
- **Literacy Screening -** A single reading task from the Aphasia Language Performance Scale (ALPS) (Keenen & Brassell, 1975) was used. The task required participants to read the following sentence and perform what it says, “Point to the second word in this sentence."
- **Cognitive Screening -** The Montreal Cognitive Assessment (MoCA: Nasreddine et al., 2005) is a short test consisting of 30 questions used to screen for mild cognitive impairment. The cut-off scores to determine if a participant passed the screener were determined using scores obtained by the study completed by Rosetti, Lacritz, Cullum & Welner (2011). All participants in the current study had an education of 12 years or more.

Hence, the cut-off score for an individual younger than 35 years was 26, and the oldest group of 70 -80 years was 22 (Rosetti et al., 2011). Some participants were above 80 years; hence, a cut-off score of 22 was maintained for these individuals.

Participants also completed the Mobile Device Proficiency Questionnaire-16 (MDPQ-16; Roque & Boot, 2018) to differentiate those with technology experience from those with less experience. The MDPQ-16 (Roque & Boot, 2018) provided a method to determine mobile technology experience for the two older adult groups since the two AAC interfaces used in this study were presented via a touch screen mobile device.

- **Technology Experience -** The Mobile Device Proficiency Questionnaire-16 (MDPQ-16) was used to identify older adults' proficiency level in using mobile devices such as a smartphone or tablet (Roque & Boot, 2018). A cut-off score of 32 was used to indicate relatively more experience in using a mobile device; therefore, as having technology experience. On the contrary, those who received a score of less than 32 were identified as having less technology experience.

Study Materials

Composite Pictures

The two single pictures developed by Nicholas and Brookshire (1992) was used for the picture description task. A different image that was not used during the experimental task was used as the practice picture. See Appendix B for pictures used for the experimental task.

AAC Interfaces

The two interfaces used in the study include a grid display and a VSD. The grid display was programmed using the Proloquo2Go™ application (app), and the VSD was programmed using the Snap Scene™ app. Both apps were presented on a single iPad that allowed the touch screen option for direct access to target words needed for the task.

Identifying Vocabulary for the Interfaces

Several steps were followed to determine the target vocabulary for programming on each interface. Initially, the two composite pictures for the experimental task were presented to three individuals, one older adult and two young adults independently. Each individual was asked to describe each picture orally. The descriptions were audio-recorded using the Easy Voice Recorder, version 1.9.14 software on a Google Nexus seven-inch tablet device. The tablet was placed in front of the speaker and was transcribed off-line by a research assistant. Subsequently, two researchers familiar with AAC separately examined the language samples to identify the target words to be programmed; these include nouns, verbs, prepositions, and adjectives. The identified target words were compared, and differences between the two researchers were resolved through discussion. A total of 33 target words were determined for each composite picture. Some words identified in the first composite picture were also identified as target words in the second composite picture; hence, the total number of different target words for both pictures was 57. See Appendix C for the target words. The same target words were programmed on both the grid display interface and the VSD interface. The words that were not required when describing one picture acted as word foils.

The words required for the practice picture were also identified by eliciting language samples from two individuals; thereafter, target words were determined using the same procedure described above for target words related to Nicholas and Brookshire (1993) images. A total of 36 target words were identified for the practice image.

The Symbols for the Grid Interface

A rating scale was used to determine the appropriateness of each symbol used to represent each word. Raters were asked, "How much does this pictograph depict the target word?" using a 5-point equal appearing Likert scale from Not at all (rated "1") to Exactly (rated "5"). See Appendix D for the rating scale. The pictographs for the grid display were symbols that were already available on the proloquo2Go app; these symbols are known as SymbolStix™, which represent stick figures.

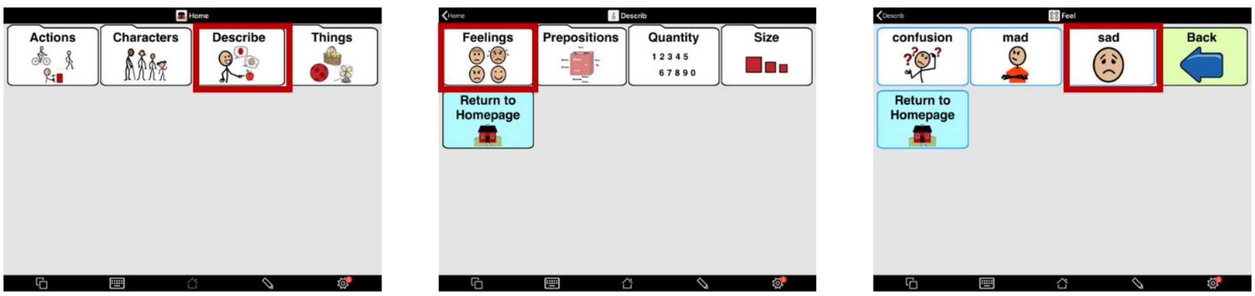
Two research assistants individually rated the pictures. If a symbol received a rating of moderate (a score of 3) or less by both raters, then a different symbol was selected from the app. Consensus regarding the newly selected symbol's suitability was obtained through discussion with raters and a third researcher. In the instance, when there was no other symbol, then the available symbol was maintained.

Six out of the 57 (10.53%) symbols received a rating of moderate or low by both raters. These words included 'bite', 'bring', 'come', 'ground', ''on, and 'try'. Of these five words, the symbol for 'bite,' 'bring,' 'come,' and 'on' were replaced (7.02%) with more suitable symbols found within the app. Symbols for the word 'ground' and 'try' were maintained as none of the other options available appeared to be more appropriate.

Organization of Folders and Words on the Grid Interface

A 3-Level hierarchical grid display was developed using the Proloquo2Go[1] app. Hence, participants must navigate to Level 3 (also known as page 3) to activate a target word. A previous study found that the use of a fewer number of levels can increase accuracy and reduce response time (Petroi et al., 2014); therefore, the number of Levels were maintained to just 3. See Figure 4 for an example of the three levels used in the experimental task.

The homepage of the grid display consisted of four superordinate category folders labeled as actions, characters, describe, and things. Touching a required superordinate category folder (e.g., things) opens Level 2. The number of ordinate category folders (e.g., household items and animals) subsumed within each superordinate category folder varied from two to six subfolders. A similar number of ordinate categories was used successfully with people with aphasia (Wallace & Hux, 2014). Touching an ordinate category folder (e.g., animals) opens Level 3 with the target words (e.g., cat, bird, and dog).



Level 1 Level 2 Level 3

Figure 4. The Grid Display Interface with Three Levels Used in the Study
Note. The screen on the right is the appearance of the homepage also known as the Level 1. Selection of superordinate category folder will open the image in the middle (Level 2) which include ordinate categories. Selection of an ordinate category will bring you to the image of the far right which includes superordinate words (Level 3). These screenshots of Proloquo2Go pages have been customized for this study and used with permission

The number of words available for direct activation on each ordinate category folder varied between one word to 10 words. Petroi et al. (2014) found that people with aphasia as well as healthy controls responded faster when there were fewer symbols per page. To navigate Levels, a button labeled as ‘returned to homepage’ and a button labeled as ‘back’ was available. The ‘return to homepage’ button was available on both Level 2 and 3 screens and allowed direct navigation back to the homepage. The ‘back’ button was only found on Level 3, and this allowed moving one level up; consequently, directing back to Level 2.

A similar layout was used for programming words for the practice picture, including the same superordinate category folders for Level 1. However, the Level 2 ordinate category folders and some target words at Level 3 differ per the needs of the picture that was described.

Developing Scenes for the VSD Interface

A total of 25 scenes were developed for the VSD interface. These scenes included pictures photographed explicitly by one of the researchers for the study (n = 3), personal photographs obtained by researchers (n =13), and through internet searches (n = 9). Prior to identifying the final 25 scenes that were used in the experimental task, these scenes were rated for the level of contextualization (Dietz et al., 2006) by a research assistant who was given instructions on rating scenes for context. Three scores were used for the rating. A score of one indicated that the scene had no-context, a score of two indicated low-context, and a score of three indicated high-context. No- context images consist of isolated people or objects in front of a neutral background, and a low-context image includes a natural environment in the absence of interaction between the different characters (e.g., people and animals) and the environment (Wallace, Dietz, Hux, & Weissling, 2012). For example, characters can be found engaged towards the camera instead of the objects. On the contrary, a high-context image includes a natural environment with characters interacting with each other and the environment (Wallace et al., 2012). Hence, in a high-context image, the characters are engaged with each other or with objects found on the scene. Furthermore, characters should not be looking directly at the camera. Of the initial 25 scenes, two obtained a score of two, indicating they were low-context and were replaced by new high-context scenes. The visual scenes were uploaded to the Snap Scene™ app; hotspots were created within scenes to represent the same 57 words programmed on the grid display. A written word to correspond with the target word was also available near the hotspot.

The font color of the written words was mostly in white, and a few were in black to increase contrast based on the background on each scene. A native speaker of American English recorded each corresponding word in a sound booth for the hotspots. Consequently, touching a hotspot resulted in a verbal output. A second native English speaker listened to each word in the absence of the image and was asked to repeat each word; this helped ascertain recording intelligibility.

Organization of the Scenes for the VSD Interface

The 25 scenes used for the experimental task were organized by including scenes involving mostly children at the beginning, followed by scenes with animals, and then scenes that include mostly adults. The number of target words represented as hotspots on a scene ranged from two to six. A characteristic of high-context scenes is its ability to provide more content within a scene (Brown & Thiessen, 2018; McKelvey, Hux, Dietz, & Beukelman, 2010); consequently, some target words were repeated across multiple scenes based on the information found (e.g., a hotspot for ground can be found in a scene with children playing in the garden, as well an in another scene that depicts a man playing outdoors with his dog). Hence, there was a total of 99 hotspots across the 25 scenes.

The imageability of the hotspots was also rated by two research assistants independently using a 5-point scale. The rating scale consisted of a 5-point scale rating from a low (rated "1") to high (rated "5"): Not at all, a little, moderately, a lot, and exactly. See Appendix D for the rating scale. One of the two raters gave a score of 3 for the target words 'climb' and 'eat', which indicated moderate imageability. However, the second-rater gave a score of 5 for the same target words.). The researchers decided to continue with these images because the second-rater provided a rating of 5 for words 'climb' and 'eat'. For all other target words, both raters gave a score of 4 or 5, indicating that the image depicts the target word a lot or exactly. See Figure 5 for the visual presentation of scenes organized in the VSD.

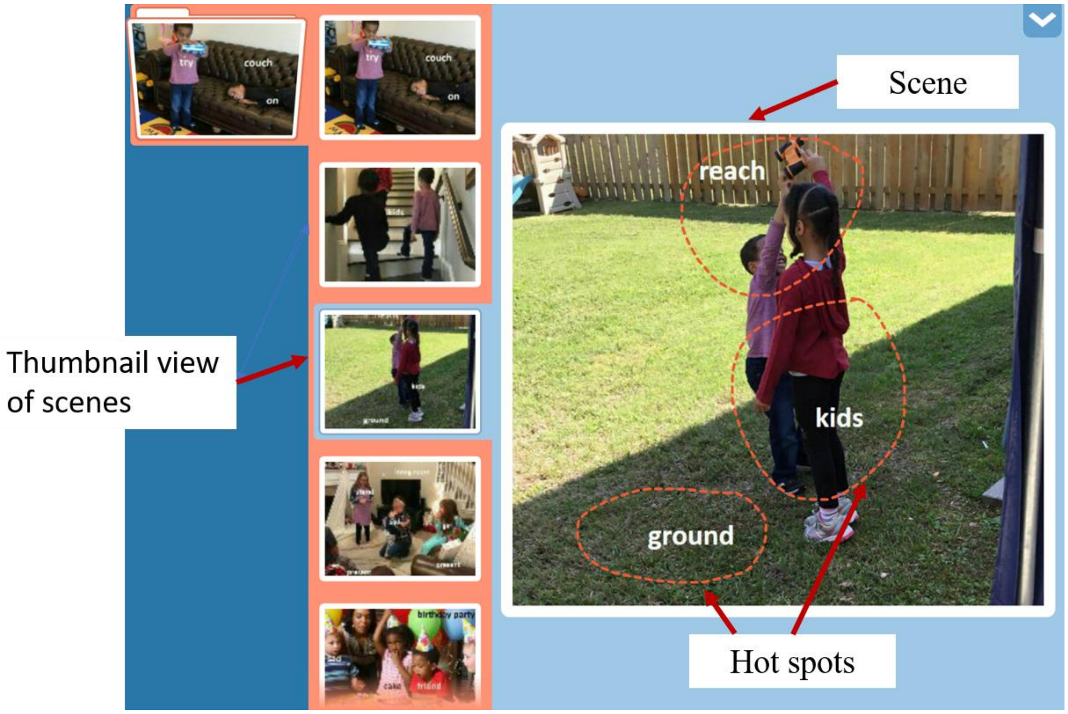


Figure 5. An Image of the Visual Scene Display (VSD) Used in the Study
Note. The thumbnail view of the scenes can be found on the left of the screen. The enlarged scene with embedded hotspots of the selected thumbnail can be found on the right. This VSD interface has been adapted with permission from Tobii Dynavox, LLC. Copyright 2020 by Tobii Dynavox.

A similar procedure was used when developing scenes for the practice task. Consequently, a set of 16 scenes with 56 hotspots were used to represent the 36 target words.

Demographic Questionnaires and Other Equipment

Study materials also included two questionnaires. One questionnaire was used to collect demographic information of participants. See Appendix E. The second was an interviewer-guided questionnaire to be completed at the end of the experiment. The questionnaire included three questions: one about participant preference for the two AAC interfaces; the second about reasons for preferences; and the third asked for reasons one app was not preferred over the other.

See Appendix F for the questionnaire. In addition to these materials, the study used a video camera and audio recorder to record experimental tasks. More detailed information on how the video and audio recordings were carried out can be found in the study procedures.

Study Setting

The study was conducted at the Department of Communication Sciences and Disorders at Louisiana State University or at a place that was convenient for the participant. Some of these settings include churches and participants' homes. The screening and experimental tasks were conducted in a quiet room to limit distraction.

Study Procedure

Once the study procedure and tools were approved by the IRB, participant recruitment was initiated. Potential participants were provided with written consent forms with information regarding the study; furthermore, they had the opportunity to ask questions to clarify any information necessary for the study. Once consent was obtained, participants completed screening for vision, hearing, literacy, and cognition. All participants who passed the screening continued to the next stage of the study completed the demographic questionnaire and the MDPQ-16 (Roque & Boot, 2018).

The type of AAC interface used first was counterbalanced for each participant across groups to eliminate the order of presentation on performance. The order in which the two composite pictures were presented was also counterbalanced across participant and AAC interfaces. Before beginning each experimental task, participants were provided with instructions on how to use each interface based on the beginning AAC interface; for example, if the participant was using the grid display as the first interface, then the researcher demonstrated how to use the grid display with the practice item.

For training and experimental tasks, each participant sat at a table with the iPad positioned a comfortable distance to allow the participant to reach and touch the device screen. A single video camera mounted on a tripod was placed behind the participant's shoulder to capture how the participant navigated on the iPad to complete tasks. The investigator manually switched the video camera immediately before describing the pictures during the experimental task. Thereafter, the camera was switched off after both pictures were described with each interface. Participants had 4-minutes to describe each composite picture. Brookshire and Nicholson (1993) gave participants one minute to describe each composite picture used in this study; however, one of the common characteristics of speech produced with AAC systems is the increased time needed to produce messages. For this reason, participants had four minutes to describe as much as they can what they see in the picture using the given AAC interface. Prior to initiating the study, an older adult who was not included in the study analysis was asked to complete the study task to ascertain the appropriateness of the time allocated. It was found that a two-minute duration was inadequate to collect a sufficient language sample; hence, a four-minute period was used.

Additionally, a Google Nexus 7-inch tablet device with the Easy Voice Recorder, version 1.9.14 software, was used to record post-task interviews. The interviewer placed the tablet with the recorder on the table in front of the participant, switched it on at the beginning of the interview, and stopped at the end of the interview.

During the practice, how to activate buttons, return to the homepage, and move across different Levels of folders using the back button is demonstrated with the grid display. With the VSD, the researcher demonstrated how to scroll, open thumbnail view to pull up the scenes, and how to activate a hotspot. Besides demonstrating navigation, the researcher modeled two utterances on each interface with the practice picture by producing a 2-word utterance (i.e., seagulls fly) and a 6-word utterance (i.e., woman sit on chair read book). At the end of the practice, participants had the opportunity to navigate the interface to produce the same modeled utterances. If participants were unable to produce the two modeled utterances, the investigator re-modeled the production. A maximum of three trials were provided for participants to produce the modeled utterances. Subsequently, participants were given an opportunity to make a novel utterance. Since the current study aimed to examine individuals' initial experience using two interfaces, participants were not required to meet a predetermined criterion to commence the experimental task.

Once the practice trial was completed, participants were familiarized with the vocabulary found on the first interface used. Hence, participants had the opportunity to open each folder in the grid display and look through scenes on the VSD within a two-minute duration.

At the end of the allocated time for familiarization, the participants were given the first interface with one of the composite pictures (Interface 1, Picture 1) using the same interface demonstrated during the practice trial. At the end of the allocated time, the second picture (Interface, Picture 2) was provided, and the process was repeated using the same interface. In other words, participants were given two different pictures with the same interface. Once the participant completed the task with the first interface, they received a five-minute break. After the five-minute break, the practice trial for the second interface was completed. Subsequently to the practice trial with the second interface, participants commenced the experimental task by describing one composite picture (Interface 2, Picture 1) followed by the next composite picture (Interface 2, Picture 2). At the end of the experiment tasks, a short interview was completed to understand interface preference and reasons for the choice. See Appendix G for more detailed instructions provided to participants during the practice and experimental tasks.

Measurement Variables

All sessions were video recorded to allow off-line scoring of the three dependent variables: 1) The total number of Correct information Units (CIUs; Nicholas & Brookshire, 1993), 2) the percentage of CIUs, and 3) the number of CIUs per minute.

- **Correct information Units (CIUs) -** According to Nicholas and Brookshire (1993), CIUs are "words that are intelligible in context, accurate in relation to the picture(s) or the topic, and relevant to and informative about the content of the pictures(s) or topic" (p. 348). Scoring and counting of CIUs in this study followed the guidelines provided by these authors. However, some modifications were made to account for single-word productions, abandonment of utterances, and the difficulty in understanding the beginning and end of an utterance, that could occur when producing language using AAC. See Appendix H for instructions on counting CIUs.
- **Percentage of CIUs -** This was calculated by dividing the total number of CIUs from the total number of words produced.
- **Number of CIUs per minute -** This was calculated by dividing the total number of CIUs by the total time spent describing the picture.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS), version 25, was used for descriptive and inferential statistics. A mixed analysis of variance (ANOVA), also known as the split-plot analysis was utilized to answer the primary research questions related to the quantitative data (Tabachnick & Fidell, 2013). Three separate analyses were completed for the three measurement variables; hence, the Bonferroni-corrected $\alpha = 0.016$ (0.05/3) was used. Furthermore, a Chi-square analysis was conducted with the preference data to examine the relationship between groups and preferred interface.

Data Screening

Before the analysis, the data were screened for missing data. According to descriptive tables obtained using SPSS, there were no missing data.

Reliability Testing

Inter-rater reliability of transcribing words produced and the total number of CIUs were examined for 20% of the total sample. Hence a total of 13 recordings were transcribed and coded by a research assistant. The inter-rater reliability for words was 98.73%, and the total number of CIUs was 90.47%.

Testing Assumptions for Mixed Design ANOVA

- **Absence of Outliers -** Univariate outliers were examined using standardized scores, which are the z scores. None of the variables had a z score of greater than 3.29 to be considered as an outlier (Tabachnick & Fidell, 2013). Box plots were also examined as a graphical method to identify outliers. Data for three participants were identified as outliers with Box plots. Hence, data were analyzed with and without the three outliers.
- **Normality –** This assumption was tested using histograms and the Shapiro-Wilk test. All except one variable obtained a significant score of greater than 0.05 on the Shapiro-Wilk test. This analysis indicates that the assumption for normality was held for all other variables except for the percentage of CIUs for the older group with technology experience ($p = 0.04$). Histograms were also examined.

- **Equality of Covariance Matrices** – A variance-covariance matrix provides variances and covariances related to variables. This was tested using Box’s M test. As the test results were not significant ($p > 0.05$), this assumption was not violated.

Analysis of Interviews

All interviews were transcribed to obtain data regarding the preferred interface and to identify the reasons for preferences. The Chi-square analysis was used to examine if there was a significant relationship between groups and the preferred app.

The remaining interviews were examined to identifying reasons for liking or disliking an interface. Several steps were completed to extract the reason for the preferred app. Initially, the statements indicating likes and dislikes were identified by examining transcribed interviews; thereafter, the researcher developed a short phrase to summarize each statement. The summary statements were discussed with a research assistant for clarity and accuracy.

RESULTS

Three out of the 62 participants were identified as outliers based on box plots during testing of assumptions before assumption prior to statistical analysis. Box plot analysis indicated that the three participants performed differently compared to the rest of the sample; therefore, they were outliers. Of the three participants who were identified as outliers, two belonged to the older adult group with technology experience, and the remaining participant belonged to the older adult group with limited technology experience. See Table 3 for demographic information after excluding participants who are outliers.

Table 3. Mean Age, Age Range, Gender and Ethnicity of the 59 Participants

	Young Adults (*n* = 18)	Older adults with technology experience (*n* = 22)	Older adults with limited technology experience (*n* = 19)
Mean Age	26.94 (*SD* = 6.13)	68.00 (*SD* = 6.96)	71.16 (*SD* = 9.03)
Age Range	18 - 38	61 - 83	61 - 91
Gender			
Male	7	5	6
Female	11	17	13
Ethnicity			
American Indian/Alaska Native	1	0	0
African American/Black	4	4	6
Hispanic/Latino	1	0	0
White	10	17	13
Mixed Ethnicity	2	0	0
Other	0	1	0

Note. n = number of participants; *SD* = Standard Deviation; Mixed ethnicity included: American Indian/Alaska Native and White (*n* =1), Hispanic/Latino and White (*n* =1)

Based on a t-test, the mean age of the older adult groups did not differ even after participants were excluded, $t(39) = -1.264$, $p = .170$. Similarly, the Chi-square statistic showed no significant relationship between gender and two older adult groups, χ^2 (1, $N = 41$) = 0.407, $p = .524$. Due to the identification of outliers based on box plots, the analysis was completed with and without outliers. In instances where outliers are identified, the analysis can be completed with the outliers and compared to the findings obtained when outliers were excluded (Tabachnick & Fidell, 2013).

Three of the 62 participants behaved as outliers. In other words, the three individuals performed differently on the experimental task compared to the other participants within the study sample. However, results from statistical analyses obtained for the 62 participants did not differ from the conclusions for the 59 participants.

The within-subject effect that looks at the differences between the two interfaces based on the three dependent variables and the between-subject effects by comparing the differences across the three participant groups based on 1) the total number of CIUs, 2) Percentage of CIUs, and 3) CIUs per minute were examined using descriptive statistics. See Figure 6 for an illustration of the dependent variables.

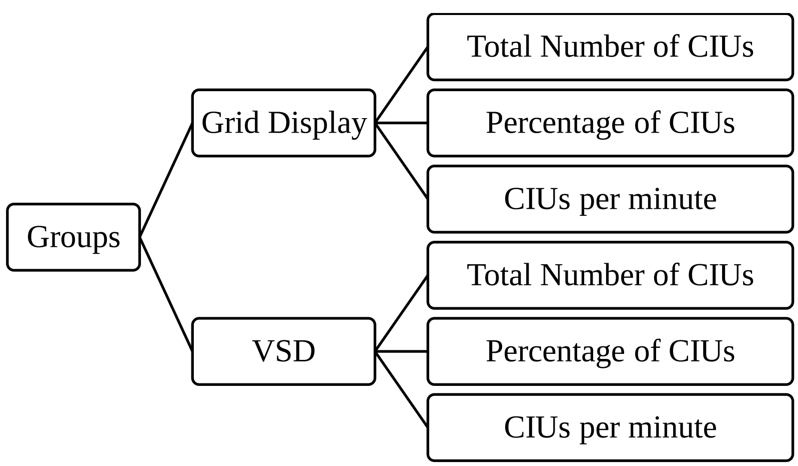


Figure 6. The Three Dependent Variables Measured Across Interfaces

Subsequently, inferential statistics were obtained via Mixed-design ANOVA completed separately for each variable. Consequently, a Bonferroni-corrected alpha value was utilized.

Results from Data with Outliers Included

The data were initially analyzed by including all 62 participants. See Table 4 for descriptive statistics for means and standard deviations across groups and interfaces.

Table 4. Means and Standard Deviations for the Total Number of CIUs, Percentage of CIUs and CIUs per minute Across the Interfaces and Groups (n = 62)

	Young Adults (*n* = 18)	Older Adults with Technology Experience (*n* = 24)	Older Adults with limited Technology Experience (*n* = 20)
CIUs in GD	41.06 (10.56)	29.58 (8.38)	26.05 (9.65)
CIUs in VSD	38.33 (7.01)	28.50 (7.35)	23.85 (6.97)
Percentage of CIUs in GD	87.65 (8.24)	84.46 (8.67)	82.24 (9.91)
Percentage of CIUs in VSD	87.90 (8.97)	88.94 (9.08)	82.07 (13.52)
CIUs per minute in GD	5.13 (1.31)	3.70 (1.05)	3.26 (1.21)
CIUs per minute in VSD	4.79 (0.88)	3.57 (0.92)	2.98 (0.87)

n = number of participants; CIUs = Correct Information Units; GI = Grid Display; VSD = Visual Scene Display

Are there differences between groups?

***Total number of CIUs*.** Based on descriptive data, the total number of CIUs varied across the three groups across apps. Young adults produced a greater number of CIUs with the grid display (*M* = 41.06, *SD* = 10.56) and in the VSD (*M* = 38.33, *SD* = 7.01) compared to older adults. Descriptively, older adults with technology experience produced more CIUs in both the grid display and VSD (*M* = 29.58, *SD* = 8.38 and *M* = 28.50, *SD* = 7.35) than older adults with limited technology experience (*M* = 26.05, *SD* = 9.65 and *M* = 23.85, *SD* = 6.97).

According to the test of between-subject effect for the total number of CIUs, there was a significant main effect for groups, $F(2, 59) = 19.79$, $p < .000$. Post-hoc analysis with multiples comparisons showed the significant differences to exist between younger adults and older adults who have technology experience ($p < .000$) as well as between younger adults and older adults with limited technology experience ($p < .000$). There was no difference between the two older adult groups ($p = .172$).

Percentage of CIUs. For the percentage of CIUs, there was no significant main effect across groups, $F(2, 59) = 2.822$, $p = .068$. Furthermore, post-hoc multiple comparisons show no significant differences across groups.

CIUs per minute. The number of CIUs produced within a minute showed a significant main effect for groups, $F(2, 59) = 19.777$, $p = .000$. Post-hoc analysis using multiple comparisons showed the younger group to be statistically different from the older group with technology experience ($p < .000$) and the older group with limited technology experience ($p < .000$). Additionally, there was no statistically significant difference between the older adult group with technology experience and the older adult group with limited technology experience ($p = .222$).

Are there Differences in Performance Across Interfaces?

Total number of CIUs. The descriptive data indicated the production of more CIUs with the grid display ($M = 41$, $SD=10.56$) than with the VSD ($M = 38.33$, $SD = 7.01$) by young adults. A similar outcome was observed with both older adult groups.

In the older adults with technology experience, the total number of CIUs produced was higher on the grid display ($M =29.58$, $SD = 8.38$) than on the VSD ($M = 28.50$, $SD = 7.35$). The older adults with limited technology experience also produced more CIUs with the grid display ($M = 26.05$, $SD = 9.65$) compared to the VSD. See table 3 for descriptive statistics for data analyzed without excluding outliers.

Test of within-subject effects showed a significant main effect for the type of interface when considering the total number of CIUs, $F(1, 59) = 4.08$, $p = .048$. However, this significance did not hold for Bonferroni adjustment for three repeated analyses ($p = 0.016$). There was no significant interaction effect for the within-subject effect, $F(2, 59) = 0.249$, $p = .780$.

Percentage of CIUs. The percentage of CIUs were almost the same in the grid display (*M* = 87.65, *SD* = 8.24) and the VSD (*M* = 87.90, *SD* = 8.97) for young adults. For older adults with technology experience, the percentage of CIUs produced were descriptively higher on the VSD (*M* = 88.94, *SD* = 9.08), compared to the grid display (*M* = 84.46, *SD* = 8.67). The older adult group with limited technology experience performed similarly in the grid (*M* = 82.24, *SD* = 9.91) and VSD (*M* = 82.07, *SD* = 13.52) in terms of percentage of CIUs.

The test of within-subject effects for the percentage of CIUs produced show no significant main effect for the type of interface used, $F(1, 59) = 1.007$, $p =.320$ or an interaction effect, $F(2, 59) = 1.045$, $p = .358$

CIUs per minute. Based on descriptive data for the number of CIUs produced per minute, young adults produced more CIUs within a minute with the grid display (*M* = 5.13, *SD* = 1.32) compared to the VSD (*M* = 4.79, *SD* = 0.88). In the older adult group with technology experience, a similar number of CIUs were produced on the grid display (*M* = 3.70, *SD* = 1.05) and the VSD (*M* = 3.57, *SD* = 0.92).

Similarly, older adults with limited technology experience performance on the interface did not vary with slightly more words produced on the grid display (*M* = 3.26, *SD* = 1.21) compared to the VSD (*M* = 2.98, *SD* = 0.87).

The number of CIUs produced per minute showed a statistically significant main effect for the interfaces, $F(1, 59) = 4.059$, $p = .049$. However, this significance did hold for Bonferroni adjustments. Once again there was no significant interaction effect, $F(2, 59) = 0.251$, $p = .779$.

Results from Data with Outliers Excluded

The study data was analyzed by excluding three participants who were identified as acting as outliers from the rest of the sample. These outliers were determined by using box plots.

See Table 5 for means and standard deviations for each of the variables measured.

Are there Differences in Performance Across Groups?

Total number of CIUs. There was a statistically significant group difference, $F(2, 56) = 23.617$, $p < .000$ and an interaction effect, $F(1, 56) = 1096.944$, $p < .000$. Post-hoc analysis using multiple comparisons show a significant difference between young adults and the older adult group with technology experience (p < .000) and a significant difference between the young adults and the older adults with limited technology experience ($p < .000$). There was no significant difference between older adult groups ($p = .074$).

Table 5. Means and Standard Deviations for Total number of CIUs, Percentage of CIUs, and CIUs per minute Across Interfaces and Groups Once Outliers were Excluded (n = 59)

	Young Adults (*n* = 18)	Older Adults with Technology Experience (*n* = 22)	Older Adults with Limited Technology Experience (*n* = 19)
CIUs in GD	41.06 (10.56)	29.86 (8.71)	24.74 (7.87)
CIUs in VSD	38.33 (7.01)	27.95 (7.40)	23.11 (6.29)
Percentage of CIUs in GD	87.66 (8.24)	86.31 (6.16)	81.78 (9.95)
Percentage of CIUs in VSD	87.90 (8.97)	89.54 (8.94)	81.94 (13.88)
CIUs per minute in GD	5.13 (1.32)	3.74 (1.09)	3.10 (0.98)
CIUs per minute in VSD	4.79 (0.88)	3.50 (0.93)	2.89 (0.79)

n = number of participants; CIUs = Correct Information Units; GD = Grid Display; VSD = Visual Scene Display

Percentage of CIUs. There was a statistically significant group difference, $F(2, 56) = 4.088$, p = .022; however, it did not withstand Bonferroni adjustments. There was a statistically significant interaction effect, $F(1, 56) = 7612.968$, $p < .000$). Post-hoc analysis showed a significant difference between the two older adult groups ($p = .034$); however, this did not withstand Bonferroni correction.

No statistically significant difference was seen between the young adult group and the older adult group with technology experience ($p = .998$) or the young adult group and older adult group with limited technology experience ($p = .052$).

CIUs per minute. There was a statistically significant main effect for groups, *F*(2, 56) = 23.599, *p* < .000, and an interaction effect, *F*(1, 56) = 1098.368, *p* < .000. Post-hoc analysis using multiple comparisons show a significant difference between young adults and older adults with technology experience (*p* < .000) and between young adults and older adults with limited technology experience (*p* < .000). There was no statistically significant difference between the older adult groups (*p* = .074).

Are there Differences in Performance Across Interfaces?

Total number of CIUs. According to descriptive statistics, the total number of CIUs produced with the grid display was greater (*M* = 41.06, *SD* = 10.56) than with the VSD (*M* =38.33, *SD* = 7.01) for young adults.

The older adults with technology experience also performed better on the grid display (*M* = 29.86, *SD* = 8.71) than on the VSD (*M* = 27.95, *SD* = 7.40). The older adult with limited technology experience similarly performed better on grid display (*M* = 24.74, *SD* =7.87) than on the VSD (*M* = 23.11, *SD* = 6.29). The test of within-subject effects shows a significant main effect for interfaces, *F*(1, 56) = 4.437, *p* = .040. However, the significance did not withstand Bonferroni corrections.

Percentage of CIUs. The test of within-subject effects shows no significant difference across interfaces, *F*(1, 56) = 0.626, *p* = .432. There was no significant interaction effect, *F*(2, 56) = 0.455, *p* = .637.

CIUs per minute. The test of within-subject effects showed a significant main effect for interfaces, *F*(1. 56) = 4.412, *p* = 040. This significance did not withstand Bonferroni correction. Furthermore, there was no significant interaction effect, *F*(2, 56) = 0.102, *p* = .903.

Preference for the Interfaces

Preference data were examined for the sample of 62 participants as well the 59 participants (3 participants excluded as outliers) using the Chi-square analysis. See Figure 7 for a visual presentation of the preference results obtain from the 62 participants.

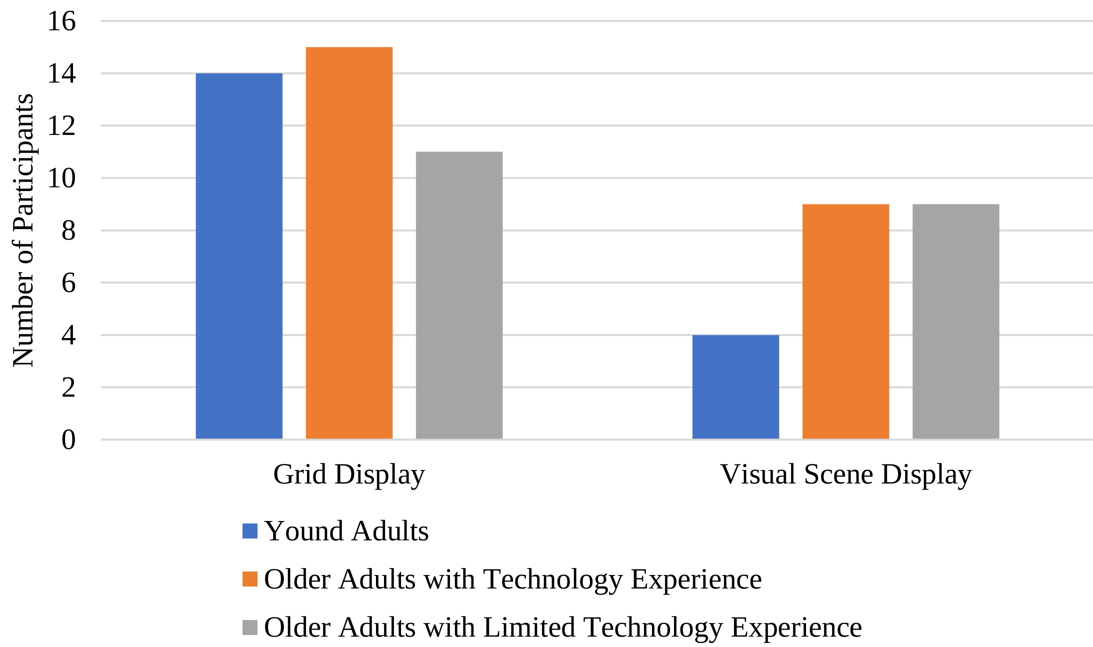


Figure 7. Results on Interface Preference of the 62 Participants.

According to the Chi-square analysis, there was no significant relationship between the type of group and preferred interface prior to excluding outliers, (2, *N* = 62) = 2.217, *p* = 330. Of the 18 young adults, 14 preferred the grid display, and four preferred the VSD.

In the older adults with technology experience, 15 preferred the grid display, and the remaining nine preferred the VSD. Of the 20 older adults with limited technology experience, 11 preferred the grid display, and nine preferred the VSD.

Similarly, when outliers were excluded, there was no significant relationship between the type of group and preferred interface, (2, *N* = 59) = 2.696, *p* =.260. Of the 18 young adults, 14 preferred the grid display, while four preferred the VSD. In the older adult group with technology experience, 13 preferred the grid display while the remaining nine preferred the VSD.

Likewise, in the older adult group with limited technology experience,10 preferred the grid display, and the remaining nine preferred the VSD. See Figure 8 for preferences, as expressed by the 59 participants.

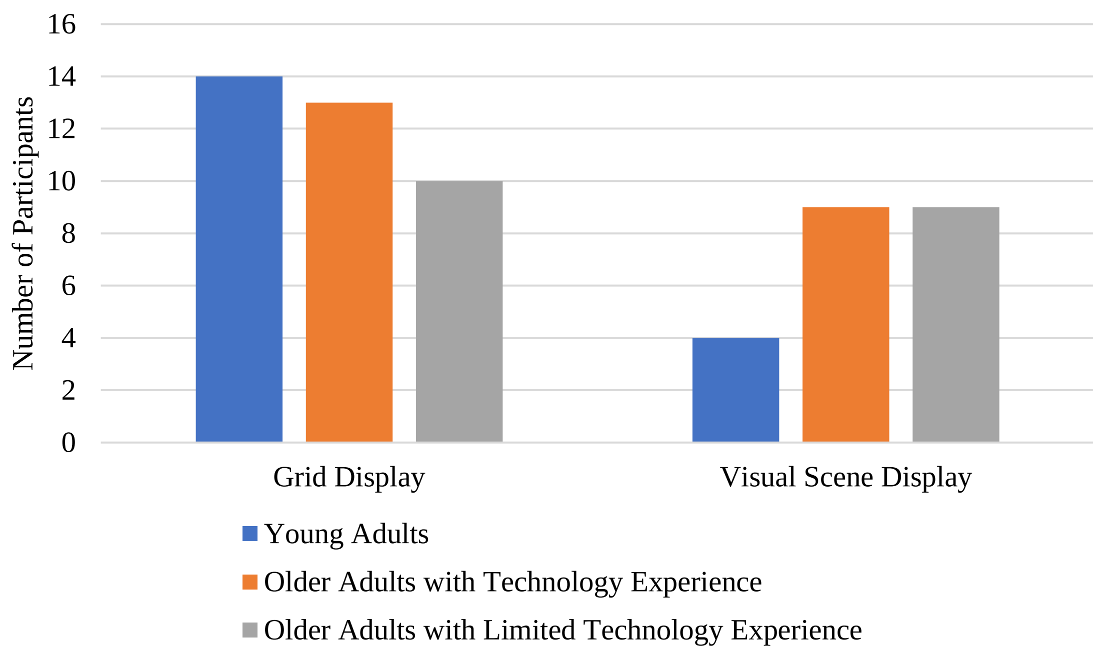


Figure 8. Results on Interface Preference of the 59 Participants.

Reasons for Preference

The interviews were examined to understand the reasons for the preference of a particular interface. Participants provided various reasons why they liked or disliked an interface.

Reasons for Liking the Grid Display

In the young adult group, half of the participants (*n* = 9) indicated the grid display to be more organized. Young adults further found target words easier to locate (*n* = 6), and that folder labels and images helped locate the words (*n* = 5). One feature commonly liked by older adults with technology experience was the availability of categories and subcategories (*n* = 5).

Additionally, they found the grid display to be more accessible when locating words (*n* = 5). Like young adults, these participants found the labels and images on folders to be helpful in locating target words (*n* = 4). Even though the grid display and the VSD interface had the same word options, the older adults with technology experience felt the grid display had more word choices (*n* = 4).

The features commonly liked by older adults with limited technology experience were the organization of words in categories (*n* = 5) and the capacity to locate words more easily (*n* = 4). They also felt there were more word choices with the grid display SD (*n* = 4). See Table 6 for other reasons for liking the grid display across groups.

Reasons for Disliking the Grid Display

The reasons for disliking the grid display varied across participants. Consequently, common reasons for disliking were limited. Some reasons for disliking the grid display include the need to search in multiple folders (*n* = 5), uncertainty about available word options in folders (*n* = 5), difficulty in remembering the location of words (*n* = 5), difficulty in locating words (*n* = 5), and difficulty in locating verbs (*n* = 4). See Table 7 for more reasons for disliking the grid display, as expressed by each group.

Table 6. Reasons for Liking the Grid Display as Described by Participants

Reasons for Liking	Group 1 (*n*)	Group 2 (*n*)	Group 3 (*n*)
Able to learn the system faster	1	0	0
Aligns with how words are processed to form sentences	2	1	0
Aligns with the individual's way of processing thoughts	1	3	0
Appears to have more word choices	1	4	4
Appears to have more prepositions	0	0	2
Aware of where to find words	3	1	1
Use of categories and subcategories	1	5	2
Organization of words in categories	3	2	5
Categorization makes it easier to locate words	1	0	0
Easier to know what's in each folder	2	0	1
Easier to locate words	6	5	4
Easier to make sentences	1	1	0
More flexible to make sentences	0	0	2
Easier to navigate	4	2	0
Easier to remember where words are	3	2	0
Easier to locate prepositions	1	0	0
Easier to form complex sentences	1	0	0
Easier to locate words a second time	1	0	0
Easier after exposure	0	0	1
Easier to see	0	1	2
Easier	2	4	3
Faster	2	1	1
Folder labels	0	1	0
Folder label/image prompts possible word options	5	4	0
Gave structure and direction to search for words	0	2	0
Information is condensed	1	0	0
Intuitive	0	1	0
Less distracting	0	0	1
logical	1	0	1
More descriptive	0	1	0
More organized	9	2	1
Clearer	0	1	0
Narrows down the search for words	0	1	0
No scrolling involved	1	0	0
Reduces excessive scrolling/searching	0	2	1
Symbols	2	1	3
A small number of categories	1	0	0
Similar to operating a computer/familiar interface	0	2	0

n = number of participants; Group 1 = Young Adults; Group 2 = Older Adults with Technology Experience; Group 3 = Older Adults with Limited Technology Experience.

Table 7. Reasons for Disliking the Grid Display as Described by Participants

Reasons for Disliking	Group 1 (*n*)	Group 2 (*n*)	Group 3 (*n*)
A word can be in multiple folders, but was not	0	1	0
Complicated	0	0	1
Confusing	0	0	1
Difficult	1	0	0
Difficult to locate words	1	3	3
Difficult to locate verbs	0	1	3
Difficult to search in folders	0	1	2
Difficult to remember the location of words	0	2	3
Difficult to navigate	0	2	0
Difficult to understand navigation	0	0	1
Disagree with how words are organized within folders	0	3	0
Does not draw one's attention	0	0	1
Folders are too similar	0	1	0
Frustrating	0	1	1
Intended sentence is forgotten when searching across folders	1	0	0
Involves more thinking	1	3	0
Involves more guessing	0	0	1
Limited word choices within folders	1	0	0
Made too many mistakes	0	1	0
Not colorful	0	1	1
Not intuitive	0	1	1
Organization of words in categories	0	2	0
Too many folders	1	0	0
Takes more time	0	2	2
Requires more effort	0	1	0
Requires more exposure	0	1	1
Requires more memorization	1	0	1
Requires searching in multiple folders	2	1	2
Requires thinking of word associations	0	1	0
Return to the homepage is confusing	0	1	0
The organization of words within categories	1	0	0
Symbols	0	0	1
Stressful	0	1	0
Uncertainty about available word options in folders	1	2	1

n = number of participants; Group 1 = Young Adults; Group 2 = Older Adults with Technology Experience; Group 3 = Older Adults with Limited Technology Experience.

Reasons for Liking the VSD Interface

The young adults did not express many shared reasons for liking the VSD interface. However, some shared reasons for liking the VSD include the pictures (*n* = 3), use of real pictures (*n* = 2), appears to have more word choices (*n* = 2), and easier to assume the available word options based on the scene (*n* = 2).

The older adult group with technology experience also found it easier to assume available word options with scenes (*n* = 4). The older adult group with limited technology experience had more shared reasons for liking the VSD than the other two groups. These participants with limited technology experience liked the VSD interface because it was easier to locate words (*n* = 5), it was easier to recognize the words (*n* = 5), and they liked the pictures (*n* = 6). See Table 8 for the various reasons for liking the VSD and the number of participants who mentioned similar reasons.

Reasons for Disliking the VSD Interface

The young adults disliked the VSD interface because they did not like the action of scrolling (*n* = 6), they found the organization of target words to be random (*n* = 5) and indicated that it was difficult to see the content of the thumbnail view (*n* = 4).

The older adults with technology experience disliked the VSD because they found target words randomly organized (*n* = 4). They also indicated that it was challenging to locate target words (*n* = 3), it required more scanning and searching to find the target word (*n* = 3) and required memorization (*n* = 3).

The older adults with limited technology experience also found it difficult to see the target words in the thumbnails (*n* = 4) and felt they had to search more (*n* = 3). See Table 9 for other reasons for disliking the VSD, as expressed by the three groups.

Table 8. Reasons for Liking the VSD as Described by Participants

Reasons for Liking	Group 1 (*n*)	Group 2 (*n*)	Group 3 (*n*)
Appears to have more word choices	2	0	3
Can make a sentence using a single scene	0	1	0
Draws attention	0	0	2
Easier to locate words	0	3	5
Easier to navigate	1	1	0
Easier to remember where words are	1	1	1
Easier to assume possible word options based on the scene	2	4	0
Easier to recognize target words	1	0	5
Easier to make sentences	0	0	1
Easier to learn	0	0	1
Easier to see	0	1	2
Easier with exposure	0	2	0
Easier with people-focused images	0	2	0
Easier	0	2	0
Faster	0	1	0
Pictures	3	3	6
Use of real pictures	2	1	3
Provides more information	1	2	3
Intuitive	0	1	0
More colorful	0	0	4
More opportunity to locate words	1	0	0
More descriptive	1	0	1
More meaningful	0	0	1
Multiple words related to the scene are grouped together	1	2	3
More words within a scene	2	1	0
Not required to search in multiple folders	0	1	1
Not required to remember folder options	0	0	1
Organization of words	0	0	1
Colorful	0	2	0
Reduces excessive searching	0	2	0
Same word in multiple scenes	1	1	0
Scenes help narrate a story	0	1	0
Scrolling	0	1	1
Simple to use	0	1	0
Thumbnails	0	2	0
Visually appealing	0	1	1

n = number of participants; Group 1 = Young Adults; Group 2 = Older Adults with Technology Experience; Group 3 = Older Adults with Limited Technology Experience.

Table 9. Reasons for Disliking the VSD as Described by Participants

Reasons for Disliking	Group 1 (*n*)	Group 2 (*n*)	Group 3 (*n*)
All content within scenes are not labeled as target words	2	3	0
Background makes it difficult to find words/distracting	0	1	0
Difficult to see content in thumbnail view	4	2	4
Need to open each thumbnail to see the image	2	1	1
Can only make a few sentences	1	0	0
Can only produce random sentences/difficult to narrate	0	1	0
Difficult when unfamiliar with scenes	1	0	0
Difficult to locate words	2	3	1
Difficult to locate abstract words	1	0	0
Difficult to locate prepositions	1	0	0
Difficult to locate verbs	0	1	0
Difficult to make sentences while scrolling across scenes	1	0	0
Difficult to remember where words are within scenes	2	2	2
Difficult to understand how to use the interface	1	0	0
Difficult to see	0	0	1
Disagree with labels	1	0	0
Easily distracted by pictures	0	1	0
Interferes in formulating sentences	0	1	0
Organization	1	0	0
Organization is random	5	5	1
Lack of organization	2	3	1
Lag time while pulling up scenes	1	1	0
Looking through scenes to find words	0	1	0
Requires time to familiarize/learn	1	1	0
Requires more scanning/searching	0	3	3
Requires memorization	0	3	0
Scenes are crowded	1	0	0
Scrolling	6	0	1
Same word in multiple places	0	2	0
Takes more time	1	2	0
Too few words in a scene	1	1	1
Too many scenes	1	0	0
Pictures are too small	0	1	0
Too much information/distracting	1	2	1
Not familiar with the available word options	0	0	1
Visibility affected when reaching for thumbnail	1	0	0
Visual images are not necessary	0	0	1

n = number of participants; Group 1 = Young Adults; Group 2 = Older Adults with Technology Experience; Group 3 = Older Adults with Limited Technology Experience.

As presented in the above tables, the findings from interviews indicated some similarities across groups for liking and disliking the two interfaces. In contrast, other reasons were limited to a group or individual.

DISCUSSION

The purpose of the current study was to understand how healthy individuals of varying ages and technology experience use two different AAC interfaces to describe pictures. The study looked at group differences on performance based on three dependent variables, which included the total number of CIUs produced, the percentage of CIUs, and the number of CIUs produced per minute. Additionally, the study examined the relationship between the preferred choice of AAC interface with the three study groups. Furthermore, participants had the opportunity to share their thoughts on the various features preferred on the two AAC interfaces.

The process involved in adopting AAC by individuals with acquired communication deficits may be different compared to its adoption by individuals with developmental communication deficits. This distinction occurs as individuals with developmental deficits are often exposed to AAC early on in their lives. Additionally, individuals with developmental communication deficits do not have a pre-established spoken language, unlike those with acquired communication deficits. Consequently, individuals with developmental communication deficits have the opportunity for AAC to be acquired rather than learned.

On the contrary, those with acquired communication deficits once predominantly used spoken language to meet their communication needs. Despite that, they must now learn a communication system that relies on a different set of skills (Bartlett et al., 2007; Linebarger et al., 2008; Petroi et al., 2014). Additionally, learning new skills for AAC may be more challenging due to neurological changes that occur with stroke as well as from aging. Likewise, the increased use of high-tech AAC may have an added disadvantage for older adults. However, at present, there is little data to compare the use of high-tech AAC among healthy adults of varying ages to substantiate this claim.

Thus, the current study investigated how healthy adults use high-tech AAC, the impact of age on high-tech AAC, and the effect of technology experience on high-tech AAC in older adults. Additionally, the study compared the grid display and the VSD interfaces in response to the limited research on their comparative usefulness. I used two commercially available AAC apps to program the two AAC interfaces as they are relatively inexpensive than dedicated SGDs. The grid display was programmed on the Proloquo2Go^{TM} while the VSD was programmed on the Snap Scene^{TM} and presented via iPad.

The findings from the current study allow a better understanding of how healthy individuals perform on two AAC interfaces, which should inform performance expectations by those with acquired language deficits such as aphasia. Additionally, it provides descriptive information to improve these AAC interfaces before introducing these systems to people with aphasia.

Are there Differences Among Groups?

It was hypothesized that there would be a significant difference between the young adults who are between the ages of 18 to 39 years and the two older adult groups who are 60 to 91 years. According to Czaja et al. (2006), age was one of many factors that predicted technology use. Hence, I anticipated that young adults would have an advantage over the older groups when using high-tech AAC interfaces via iPad. Furthermore, I expected this difference because young adults may have been exposed to technology at an earlier age than older adults and would thus, be more able to use it efficiently. Additionally, young adults may have been using technology for a longer duration with various activities. Hence, young adults would be more familiar with technology; therefore, less anxious to use unfamiliar high-tech AAC systems.

Conversely, older adults who have limited experience with technology can experience anxiety when introduced to technology (Chiu et al., 2016). Apart from familiarity with technology, age-related changes may affect performance on AAC interfaces. Motor ability, perceptual ability, working memory, and attention play a role when using symbol-based AAC apps as used in the current study (Bartlett et al., 2007; Dukhovny & Zhou, 2016; Linebarger et al., 2008; Petroi et al., 2014). However, healthy aging results in changes in these abilities (Anderson, 2012; Kennedy & Raz, 2009; Tse et al., 2010). For example, older adults take a longer time to point to targets presented on a screen for both single pointing and back-and-forth pointing (Teeken et al., 1996). Also, older adults take more time to process symbols found on mobile phones (Chiu et al., 2006). Hence, older adults may have similar challenges when using an AAC app.

As hypothesized, there was a significant difference between how young adults described composite pictures via AAC interfaces compared to older adults. This significant difference was evident in two of the three measurement variables, which included the total number of CIUs and the number of CIUs per minute. However, there was no significant difference in the percentage of CIUs produced across groups. There are no known studies that compared healthy adults across different ages involved in a picture description task using high-tech AAC interfaces. Hence, I cannot compare the results of this study with any previous AAC study. However, results did align with what we know of older adults' use of technology and age-related changes.

Based on my findings, the total number of CIUs produced, and the number of CIUs per minute differed significantly for both older adult groups when compared with the young adults. This result allowed me to reject the null hypothesis and corroborate existing findings that older adults take more time to identify symbols, are slower at processing information, and slower at pointing to symbols (Chiu et al., 2006; Kennedy & Raz, 2009; Teeken et al., 1996). As expected, the slower processing and pointing to symbols may have led to older adults producing fewer CIUs per minute in the current study.

One measurement variable that had no significant difference across ages was the percentage of CIUs. The percentage of CIUs was calculated using the total number of words produced and the number of CIUs produced. Two reasons may have led to the non-significant difference in the percentage of CIUs produced. The number of foil words programmed on the interfaces was limited and similar for all participants. Consequently, all participants had an equal number of opportunities to use an incorrect word. Also, participants in the current study were healthy adults without communication deficits. Hence, there was a lower probability of using an irrelevant word when describing the pictures.

If technology experience was crucial for AAC app use, then a significant difference in performance between the two older adult groups (mean age and gender matched) should occur. However, findings indicated that there was no significant difference between the older adult groups. Hence, the results suggest the variation across groups may not so much be due to technology experience but more to do with age.

As age was a significant factor, then age-related changes in skills for AAC, such as visual cognition, motor, attention, working memory, and executive functioning, could have a more substantial impact on AAC use than technology experience.

A combination of different factors associated with aging may have resulted in the differences in AAC performance. Based on prior studies of pointing movement, age does impact the time required to point or point back and forth on a screen (Teeken et al., 1996). Additionally, the task used in the Teeken et al. (1996) was time-sensitive. Hence, it may have limited the number of CIUs that older adults could produce due to slower response time. This behavior was evident in the current study data with younger adults producing significantly more CIUs per minute compared to the older adults.

Are there Differences in Performance Across the Two AAC Interfaces?

I hypothesized a significant difference across the two interfaces. The two interfaces in the current study varied based on symbol organization. The grid display used a hierarchical structure with target words grouped within categories, also known as folders. Participants must follow several steps to identify target words on the grid display to describe composite pictures. First, participants must identify the superordinate category associated with a target word. Second, they must identify the subfolder within the superordinate category and finally select the target word. In addition, if an incorrect target word was selected, then the participant must recall navigation steps to return to the homepage and reattempt the search for the target word.

On the contrary, the VSD interface had scenes with target words embedded within scenes. Participants had to navigate across multiple scenes by scrolling up and down a set of thumbnails (e.g., represents the identical scene in a smaller size) provided on the left side of the iPad screen. Participants had to tap the corresponding thumbnail to see the enlarged view and select a word embedded in a scene. The context of the photographs should have prompted the participant to locate target words. There was no requirement to think of semantically related superordinate categories with the VSD interface. For example, to produce the word sandcastle, participants had to find the corresponding image, such as a beach scene. Participants may also scroll across all scenes without considering the relationship between the target words and context until they locate relevant target words.

I hypothesized that there would be a significant difference in performance across interfaces based on several factors. Studies on visual attention have found that healthy adults attend more quickly with a higher preference when images include human figures (Wilkinson & Light, 2011). Additionally, healthy adults fixated more quickly to objects acted upon by human figures, also known as task-engaged images (Thiessen et al., 2014). Individuals with aphasia have also responded in a similar manner (Thiessen et al., 2014). According to Thiessen et al. (2014), objects presented in task-engaged contextual photographs drew more fixations than camera-engaged contextual photographs. The VSD interface used in the current study incorporated task-engaged contextual photographs. Hence, it was expected that participants would identify required target words more accurately and quickly resulting in better performance with the VSD interface. There is a paucity of research comparing grid display to VSD. There was only one known study that compared grid displays with VSD for adults with aphasia (Brock et al., 2017). In Brock et al. (2017), the two participants in the study demonstrated better turn taking and less frustrated with the VSD. Additionally, generalization to untrained narration was observed with VSD interface (Brock et al., 2017). These findings indicated better performance with the VSD, and a similar outcome was anticipated in the current study.

However, the VSD interface used in the Brock et al. (2017) study was different from the scenes used in the current study. The current study used hotspots that allowed single words to be selected (i.e., one word at a time was combined to formulate utterances). Furthermore, the contextual images programmed on the VSD interface were not identical to the pictures described. Consequently, a different outcome was plausible with this design, despite there being no known studies with this design for healthy adults or people with aphasia.

The study findings show that the hypothesis did not hold because no significant differences were demonstrated between the grid and VSD interfaces for any of the measurement variables. Hence, participants in the current study did not respond differently across the two interfaces. Thus, based on these findings, either the grid or the VSD interface could be used for a picture description task with both younger and older participants.

The AAC literature has demonstrated that people with aphasia use the grid display successfully for various functions. The grid display can be used to formulate short utterances for requests and produce sentences with differing syntactic levels (Hough & Johnson, 2009; Johnson et al., 2008; Koul et al., 2008). The current study also gives additional evidence for using the grid display to formulate utterances when healthy adults describe composite pictures. In fact, participants completed the experimental task successfully despite the relatively abbreviated training they received; familiarizing with display functions, producing three utterances to describe a practice picture, and looking at the task-related vocabulary for 2-minutes. The training took approximately 15-20 minutes with each interface.

The VSD interface has grown in popularity. Proponents have argued that it is a more suitable option for people with aphasia (Light et al., 2019; Nicholas & Connor, 2017; Purdy & Dietz, 2010). To use an AAC system, the individual must maintain the target word in memory and attend to the visual information while searching for the target word (Petroi et al., 2014; Purdy & Dietz, 2010). However, individuals with aphasia may have deficits in working memory, visual attention, and executive functioning (Nicholas et al. 2011; Purdy & Wallace, 2016; Tse et al., 2010). Consequently, to overcome these deficits, the VSD interface has been recommended over the grid display. Unlike the grid display, individuals do not need to remember different navigation steps for target words when using the VSD (Nicholas & Connor, 2017). Instead, participants can look at contextually rich images to prompt them to find target words. Additionally, VSD interfaces use contextual images that draw attention to target words (Wilkinson & Light, 2011). However, despite the benefits of the VSD interface, the findings from this study do not suggest that it is any better than the grid display for healthy adults with adequate vision, hearing, and cognition.

In the present study, there may have been several reasons why the VSD was not statistically better than the grid display. For example, previous studies have used VSDs with preprogrammed utterances and not with single word hotspots (Brock et al., 2017; Dietz et al., 2014; Griffith et al., 2014). Using preprogrammed utterances restrict the ability to produce novel statements. However, if the aphasia severity is greater, then programmed utterances may help maintain communication interactions, which may reduce isolation and improve quality of life. Additionally, the majority of research on VSDs have focused on narration (Dietz et al., 2018; Griffith et al., 2014). Due to the increased time taken when navigating from one level to another level in the grid display, narrating a story may be more difficult with the grid display compared to using the VSD.

Furthermore, previous studies used familiar (e.g., personal photographs) contextual images or identical images to the story that was narrated. For example, in Brock et al. (2014) study, participants described episodes of a television program. Hence, the researchers took pictures from the television episodes and included them in the VSD interface. However, in the current study, the VSD interface had contextual images that were different from the pictures described. Using identical pictures restricts the usability of the VSDs to a stimulus (e.g., the composite picture, or story). Furthermore, it may not encourage generalization when the individual must describe a different set of composite pictures. Also, caregivers and others who are involved in programming the AAC devices may have the added burden of developing a new set of scenes based on each task. Furthermore, using identical pictures would make it difficult to justify if the selection of target words and messages occurred as a means of meaningful and authentic communication and not as random matching. For these reasons, the current study departed from programming identical composite pictures used for the task on to the VSD.

AAC studies have indicated that individuals with aphasia require training over several sessions to show improvements in treatment outcomes (Brock et al., 2017; Dietz et al., 2018; Purdy & Wallce, 2016; Waller et al., 1998). However, some exploratory investigations examined AAC use in the absence of more intensive training as done in the current study (Dietz et al., 2014; Griffith et al., 2014; Hux et al., 2010). Hence, it may be possible that the performance on each AAC interface to change with increased training and should be investigated in the future. Individuals in the current study did not have language deficits. Individuals who use AAC must use different skills not required in spoken language (Bartlett et al., 2007; Linebarger et al., 2008; Petroi et al., 2014). However, there is a gap in the literature to understand how healthy aging and experience in technology effect AAC outcomes. Therefore, the current study included healthy adults. However, these outcomes may vary with replication using individuals with aphasia.

The current study did not find the VSD interface to be superior to the grid display on the variables measured. Hence, participants did not produce more information in terms of CIUs with the VSD compared to the grid display. Similarly, the speed of producing CIUs as determined by the number CIUs per minute was also not better. However, there are no known studies that examine the VSD interface organized with single word hotspots for people with aphasia or healthy adults in a picture description task to compare findings. According to the AAC literature, individuals with aphasia can use the grid display interface to combine single words to formulate utterances (Johnson et al., 2008; Koul et al., 2008). Similarly, the current study gives evidence that healthy adults can use VSD interfaces with single word hotspots, which involves combining single words. Furthermore, participants in the current study performed on VSDs with single words similar to the grid display when formulating utterances. Therefore, VSD interfaces with hotspots may be a useful tool for individuals with aphasia and should be investigated further in the future. In fact, VSD interfaces with hotspots may be a more accessible alternative to folders found in the grid display as it reduces demand for linguistic ability when searching for target words

What was the Preferred AAC Interface?

I hypothesized more individuals would prefer the VSD interface based on various features of the VSD interface and its documented benefits. However, the hypothesis did not hold, as descriptively more individuals preferred the grid display interface over the VSD interface. Additionally, there was no statistically significant relationship between groups and AAC interface preference.

Descriptively, more young adults preferred the grid display, as did the older adults with technology experience. However, for the older adults with limited technology experience preference for the grid display and the VSD interface was nearly equal. Consequently, based on these findings, neither age, nor technology experience determined the choice for an AAC interface.

Reasons for liking and disliking each interface

Participants expressed various reasons for liking and disliking each interface. Some reasons were shared across groups, while other reasons were limited to a group or individual. Most individuals, especially young adults found the grid display interface to be more organized.

Other features commonly liked about the grid display include the use of categories and subcategories, and the use of labels and images on folders to help participants locate words.

Although some participants found it easier to locate words on the grid display, others found it more challenging.

In fact, some participants found it challenging to locate action words on the grid display. This may indicate the need to change the presentation of the action folders by either changing the labels or symbols used. Additionally, some participants indicated issues related to the organization. For example, some indicated that they did not like the organization of words in categories, while others mentioned disagreement on word categorization within folders. Other reasons for disliking the grid display interface include having to search in multiple folders, uncertainty about available word options in folders, and difficulty remembering the location of words.

In the VSD interface, all groups and participants liked the pictures. Some participants specifically indicated that they preferred the real-life pictures found on the VSD. Participants found the VSD interface to be less organized than the grid display interface. In the future, the organization may be improved by labeling scenes and by explaining the grouping with increased training. Some participants indicated that it was difficult to locate prepositions on the VSD. Thus, grouping prepositions within the same scene (e.g., have the words on and under in the same scene instead of in two different scenes) may help. It was apparent that the thumbnail view was too small for some participants. However, I could not change the size of thumbnails due to app constraints. Some individuals wanted more words to be hotspots within scenes, while others mentioned that they did not like having the same target word in multiple places. However, programming each concept that appears on a scene as a hotspot would inadvertently result in the same target word appear in multiple places, and these variations in presenting target words should be addressed in future studies.

Overall, some features were commonly preferred, while other features may be specific to the individual or group. Additionally, there was disagreement among participants regarding various features for both interfaces. For example, some individuals did like the organization of words in categories found on the grid display. In contrast, others indicated that they did not like the organization of words in categories. Some felt there were more word choices in the grid display, while others found more word choices on the VSD interface. Similarly, some thought it was easier to locate words on the grid display while others found it challenging to locate words. These various reasons that participants liked or disliked an interface underscore the importance of considering individual differences and needs. The various features preferred highlight the importance of involving the individual who requires the AAC system, their families, and to consider individual preferences when recommending an AAC interface.

Clinical Implications

The study findings provide a preliminary understanding of how healthy individuals across different ages and technology experience used two different AAC interfaces. Although the current study did not include individuals with communication deficits, the findings can inform expectations for those with communication deficits such as aphasia. The results demonstrated that young adults performed at a higher level than older adults on measurement variables such as the number of CIUs and the number of CIUs per minute with limited opportunity for practice. However, these measurements may improve in older adults when combined with more intensive training or with increased exposure.

Often, due to a lack of familiarity with technology, older adults may be reluctant to adopt a high-tech AAC system. However, according to the current study, limited technology experience did not significantly impact performance on either the grid or VSD high-tech AAC interfaces. These findings may help motivate clinicians to consider using a high-tech AAC interface via iPad for older adults with aphasia who require AAC.

Based on this study's results neither the grid display nor the VSD interface was better for completing a picture description task, although VSD interface use seems to be gaining favor in AAC use. Consequently, clinicians may use the VSD interface with single word hotspots as an alternative interface. The novel use of the VSD interface for sentence construction was based on Light and colleagues' (2019) recommended future AAC research examine different design options for both individuals with developmental and acquired communication deficits.

Participants in the present study reported their likes and dislikes for various features on each interface. These comments may be valuable information to future researchers and clinicians when designing AAC interfaces. For example, most participants indicated that they liked the pictures used in the VSD interface. Hence, real-life images instead of pictographs can be incorporated even in the grid display. In the VSD, some participants found the thumbnail view too small and could not be adjusted. This is invaluable information for app designers and developers to produce user-friendly AAC apps. Furthermore, findings from interviews suggested that those who require AAC may have individual preferences that need to be considered when personalizing AAC systems to meet their needs.

Limitations

There were no statistically significant differences in mean-age and gender matched participants in the two older adult groups. However, descriptively the mean age in the older adult group with limited technology experience was greater than the older group with technology experience. Consequently, the results of this study may be stronger if each participant across the older adult groups was age-matched one-to-one. Additionally, snowball sampling used in recruitment may have resulted in a sample that is not representative of the entire population.

The current study utilized two commercially available apps to program the grid display interface and VSD interface. Due to app constraints, I could not make some required changes that would have been beneficial. The Snap Scene™ app was used for the VSD interface. The thumbnail view for this app had only two size options. Although the larger thumbnail size was selected, it may have been relatively small for the older adult groups. Additionally, there was a lag time between touching the thumbnail and the scene opening, which may have increased the time taken to use the app. In fact, participants did indicate that the VSD interface takes more time, and some mentioned the lag time when pulling up scenes. One participant indicated that as a right-hander, moving her to thumbnails on the left hand made it difficult to see the enlarged scene that opened on the right side. All these reasons should be considered when designing displays.

Participants had to use each AAC app within an allocated time interval, which may have been a disadvantage for older adults who may require more time than the younger adults to navigate the apps to formulate utterances. The composite pictures and measurement variables in the current study were developed by Nicholas & Brookshire (1993). These investigators asked people with aphasia to describe the pictures using spoken language within a specific time duration. Hence, in the current study, a similar protocol was followed. However, if older adults were not timed, then the study findings might vary. Consequently, performance without time restrictions should be investigated in a future study because older adults may increase the number of CIUs produced when they have more time to complete the task.

Based on research, individuals with aphasia adopted AAC systems with increased training. However, for exploratory purposes, some research used limited training similar to the current study (Dietz et al., 2014; Griffith et al., 2014). However, using a longer training protocol, or providing multiple opportunities with the task might change outcomes.

Recommendations

Participants had only two opportunities (i.e., two composite pictures in a single session) to engage in the experimental task with each AAC interface. However, the opportunity to use each interface multiple times can increase familiarity with the available vocabulary and navigation. Thus, there may be a significant difference in performance between the interfaces when given multiple opportunities to complete the task. In other words, in the absence of training, more exposure could lead to a different outcome and should be investigated in a future study.

The present study was completed in one visit. Participants had three practice attempts during training with each interface. During the practice, all participants successfully produced a novel utterance without the support of the investigator. However, best practices indicated the importance of providing more intensive training for AAC (Brock et al., 2017; Dietz et al., 2018; Purdy & Wallace, 2016; Waller et al., 1998). Consequently, the current study could be repeated by providing training over multiple session.

Some participants did not like it when target words appeared in multiple scenes on the VSD interface. Research with the grid display interface found the fixed location for target words to be more beneficial than in multiple locations (Dukhovny & Zhou, 2016). Similarly, in the future, the benefit of fixed locations should be investigated for VSD interfaces.

Most participants indicated that they liked the real-life images used in the VSD. Hence, I could replicate this study by incorporating real-life pictures to the grid display to investigate the effect of the image on performance and interface preference.

Once the grid interface and VSD interface are improved based on findings from this study, the next appropriate step would be to compare the two interfaces with individuals with aphasia. Individuals with an intact language system may engage different processes to complete the task than those with language deficits. The grid display relies on linguistic information such as word associations when searching for target words located in category folders. For those without language deficits, using word associations as required for the grid display interface would not be a challenge. In fact, healthy adults may easily think words as related to categories. Hence, participants in this study may have found the grid display easier to use, unlike those with communication deficits. Furthermore, Subsequent studies should investigate the use of these interfaces for different language functions, such as sharing personal information, conversations, and story narratives.

Conclusion

Previous research has provided preliminary evidence to indicate that AAC systems can be beneficial for people with aphasia. However, a scarcity of knowledge exists on how age and technology experience effect high-tech AAC use. It is evident that individuals with aphasia are predominantly older adults, and some may have limited technology experience. As discussed, AAC involves using skills that are different from spoken language. Hence, it is crucial to understand how healthy adults use different AAC interfaces to inform performance expectations for people with aphasia. Consequently, the current study attempted to address this gap in the AAC literature.

This study found that young adults were better at producing more CIUs and at a greater speed with AAC apps than older adults. Therefore, age does impact performance on high-tech AAC systems such as AAC apps. This study disapproved that older adults need more technology experience to use AAC apps. Hence, older adults who are AAC consumers should feel encouraged to use these systems despite their prior experience with technology. Furthermore, there was no difference in whether the grid display or the VSD was used to make utterances. Hence, neither interface was superior to the other when describing pictures. Most participants liked the grid display, but neither age nor technology experience determined this preference. The current study investigated the use of a VSD interface with single-word hotspots, which has no documented use with adults. Despite being a novel method for this population, the performance on the VSD was similar to the more widely used grid display interface. However, future research with people with aphasia is warranted to understand the use of this design better.

APPENDIX A. IRB FORM

ACTION ON PROTOCOL APPROVAL REQUEST

Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/research

TO: Neila Donovan
Communication Sciences and Disorders

FROM: Dennis Landin
Kinesiology

DATE: June 11, 2019

RE: IRB# 4246

TITLE: Comparison of High-tech Augmentative and Alternative Communication Interfaces: Do Age and Technology Experience Matter

New Protocol/Modification/Continuation: New Protocol

Review type: Full ____ Expedited _X_ **Review date:** 6/3/2019

Risk Factor: Minimal ___X___ Uncertain ______ Greater Than Minimal______

Approved _____X_____ **Disapproved**__________

Approval Date: 6/11/2019 **Approval Expiration Date:** 6/10/2020

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 75

LSU Proposal Number (if applicable):

By: Dennis Landin, Chairman D Landin

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. **SPECIAL NOTE: When emailing more than one recipient, make sure you use bcc.**

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

APPENDIX B. PICTURES FOR EXPERIMENTAL TASK

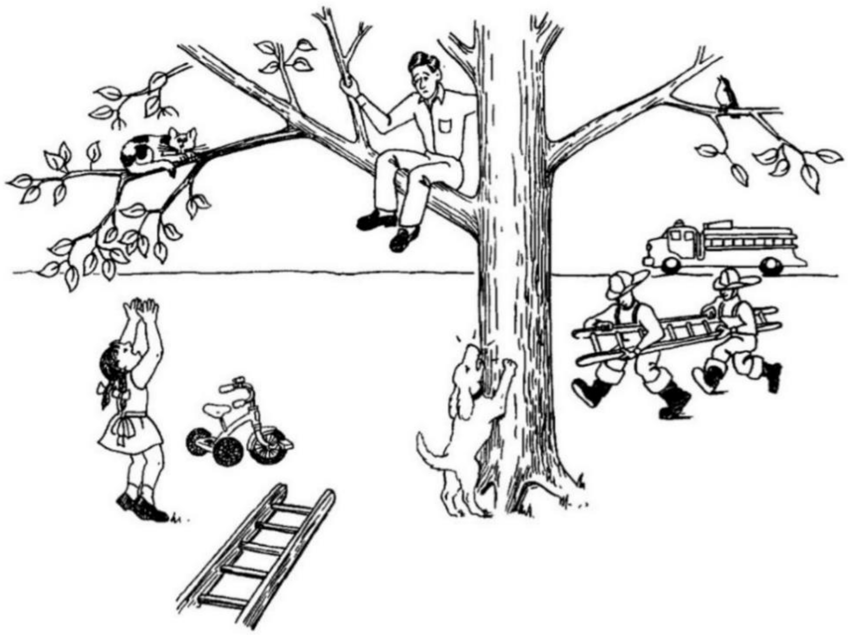


Figure B.1. Picture ne used for the study task take from Nicholas and Brookshire (1993)

Figure B.2. Picture Two used for the study task taken from Nicholas and Brookshire (1993)

APPENDIX C. TARGET WORDS FOR THE EXPERIMENTAL TASK

1. Arms
2. Bark
3. Big
4. Bird
5. Birthday party
6. Bite
7. Boy
8. Branch
9. Bring
10. Broom
11. Cake
12. Cat
13. Chase
14. Climb
15. Come
16. Confusion
17. Couch
18. Cry
19. Dog
20. Down
21. Eat
22. Fall
23. Firemen
24. Firetruck
25. Friend
26. Girl
27. Ground
28. Guests
29. Help
30. Hide
31. Hit
32. in
33. Jump
34. Kids
35. Knock over
36. Ladder
37. Little
38. Livingroom
39. Look
40. Mad
41. Man
42. On
43. Pawprints
44. Present
45. Reach
46. Sad
47. Sing
48. Stand
49. Stuck
50. Take
51. Tree
52. Tricycle
53. Try
54. Two
55. Under
56. Up
57. Woman

APPENDIX D. SCALES FOR RATING IMAGEABILITY AND CONTEXT

- Scale 1 for rating imageability of pictographs used in the grid display and hotspots on VSD

  1 = Not at all

  2 = A little

  3 = Moderately

  4 = A lot

  5 = Exactly

- Scale 2 for rating contextualization of scenes for VSD

  1 = No Context

  2 = Low Context

  3 = High Context

APPENDIX E. QUESTIONNAIRE FOR DEMOGRAPHIC INFORMATION

Participant #: ______________ Examiner: _______________ Date: __________

1. What is your age? __________________

2. What is your gender? _____________

3. What is your ethnicity?

_____ American Indian or Alaska Native
_____ Asian
_____ Black or African American
_____ Hispanic/Latino
_____ Native Hawaiian or Pacific Islander
_____ White
_____ Other: ____

4. Do you have difficulty with vision?

_____ Yes
_____ No

5. Do you wear glasses or contacts to correct your vision?

_____ Yes
_____ No

6. Do you have difficulty with hearing?

_____ Yes
_____ No

7. Do you wear hearing aids to correct your hearing?

_____ Yes
_____ No

8. Do you speak any languages other than English?

_____ Yes, please list: ____
_____ No

9. Can you read English?

_____ Yes
_____ No

10. What is the highest degree or level of school you have completed? If currently enrolled, highest degree received.

_____ Grade school
_____ Some College
_____ 2-year college degree
_____ 4-year college degree
_____ Master's degree
_____ PhD
_____ Other: ____

11. Which of the following best describes your current occupation.

______ Student Major ____
______ Educator
______ Business
______ Medicine
______ Communications
______ Other: ______________________________

12. Do you have any known communication difficulty?

______ Yes
______ No

13. Do you have any neurological condition?

______ Yes
______ No

14. Do you have a history of substance abuse?

______ Yes
______ No

15. Do you have any known mental illness?

______ Yes
______ No

16. Have you ever used a smartphone?

______ Yes
______ No

17. Have you ever used a tablet (i.e., iPad, Kindle reader, Android tablet)

______ Yes
______ No

18. On average, how many hours do you spend using a tablet (i.e., iPad, Kindle, Nook, etc.) per day?

____ 0-1
____ 1-2
____ 3-4
____ 4 or more

19. Which of the following best describes your total household income before taxes in the past 12 months? For Students, mark both parents (mark with the letters- MF) and personal income (mark with letter – P).

____ Less than $15,000

____ $15,000-$29,999

____ $30,000-$44,999

____ $45,000-$59,999

____ $60,000-$74,999

____ $75,000-$99,999

____ $100,000-$149,999

____ $150,000 or more

APPENDIX F. POST TESTING INTERVIEW QUESTIONNAIRE

1. Which Display did you like? (Point to the two displays) ___________

2. What did you like about it?

3. What did you not like about the other one?

APPENDIX G. STUDY INSTRUCTIONS

General Instructions about the Study

This study involves producing sentences by combining words to describe what's happening in pictures.
You will describe pictures using words found in two programs, also known as apps on an iPad.
You cannot use your speech to describe the pictures.
For this task, grammar is not important. What's important is that you combine words to form as many sentences as possible for each picture.
For example, you may want to say, 'the boy is drinking water,' but the program will not have words such as 'the,' 'is,' and the grammatical endings such as 'ing' in the word 'drinking.' You may only find the words 'boy' 'drink' 'water.' So, you can describe the picture by pointing to the words 'boy drink water.'
Also, there will be no past tense verbs, so if you want to say 'drank,' you will have to select the word 'drink.'
We will practice how to describe a picture before you start the actual study.
After the practice, I will give you the program on the iPad with the words needed for the study pictures.
You have 2 minutes to look at the words available. At the end of 2 minutes, we will start the study. For the study, you will describe two pictures.
We will have a 5-minute break, and then we will practice using the second program on the iPad using the same procedures. Then you will describe the same two pictures.
I cannot help you when you are describing the two pictures. So, if you have any questions, please ask me now or during practice time.
Do you have any questions?
(Respond to questions and move onto the practice session for the first display. The starting display is counterbalanced for each participant, so use the instructions for each display accordingly)

<u>Instruction for Grid Display for Practice Picture</u>

a. Introducing the Grid display and navigation

In this program (open the grid display for the practice item), w*ords are organized in folders.*
This first page is called the homepage (point to the homepage).
The homepage has folders that have words related to a particular category. For example, this homepage consists of the folders, 'actions,' 'characters,' 'describe,' and 'things.' (show the folders).
All keywords that you need to describe the pictures are grouped in these folders. You open each folder by touching it.
When you touch a folder on the homepage, it takes you to a second level with subfolders. (touch the folder 'things' to open it).
Let's say you wanted to find the word "ball," then you will touch a subfolder that is related to the word ball. I think the word 'toys' is related to the word 'ball,' so let's try to open the subfolder 'toys' to see if we can find the word ball in there. Remember, to open a folder, you need to touch it. (Touch the subfolder 'play')

Here is ball (point to the word ball without touching it).
If you want to say 'ball,' you can select it by touching it. (Touch the word ball).
If, by any chance, you touch the wrong word, don't worry, keep going and try to find the correct word.
There are some more buttons that you need to know. Let's say you were looking for the word "boat" and it was not in the subfolder for "toys," you can use this "back" button to go back one level up to see the other subfolders under the main folder "things". Let's try it (Touch the back button to go back one level up). *See, it took you one level up. You can try a different subfolder for the word you are looking for. Where can you find a 'boat'?* (Wait for the participant to respond and search for the word. If a. participant does not find it, then you can show how to find it). [*I think the subfolder vehicles might be an appropriate place to find a boat* (touch the folder), *here it is*]
Let's say you wanted to go back to the homepage, which is the first page; then, you can use the "Return to homepage" button. (Touch the "Return to homepage" button found in the third level). *You can also use the back button, but it only takes you one level up, so you will have to use several back buttons to get you to the first page. Let me show you.* (Go back to the 3rd level by selecting 'Character –people – woman' and demonstrate how to use the back button.)
Do you have any questions?

b. Practicing sentence production for the grid display

Now that you know how to use the program, let's practice making sentences. First, let's go through the folders to see what word options we have. (Go through each folder looking at the words available).
Now, let's make some sentences to describe this picture. (Show practice picture)
Let's say you want to say, 'the woman is sitting on a chair and reading a book', you will say it like this (produce the sentence – woman sit on chair read book).
I'm going to bring you back to the homepage. (Go back to the homepage)
Now you can try to make that same sentence.
Let's try another sentence. If I want to say, 'birds are flying". I will say it like this (model how to produce it – bird fly)
Now you make that sentence.
*If you select the wrong word while making a sentence, just ignore the error and try to find the correct word needed to make the sentence. (*Model a sentence with an incorrect word – woman read <u>ball</u> book*).*
Now it's your turn to make your sentence to describe what's happening in this picture (Point to the practice picture and wait for the participant to create a new sentence).

c. Familiarizing the study display for the grid display

(Once the practice has been completed, give the participant the grid display that will be used for the study task.)
Here's what you will use for the study task. You have 2 minutes to look at the words available. At the end of the two minutes, we will start describing the study pictures. You have 4-minutes to describe each picture.

d. Study Experiment for grid display

(Once the participant has looked through the display. Switch on the video camera.).
(Place the first composite picture in front of the participant to the right of the tablet. Point to the picture and say)
You have 4 minutes to tell me as much as you can about what's happening in this picture. And your time starts now (start the timer, tell the participant to stop describing the picture at the end of 4 minutes).
(Give the participant the second picture and repeat the instructions) *Now, tell me as much as you can about what's happening in this picture. And your time starts now (*start the timer, tell the participant to stop describing the picture at the end of 4 minutes).
Take a five-minute break before moving on to the second practice with the other app.

<u>Instruction for Visual Scene Display for Practice Picture</u>

a. Introducing VSD and navigation

In this program (open the VSD for the practice item), *words are organized in scenes*.
All the scenes you will need can be found here (point to the bar on the left with different scenes*).*
Move your finger up and down to see all the scenes. (demonstrate). *All the keywords that you need to describe the picture are found within the scenes*. (move from one scene to the next by tapping on the scenes found in the folder so that the participant can see the words).
If you want to say a word, you have to touch the area inside the circle with the written word (point to the hotspots without touching)
Let's say you wanted to find the word 'ball' then you will move through each scene to find it (demonstrate it)
Here is ball (point to the hotspot that shows ball without touching it).
Now that you found the ball, you can select it by touching it. (Touch the hotspot for ball).
If by any chance you touch the wrong word, that's fine; just try to find the correct word needed.
Do you have any questions?

b. Practicing sentence production for VSD with Snap Scenes App

Now that you know how to use the program, let's practice making sentences. First, let's go through the scenes to see what word options we have. (Go through each folder looking at the words available).
Now, let's make some sentences to describe this picture. (Show practice picture)
Let's say you want to say, 'the woman is sitting on a chair and reading a book', you will say it like this (produce the sentence – woman sit on chair read book).
Now you make that same sentence.
Let's try another sentence. If I want to say, 'birds are flying'. I will say it like this (model how to produce it – birds fly)
Now you make that sentence.
*Like I said, if you select the wrong word while making a sentence, just ignore the error and try to find the correct word needed to make the sentence. (*model a sentence with an incorrect word – woman read <u>ball</u> book*)*

Now it's your turn to make your own sentence (wait for the participant to make a new sentence).

c. Familiarizing the study display for VSD with Snap Scenes App

(Once the practice has completed, give the participant the visual scene display that will be used for the study task).
Here's what you will use for the task. You have 2 minutes to look at the words available. At the end of the two minutes, you will start describing the study pictures. You have 4-minutes to describe each picture.

d. Study Experiment for VSD with Snap Scenes App

(Once the participant has looked through the display. Switch on the video camera. Place the first composite picture in front of the participant to the right of the tablet.)
(Point to picture and say)
You have 4 minutes to tell me as much as you can about what's happening in this picture. And your time starts now (start the timer, tell the participant to stop describing the picture at the end of 4 minutes).
(Give the participant the second picture and repeat the instructions) *Now, you have 4 minutes to tell me as much as you can about what's happening in this picture. And your time starts now* (start the timer, tell the participant to stop describing the picture at the end of 4 minutes).

APPENDIX H. RULES FOR COUNTING WORDS AND CIUS

The following rules are based on Nicholas & Brookshire (1993) with additional examples to count words and CIUs when speech is produced using AAC.

RULES FOR COUNTING WORDS

- Count all the words produced using the AAC app. Do not count any words produced using oral speech.
- Unintelligible words and utterances coded using X or XX should be placed within parenthesis.
  Example: The **(X)** and **(XXX)** here.
  It is unlikely that there would be any unintelligible words due to the use of video recording.
- The following words will be counted as one word
  Living room, birthday party, knock over – these will be identified as compound words and should be typed as follows in SALT.
  living_room, birthday_party, knock_over

RULES FOR COUNTING CIUs

place the coding [CIU] next to the word that is included as a correct information unit.

DO NOT COUNT THE FOLLOWING

(In this section, words in **bold** print would <u>not</u> be counted as correct information units.)

- Words that do not accurately portray what is in the picture(s)
  Example: **Woman** reach cat. (the picture shows a girl reaching for a cat.) If a participant uses the word '**kids'** instead of 'girl' in this same sentence, do not count kids because the target word can be found in the app.

- Repetitions of words or ideas that do not add new information to the utterance are not necessary for cohesion or grammatical correctness and are not purposely used to intensify meaning.
  Example: **Man branch**. Man[CIU] tree[CIU] branch[CIU]
  Kids bring present. Friend[CIU] bring[CIU] present[CIU]. **Boy bring present**. (friend/ kids/ boy indicates the same information.)
  Girl[CIU] bring[CIU] present[CIU]. Boy[CIU] bring[CIU] present[CIU]. Words in both utterances are counted as the two sentences provide specific information about who is bringing presents. If the same participant later uses the utterance, 'kids bring presents', or 'friends bring present', these utterances are not counted as they do not provide any additional information to what was previously expressed.
  If two sentences have similar or identical meanings, only count one sentence. Count the sentence that uses <u>**a greater**</u> number of words appropriately.
  Example: man tree
  man[CIU] in[CIU] tree[CIU]
  Only count similar words if it is adding to the informativeness of the message

Example: dog bite eat cake.
Count either bite or eat and not both.

- Errors in the use of prepositions are not counted if the use of the incorrect preposition leads to misunderstanding the meaning
  Example: dog[CIU] bark[CIU] in tree[CIU]. The word 'in' is not counted because the dog is under the tree and not in the tree.
- Word order errors that make it difficult to ascertain the meaning is not counted
  Example: firetruck[CIU] ground[CIU] on
  Do not count on because it is unclear if the participant was planning to produce any words following the word 'on'

COUNT THE FOLLOWING

(In this section, words that are underlined would be counted as correct information units.)

- Words that are grammatically incorrect can be counted.
  Example: Woman[CIU] come[CIU]
- If several people are involved in an action and only one of them is mentioned, the mentioned one is still counted as a correct information unit.
  Example: Boy[CIU] come (the picture shows a boy and a girl arriving.)

If an utterance is incomplete, but some information about the picture(s) or topic has been given, count that information.

Example: Little[CIU] girl[CIU] …

- If a word is produced in isolation and is not related to the previous or following utterance, the word can only be counted if the particular word is meaningful based on the picture and have not been used in a different sentence
  Example: Dog bark.
  Man stuck in tree.
  Girl[CIU].
  The word girl will be counted along with all the words used in the example because there is a girl in the picture.

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