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Speech Output Technologies in Interventions for Individuals with Aphasia: A Scoping Review

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Speech Output Technologies in Interventions for Individuals with Aphasia: A Scoping Review

by

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Dedication

To Jordan.

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Abstract

Speech Output Technologies in Interventions for Individuals with Aphasia: A Scoping Review

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Purpose: Due to the rapid advancements in computer technology, technology-based AAC interventions have become increasingly available for people with aphasia (PWA). Technology-based AAC interventions include speech generating devices (SGDs) and/or mobile technology applications or software programs that produce speech output upon selection of a message. The purpose of this scoping review is to outline the current research evidence related to the effectiveness of AAC interventions using speech output technologies for PWA; identify gaps in the current literature; and propose directions for future research.

Methods: To be included in this review, studies had to meet the following inclusion criteria: (a) the study's intervention variables were related to the implementation of AAC using SGDs and/or mobile technology applications or software programs that turn computers into SGDs; (b) the studies included dependent variables which related to a change in behavior observed secondary to AAC intervention using speech-output technologies (i.e., SGDs, AAC apps, talking word processors, etc.); (c) participants in the studies had a primary diagnosis of aphasia whose etiologies included, but were not limited to, stroke, TBI, and PPA (d) statistical data from group designs allowed for effect sizes to be calculated (i.e., Cohen's d, Pearson's product moment correlation coefficient r, partial eta-squared), and data from single-subject experimental designs allowed for Nonoverlap of All Pairs (NAP) to be calculated; (e) studies were published in peer reviewed journals, in English, and between the years 1990 and 2020.

Results: Our search methods yielded 16 pre-experimental and experimental studies that met our inclusion criteria. Effect sizes for functional communication outcome measures as well as behaviors related to symbol identification, symbol combination, and navigation of the AAC system ranged from small to large for both single subject and group designs. Of the included experimental studies, only three were appraised as providing conclusive evidence. The remaining studies were appraised as providing preponderant ($n = 2$), suggestive ($n = 2$), and inconclusive ($n = 2$) evidence.

Conclusion: Gaps in the research included limited data on generalization and maintenance across functional communication behaviors and communication environments. Future research must focus on discovering and understanding variables that lead to effective use of AAC strategies and techniques across communicative contexts and partners.

Table of Contents

List of Tables

List of Figures

I. Introduction

Aphasia is a language disorder caused by damage to areas of the brain responsible for the comprehension and production of language. Twenty five percent of people with aphasia (PWA) experience severe aphasia (Engler et al., 2006), which results in persistent language deficits and difficulties with communication (Russo et al., 2017). These deficits can significantly limit a PWA's independence (i.e., through access to meaningful employment, education etc.) and social relationships. To compensate for persistent language deficits and difficulties with communication, PWA may be recommended augmentative and alternative communication (AAC) techniques and strategies (Russo et al., 2017). AAC intervention entails supplementing or replacing natural speech through either aided (e.g., speech-generating devices, apps, etc.) and/or unaided (e.g., manual signs, gestures, etc.; Schlosser & Koul, 2015) methods. In this paper, we define high-tech AAC devices as electronically powered devices that utilize speech output and allow users to store and retrieve stored messages as well as to produce novel messages (Koul, 2011). Additionally, speech output technologies are defined as speech generating devices (SGD) and/or mobile technology applications or software programs that produce digitized and/or synthetic speech output (Schlosser & Koul, 2015).

The purpose of this scoping review is to map the research evidence to date on the effectiveness of interventions involving speech output technologies for PWA. Furthermore, this scoping review aims to summarize the research findings and identify gaps in the existing literature.

1.1 APHASIA

According to the National Institute on Deafness and Other Communication Disorders (NIDCD; 2015) approximately 1 million people, or 1 out of 250 people, in the United States are living with Aphasia. Aphasia is an acquired communication disorder (i.e., brain lesion induced), as opposed to congenital (i.e., genetic or environmentally induced) condition. (Sarno, 1998). The most common etiology of aphasia is a cerebrovascular accident (i.e., stroke; CVAs; Koul, 2011). Approximately 30% of stroke survivors acquire aphasia (Engler et al., 2006). Other etiologies include traumatic brain injuries (TBIs), toxicities, infections, and intracranial tumors (Koul & Corwin, 2003).

Aphasia is characterized by varying levels of impairment in either all or some of the following language domains; spontaneous speech, auditory comprehension, reading and writing (Koul, 2011). The specific pattern of deficits experienced by a PWA are based upon the location and size of the lesion to the brain (Goodglass & Kaplan, 1983; Kertesz, 1982; Mountcastle, 1978; Sarno, 1998). One way that these patterns of deficits can be organized is using the "Boston" Classification for Aphasia (Beeson & Rapcsak, 2006; Sarno, 1998). This organizational scheme involves a series of binary decisions. First it classifies aphasia subtypes by level of fluency (i.e., fluent versus nonfluent). Nonfluent variants of aphasia are characterized by reduced verbal output with: impaired speech prosody (i.e., slow, halting, effortful, and aprosodic speech output), reduced mean length of utterance, articulatory struggle, and telegraphic speech (i.e., speaking primarily in nouns). Fluent variants of aphasia are characterized by fluent verbal output with relatively typical speech prosody, relatively normal mean length of utterance, relatively preserved articulation, lack of meaningful content (i.e., empty speech), as well as semantic and phonemic paraphasias. Aphasia subtypes are then organized by their auditory comprehension abilities (i.e., good or poor) and their repetition ability (i.e., good or poor).

This classification scheme provides a way for professionals to communicate about a person's current aphasia profile (Beeson & Rapcsak, 2006).

Two subtypes of aphasia that frequently require intervention through the implementation of AAC approaches and strategies are chronic severe Broca's aphasia and Global aphasia (Koul & Corwin, 2003). Broca's aphasia is a nonfluent variant of aphasia characterized by relatively spared auditory comprehension and poor repetition abilities (Beeson & Rapcsak, 2006). Global aphasia, also a nonfluent variant of aphasia, is characterized by poor auditory comprehension and poor repetition abilities (Beeson & Rapcsak, 2006). Individuals with Global aphasia have a nearly complete loss of the ability to comprehend or generate verbal communication (Sarno, 1998). Figure 1, adapted from an article authored by Beeson & Rapcsak (2006), visually depicts the "Boston" Classification for Aphasia organizational scheme.

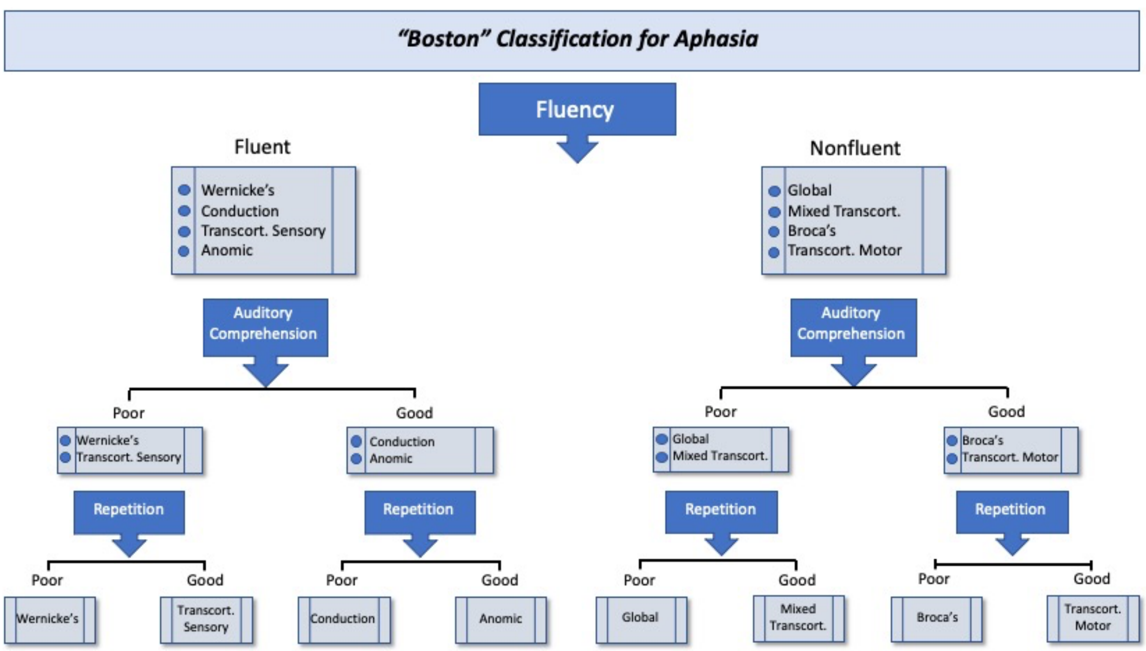

Figure 1: "Boston" Classification for Aphasia (Beeson & Rapcsak, 2006)

Speech and language therapy for PWA includes a restoration of skills or a compensation for deficits approach (Russo et al., 2017). Restorative approaches focus on treating the deficits which accompany aphasia (i.e., anomia) and bringing the patient to a pre-injury level of communication ability (Russo et al., 2017). A compensation for deficits approach focuses on maximizing functional communication for each individual patient (Russo et al., 2017). An example of a compensatory strategy for PWA is the use of augmentative and alternative communication (AAC) methods (Koul et al., 2005). AAC compensatory strategies include modes of expressive and receptive communication to supplement or replace natural speech (Koul et al., 2005). AAC strategies are sometimes mistakenly thought of as a replacement for natural speech (American Speech-Language-Hearing Association, 2019). The goal of AAC intervention is perhaps more appropriately viewed as a complement, where AAC approaches are implemented alongside a restorative intervention approach. This combined approach provides support to PWA to recover access to impaired natural language abilities, thus potentially reducing the impact of aphasia and lowering barriers to communication (Dietz et al., 2020). For example, one strategy which facilitates spoken language production is to utilize AAC devices to self-cue (Linebarger et al., 2008). This may be a functional strategy for PWA to use during anomic events or communication breakdowns (Dietz et al., 2020). AAC may also contribute to increased confidence to communicate in a variety of situations because individuals with aphasia have multimodal support to meet their communication needs. AAC interventions have the potential to enrich a PWA's communication environment while simultaneously reducing the pressure of independently accessing target concepts (Dietz et al., 2020).

PWA may experience spontaneous physiological restitution for months following onset of the disorder (Koul, 2011). Additionally, functional restitution, behavioral substitution, and strategic compensation may facilitate recovery for years. The trajectory of a PWA's recovery is highly variable across individuals. Some individuals recover to pre-injury level of communication, while others do not experience a significant recovery of their pre-injury communication abilities despite undergoing intensive traditional speech-language intervention (Koul & Corwin, 2003). Individuals with chronic severe aphasia who have undergone intensive speech and language therapy but are still unable to communicate their message independently and effectively using speech should be provided access to AAC strategies and techniques (Koul, 2011).

1.2 AAC Intervention approaches

AAC intervention for PWA emphasizes successful functional communication through the use of multiple modalities (e.g., verbal, written, SGD, gestures; Buzolich, 2006). The specific AAC intervention approach chosen depends on factors such as the specific pattern of deficits presented by the PWA, severity of communication impairment, and financial considerations (Ellman, 2005). Each strategy is typically multifaceted with the intention to facilitate expressive/receptive language, decrease cognitive load, facilitate executive function, and increase participation in a variety of communicative situations (Brock et al., 2017; Chavers et al., 2021; Dada et al., 2019; Garret & Lasker, 2005; Koul et al., 2008; Koul, 2011). The facilitative effects of AAC are well documented, but it may unfortunately not be considered as a primary treatment resource for PWA until restorative therapy has failed in reestablishing natural speech and language as the primary means of communication (Chavers et al., 2021; Frankoff & Hatfield, 2011). However, available data indicates that AAC facilitates the recovery of natural speech and language and compensates for severe communication impairments in PWA (Aftonomos et al, 2001, Dietz et al., 2018; Garrett & Lasker, 2005; McCall et al., 2000; Weinrich et al., 1995, Weinrich et al., 1999).

AAC intervention approaches are categorized into no technology-based and technology-based AAC interventions (Koul, 2011). No technology-based AAC strategies are those that do not involve speech output when a message is selected (Koul, 2011). For PWA, these strategies consist of rating scales, communication boards (i.e., picture board, spelling board), photo albums, drawings, and cue cards (Chavers et al., 2021; Koul & Corwin, 2003). No technology-based AAC approaches are typically easy to use, have a minimal financial impact on the PWA, and are well-suited to assist in communication for PWA in early stages of recovery (Chavers et al., 2021). On the other hand, technology-based AAC intervention approaches include the use of dedicated speech generating devices (SGDs) and/or software applications that turn computers or hand-held multipurpose electronic devices (e.g., Apple iPad™, Microsoft Surface™, Google Android™) into communication aids that produce synthetic or digitized speech upon selection of a message (Koul, 2011). Substantial research evidence supports the effectiveness of both technology-based and no technology-based AAC intervention approaches in facilitating communication for PWA (e.g., Alam et al., 2021; Ball & Lasker, 2013; Dietz et al., 2018; Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998; Koul & Lloyd, 1998; McKelvey et al., 2007; Mooney et al., 2018; Nicholas et al., 2005; Wallace et al., 2012).

1.3 AAC TECHNOLOGIES

Due to the rapid advancements in technology, technology-based AAC interventions have become increasingly available for PWA. This is largely due to SGDs becoming portable (i.e., increasing their ease of use) and having the ability to utilize communication software programs on multipurpose devices (i.e., iPad; Microsoft Surface, Google Android; Koul, 2011; Koul et al, 2010). Advancements in computer technology have resulted in substantial improvements in speech output and organization of messages (Brock et al., 2017).

1.3.1 Speech Output Technologies

SGDs and/or mobile technology applications or software programs that produce speech output have built-in technology that allows a person to use digitized and/or synthetic speech (Schlosser & Koul, 2015). According to Schlosser & Koul (2015), digitized speech is created through recording a human voice and converting it into digits. This is completed by sampling the speech waveform at equal intervals and then storing the data as numbers. Sampling rate is an important factor in determining the quality of digitized speech. A low sampling rate (i.e., collecting less frequent samples of the speech waveform) facilitates a lower quality, and less natural digitized speech. The use of a higher sampling rate (i.e., collecting more samples of the speech waveform) facilitates higher quality, or more natural sounding, digitized speech. Another important factor to consider about sampling rate is the storage required for the data. For example, a high sampling rate may require more data storage on a SGD. This is likely accompanied by a higher cost (Schlosser & Koul, 2015). An advantage of utilizing digitized speech is that it is perceived by the listener as more natural and more intelligible (Drager et al., 2006). A disadvantage to utilizing digitized speech is that the utility of digitized speech is dependent on the quality of the recording of a person's speech (Schlosser & Koul, 2015). It also limits a person's communication output to a library of pre-stored messages. Examples of SGDs with digitized speech output include SpringBoard Lite™ and Tango™ (Schlosser & Koul, 2015).

Synthesized speech involves text-to-speech synthesis. The advantage of synthesized speech is that it allows for an unlimited amount of spontaneous speech by converting data such as: digits, alphabets, words, and sentences into synthesized speech (Schlosser & Koul, 2015). The intelligibility of synthesized speech is highest when closely approximating the qualities of natural speech (Duffy & Pisoni, 1992; Koul & Allen, 1993; Koul & Hester, 2006). Despite substantial improvements in the quality of synthetic speech production in recent years, differences between synthetic and natural speech are still apparent (Hux et al., 2017). For example, there are significant differences in the suprasegmental elements of natural speech in comparison to synthetic speech such as: timing, stress, and inflection (Koul, 2003). These differences have been found to make sentences and extended discourse produced in synthetic speech more cognitively demanding for listeners to interpret than when produced in natural speech (Koul, 2003; Koul & Dembowski, 2011). It has also been found that PWA perform more accurately on tasks of comprehension when provided with digitized natural speech as opposed to synthesized speech (Hux et al., 2017). The same study found that digitized natural speech was ranked as a preferred speech output for AAC devices by PWA (Hux et al., 2017).

1.3.1.1 Selection Set Displays

A challenging aspect of speech output technologies is the organization of the messages on AAC interfaces for use by the AAC user (Koul, 2015; Koul & Chavers, 2019). Organizational strategies typically fall into two main categories: grid displays and visual scene displays (VSDs; Beukelman & Light, 2020). On a grid display, individual symbols, pictures, or text are organized in a grid pattern. On a VSD, events, people, objects, and actions are presented in personally relevant contextualized scenes (Blackstone, 2004). Many speech output technologies allow users to choose between or access a combination of the grid and VSD schemes (Koul & Chavers, 2019; Petroi, 2011).

Taxonomic grid displays allow for presentation of messages/symbols in a grid pattern across multiple screens in a logical sequence (Koul & Chavers, 2019). Figure 2, provides an example of a taxonomic grid display. For example, the first page may contain superordinate categories (i.e., clothing) for a PWA to select. This will bring up a second page with subordinate categories for types of clothing (e.g., pants, socks, hats). Selecting "hats" on the second page will bring up the next with subordinate categories for hats (e.g., baseball cap, fedora, sun hat). Once a target symbol or message has been identified, the PWA has the option to turn it into speech output. PWA have been shown to access, identify, manipulate, and combine symbols using taxonomic grid displays to produce simple sentences and phrases (Koul & Harding, 1998; Koul et al., 2005; Koul et al., 2008; Petroi et al., 2014).

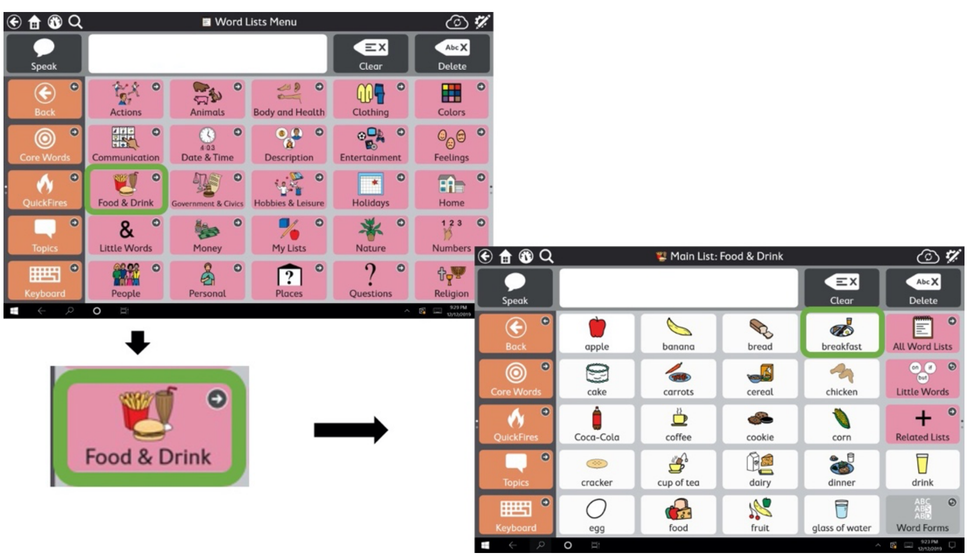

Figure 2: Taxonomic grid display (Tobii Dynavox, 2019a)

Semantic-syntactic grid displays arrange items according to the parts of speech (i.e., nouns, verbs, prepositions, and wh- words) as well as their syntactic relationships. This grid option is typically utilized for children with developmental speech and language impairment (Beukelman & Light, 2020). In this grid display, vocabulary is organized from left to right to promote the construction of sentences, and color coded to promote accessibility (Koul, 2011). There is no data which examines the effectiveness of semantic-syntactic grid displays for PWA (Beukelman & Light, 2020). This is likely due to the fact that people with non-fluent aphasia experience severe syntactic deficits (Koul, 2011).

VSDs are a highly contextualized way to organize messages that are personized to the individual, and the communicative context. Figure 3, provides an example of a VSD. VSDs are typically a photo in which an individual can select messages which correspond to the scene presented. Selection of messages result in speech output. For example, a PWA could have a visual scene of him or her at the horse stables with their horse. When they select the image of his/her horse, speech output could be activated to produce the message, “This is my horse Zee.” PWA can navigate through multiple visual scenes using a navigation ring (i.e, a D-shaped layout which contains thumbnails of their visual scenes). This allows the individual to utilize thumbnails as opposed to words and icons to navigate their device (Beukelman et al., 2015; Wallace & Hux, 2014). The VSDs typically contain contextual and personally relevant information to enhance their effectiveness (Beukelman et al., 2015; Griffith et al., 2014; McKelvey et al., 2007; McKelvey et al., 2010).

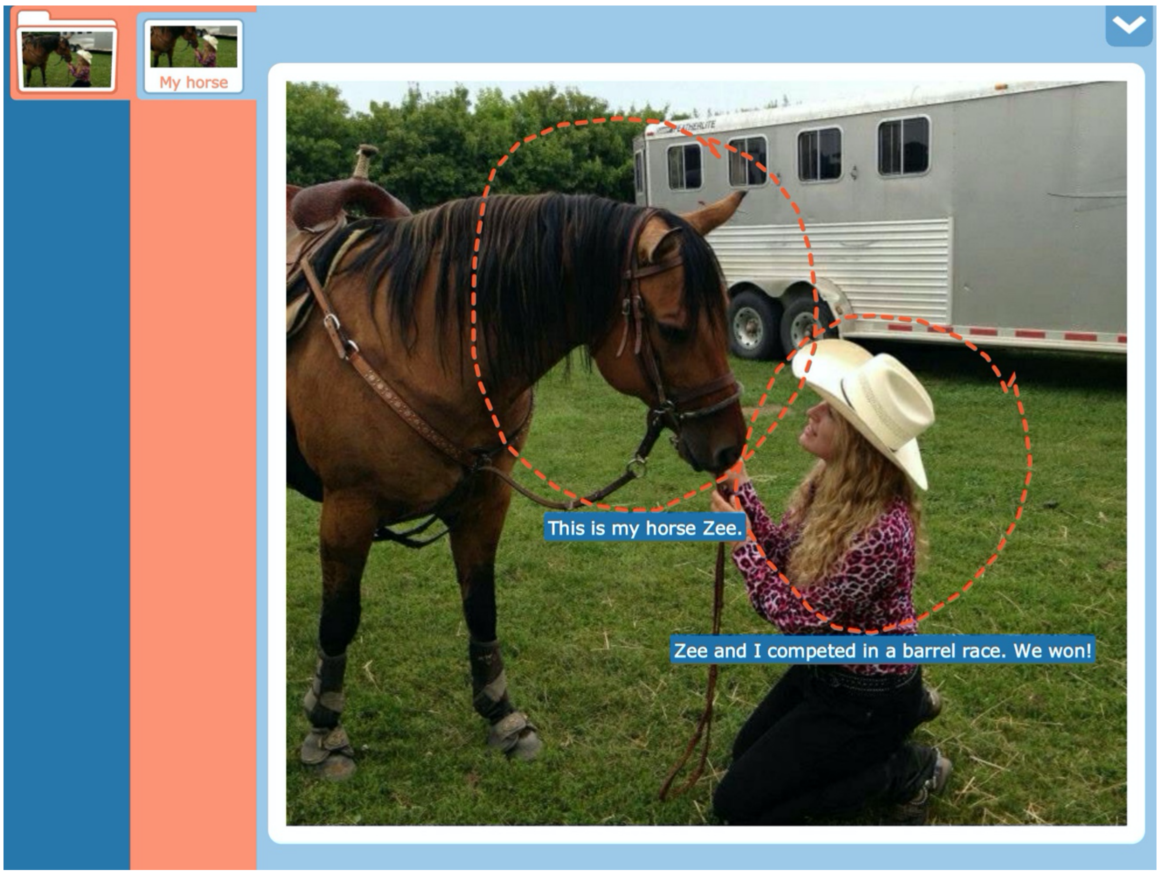

Figure 3: VSD (Tobii Dynavox, 2019b)

The effectiveness of taxonomic grid displays versus VSDs in communication tasks between a PWA and their communication partner was investigated by Brock et al. (2017). In the first experiment, a participant with aphasia watched an episode of *I Love Lucy* and was provided with training to engage in conversation regarding the content of the episode with both a VSD and a taxonomic grid display. In the second experiment, the participant watched a different episode of *I Love Lucy* but did not receive training to engage in conversation regarding the content with a VSD or taxonomic grid display. Across both experiments, results indicated that the participant's use of VSD led to increased conversational turns; fewer navigational errors; greater response accuracy; and production of longer and more complex utterances in comparison with the taxonomic grid displays. These results suggest that VSDs may be less cognitively demanding than taxonomic grid displays (Brock et al., 2017). Taxonomic grid displays require a PWA to navigate multiple screens to produce phrases and sentences. VSDs accomplish this same task through the use of contextually rich photographs. VSDs are advantageous in comparison to grid displays due to their relative ease of use, increased navigational accuracy, and a higher frequency of efficient and effective communication exchanges (Beukelman et al., 2015; Brock et al., 2017, Koul, 2011).

Due to the heterogeneity of PWA's behavioral profiles, it is important to of ensure that the specific type, format, and display of an AAC device is individually tailored to the needs, abilities (i.e., cognitive, linguistic, motoric) and preferences of the PWA.

1.3.2 AAC Device Acceptance

Acceptance, rejection, and abandonment of AAC strategies and techniques are important considerations in the AAC intervention process. Acceptance is when a person accepts a professional recommendation to utilize an AAC system for communication. Rejection of an AAC system is when a person does not accept the recommended AAC system and the associated therapy to use the device (Johnson et al., 2006; Pampoulou, 2019). Abandonment of an AAC system is when a person has received an AAC system, participated in an AAC intervention, benefits from using an AAC system to communicate, and has chosen not to communicate with the assistance of the AAC system. The application of these definitions extends to both the structured therapy setting as well as functional communication settings (Pampoulou, 2019).

There are a number of factors that influence acceptance, rejection, or abandonment of an AAC device. Time since onset of disability has been shown to be related to AAC acceptance. For example, in the initial period of time after onset of disorder, participants were less likely to accept a device or receive speech therapy (Pampoulou, 2019). People's attitude towards their communication partner has also been shown to influence AAC acceptance. Participants were more motivated to use an AAC system with familiar communication partners (Pampoulou, 2019). Perceptions of clients and families regarding AAC systems are influential in AAC acceptance. For example, they may have beliefs about an AAC system's impact on the participant's ability to regain use of natural speech (Pampoulou, 2019). PWA may choose to reject or abandon AAC devices thinking that AAC devices impact their ability to regain natural speech (Baxter et al., 2012; Beukelman & Ball, 2002; Lasker et al., 2001). Lastly, AAC systems can be seen to put additional demands on the participant and their communication facilitators. Families often have many caregiving duties (e.g., changing clothes, assisting with the restroom) in addition to their role as a communication facilitator (Pampoulou, 2019). This highlights an important concept in AAC implementation, ensuring that the technology meets the needs of the PWA as well as their communication facilitators (Beukelman & Ball, 2002).

1.4 EFFICACY OF SPEECH OUTPUT TECHNOLOGIES IN PERSONS WITH APHASIA

Previous research supports the efficacy of implementing technologically-based AAC interventions with PWA (Koul & Harding, 1998; Koul et al., 2008; McKelvey et al., 2007; Nicolas et al., 2005). For instance, Koul et al. (2010) conducted a meta-analysis to investigate the efficacy of AAC intervention using SGDs for PWA. Their comprehensive search of various databases yielded five single-subject design studies and two group design studies that met the inclusion criteria. Studies were summarized in terms of participant characteristics, intervention, design, dependent measures, and outcomes. Identification of graphic symbols, sentence production using graphic symbols, and learning to use SGDs were the focus in the majority of the studies. The authors concluded that the majority of the studies reported improvements in the dependent variables studied as a result of SGD based AAC intervention. The variability of the results across participants in included studies suggested that predictions regarding the effectiveness of these interventions could not be determined at the time of the review. Due to the paucity of data on SGD based AAC interventions, the authors suggested that future research collect efficacy data on the participants using controlled research designs (i.e., ruling out threats to internal validity; Koul et al., 2010).

Russo et al. (2017) investigated the efficacy of high-technology AAC interventions for persons with post-stroke aphasia. Their literature search yielded 30 studies which met their inclusion criteria. Studies were summarized in terms of participant characteristics, study characteristics, study quality, features of AAC systems, intervention description, and summary of intervention outcomes. The authors concluded that the majority of the studies reported intervention outcomes which were positive or mixed (90%). However, they made the following observations on the current state of research: (a) predominance of single case and small group study designs; (b) absence of studies investigating the percentage of acceptance of AAC systems by PWA (i.e., paucity of generalization and maintenance data); (c) lack of communication partner training; (d) an overestimation of linguistic factors in successful communication (i.e., not considering additional cognitive factors associated with communicating with AAC systems); and (e) not accounting for the effects of confounding variables (i.e., presence of apraxia of speech). The authors suggested that future research is necessary to evaluate the effectiveness of AAC interventions for poststroke aphasia. They also suggest that the future studies should better describe the studied population by including detailed participant demographics such as age, gender, location of lesion, cognitive status prior to stroke, and setting of the proposed intervention (Russo et al., 2017).

The purpose of this scoping review is to provide a comprehensive review of AAC intervention studies which involve a speech output technology as part of the treatment package for PWA. Specifically, the objectives of this review are to present the existing evidence regarding the effectiveness of AAC interventions using speech output technologies for PWA, identify gaps in the current literature, and propose directions for future research.

II. Methods

The purpose of this chapter is to provide a comprehensive description of the methodology employed to conduct this scoping review. The objectives of this chapter are: (1) to describe the inclusion criteria, (2) outline the search methods, (3) to describe how studies were selected and analyzed for the purposes of this review, (4) to provide description of reliability measures

2.1 Inclusion Criteria

To be included in this review, studies met the following inclusion criteria:

1. The study's intervention variables were related to the implementation of AAC using SGDs and/or mobile technology applications or software programs that utilize computers that produce speech output. The speech output may be in a digitized and/or synthetic form.
2. The studies included dependent variables which related to a change in behavior observed secondary to AAC intervention using speech-output technologies (i.e., SGDs, AAC apps, talking word processors, etc.).
3. Participants in the studies had a primary diagnosis of aphasia whose etiologies included, but were not limited to, stroke, TBI, and PPA.
4. Statistical data from group designs allowed for effect sizes to be calculated (i.e., Cohen's d, Pearson's product moment correlation coefficient r, partial eta-squared), and data from single-subject experimental designs allowed for determination of Nonoverlap of All Pairs (NAP). NAP was selected for its

external validation (i.e., relative to R^2 and visual analysis judgements) as well as its accuracy (Parker & Vannest, 2009).

5. Studies were published in peer reviewed journals, in English, and between the years 1990 and 2020.

2.2 SEARCH METHODS

Search methods utilized included (a) electronic database searches (PubMed, PsychINFO, Cumulative Nursing and Allied Health Literatures [CINAHL], Educational Resources Information Center [ERIC], Linguistics and Language Behavior Abstracts [LLBA], Medline, and Dissertations & Theses Global); and (b) ancestry searches of articles that qualified for inclusion and previous reviews related to the topic (e.g. Baxter et al., 2012; Beukelman et al., 2007; Beukelman et al., 2015; Dietz et al., 2020; Fried-Oken et al., 2012; Fried-Oken et al., 2015; Jacobs et al., 2004; Koul et al., 2010; Light & McNaughton, 2014; Russo et al., 2017; Taylor et al., 2019; van de Sandt-Koenderman, 2004; van de Sandt-Koenderman, 2011). Database specific strategies are included in Table 1. All of this search was completed in July of 2020 with the exception of the Dissertations & Theses Global ProQuest search which was completed in January of 2021. In response to a paucity of studies which mitigated internal validity concerns, case studies were gathered following the search methods in January of 2021.

Table 1. Search Strategies and Yields for Electronic Databases.

Database	Search Strategy	Yield

PubMed (1990 to present)	ALL FIELDS ("Aphasia") AND (("AAC" [Title/Abstract]) OR ("Augmentative and Alternative Communication" [Title/Abstract]))	43
	ALL FIELDS ("Aphasia") AND (("Speech Generating Device" [Title/Abstract]) OR ("SGD" [Title/Abstract]) OR ("Voice Output Communication Aid"[Title/Abstract]))	1
	ALL FIELDS ("Aphasia") AND (("Augmentative and Alternative Communication" [Title/Abstract]) OR ("AAC" [Title/Abstract])) AND ("High Technology" [Title/Abstract])	5
	ALL FIELDS ("Aphasia") AND ("Graphic Symbols" [Title/Abstract])	4
	ALL FIELDS ("Aphasia") AND ("AAC Interfaces" [Title/Abstract])	1
	ALL FIELDS ("Aphasia") AND ("Display" [Title/Abstract])	69
	ALL FIELDS ("Aphasia") AND ("Visual Scenes" [Title/Abstract])	3
	ALL FIELDS ("Aphasia") AND ("Drawing" [Title/Abstract])	69
	ALL FIELDS ("Aphasia") AND ("Nonverbal Communication" [Title/Abstract])	8
	ALL FIELDS ("Aphasia") AND ("Written Communication" [Title/Abstract])	8
	ALL FIELDS ("Aphasia") AND ("Technological AAC intervention" [Title/Abstract])	0
PsychINFO (EBSCOhost) (1990 to present)	SU ("Aphasia") AND (ti ("AAC") OR ti ("Augmentative and Alternative Communication")) – (peer-reviewed as limiter)	346
	SU ("Aphasia") AND (ab ("AAC") OR ab ("Augmentative and Alternative Communication")) – (peer reviewed as limiter)	958
	SU ("Aphasia") AND (ti ("Speech Generating Device") OR ti ("SGD") OR ti ("Voice Output Communication Aid")) - (peer-reviewed as limiter)	16
	SU ("Aphasia") AND (ab ("Speech Generating Device") OR ab ("SGD") OR ab ("Voice Output Communication Aid")) - (peer-reviewed as limiter))	190
	SU ("Aphasia") AND (ti ("Augmentative and Alternative Communication") OR ti ("AAC")) AND ti ("High Technology") – (peer-reviewed as limiter)	8

	SU ("Aphasia") AND (ab ("Augmentative and Alternative Communication") OR ab ("AAC")) AND ab ("High Technology") – (peer-reviewed as limiter)	59
	SU ("Aphasia") AND ti ("Graphic Symbols") – (peer-reviewed as limiter)	2
	SU ("Aphasia") AND ab ("Graphic Symbols") – (peer-reviewed as limiter)	4
	SU ("Aphasia") AND ti ("AAC Interfaces") – (peer-reviewed as limiter)	0
	SU ("Aphasia") AND ab ("AAC Interfaces") – (peer-reviewed as limiter)	1
	SU ("Aphasia") AND ti ("Display") – (peer-reviewed as limiter)	1
	SU ("Aphasia") AND ab ("Display") – (peer-reviewed as limiter)	59
	SU ("Aphasia") AND ti ("Visual Scenes") – (peer-reviewed as limiter)	1
	SU ("Aphasia") AND ab ("Visual Scenes") – (peer-reviewed as limiter)	1
	SU ("Aphasia") AND ti ("Drawing") – (peer-reviewed as limiter)	21
	SU ("Aphasia") AND ab ("Drawing") – (peer-reviewed as limiter)	85
	SU ("Aphasia") AND ti ("Nonverbal Communication") – (peer-reviewed as limiter)	1
	SU ("Aphasia") AND ab ("Nonverbal Communication") – (peer-reviewed as limiter)	16
	SU ("Aphasia") AND ti ("Written Communication") – (peer-reviewed as limiter)	3
	SU ("Aphasia") AND ab ("Written Communication") – (peer-reviewed as limiter)	11
	SU ("Aphasia") AND ti ("Technological AAC intervention") – (peer-reviewed as limiter)	0
	SU ("Aphasia") AND ab ("Technological AAC intervention") – (peer-reviewed as limiter)	0
CINAHL (EBSCOhost) (1990 to present)	SU ("Aphasia") AND (ti ("AAC") OR ti ("Augmentative and Alternative Communication")) – (peer-reviewed as limiter)	434
	SU ("Aphasia") AND (ab ("AAC") OR ab ("Augmentative and Alternative Communication")) – (peer reviewed as limiter)	952

SU ("Aphasia") AND (ti ("Speech Generating Device") OR ti ("SGD") OR ti ("Voice Output Communication Aid")) - (peer-reviewed as limiter)	24
SU ("Aphasia") AND (ab ("Speech Generating Device") OR ab ("SGD") OR ab ("Voice Output Communication Aid")) - (peer-reviewed as limiter))	181
SU ("Aphasia") AND (ti ("Augmentative and Alternative Communication") OR ti ("AAC")) AND ti ("High Technology") – (peer-reviewed as limiter)	20
SU ("Aphasia") AND (ab ("Augmentative and Alternative Communication") OR ab ("AAC")) AND ab ("High Technology") – (peer-reviewed as limiter)	67
SU ("Aphasia") AND ti ("Graphic Symbols") – (peer-reviewed as limiter)	3
SU ("Aphasia") AND ab ("Graphic Symbols") – (peer-reviewed as limiter)	6
SU ("Aphasia") AND ti ("AAC Interfaces") – (peer-reviewed as limiter)	0
SU ("Aphasia") AND ab ("AAC Interfaces") – (peer-reviewed as limiter)	1
SU ("Aphasia") AND ti ("Display") – (peer-reviewed as limiter)	1
SU ("Aphasia") AND ab ("Display") – (peer-reviewed as limiter)	41
SU ("Aphasia") AND ti ("Visual Scenes") – (peer-reviewed as limiter)	1
SU ("Aphasia") AND ab ("Visual Scenes") – (peer-reviewed as limiter)	1
SU ("Aphasia") AND ti ("Drawing") – (peer-reviewed as limiter)	11
SU ("Aphasia") AND ab ("Drawing") – (peer-reviewed as limiter)	51
SU ("Aphasia") AND ti ("Nonverbal Communication") – (peer-reviewed as limiter)	0
SU ("Aphasia") AND ab ("Nonverbal Communication") – (peer-reviewed as limiter)	8
SU ("Aphasia") AND ti ("Written Communication") – (peer-reviewed as limiter)	0
SU ("Aphasia") AND ab ("Written Communication") – (peer-reviewed as limiter)	6
SU ("Aphasia") AND ti ("Technological AAC intervention") – (peer-reviewed as limiter)	0

	SU (“Aphasia”) AND ab (“Technological AAC intervention”) – (peer-reviewed as limiter)	0
ERIC (EBSCOhost) (1990 to present)	SU (“Aphasia”) AND (ti (“AAC”) OR ti (“Augmentative and Alternative Communication”)) – (peer-reviewed as limiter)	115
	SU (“Aphasia”) AND (ab (“AAC”) OR ab (“Augmentative and Alternative Communication”)) – (peer reviewed as limiter)	311
	SU (“Aphasia”) AND (ti (“Speech Generating Device”) OR ti (“SGD”) OR ti (“Voice Output Communication Aid”)) - (peer-reviewed as limiter)	8
	SU (“Aphasia”) AND (ab (“Speech Generating Device”) OR ab (“SGD”) OR ab (“Voice Output Communication Aid”)) - (peer-reviewed as limiter))	48
	SU (“Aphasia”) AND (ti (“Augmentative and Alternative Communication”) OR ti (“AAC”)) AND ti (“High Technology”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND (ab (“Augmentative and Alternative Communication”) OR ab (“AAC”)) AND ab (“High Technology”) – (peer-reviewed as limiter)	2
	SU (“Aphasia”) AND ti (“Graphic Symbols”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“Graphic Symbols”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ti (“AAC Interfaces”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“AAC Interfaces”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ti (“Display”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“Display”) – (peer-reviewed as limiter)	5
	SU (“Aphasia”) AND ti (“Visual Scenes”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ab (“Visual Scenes”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ti (“Drawing”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ab (“Drawing”) – (peer-reviewed as limiter)	8
	SU (“Aphasia”) AND ti (“Nonverbal Communication”) – (peer-reviewed as limiter)	0

	SU (“Aphasia”) AND ab (“Nonverbal Communication”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ti (“Written Communication”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“Written Communication”) – (peer-reviewed as limiter)	2
	SU (“Aphasia”) AND ti (“Technological AAC intervention”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“Technological AAC intervention”) – (peer-reviewed as limiter)	0
LLBA (ProQuest) (1990 to present)	SU (“Aphasia”) AND ((ti (“AAC”) OR ti (“Augmentative and Alternative Communication”)) – (peer-reviewed as limiter)	24
	SU (“Aphasia”) AND (ab (“AAC”) OR ab (“Augmentative and Alternative Communication”)) – (peer reviewed as limiter)	54
	SU (“Aphasia”) AND (ti (“Speech Generating Device”) OR ti (“SGD”) OR ti (“Voice Output Communication Aid”)) - (peer-reviewed as limiter)	2
	SU (“Aphasia”) AND (ab (“Speech Generating Device”) OR ab (“SGD”) OR ab (“Voice Output Communication Aid”)) - (peer-reviewed as limiter))	6
	SU (“Aphasia”) AND (ti (“Augmentative and Alternative Communication”) OR ti (“AAC”)) AND ti (“High Technology”) – (peer-reviewed as limiter)	2
	SU (“Aphasia”) AND ab ((“Augmentative and Alternative Communication”) OR ab (“AAC”)) AND ab (“High Technology”) – (peer-reviewed as limiter)	4
	SU (“Aphasia”) AND ti (“Graphic Symbols”) – (peer-reviewed as limiter)	5
	SU (“Aphasia”) AND ab (“Graphic Symbols”) – (peer-reviewed as limiter)	4
	SU (“Aphasia”) AND ti (“AAC Interfaces”) – (peer-reviewed as limiter)	2
	SU (“Aphasia”) AND ab (“AAC Interfaces”) – (peer-reviewed as limiter)	2
	SU (“Aphasia”) AND ti (“Display”) – (peer-reviewed as limiter)	7
	SU (“Aphasia”) AND ab (“Display”) – (peer-reviewed as limiter)	67
	SU (“Aphasia”) AND ti (“Visual Scenes”) – (peer-reviewed as limiter)	5

	SU (“Aphasia”) AND ab (“Visual Scenes”) – (peer-reviewed as limiter)	8
	SU (“Aphasia”) AND ti (“Drawing”) – (peer-reviewed as limiter)	19
	SU (“Aphasia”) AND ab (“Drawing”) – (peer-reviewed as limiter)	119
	SU (“Aphasia”) AND ti (“Nonverbal Communication”) – (peer-reviewed as limiter)	5
	SU (“Aphasia”) AND ab (“Nonverbal Communication”) – (peer-reviewed as limiter)	45
	SU (“Aphasia”) AND ti (“Written Communication”) – (peer-reviewed as limiter)	3
	SU (“Aphasia”) AND ab (“Written Communication”) – (peer-reviewed as limiter)	8
	SU (“Aphasia”) AND ti (“Technological AAC intervention”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“Technological AAC intervention”) – (peer-reviewed as limiter)	0
MEDLINE (EBSCOhost) (1990 to present)	SU (“Aphasia”) AND (ti (“AAC”) OR ti (“Augmentative and Alternative Communication”)) – (peer-reviewed as limiter)	244
	SU (“Aphasia”) AND (ab (“AAC”) OR ab (“Augmentative and Alternative Communication”)) – (peer reviewed as limiter)	662
	SU (“Aphasia”) AND (ti (“Speech Generating Device”) OR ti (“SGD”) OR ti (“Voice Output Communication Aid”)) - (peer-reviewed as limiter)	39
	SU (“Aphasia”) AND (ab (“Speech Generating Device”) OR ab (“SGD”) OR ab (“Voice Output Communication Aid”) - (peer-reviewed as limiter))	723
	SU (“Aphasia”) AND (ti (“Augmentative and Alternative Communication”) OR ti (“AAC”)) AND ti (“High Technology”) – (peer-reviewed as limiter)	7
	SU (“Aphasia”) AND (ab (“Augmentative and Alternative Communication”) OR ab (“AAC”)) AND ab (“High Technology”) – (peer-reviewed as limiter)	28
	SU (“Aphasia”) AND ti (“Graphic Symbols”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ab (“Graphic Symbols”) – (peer-reviewed as limiter)	3
	SU (“Aphasia”) AND ti (“AAC Interfaces”) – (peer-reviewed as limiter)	0

	SU (“Aphasia”) AND ab (“AAC Interfaces”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ti (“Display”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“Display”) – (peer-reviewed as limiter)	41
	SU (“Aphasia”) AND ti (“Visual Scenes”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ab (“Visual Scenes”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ti (“Drawing”) – (peer-reviewed as limiter)	6
	SU (“Aphasia”) AND ab (“Drawing”) – (peer-reviewed as limiter)	41
	SU (“Aphasia”) AND ti (“Nonverbal Communication”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“Nonverbal Communication”) – (peer-reviewed as limiter)	7
	SU (“Aphasia”) AND ti (“Written Communication”) – (peer-reviewed as limiter)	1
	SU (“Aphasia”) AND ab (“Written Communication”) – (peer-reviewed as limiter)	5
	SU (“Aphasia”) AND ti (“Technological AAC intervention”) – (peer-reviewed as limiter)	0
	SU (“Aphasia”) AND ab (“Technological AAC intervention”) – (peer-reviewed as limiter)	0
Dissertations & Theses Global (ProQuest)	SU (“Aphasia”) AND (ti (“AAC”) OR ti (“Augmentative and Alternative Communication”)) – (peer-reviewed as limiter)	2
	SU (“Aphasia”) AND (ab (“AAC”) OR ab (“Augmentative and Alternative Communication”))	8
	SU (“Aphasia”) AND (ti (“Speech Generating Device”) OR ti (“SGD”) OR ti (“Voice Output Communication Aid”))	0
	SU (“Aphasia”) AND (ab (“Speech Generating Device”) OR ab (“SGD”) OR ab (“Voice Output Communication Aid”)	0
	SU (“Aphasia”) AND (ti (“Augmentative and Alternative Communication”) OR ti (“AAC”)) AND ti (“High Technology”)	0
	SU (“Aphasia”) AND (ab (“Augmentative and Alternative Communication”) OR ab (“AAC”)) AND ab (“High Technology”)	0

SU (“Aphasia”) AND ti (“Graphic Symbols”)	0
SU (“Aphasia”) AND ab (“Graphic Symbols”)	0
SU (“Aphasia”) AND ti (“AAC Interfaces”)	0
SU (“Aphasia”) AND ab (“AAC Interfaces”)	0
SU (“Aphasia”) AND ti (“Display”)	1
SU (“Aphasia”) AND ab (“Display”)	12
SU (“Aphasia”) AND ti (“Visual Scenes”)	0
SU (“Aphasia”) AND ab (“Visual Scenes”)	1
SU (“Aphasia”) AND ti (“Drawing”)	3
SU (“Aphasia”) AND ab (“Drawing”)	9
SU (“Aphasia”) AND ti (“Nonverbal Communication”)	0
SU (“Aphasia”) AND ab (“Nonverbal Communication”)	0
SU (“Aphasia”) AND ti (“Written Communication”)	1
SU (“Aphasia”) AND ab (“Written Communication”)	2
SU (“Aphasia”) AND ti (“Technological AAC intervention”)	0
SU (“Aphasia”) AND ab (“Technological AAC intervention”)	0

2.3 Selection of Studies and Data Extraction

The primary researcher and a PhD student in Speech-Language Pathology with expertise in systematic review methodology independently completed the search methods by reading the abstract, and if needed, the full text of each potential study. All included studies were approved for inclusion by both the primary researcher and the Ph.D. student. Inter-rater agreement (IOA) for inclusion was determined to be 100%. IOA was calculated by dividing the total number of agreements by the total number of agreements and disagreements. This value was then multiplied by 100.

Data extraction was completed following the protocol outlined in Schlosser et al. (2009). Each study was summarized as (a) authors, (b) purpose, (c) participants (i.e., total number, chronological ages, and concomitant diagnoses), (d) design, (e) speech output, (f) outcomes (i.e., dependent variable), (g) effectiveness (i.e., NAP, Cohen’s d, Pearson’s product moment correlation coefficient r, or partial eta-squared) and (h) quality appraisal (Schlosser et al., 2009). For single subject designs, effectiveness was measured using NAP with a 95% confidence interval because of its strengths related to accuracy and external validation relative to R^2 and visual analysis judgements (Parker & Vannest, 2009). NAP summarizes data overlap between each baseline phase data point and each intervention phase data point (Parker & Vannest, 2009). An intervention phase data point greater than its paired baseline data point results in a non overlapping pair. NAP is calculated by dividing the number of comparison pairs showing no overlap by the total number of comparisons. Parker and Vannest (2009) outlined a tentative set of NAP effect size ranges based on expert visual judgements. NAP scores < 0.65 indicate a weak effect, NAP scores between 0.66 and 0.92 indicate a medium effect, and NAP scores between > 0.93 indicate a strong effect (Parker & Vannest, 2009).

For effect size calculation involving group designs Cohen's d was calculated through the use of an online effect size calculator titled "Practical Meta-Analysis Effect Size Calculator," based on the book titled "Practical Meta-analysis," (Lipse & Wilson, 2000). The effect size calculations were interpreted using the Cohen's guidelines of effect sizes with 0.20, 0.50, and 0.80 equating to small, medium, and large effects respectively (Cohen, 1988). Pearson's product moment correlation coefficient (r) was reported for Petroi et al. (2014). These values were interpreted with the framework outlined by Hinkle et al. (2003). A correlation size from 0.90 to 1.00 or -0.90 to -1.00 indicates a very high positive, or negative, correlation. A correlation size of 0.70 to 0.90 or -0.70 to -0.90 indicates a high positive, or negative, correlation. A correlation size of 0.50 to 0.70 or -0.50 to -0.70 indicates a moderate positive, or negative, correlation. A correlation size of 0.30 to 0.50 or -0.30 to -0.50 indicates a low positive, or negative, correlation. Finally, a correlation size of 0.00 to 0.30 or 0.00 to -0.30 indicates a negligible correlation (Hinkle et al., 2003). One study reported effect size calculation in terms of partial eta-squared (Petroi et al., 2014). These values were interpreted according to Cohen (1969) defining small, medium, and large effect sizes as partial eta-squared values of 0.0099, 0.0588, and 0.1379, respectively.

Table 2: Effect size interpretations

Effect Size	Interpretation	Low value	High value
Nonoverlapping Pair (NAP; Parker & Vannest, 2009)	Strong effect	0.93	1.00
	Medium effect	0.66	0.92
	Weak effect	0.00	0.65
Cohen's d (d; Cohen, 1988)	Large	0.80	1.00
	Medium	0.50	0.80
	Small	0.20	0.50
	Very small	-0.20	0.20
	Small	-0.50	-0.20
	Medium	-0.80	-0.50
	Large	1.00	-0.80
Pearson's product moment correlation coefficient r (r; Hinkle et al., 2003)	Very high positive correlation	0.90	1.00
	High positive correlation	0.70	0.90
	Moderate positive correlation	0.50	0.70
	Low positive correlation	0.30	0.50
	Negligible correlation	-0.30	0.30
	Low negative correlation	-0.50	-0.30
	Moderate negative correlation	-0.70	-0.50
	High negative correlation	-0.90	-0.70
	Very high negative correlation	-1.00	-0.90
Partial eta square (η^2; Cohen, 1969)	Large	0.1379	NA
	Medium	0.0588	0.1379
	Small	0.0099	0.0588
	Negligible	0	0.0099

The certainty of research evidence was classified using a framework outlined by Schlosser and Raghavendra (2003). This framework was selected as it was utilized by several authors (Dada et. al, 2020; Millar et al., 2006; Schlosser & Koul, 2015; Schlosser & Sigafoos, 2006; Schlosser & Wendt, 2008; Schlosser et al., 2009). This framework classifies the certainty of evidence into four groups based on the following three dimensions: research design, interobserver agreement (IOA) of the dependent variable, and treatment integrity (TI). Conclusive evidence suggests that the outcomes of the study are definitively related to the intervention. This includes a strong design, (e.g., randomized control trial; multiple baseline design; pre-post treatment design with control group; within-subject group design with control items; standard comparison design; cohort comparison design; etc.) and adequate or better IOA and TI. Preponderant evidence suggests that the outcomes of the study are plausible and that they are likely related to the intervention. This includes minor design flaws, such as not including a control group, and an adequate or better IOA and TI. Suggestive evidence suggests that the outcomes of the study are plausibly related to the intervention. This includes either a strong design but inadequate IOA and/or TI or minor design flaws and inadequate IOA and/or TI. Inconclusive evidence suggests that the outcomes of the study are not plausible to be related to the intervention. This is due to fatal flaws in the research design. Please see Appendices A and B for single-subject experimental design and group experimental design study appraisal scales respectively (Schlosser, & Raghavendra, 2003).

The primary researcher and a Ph.D. student in Speech-Language Pathology with expertise in systematic review methodology coded all studies independently to appraise the certainty of research evidence for the included single subject and group design studies. This resulted in an overall inter-rater agreement (IOA) of 93%. Specifically, the primary researcher's and second coder's IOA for design quality was 100%. The researcher and second coder's IOA for the dependent variables was 93%. Finally, TI was rated by the first and second coder with an IOA of 100%.

III. Results

The purpose of this chapter is to provide a comprehensive description of the results of this scoping review. The objectives of this chapter are to describe: (1) characteristics of individual studies, (2) methodological quality of studies, (3) participants' clinical characteristics and demographics (4) features of AAC intervention systems, (5) types of interventions, and (6) intervention outcomes

3.1 Study Selection and Characteristics

Table 1 provides a summary of the search strategies employed to identify studies. Our search methods yielded 16 studies that met our inclusion criteria (Figure 4). Of these studies, seven were pre-experimental studies (i.e., case studies and multiple case studies) four were single subject designs, and five were group designs. Each single subject and group design study was reviewed for following: demographic and clinical characteristics of participants (i.e., n, mean age, gender, education, months poststroke, type of aphasia, severity of aphasia), features of AAC systems (i.e., symbols, messages, type and design of AAC interface, physical characteristics of AAC interface, access strategies, and availability of speech output), dependent variables, treatment effectiveness (i.e., NAP, Cohen's d [d], Pearson's product moment correlation coefficient r [r], Partial-eta squared [η^2]), and quality appraisal. Case studies were analyzed for participants (i.e., n, mean age, gender, education, months poststroke, type of aphasia, severity of aphasia), AAC interface design, features of AAC systems (i.e., display, stimuli, access strategies, and type of speech output), and outcomes. This review incorporated case studies as there were only a limited number of studies that used experimental designs. The data extraction for all study designs are provided in Tables 3-14. Tables 3-14 are organized by experimental design (i.e., case study, single-subject design, group design), and the studies are listed in alphabetical order.

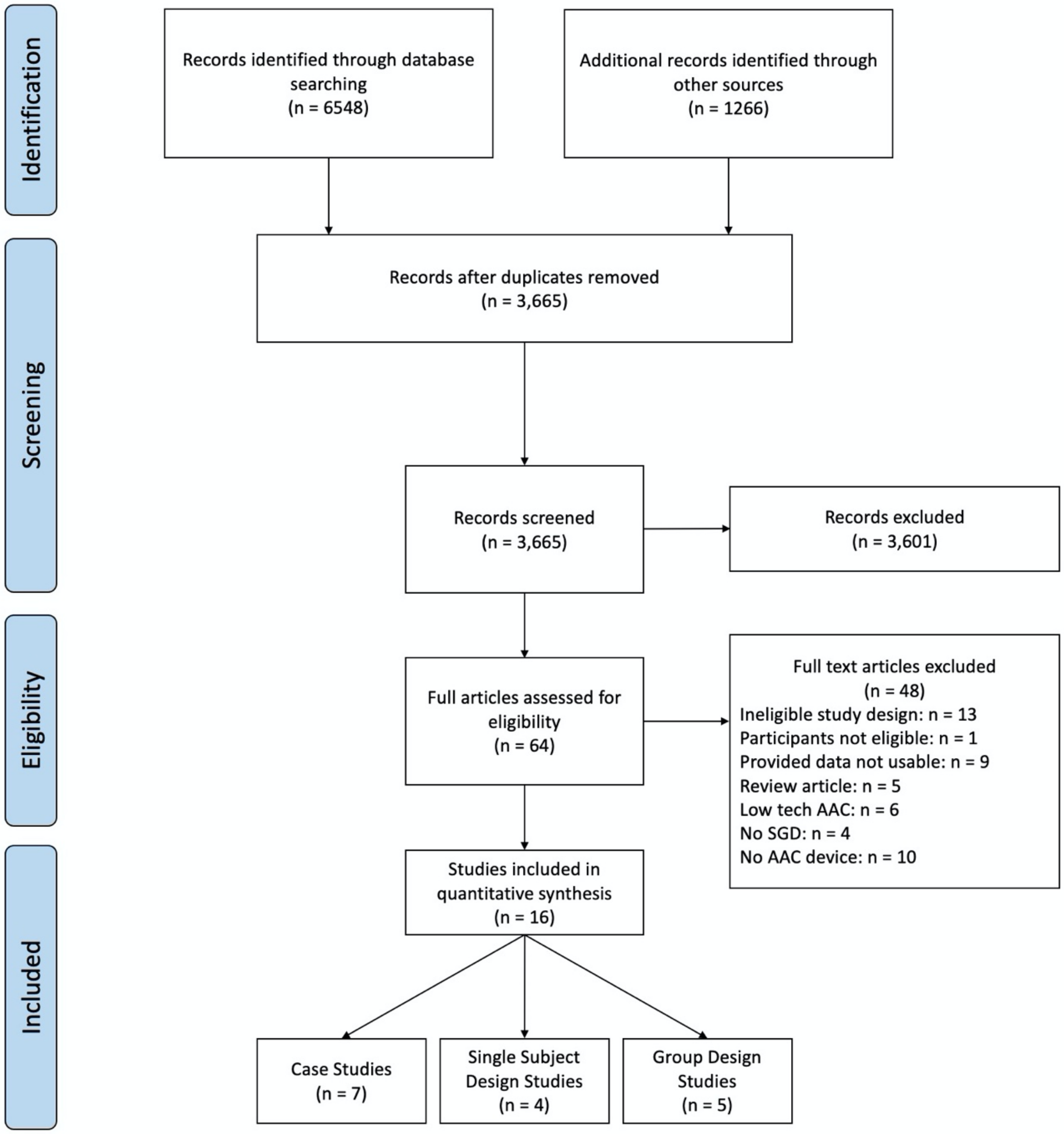

Figure 4: Search strategies

3.2 STUDY QUALITY

Study quality is reported in Tables 13-14. Case studies were not appraised for their methodological quality. Although case studies are essential precursors to single-subject and group experimental designs, they by their very nature are unable to eliminate threats to internal validity and rule our competing hypothesis. Of the included experimental SSD and group studies, three were appraised as providing conclusive evidence (i.e., Koul et al., 2005; Dietz et al., 2018; Petroi et al., 2014). These studies collectively had strong research designs (e.g., randomized control trial, multiple baseline design, pre-post treatment design with control group, within-subject group design with control items, standard comparison design or cohort comparison design) as well as acceptable TI and IOA. Two studies were appraised as providing preponderant evidence (Koul et al., 2008; Koul & Harding, 1998). These studies had a strong research design, acceptable IOA, but a lack of TI. Two studies were classified as providing suggestive evidence (Bartlett et al., 2007; Nicholas et al., 2011) due to minor design flaws and no TI and IOA data. Two studies were appraised as providing inconclusive evidence (Nicholas et al., 2005; Steele et al., 2010). These studies had serious threats to internal validity as well as no TI and IOA data.

3.3 PARTICIPANT CHARACTERISTICS

Participant characteristics are summarized in Tables 3 - 5. Participants included in the current review had non-progressive aphasia (n = 119) due to CVA (n = 117), TBI (n = 1), and subarachnoidal bleeding (n = 1). The mean sample size across studies was 7.38 (SD = 7.31; range = 1-22). One study included a control group in their experimental design (Petroi et al., 2014). Participant characteristics were as follows: age (M = 56.91, SD = 9.70, range = 31-69.3), gender (male = 70, female = 49), education (M = 14.87, SD = 1.28, range = 13.2-16.8, 50% of studies did not report), and months post onset (range = 3-252).

The most common subtype of aphasia included in our review were nonfluent aphasias, including Broca's, transcortical motor and Global aphasia profiles (n = 108; 91% of included studies). Aphasia severity was reported in 15 of the studies (94%). Specifically, data was reported for individuals with severe aphasia in 12 studies (75%), moderate aphasia in 5 studies (31%), and mild aphasia in 2 studies (13%).

3.4 Features of AAC Systems

Tables 6 - 8 outline the features of AAC systems. We adapted Russo et al., (2017) classification system to categorize included studies. First, "AAC computer software," (n = 11, 69%) encompasses software programs that are installed on a desktop computer or a laptop and turn those into SGDs (Albright & Purves, 2008; Bartlett et al., 2007; Koul et al., 2005; Koul & Harding, 1998; Linebarger et al., 2008; Nicholas et al., 2005; Nicholas et al., 2011; Rostron et al., 1996; Steele et al., 2010; van de Sandt-Koenderman et al., 2005; Waller & Newell, 1997). Second, "Dedicated AAC devices," (n = 5, 31%) are devices that are primarily used for communication purposes by individuals with severe communication impairment (Brock et al., 2017; Dietz et al., 2014; Dietz et al., 2018; Koul et al., 2008; Petroi et al., 2014). There were nine different types of AAC computer software used in the included studies: C-Speak Aphasia (n = 2, 13%; Nicholas et al., 2005; Nicholas et al., 2011); SentenceShaper™ (n = 2, 13%; Albright and Purves, 2008; Bartlett et al., 2007); SentenceShaper To Go™ (n = 1, 6%, ; Linebarger et al., 2008); Easy Speaker (n= 1, 6%; Rostron et al., 1996), Portable Communication Assistant for people with Dysphasia (n=1; PCAD; van de Sandt-Koenderman et al., 1997), TalksBac™ (n = 1, 6%; Waller & Newell, 1997), Gus software program (n=1; Koul et al., 2005), TS software program (n = 1, 6%;

Koul and Harding, 1998), and Lingraphica® (n = 1, 6%; Steele et al., 2010). There were 2 different types of dedicated devices used in the included studies: DynaVox Vmax™ (n = 4, 25%; Brock et al., 2017; Dietz et al., 2014; Dietz et al., 2018; Petroi et al., 2014), and DynaMyte 3100 (n=1; Koul et al., 2008).

VSDs were used to organize messages in three studies (19%; Brock et al., 2017; Dietz et al., 2014; Dietz et al., 2018). Dietz et al. (2014), investigated the use of four different types of visual scene displays in five PWA. They concluded that PWA perceived personally relevant photos and related text as useful during conversation (Dietz et al., 2014). Taxonomic grid displays were utilized in fourteen studies (88%; Albright & Purves, 2008; Bartlett et al., 2007; Brock et al., 2017; Koul et al., 2005; Koul et al., 2008; Koul & Harding 1998; Linebarger et al., 2008; Nicholas et al., 2005; Nicholas et al., 2011; Petroi et al., 2014; Rostron et al., 1996; Steele et al., 2010; van de Sandt-Koenderman et al., 2005; Waller & Newell, 1997). Brock et al. (2017) compared performance on several communicative dependent variables across VSD and taxonomic grid displays.

A variety of messages were utilized across studies: written words, icons, audio files, photographs, graphic symbols, drawings, and orthographic symbols. PWA have been found to successfully identify, manipulate, and combine graphic symbols to produce phrases and sentences of varying levels of complexity using an AAC device (Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998).

Speech output included digitized or synthetic speech output. Digitized speech was used in four studies (25%; Albright & Purves, 2008; Bartlett et al., 2007; Linebarger et al., 2008; van de Sandt-Koenderman et al., 2005). Synthetic speech was utilized in the majority of studies (n = 13, 81%; Brock et al., 2017, Dietz et al., 2014; Dietz et al., 2018; Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998; Nicholas et al., 2005; Nicholas et al., 2011; Petroi et al., 2014; Rostron et al., 1996; Steele et al., 2010; van de Sandt-Koenderman et al., 2005; Waller & Newell et al., 1997). One study utilized both synthetic and digitized speech output as well as pictures, symbols, text, and sounds to support communication (van de Sandt-Koenderman et al., 2005).

3.5 DESCRIPTION OF AAC INTERVENTIONS

Tables 9 – 11 describe the AAC interventions included in this scoping review. All of the interventions were provided individually, as opposed to in a group setting. A variety of different experimental designs investigated the outcomes of SGD based AAC interventions. Case studies or multiple case studies accounted for seven (44%) of the included articles (Alright & Purves, 2008; Brock et al., 2017; Dietz et al., 2014; Linebarger et al., 2008; Rostron et al., 1996; van de Sandt-Koenderman et al., 2005; Waller & Newell et al., 1997). Multiple baseline single subject designs accounted for four (25%) of studies (Koul et al., 2005; Koul et al., 2008; Koul and Harding, 1998; Nicholas et al., 2005). The following group design studies were used: aided effects/repeated measures design (Barlett et al., 2007), pre-post treatment design with a control group (Dietz et al., 2018), observational descriptive study design (Nicholas et al., 2011), standard comparison or cohort comparison design (Petroi et al., 2014) and ex-post facto or retrospective design (Steele et al., 2010).

The setting of the AAC intervention varied across studies. Seven studies (44%) investigated AAC intervention in hospital settings (Albright & Purves, 2008; Dietz et al., 2014; Linebarger et al., 2008; Nicholas et al., 2005; van de Sandt-Koenderman et al., 2005; Waller & Newell et al., 1997). Five studies (31%) evaluated intervention in the home setting (Albright & Purves, 2008; Koul et al., 2005; Linebarger et al., 2008; Rostron et al., 1996; van de Sandt-Koenderman, 2005). Four studies (25%) evaluated intervention in the university clinic setting (Brock et al., 2017; Koul et al., 2008; Petroi et al., 2014; Steele et al., 2010). One intervention (6%), was conducted in a long-term care facility (Koul & Harding, 1998). Two studies (13%) did not include their setting as a part of their research methodology (Dietz et al., 2018; Nicholas et al., 2011).

Multiple studies reported the number of intervention sessions (Bartlett et al., 2007; Brock et al., 2017; Dietz et al., 2014; Dietz et al., 2018; Nicholas et al., 2005; Nicholas et al., 2011; Linebarger et al., 2008; Petroi et al., 2014; Rostron et al., 1996; van de Sandt-Koenderman et al., 2005; Waller & Newell et al., 1997) and number of probes (Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998). The number of sessions ranged from 1 to 48. The average number of sessions was eighteen (STD = 15.99, range = 1-48). The number of probes for dependent measures ranged from 25-205. Number of sessions or number of intervention probes were not reported for two studies (Albright & Purves, 2008; Steele et al., 2010). The intervention period ranged from <4 to 24 weeks. Three studies did not report a specific time period for their study (Brock et al, 2017; Dietz et al., 2014; van de Sandt-Koenderman et al., 2005).

3.6 SUMMARY OF INTERVENTION OUTCOMES

Tables 12 - 14 describe the intervention outcomes.

3.6.1 Syntactic Complexity

Three of the studies (19%) investigated the production of sentences of varying grammatical complexity using speech generating devices (Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998). Koul & Harding (1998) investigated the ability of 5 participants with aphasia to identify and combine graphic symbols across screens. This study found that the participants were able to access, manipulate, and combine the graphic symbols to produce simple sentences. Specifically, participants identified noun symbols with a higher accuracy in comparison to symbols from other word classes (NAP=1.0). The authors attribute this finding to the iconicity of noun symbols having a facilitative effect on learning of graphic symbols in PWA (Koul & Harding, 1998; Koul et al., 1997). All participants identified verbs (NAP = 0.9884) and subject verb combinations (NAP = 0.9972) with varying degrees of success.

Koul et al. (2005) investigated the ability of participants with Broca's or Global aphasia to combine graphic symbols to produce sentences of varying syntactical complexity. Seven of the participants had Broca's aphasia and two of the participants had Global aphasia. Overall, the participants with Broca's aphasia were able to produce sentences that included agent + action or action + object constructions (NAP = 0.6609), constructions with morphological inflections (NAP = 0.7119), and sentences with a combination of noun and verb phrases with agent + action + object or object + preposition + object (NAP = 0.6609). Furthermore, participants with Broca's aphasia demonstrated difficulty in the production of sentences which involved production of complex passive sentences (NAP = 0.6393) and or conjoined sentences (NAP = 0.567). The results also indicated that participants with Global aphasia were able to identify symbols across screens in a grid display, but were unable to combine symbols to produce sentences. These results show that with the assistance of a SGD, PWA are able to locate and combine graphic symbols to produce phrases and sentences of varying degrees of syntactical complexity in experimental contexts.

Additionally, Koul et al. (2008) investigated the ability of three participants with chronic severe Broca's aphasia to manipulate and combine graphic symbols to create sentences using a SGD. Results indicated that these individuals were able to use graphic symbols to create sentences with varying degrees of syntactical complexity in experimental contexts. These results are in agreement with observations from Koul et al., 2005.

3.6.2 Unaided Versus Aided AAC Interventions

Six of the studies (38%) compared aided AAC intervention to traditional speech language intervention and unaided AAC intervention (Albright & Purves, 2008; Bartlett et al., 2007; Dietz et al., 2018; Nicholas et al., 2001; Nicholas et al., 2005; Steele et al., 2010). Albright & Purves (2008) compared narrative production before and after twelve weeks using a beta version of the SentenceShaper™ SGD. The SentenceShaper™ is a software program designed to facilitate communication for individuals with non-fluent aphasia. This device minimizes the demands of spoken language production by allowing the PWA to convert their natural speech into digitized speech. These recordings are associated with visual icons, which may be manipulated on the computer screen. This allows the PWA to create messages with more content as they can activate, select, record, and order the constituent elements of their message with both visual and auditory support (Bartlett et al., 2007). Progress was measured through narration of a familiar and unfamiliar story at the beginning, middle, and end of the intervention period. These stories were then transcribed and analyzed with Quantitative Production Analysis (QPA), which measures features of morphosyntax. Following the intervention, participants improved structural and morphological components of their narrative production in both the unaided and aided conditions. It is important to note that, although the participant's sentences were grammatically more complex, the propositional content included in the narratives remained unchanged. From the listener's perspective, the narratives produced with the SSR were rated as more informative and efficient than the narratives produced under the unaided conditions.

Nicholas et al. (2005) investigated the use of the C-Speak aphasia program with five participants with severe non-fluent aphasia. C-Speak aphasia is a SGD software program that was developed for PWA. The targeted behaviors in this study were: responding to questions, communicating on the telephone, describing pictures and videos, and writing. These behaviors were studied for two conditions: "on-computer," using C-Speak Aphasia, and "off computer," not using C-Speak Aphasia. Response to treatment was measured by units of discrete information using any modality (e.g., drawing, gesturing, etc.). For example, a PWA who produced a gesture representing drinking would receive one communication unit. Three out of the five participants communicated more units of discrete information on experimental probes utilizing C-Speak Aphasia (NAP = 0.6901, medium effect). The strongest treatment effect was for the picture description probe (NAP = 0.825, medium effect) followed by the phone on-computer probe (NAP=0.7304, medium effect). Overall results indicated that performance across all tasks and participants was superior when using C-Speak Aphasia in comparison to their performance when they did not use C-Speak Aphasia.

Bartlett et al. (2007) investigated the informativeness of narratives constructed by PWA on the SentenceShaper™ (SSR) communication device. Each participant produced narratives for different topics under unaided (U; e.g., unaided spoken narrative), aided (SSR; e.g., utilizing the SSR communication device for the narrative), and post-SSR unaided (Post-U; e.g., producing an unaided spoken narrative following intervention with the SSR) conditions. To measure informativeness of narratives, graduate students in speech-language pathology rated the narratives with Direct Magnitude Estimation (DME; Stevens, 1975). These ratings revealed functional narratives produced with the assistance of the SSR were more informative than those in the unaided condition. For example, in the EC Glove unaided condition, no significant effects were obtained and in the EC Glove aided condition there was an effect size of d = 2.010015. Two participants also experienced topic-specific carryover in the post-SSR unaided condition following the SSR condition.

While the majority of the studies included individuals with moderate to severe aphasia, one of the studies looked at SGD use in a person with mild agrammatic aphasia. Linebarger et al. (2008) conducted a study to investigate the use of SentenceShaper™ and SentenceShaper To Go™ to create narratives in a person with mild agrammatic aphasia.

Results indicated that the participant produced greater number of CIUs (Nicholas & Brookshire, 1993) during narrative production with the assistance of the SentenceShaper™ device. During the cooking test narrative, percent CIUs (Nicholas & Brookshire, 1993) increased by 40.6% in comparison to baseline measures. The participant also produced narratives utilizing the handheld SentenceShaper To Go™ device to cue spontaneous speech. During the same cooking test narrative task, percent CIUs (Nicholas & Brookshire, 1993) increased by 17.9% in comparison to baseline measures. The participant preferred spontaneous speech facilitated by self-cueing versus playing recorded material on the SentenceShaper™ device. These results indicate that the participant successfully used the SGD as a self-cueing strategy.

Dietz et al. (2018) investigated narrative retell under two conditions: "retell with the AAC device," (i.e., DynaVox Vmax™) and "retell without the AAC device." They also investigated the differences between the "usual care," group (i.e., traditional restorative treatment strategy following Schuell's stimulation approach) and "AAC treatment group," (i.e., using the DynaVox Vmax™). Participants in the AAC group were found to have greater improvement on measures of informativeness and complexity in comparison to the usual care group. For example, the percent counted words for the retell with the AAC device, had an effect size of $d = 0.83$, and for the retell without the AAC device, had an effect size of $d = 0.37$. In the AAC group, individuals with fluent aphasia and non-fluent aphasia produced more counted words, increasing their correct information units (CIUs; Nicholas & Brookshire, 1993) and T-units (Hunt, 1970) on average. To support the argument for AAC-induced language recovery, both the AAC treatment group and the usual care group demonstrated an overall decrease in aphasia severity on the Western Aphasia Battery (WAB-R) Aphasia Quotient (AQ; Kertesz, 2006) following treatment (d = 0.27). The AAC treatment group, however, trended to have a greater decrease in severity (Dietz et al., 2018).

Nicholas et al. (2011) conducted a study on the effects C-Speak Aphasia on functional communication tasks in ten participants with severe non-fluent aphasia. The targeted behaviors in this study were: responding to questions, communicating on the telephone, describing pictures and videos, and writing. These behaviors were studied for two conditions: “on-computer,” using C-Speak Aphasia, and “off computer,” not using C-Speak Aphasia, following an AAC treatment intervention. Results indicated significantly improved performance on functional communication tasks, such as a telephone call task, when utilizing C-Speak Aphasia. Four of the participants communicated substantially more information units on selected probe tasks across the treatment phase. Two participants demonstrated modest improvements on selected probe tasks across the treatment phase. Most substantial improvements were noted in the telephone calls probe task with an effect size ranging from (d = 0.2 to d = 2.1) for the on computer condition. There was notable variability in the performance across participants on experimental tasks.

Steele et al., (2010) conducted a retrospective analysis of twenty individuals with Global aphasia who were trained to use the Lingraphica® SGD. The dependent variable in this study were scores on the WAB-R (Kertesz, 2006) and Communicative Effectiveness Index (CETI; Lomas et al., 1989) at intake and discharge. Results indicated significant improvement in the auditory verbal comprehension and naming subtests of the WAB-R

(Kertesz, 2006). This resulted in eight of the twenty participants being recategorized as Broca's aphasia. Communication partners scores on the CETI (Lomas et al., 1989) indicated 4.8% to 19% improvement across the participants. Notably there was significant improvement in 14 out of the 16 CETI questions.

3.6.3 Dependent Measures; Functional Communication Tasks vs. Structured Contrived Tasks

Nine of the studies (56%) investigated use of AAC techniques and strategies in structured contrived tasks (Albright & Purves, 2008; Brock et al., 2017; Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998; Nicolas et al., 2005; Petroi et al., 2014; Rostron et al., 1996; Steele et al., 2010). Albright & Purves (2008) utilized predetermined narratives to measure communicative performance during component one of their study. Brock et al. (2017) used *I Love Lucy* episodes as conversational stimuli. Koul & Harding (1998) utilized graphic symbols from a variety of different grammatical classes to measure PWA's ability to use a computer-based graphic symbol communication system. Koul et al. (2005) and Koul et al. (2008) utilized sentences of varying levels of syntactic complexity to measure PWA's ability to use a computer-based graphic symbol communication system. Nicolas et al. (2005) used biographical questions and describing pictures to measure performance using the *C-Speak Aphasia*. Rostron et al. (1996) utilized standardized phrases to measure accuracy of AAC use, recall, familiarity, etc. Steele et al. (2010) used scores on the WAB-R (Kertesz, 2006) and CETI to measure communication outcomes following intervention in a university speech clinic with the Lingraphica® SGD.

Eight of the studies (50%) investigated AAC use in functional communication tasks (Albright & Purves, 2008; Bartlett et al., 2007; Dietz et al., 2014; Dietz et al., 2018; Linebarger et al., 2008; Nicolas et al., 2011; van de Sandt-Koedeman et al., 2005; Waller & Newell, 1997). Albright & Purves (2008) measured impact of an SGD on everyday communication through participant observation in natural communication settings, pre and post interviews with the participant and caregiver, and transcribed conversations between the researchers and participant during component two of their study. Dietz et al. (2014) created VSDs with and without personally relevant pictures to support participants with aphasia in facilitated narrative generation. Linebarger et al. (2008) utilized the Amsterdam-Nijmegen Everyday Language Test (ANELT) and functional test narratives, such as parking and cooking, to measure a PWA's ability to produce functional narratives following AAC intervention. Bartlett et al. (2007) also utilized ANELT narratives as a method of narrative elicitation. Van de Sandt-Koedeman et al. (2005) utilized functional communication settings, such as shopping, to evaluate acceptance of an AAC device. Waller & Newell (1997) utilized functional narratives (e.g., a narrative about the participant's dog) to measure narrative production in PWA using an AAC device. Nicolas et al. (2011) utilized functional probe tasks to measure response to treatment. These probes consisted of tasks such as responding to seven autobiographical questions, describing five pictures, describing a one-minute wordless video, making two phone calls, and writing out a birthday card as well as a grocery list.

3.6.4 Outcomes related to display features and navigation

Two of the studies (12.5%) investigated AAC display features and navigation. Petroi et al., (2014) investigated the ability of individuals with severe Broca's aphasia to complete a series of experimental tasks involving identification of single symbols and subject-verb-object sentences on an SGD. Participants included ten individuals with aphasia and ten neurologically normal individuals who served in the control group. Results indicated that both the complexity of the navigation and the number of symbols on the display had a significant effect on the latency and accuracy of symbol identification for taxonomic grid displays. Participants with aphasia demonstrated greater accuracy and identified symbols faster when navigation requirements were minimal. Having fewer number of symbols on the display also enhanced identification accuracy. However, navigation was observed to have a greater impact on identification of symbols than number of symbols on the display.

Dietz (2014) investigated the efficacy of four different VSD layouts with five PWA. At the beginning of the intervention the participants co-constructed personal narratives with a researcher. Four of these narratives were uploaded on to the DynaVox Vmax™ in VSD format. Two of the VSD included personally relevant pictures, and two included non-personally relevant photos. Results indicated that personally relevant photographs and text support facilitated narrative generation.

Brock et al., (2017) investigated the relative effectiveness of taxonomic grid displays and VSDs in variety of communication tasks between a PWA and their communication partner. In the first experiment, a participant with aphasia watched an episode of *I Love Lucy* and was provided with training to engage in conversation regarding the content of the episode with both a VSD and a taxonomic grid display. In the second experiment, the participant watched a different episode of *I Love Lucy* but did not receive training to engage in conversation regarding the content with a VSD or a taxonomic grid display. Across both experiments, results indicated that the participant's use of VSD led to increased conversational turns; less navigational errors; greater response accuracy; and production of longer and more complex utterances in comparison with the taxonomic grid displays. Studies such as those included in this section, suggest that clinicians must optimize displays for PWA by minimizing cognitive effort and making navigation relatively easy.

Nicholas et al. (2011) examined the effects of C-Speak Aphasia on functional communication tasks in ten participants with severe non-fluent aphasia. Part of their analysis evaluated whether scores on cognition, auditory comprehension, and semantic processing could predict performance on dependent measures following an AAC intervention. The participant's auditory comprehension scores on the BDAE-3 (Goodglass et al., 2000) and on tasks of semantic processing were observed to be nonsignificant in predicting a participant's response to an AAC intervention. However, the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001) nonverbal composite scores were found to be significant in predicting a participant's treatment outcomes following an AAC intervention. The authors suggested that basedline measures of non-linguistic executive functioning abilities such as: visual attention, discrimination, scanning, and memory may impact treatment response with a high tech AAC device.

3.7 Acceptance of an AAC Device

Four of the studies (25%) investigated acceptance of an AAC device (Albright & Purves, 2008; Roston et al., 1996; van de Sandt-Koenderman et al., 2005; Waller & Newell, 1997). There are varying levels of acceptance reported across the included studies. Along with analyzing structural and morphosyntactic components of narratives, Albright & Purves (2008) looked at the participant's acceptance of the AAC device. The participant was reported to rarely utilize SentenceShaper™ spontaneously in natural conversation settings. Following the treatment, the participant stated that the "SentenceShaper is not real life." This was followed by reporting that she may use the device to construct emails in the future, as opposed to using it in functional communication settings. Roston et al. (1996) investigated the use of EasySpeaker software for a PWA. This case study reported that a PWA could learn to utilize the SGD. However, the intervention did not result in acceptance, and the use of device for functional communication. Van de Sandt-Koenderman et al. (2005) taught twenty two PWA to use the Portable Communication Assistant for People with Dysphasia (PCAD). They reported that 70% of participants accepting use of the device in functional communication situations (van de Sandt-Koederman et al., 2005).

Table 3. Summary of Demographic and Clinical Characteristics of Participants – Case Study Design

Study	N	Mean age (years)	Gender (M/F)	Mean Education (years)	Months post onset	Type of aphasia	Severity of aphasia
Albright & Purves, 2008	1	31	F	NE	48	Non-fluent (100%)	Moderate
Brock et al., 2017	2	61	1M/1F	14.5	108-120	Broca's aphasia (100%)	Moderate/Severe
Dietz et al., 2014	5	57.8	3M/2F	13.2	21-252	Non-fluent (80%) (Broca's, TCM) /Fluent (20%) (TCS)	Moderate Non-fluent /NE Fluent
Linebarger et al., 2008	1	41	M	16	22	Non-fluent (100%)	Mild
Rostron et al., 1996	1	61	M	14	48	Non-fluent (100%)	Severe
van de Sandt-Koenderman et al., 2005	28	57	20M/8F	NE	3-156	Non-fluent (100%)	NE
Waller & Newell et al., 1997	1	60	F	NE	NE	Non-fluent (100%)	Severe

M: male; F: female, NE: not examined, TCS: Transcortical Sensory, TCM: Transcortical Motor

Table 4. Summary of Demographic and Clinical Characteristics of Participants – Single Subject Design

Study	N	Mean age (years)	Gender (M/F)	Mean Education (years)	Months post onset	Type of aphasia	Severity of aphasia
Koul et al., 2005	10	68	4M/6F	NE	>12	Broca's (70%) Global (20%) Anarthria and aphonia with normal language (10%)	Severe
Koul et al., 2008	3	69.3	3F	NE	12-106	Broca's (100%)	Severe
Koul & Harding, 1998	5	66.4	4M/1F	NE	8-60	Global (40%) Severe aphasia (40%)	Severe
Nicholas et al., 2005	5	51.6	3M/2F	16.8	18-90	Non-fluent (100%)	Severe

M: male; F: female, NE: not examined

Table 5. Summary of Demographic and Clinical Characteristics of Participants – Group Study Design

Study	N	Mean age (years)	Gender (M/F)	Mean Education (years)	Months post onset	Type of aphasia	Severity of aphasia
Bartlett et al., 2007	5	51.6	2M/3F	16	43-201	Non-fluent (100%)	Severe
Dietz et al., 2018	12	57	5M/7F	NE	16-170	Global (0.1%) Broca's (33%) Conduction (17%) Wernicke's (17%) Anomic (25%)	Mild/Moderate/Severe

Nicholas et al., 2011	10	53.6	7M/3F	NE	11-96	Non-fluent (100%)	Severe
Petroi et al., 2014	10	57.1	7M/3F	13.60	26-117	Broca's (100%)	Moderate/Severe
Steele et al., 2010	20	67.2	12M/8F	NE	6-108	Global (100%)	Severe

M: male; F: female, NE: not examined

Table 6. Features of AAC systems – Case Study Design

Study	AAC System	Information Systems	Display	Stimuli	Access Strategies	Speech Output
Albright & Purves, 2008	Beta version of Sentence Shaper	AAC computer software	Taxonomic grid display	Written words, icons, audio files	Mouse	Digitized speech
Brock et al., 2017	DynaVox Vmax™	Dedicated AAC Device	Visual Scene Display and Taxonomic grid display	Written words, photographs, graphic symbols	Touch screen	Synthesized speech
Dietz et al., 2014	DynaVox Vmax™	Dedicated AAC Device	Visual Scene Display	Written words, photographs, graphic symbols	Touch Screen	Synthesized speech
Linebarger et al., 2008	SentenceShaper To Go™	AAC computer software	Taxonomic grid display	Written words, icons, audio files	Touch screen	Digitized Speech

Rostron et al., 1996	Easy Speaker	AAC computer software	Taxonomic grid display	Written words, pictures, graphic symbols	Mouse	Synthesized speech
van de Sandt-Koenderman et al., 2005	Portable Communication Assistant for People with Dysphasia (PCAD)	AAC computer software	Taxonomic grid display	Written words, pictures	Touchscreen	Digitized/Synthesized speech
Waller & Newell, 1997	TalksBac™	AAC computer software	Taxonomic grid display	Written words, pictures	Mouse	Synthesized speech

Table 7. Features of AAC systems – Single Subject Design

Study	AAC System	Information Systems	Display	Stimuli	Access Strategies	Speech Output
Koul et al., 2005	Gus software program	AAC computer software	Taxonomic grid display	Graphic and orthographic symbols	Touchscreen	Synthesized speech
Koul et al., 2008	DynaMyte 3100	Dedicated AAC device	Taxonomic grid display	Graphic and orthographic symbols	Touchscreen	Synthesized speech
Koul & Harding, 1998	The TS software program, DECTalk	AAC computer software	Taxonomic grid display	Graphic symbols	Mouse, Trackball	Synthesized speech

	synthesizer (Model DTCO1-AA)					
Nicholas et al., 2005	C-Speak Aphasia	AAC computer software	Traditional grid display	Written words, photographs,	Mouse	Synthesized speech

Table 8. Features of AAC systems – Group Study Design

Study	AAC System	Information Systems	Display	Stimuli	Access Strategies	Speech Output
Bartlett et al., 2007	SentenceShaper™	AAC computer software	Taxonomic grid display	Written words, icons, audio files	Mouse	Digitized Speech
Dietz et al., 2018	DynaVox Vmax™	Dedicated AAC device	Visual Scene Display	Graphic symbols	Touch screen	Synthesized speech
Nicholas et al., 2011	C-Speak Aphasia	AAC computer software	Taxonomic grid display	Written words, photographs	Mouse	Synthesized speech
Petroi et al., 2014	DynaVox Vmax™	Dedicated AAC device	Taxonomic grid display	Graphic symbols	Touch screen	Synthesized speech
Steele et al., 2010	Lingraphica®	AAC computer software	Taxonomic grid display	Written words, icons	Touch screen, mouse	Synthesized speech

Table 9. Description of AAC Interventions – Case Study Design

Study	Design	Purpose/Objective	Setting	Instructional format	Number of sessions	Intervention period (weeks)
Albright & Purves, 2008	Case Study	To examine changes in narrative production with and after using the SentenceShaper™.	Hospital, home	1:1	NE	16
Brock et al., 2017	Case Study	To compare the effectiveness of taxonomic grid displays versus VSDs in communication tasks between a PWA and their communication partner.	University speech therapy clinic	1:1	20	NE
Dietz et al., 2014	Observational, descriptive study (i.e., multiple case study design)	To determine the communication behaviors of people with aphasia when telling a narrative with four variants of a VSD.	Hospital	1:1	1	NE
Linebarger et al., 2008	Case study	To examine the challenges of creating an SGD, and propose a portable extension of the SentenceShaper™.	Hospital, home	1:1	24	16
Rostron et al., 1996	Case study	To examine the impact of a computerized communication aid on the functional communication of a person with aphasia.	Home	1:1	10	4

van de Sandt-Koenderman et al., 2005	Observational descriptive study (i.e., multiple case study design)	To create a computerized communication aid for people with aphasia to support functional communication.	Hospital, Home	1:1	20	NE
Waller & Newell, 1997	Case Study	To examine the use of a prototype augmentative communication system focused on narrative construction.	Hospital	1:1	12	16

NE: not examined

Table 10. Description of AAC Interventions – Single Subject Design

Study	Design	Purpose/Objective	Setting	Instructional format	Number of sessions	Intervention period (week)
Koul et al., 2005	Multiple baseline design	To evaluate the ability of participants with Broca's or Global aphasia to combine graphic symbols to produce sentences of varying syntactical complexity using a SGD.	Person's home or residential setting	1:1	*52-205	NE

Koul et al., 2008	Multiple baseline design	To evaluate the ability of participants with chronic severe Broca's aphasia to manipulate and combine graphic symbols to create sentences using a SGD.	University speech therapy clinic	1:1	*85-174	5-12
Koul & Harding, 1998	Multiple baseline design	To evaluate the ability of individuals with severe or Global aphasia to utilize a SGD in addition to a graphic symbol software program to identify graphic symbols, and produce sentences of varying complexities.	Long term care facility	1:1	*25-47	NE
Nicholas et al., 2005	Multiple baseline design	To evaluate the ability of individuals with severe nonfluent aphasia to improve their functional communication skills through the use of an SGD.	Hospital	1:1	48	24

NE: not examined, *:data reported in probes instead of sessions

Table 11. Description of AAC Interventions – Group Study Design

Study	Design	Purpose/Objective	Setting	Instructional format	Number of sessions	Intervention period (weeks)
Bartlett et al., 2007	Aided effects design; repeated measures design	To evaluate the effects of Sentence Shaper™ (i.e., aided speech) on the functional communication of people with chronic aphasia.	Hospital	1:1	1	NE
Dietz et al., 2018	Pre-post treatment design with control group	To evaluate the feasibility of providing high-tech AAC treatment to people with chronic aphasia to facilitate language recovery.	NE	1:1	12	4
Nicholas et al., 2011	Observational, descriptive study	To evaluate the factors contributing to the use of C-Speak Aphasia (i.e., aided speech) on the functional communication of people with chronic aphasia.	NE	1:1	48	24
Petroi et al., 2014	Standard comparison design or cohort comparison design	To evaluate the ability of individuals with severe Broca's aphasia to complete a series of experimental tasks involving identification of single symbols and subject-verb-object sentences on an SGD.	University speech therapy clinic	1:1	2	< 4

Steele et al., 2010	Ex-post facto or retrospective design	To evaluate the ability of individuals with chronic Global aphasia to utilize a SGD for functional communication.	University speech therapy clinic	1:1	NE	NE

NE: not examined

Table 12. Effects of Speech Output Technologies on the Communication of PWA – Case Study design

Study	Results
Albright & Purves, 2008	Participant with aphasia experienced an increase in the morphosyntactic complexity of their narratives. However, informativeness and structure of the narrative remained consistent. The SentenceShaper™ was utilized for emails and conversation, but was not used by the participant in daily communication exchanges.
Brock et al., 2017	Across both experiments, results indicated that the participant's use of VSD led to increased conversational turns; less navigational errors; greater response accuracy; and production of longer and more complex utterances in comparison with the taxonomic grid displays.
Dietz et al., 2014	Participants perceived personally relevant visual scenes as helpful while participating in a narrative retell. All participants used spoken modality units on average more than other modality units (i.e., speak button, written, drawn, text box, and photographs).
Linebarger et al., 2008	Results indicated that the participant produced greater number of CIUs (Nicholas & Brookshire, 1993) during narrative production with the assistance of the SentenceShaper™ device.
Rostron et al., 1996	Participant achieved improvement in speed and accuracy in utilizing the SGD, but did not use the communication device in daily communication.
Van de Sandt-Koenderman et al., 2005	All participants (n=22) participated in the training and learned how to operate the PCAD. Seventeen participants used the PCAD functionally outside of the therapeutic setting. Five participants did not use the device outside of the therapy room, but could operate the device and use it in role play scenarios.

Waller & Newell, 1997	The participant had a significant increase in social interaction while implementing the TalksBac™ device to support narrative generation.

Table 13. Effects of Speech Output Technologies on the Communication of PWA – Single Subject Design

Study	Dependent Variable	Effectiveness (NAP; effect size interpretation; 95% confidence interval)			Appraisal
		NAP	95% Confidence Interval		
Koul et al., 2005	Level 1: two word agent + action or action + object constructions (Completed by participants 1-10)	0.6609 (Medium)	0.5702 (Weak)	0.7515 (Medium)	Conclusive evidence based on the use of a strong research design as well as acceptable IOA and TI.
	Level 2: constructions with morphological inflections (Completed by participants 1-3, 5-10)	0.7119 (Medium)	0.6364 (Weak)	0.7875 (Medium)	
	Level 3: constructions with a combination of noun and verb phrases with agent + action+object or object + preposition + object (Completed by participants 1-3, 5-10)	0.6824 (Medium)	0.6155 (Weak)	0.7493 (Medium)	
	Level 4: production of passive sentences and sentences with compound verbs (Completed by participants 1, 2, 5, 6, 8, 10)	0.6393 (Weak)	0.5557 (Weak)	0.7229 (Medium)	
	Level 5: complex sentences containing relative noun clauses or	0.567 (Weak)	0.4806 (Weak)	0.6534 (Weak)	

	compound sentences containing conjoined independent clauses (Completed by participants 1, 5, 6, 10)				
	Levels 1-5	NAP=0.6554 (Medium)	0.6041 (Weak)	0.7066 (Medium)	
Koul et al., 2008	Level 1 two word agent + action or action + object constructions (Completed by participants 1-3	0.942 (Strong)	0.7662 (Medium)	1.00 (Strong)	Preponderant evidence, strong design with acceptable IOA but lack of TI
	Level 2 constructions with morphological inflections (Completed by participants 1-3	0.9273 (Strong)	0.7754 (Medium)	1.00 (Strong)	
	Level 3 constructions with a combination of noun and verb phrases with agent + action+object or object + preposition + object (Completed by participants 1-3	0.8857 (Medium)	0.7671 (Medium)	1.00 (Strong)	
	Level 4 production of passive sentences and sentences with compound verbs (Completed by participants 2-3	0.8041 (Medium)	0.6723 (Medium)	0.936 (Strong)	
	Level 5 complex sentences containing relative noun clauses or compound sentences containing conjoined independent clauses (Completed by participant 3)	NA	NA	NA	
	Level 1-3	Combined NAP=0.9144 (Strong)	0.7914 (Medium)	1.00 (Strong)	

	Level 1-4	Combined NAP=0.8848 (Medium)	0.7815 (Medium)	0.9882 (Strong)	
	Level 1-5	Combined NAP=0.8513 (Medium)	0.7564 (Medium)	0.9462 (Strong)	
Koul & Harding, 1998	Nouns, pronouns and adjectives	1.00 (Strong)	0.8427 (Medium)	1.00 (Strong)	Preponderant evidence, strong design with acceptable IOA but lack of TI
	Verbs	0.9884 (Strong)	0.8556 (Medium)	1.00 (Strong)	
	Subjects and verbs	0.9972 (Strong)	0.8677 (Medium)	1.00 (Strong)	
Nicholas et al., 2005	Autobiography on-computer	0.5909 (Weak)	0.2987 (Weak)	0.8831 (Medium)	Inconclusive evidence based on serious threats to internal validity as well as a lack of IOA and TI
	Autobiography off-computer	0.517 (Weak)	0.2341 (Weak)	0.7999 (Medium)	
	Picture description on-computer	0.825 (Medium)	0.5317 (Weak)	1.00 (Strong)	
	Picture description off-computer	0.4125 (Weak)	0.1192 (Weak)	0.705 (Medium)	
	Video description on-computer	0.5625 (Weak)	0.0635 (Weak)	1.00 (Strong)	
	Video description off-computer	0.3986 (Weak)	0.0446 (Weak)	0.7525 (Medium)	
	Phone on-computer	0.7304 (Medium)	0.4317 (Weak)	1.00 (Strong)	
	Phone off-computer	0.5828 (Weak)	0.2856 (Weak)	0.8799 (Medium)	
	Total on-computer	0.6901 (Medium)	0.4377 (Weak)	0.9424 (Strong)	

	Total off-computer	0.4868 (Weak)	0.2356 (Weak)	0.537 (Weak)	
	Total on-computer and off-computer	0.5816 (Weak)	0.4167 (Weak)	0.7464 (Medium)	

IOA: inter-observer agreement, TI: treatment integrity

Table 14. Effects of Speech Output Technologies on the Communication of PWA – Group Study Design

Study	Dependent Variable		Effectiveness (Cohen's d (d), Pearson's product moment correlation coefficient r (r), Partial-eta squared (η2); effect size interpretation)	Appraisal
Bartlett et al., 2007	Narrative production – unaided	U< SSR; U < Post-U		Suggestive evidence based on minor design flaws as well as lack of IOA and TI
		EC glove	d=n.s.	
		EC glasses	d=n.s.	
		MAI glove	d=n.s.	
		MAI glasses	d=n.s.	
		DCN glove	d=n.s.	
		DCN glasses	d=n.s.	
		MO glove	d=n.s	
		MO glasses	d=n.s.	
		OT glove	d=n.s.	
		OT glasses	d=n.s.	
	Narrative production – aided	SSR > U		
		EC glove	d=2.010015 (Large)	
		EC glasses	d=2.019223 (Large)	
		MAI glove	d=n.s.	
		MAI glasses	d=2.019223 (Large)	

		DCN glove	d=n.s.	
		DCN glasses	d=n.s.	
		MO glove	d=3.1306 (Large)	
		MO glasses	d=2.2367 (Large)	
		OT glove	d=n.s.	
		OT glasses	d=2.3821 (Large)	
	Narrative production – post-SSR Unaided	Post-U > U		
		EC glove	d=n.s.	
		EC glasses	d=0.468 (Small)	
		MAI glove	d=n.s.	
		MAI glasses	d=n.s.	
		DCN glove	d=n.s.	
		DCN glasses	d=n.s.	
		MO glove	d=2.0621 (Large)	
		MO glasses	d=1.8549 (Large)	
		OT glove	d=n.s.	
		OT glasses	d=n.s.	
Dietz et al., 2018	Retell Condition	WAB-R AQ	d=0.27 (Small)	Conclusive evidence based on a strong research design as well as acceptable IOA and TI
	Retell with the AAC device	%Counted Words	d=0.83 (Large)	
		%CIUs	d=0.78 (Large)	
		CIUS/Minute	d=0.17 (Very small)	
		%Mazed Words	d=0.31 (Small)	
		%Tunits	d=1.09 (Large)	
		%Spoken	d=0.79 (Medium)	
		%Drawn	d=0.11 (Very small)	
		%Gesture	d=0.25 (Small)	
		%Written	d=0.34 (Small)	
		%Photograph	d=0.89 (Large)	

		%Speak Button	NA	
		%Text Box	d=0.04 (Very Small)	
	Retell without the AAC device	%Counted Words	d=0.37 (Small)	
		%CIUs	d=0.12 (Very small)	
		CIUS/Minute	d=0.72 (Medium)	
		%Mazed Words	d=0.3 (Medium)	
		%Tunits	d=0.77 (Medium)	
		%Spoken	d=0.2 (Medium)	
		%Drawn	d=0.13 (Very small)	
		%Gesture	d=1.48 (Large)	
		%Written	d=1.87 (Large)	
		%Photograph	NA	
		%Speak Button	NA	
		%Text Box	NA	
Nicholas et al., 2011	Participant 1	Autobiography questions off	d=1.4 (Large)	Suggestive evidence, minor flaws in design (i.e., no control group) as well as lack of IOA and TI
		Autobiography Questions on	d=2.2 (Large)	
		Picture Descriptions off	d=2.1 (Large)	
		Picture Descriptions on	d=2.4 (Large)	
		Video Description off	d=0 (None)	
		Video Description on	d=1.7 (Large)	
		Telephone Calls off	d=0.9 (Large)	
		Telephone Calls on	d=2 (Large)	
		Writing Tasks off	d=1.3 (Large)	
		Writing Tasks on	d=0.1 (Very small)	
	Participant 2	Autobiography Questions off	d=1.7 (Large)	

		Autobiography Questions on	d=0 (None)	
		Picture Descriptions off	d=1.1 (Large)	
		Picture Descriptions on	d=1.2 (Large)	
		Video Description off	d=1.3 (Large)	
		Video Description on	d=1.9 (Large)	
		Telephone Calls off	d=1.5 (Large)	
		Telephone Calls on	d=1.4 (Large)	
		Writing Tasks off	d=1.2 (Large)	
		Writing Tasks on	d=1.4 (Large)	
	Participant 3	Autobiography Questions off	d=0.6 (Medium)	
		Autobiography Questions on	d=0.7 (Medium)	
		Picture Descriptions off	d=0.6 (Medium)	
		Picture Descriptions on	d=1.3 (Large)	
		Video Description off	d=0.4 (Small)	
		Video Description on	d=1.2 (Large)	
		Telephone Calls off	d=0.1 (Very small)	
		Telephone Calls on	d=0.2 (Small)	
		Writing Tasks off	d=1.4 (Large)	
		Writing Tasks on	d=0.8 (Large)	
	Participant 4	Autobiography Questions off	d=1.5 (Large)	
		Autobiography Questions on	d=1.2 Large	
		Picture Descriptions off	d=5.7 (Large)	
		Picture Descriptions on	d=1.7 (Large)	
		Video Description off	d=1.5 (Large)	

		Video Description on	d=0.9 (Large)	
		Telephone Calls off	d=1.2 (Large)	
		Telephone Calls on	d=1.9 (Large)	
		Writing Tasks off	d=1.8 (Large)	
		Writing Tasks on	d=1.5 (Large)	
	Participant 5	Autobiography Questions off	d=0.4 (Small)	
		Autobiography Questions on	d=0.1 (Very small)	
		Picture Descriptions off	d=1.1 (Large)	
		Picture Descriptions on	d=1.7 (Large)	
		Video Description off	d=5 (Large)	
		Video Description on	d=2.2 (Large)	
		Telephone Calls off	d=0.6 (Medium)	
		Telephone Calls on	d=1.8 (Large)	
		Writing Tasks off	d=n.s.	
		Writing Tasks on	d=n.s.	
	Participant 6	Autobiography Questions off	d=0.9 (Large)	
		Autobiography Questions on	d=5.8 (Large)	
		Picture Descriptions off	d=1.8 (Large)	
		Picture Descriptions on	d=0.4 (Small)	
		Video Description off	d=0.5 (Medium)	
		Video Description on	d=4.0 (Large)	
		Telephone Calls off	d=1.1 (Large)	
		Telephone Calls on	d=1.5 (Large)	
		Writing Tasks off	d=1.0 (Large)	
		Writing Tasks on	d=2.2 (Large)	

	Participant 7	Autobiography Questions off	d=1.2 (Large)	
		Autobiography Questions on	d=1.8 (Large)	
		Picture Descriptions off	d=0.5 (Medium)	
		Picture Descriptions on	d=1.6 (Large)	
		Video Description off	d=0.7 (Medium)	
		Video Description on	d=4.6 (Large)	
		Telephone Calls off	d=1.1 (Large)	
		Telephone Calls on	d=1.6 (Large)	
		Writing Tasks off	d=n.s.	
		Writing Tasks on	d=1.4 (Large)	
	Participant 8	Autobiography Questions off	d=2 (Large)	
		Autobiography Questions on	d=2.3 (Large)	
		Picture Descriptions off	d=4.6 (Large)	
		Picture Descriptions on	d=4.9 (Large)	
		Video Description off	d=0.1 (Very Small)	
		Video Description on	d=0 (Very Small)	
		Telephone Calls off	d=2.3 (Large)	
		Telephone Calls on	d=1.5 (Large)	
		Writing Tasks off	d=-3 (Large)	
		Writing Tasks on	d=1.1 (Large)	
	Participant 9	Autobiography Questions off	d=2.8 (Large)	
		Autobiography Questions on	d=2.6 (Large)	
		Picture Descriptions off	d=1.6 (Large)	

		Picture Descriptions on	d=2 (Large)	
		Video Description off	d=2.2 (Large)	
		Video Description on	d=2 (Large)	
		Telephone Calls off	d=n.s.	
		Telephone Calls on	d=2.1 (Large)	
		Writing Tasks off	d=0.2 (Small)	
		Writing Tasks on	d=0.3 (Small)	
	Participant 10	Autobiography Questions off	d=2.4 (Large)	
		Autobiography Questions on	d=1.6 (Large)	
		Picture Descriptions off	d=1.4 (Large)	
		Picture Descriptions on	d=0.7 (Medium)	
		Video Description off	d=0 (None)	
		Video Description on	d=0.8 (Large)	
		Telephone Calls off	d=0.2 (Small)	
		Telephone Calls on	d=1.1 (Large)	
		Writing Tasks off	d=3.9 (Large)	
		Writing Tasks on	d=0.1 (Very small)	
Petroi et al., 2014	Task 1: Identification of Single Symbols	People in the control group symbol identification of more symbols than persons with aphasia group	d=8.7857 (Large)	Conclusive evidence based on a strong research design as well as acceptable IOA and TI
		Number of symbols	η^2=0.2237 (Large)	
		number of symbols and group	No significant interaction	
		Level of location	η^2=0.2169 (Large)	

		covariance of within-subject variables	d=8.1476 (Large)	
		Within subject test of condition	No significant interaction	
		Within subject test of interaction between condition and group	No significant interaction	
	Task 2: Identification of SVO Sentences	Tests of within-subject effects condition	No significant effect	
		sustained and divided listening condition and focused and sustained listening conditions	d=0.4233 (Small)	
		Group perception of task difficulty for single symbol task	d=3.2502 (Large)	
		Condition perception of task difficulty for single symbol task	No significant effect	
		Group perception of task difficulty for SVO sentence task	d=5.4144 (Large)	
		Condition and two-way interaction between group and condition	No significant effect	
		PWA's single symbol response accuracy and perceptual ratings in the sustained attention condition	r=-0.240 (Negligible correlation)	

		PWA's single symbol response response accuracy and perceptual ratings in the focused attention condition	r=-0.331 (Low negative correlation)	
		PWA's single symbol response accuracy and perceptual ratings in the divided attention condition	r=-0.307 (Low negative correlation)	
		Control group single symbol response accuracy and perceptual ratings in the sustained attention condition	r=-0.196 (Negligible correlation)	
		Control group single symbol response accuracy and perceptual ratings in the divided attention condition	r=-0.183 (Negligible correlation)	
		Control group single symbol response accuracy and perceptual ratings in the focused attention condition	No significant correlation	
		PWA's SVO sentence response accuracy and perceptual ratings in sustained attention	r=-0.508 (Moderate negative correlation)	
		PWA's SVO sentence response accuracy and	r=-0.403 (Low negative correlation)	

		perceptual ratings in focused attention		
		PWA's SVO sentence response accuracy and perceptual ratings in divided attention	r=0.254 (Negligible correlation)	
		Single symbol order effect	d=1.061 (Large)	
		SVO sentences order effect	No significant effect	
Steele et al., 2010	Impairment level changes after SGD use – all 20 subjects	Spontaneous speech	d=0.5456 (Medium)	Inconclusive evidence based on serious threats to internal validity as well as a lack of IOA and TI
		Auditory Verbal Comprehension	d=1.686 (Large)	
		Repetition	d=0.8139 (Large)	
		Naming	d=1.3729 (Large)	
		Aphasia Quotient	d=1.8515 (Large)	
	Functional communication changes after SGD use – all 20 subjects	CETI item bank 1-16 overall	d=3.3049 (Large)	
	Impairment level changes after SGD use – comparing changes between the GI:GI group to	Spontaneous speech	d=0.2541 (Small)	
		Auditory Verbal Comprehension	d=1.2425 (Large)	
		Repetition	d=0.1514 (Very small)	
		Naming	d=1.1106 (Large)	
		Aphasia Quotient	d=0.4183 (Small)	
		Extensive use versus dependent use	d=1.6981 (Large)	

	the GI:Br group	Extensive use versus independent use	d=2.0494 (Large)	
	Group that did not use TouchSpeak	no use versus dependent use	d=1.1577 (Large)	
		no use versus independent use	d=1.4208 (Large)	
		no use versus extensive use	d=2.1565 (Large)	

IOA: inter-observer agreement, TI: treatment integrity, U: unaided, SSR: aided, Post-U: Post-SSR Unaided

IV. DISCUSSION

The purpose of this scoping review was to present the existing evidence related to the effectiveness of AAC interventions using speech output technologies for PWA, identify gaps in the current literature, and propose directions for future research. This review informs us about outcomes in functional communication behaviors as well as behaviors related to symbol identification, symbol combination, and navigation of the AAC interface.

4.1 Designs and quality appraisal

Our search methods yielded sixteen studies that met our inclusion criteria. Of the included studies, 44% were case studies, which inherently present serious threats to internal validity. Case studies were included because of the paucity of experimental studies that ruled out serious internal validity concerns. Fifty six percent of the included studies were single subject and group designs. Only three of these studies were appraised as having conclusive evidence (Koul et al., 2005; Dietz et al., 2018; Petroi et al., 2014). The mean sample size of the included studies was 7.38. Eighty one percent of the included studies had ten or fewer participants. The lack of experimental studies with appropriate controls and small sample sizes across most experimental studies, is consistent with the findings from previous systematic reviews (Russo et al., 2017; Koul et al., 2010).

4.2 Participants

The participant clinical and demographic characteristics in the included studies were highly variable. Notably, the time post-onset had a range of 3 to 252 months. The large range of time post-onset, is a concern as PWA may experience spontaneous physiological restitution for months following the onset of the disorder (Koul, 2011). The mean age of the participants was 56.91 years (range: 31-69.3 years). This is important to note as age may be a factor that influences successful implementation of high-technology AAC intervention approaches (Russo et al., 2017). In terms of aphasia severity, data was reported for participants with severe aphasia in 75% of studies, moderate aphasia in 31% of studies, and participants with mild aphasia were included in 13% of studies. The scarcity of participant data for persons with mild aphasia is a concern because data shows that recovery of natural language in individuals with mild aphasia may be facilitated through AAC intervention (Aftonomos et al, 2001, Dietz et al., 2018; Garrett & Lasker, 2005; McCall et al., 2000; Weinrich et al., 1995, Weinrich et al., 1999).

4.3 Effects of Speech Output Technologies on the Communication of PWA

The effect size for single subject design studies (Koul et al., 2005; 2008) that investigated identification of symbols across screens, combining symbols to produce sentences of varying syntactical complexity ranged from large to medium effects as determined using NAP for two word agent + action or action + object constructions, constructions with morphological inflections, and sentence constructions with a combination of noun and verb phrases in person's with chronic severe Broca's aphasia. Additionally, weak effect sizes were noted for production of passive sentences and sentences with compound verbs and complex sentences containing conjoined independent clauses in the same individuals with Broca's aphasia. In contrast, individuals with Global aphasia (Koul et al., 2005) were unable to combine symbols to produce sentences, thus no effect sizes were determined for those individuals. In a study (Nicholas et al., 2005) that involved communicative tasks such as making telephone calls, the effect sizes ranged from weak to medium. These results indicate that AAC intervention using an SGD is effective in changing target dependent variables related to performing a communicative task and successfully navigating an SGD.

Treatment effect sizes for a group design study (Bartlett et al., 2007) varied across participants with Broca's aphasia on a narrative production task with some participants showing large effect size and others showing no treatment effects. Dietz et al., (2018) measured the mean change from pre to post-treatment between groups on a narrative retell task with the assistance of an SGD. Large treatment effect sizes were seen for percent Counted Words, percent T-units, percent CIUs, and percent Photograph expressive modality units. Medium treatment effect sizes were seen for the percent Spoken expressive modality unit. Nicholas et al., (2011) measured the response to AAC intervention with individuals with severe nonfluent aphasia (e.g., Global, Broca's, mixed) using functional communication measures (i.e., Autobiographical question, Picture description, Video description, Telephone call, and writing tasks). The effect sizes ranged from none to large. Steele et al., (2010) conducted a retrospective analysis of the scores from twenty individuals with Global aphasia on the WAB-R (Kertesz, 2006) and CETI (Lomas et al., 1989) at intake and discharge. Results indicated medium to large effect sizes following SGD use. In summary, the wide range of treatment effect size data reported across these studies highlights the variability of treatment outcomes for people with chronic severe

Broca's aphasia and Global aphasia. It is important that the AAC intervention be individually tailored to each PWA.

4.4 AAC Intervention Characteristics

An important consideration in the individualization of AAC interventions for PWA is the SGD display. Preliminary research comparing VSDs to taxonomic grid displays suggest VSDs facilitate efficient and accurate navigation and increase the number of communicative exchanges (Beukelman et al., 2015; Brock et al., 2017; Koul, 2011; Wallace & Hux, 2014). VSDs are hypothesized to minimize the linguistic and working memory demands associated with using AAC displays. VSDs are also thought to facilitate gestalt comprehension of content (Dietz et al., 2006; Wilkinson & Jagaroo, 2004; Wilkinson et al., 2012) through features such as an autobiographical organization strategy. VSDs may also allow for increased access to episodic memory (Dietz et al., 2014). In summary, VSDs are relatively more effective in facilitating communication in comparison to taxonomic grid displays due to their relative ease of use, limited navigation, and rich contextual cues (Beukelman et al., 2015; Brock et al., 2017, Koul, 2011).

Digitized (n=4, 27%; Albright & Purves, 2008; Bartlett et al., 2007; Linebarger et al., 2008; van de Sandt-Koenderman et al., 2005) and synthetic (n=12, 80%; Dietz et al., 2014; Dietz et al., 2018; Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998; Nicholas et al., 2005; Nicholas et al., 2011; Petroi et al., 2014; Rostron et al., 1996; Steele et al., 2010; van de Sandt-Koenderman et al., 2005; Waller & Newell et al., 1997) speech output were both utilized in the treatment interventions. Only one study utilized both synthetic and digitized speech output to support communication (i.e., van de Sandt-Koenderman et al., 2005). Due to the evidence suggesting that digitized speech may be preferred over synthetic speech (Hux et al., 2017), it is important for researchers to continue investigating SGDs that produce digitized speech as this may have implications for important clinical variables such as AAC acceptance versus abandonment.

Only one study investigated the differences between a traditional restorative intervention approach, in comparison to a SGD based AAC intervention (Dietz et al., 2018). Participants in the AAC group were found to have a higher rate of improvement on measures of informativeness and complexity of utterances in comparison to the usual care group. In the AAC group, individuals with fluent and non-fluent aphasia produced more counted words. Furthermore, individuals with non-fluent aphasia post treatment had greater number of average CIUs (Nicholas & Brookshire, 1993) and T-units (Hunt, 1970). Both the AAC treatment group and the usual care group demonstrated an overall reduction in aphasia severity on the WAB-R AQ (Kertesz, 2006) following treatment (Dietz et al., 2018). The AAC treatment group demonstrated a relatively larger decrease in severity (Dietz et al., 2018). This study provides evidence to suggest that AAC intervention should be viewed as a complement to a restorative intervention approach.

Despite the known benefits of communication partner training, only one study in this review included a communication partner or caregiver as a participant in their experimental design (Albright & Purves, 2008). Communication partner training has facilitative effects on the communication of PWA who use AAC strategies and techniques (Kent-Walsh et al., 2015). Communication partners assist PWA in the formulation of messages by providing them with appropriate wait time, and provide them with conversational supports (Koul, 2011). It is crucial that investigations include strategies to facilitate communication partner or caregiver participation in the AAC intervention process. For example, it is known that people's attitude towards their communication partner influences AAC acceptance and motivation to use an AAC strategies (Pampoulou, 2019). Furthermore, caregiving is both physically and emotionally demanding. For example, families can have many caregiving duties (e.g., changing clothes, assisting with the restroom) in addition to their role as a communication facilitator (Pampoulou, 2019). Additionally, PWA and their communication partners are crucial to developing and customizing the AAC interface. For effective AAC implementation, treatment strategies must be designed to ensure the communicative needs and wants of the PWA as well as their facilitators (e.g., communication partners, and caregivers) (Beukelman & Ball, 2002).

To promote use of high technology AAC systems outside experimental settings, data must be collected across a range of functional communication settings. Of the included studies, 56% investigated AAC use in structured contrived tasks (Albright & Purves, 2008; Brock et al., 2017; Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998; Nicolas et al., 2005; Petroi et al., 2014; Rostron et al., 1996; Steele et al., 2010). Functional communication contexts were utilized in 50% of the included studies (Albright & Purves, 2008; Bartlett et al., 2007; Dietz et al., 2014; Dietz et al., 2018; Linebarger et al., 2008; Nicolas et al., 2011; van de Sandt-Koedeman et al., 2005; Waller & Newell, 1997). Specifically, Nicolas et al. (2011) utilized functional communication tasks to measure response to treatment. These measures consisted of tasks such as responding to seven autobiographical questions, describing five pictures, describing a one minute wordless video, making two phone calls, and writing out a birthday card as well as a grocery list. Van de Sandt-Koedeman et al. (2005) is the only study that utilized functional communication settings, such as shopping, to evaluate effectiveness of SGD based AAC intervention.

4.5 Effects on Communication

In Koul et al. (2010), the majority of the studies that were reviewed (five in total) investigated the production of sentences of varying grammatical complexity using speech generating devices. In this current review of the literature, only three studies (20% of the included studies) investigated this topic. Overall, these studies show that participants with aphasia are able to identify, navigate, and combine symbols to produce graphic symbol sentences in experimental contexts (Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998).

4.6 Participant Factors

Despite acceptance of AAC devices being an important consideration in the intervention process, our search strategy yielded only four studies (27%) that included data regarding device acceptance or abandonment (Albright & Purves 2008; Roston et al.; 1996; van de Sandt-Koenderman et al., 2005; Waller & Newell, 1997). The results from these studies did not indicate high rates of AAC device acceptance following an AAC intervention. For example Albright & Purves (2008) noted their participant rarely utilized SentenceShaper™ spontaneously in natural conversation settings. The participant even stated: "SentenceShaper is not real life," (Albright & Purves, 2008). Without data on acceptance it remains unknown if the AAC intervention strategies are meeting PWA's functional communication needs.

Successful implementation of AAC interventions for PWA requires clinicians to consider comorbid cognitive impairments associated with the condition. For example, deficits in non-verbal cognition are commonly associated with aphasia. Non-verbal cognition consists of: cognitive flexibility (Chiou & Kennedy, 2009), attention (Murray, 2012), executive function (Frankel et al., 2007; Murray, 2017; Nicholas & Connor, 2017; Olsson et al., 2019; Purdy, 2002), and visuospatial functioning. Nicholas and Conner (2017), proposed that executive function, shift attentional set, and the inhibition of competing thoughts and responses are all important factors related to the successful implementation of AAC systems with PWA (Brock et al., 2017; Nicholas et al., 2011). These factors may influence the type of AAC system chosen for a PWA. There is additional research to suggest that there is a limited capacity of cognitive resources which is shared among targeted tasks. This capacity is further influenced by the complexity of the task and the effort required to complete the task (Navon & Miller, 2002; Pashler, 1984; Tombu & Jolicoeur, 2003). Despite the known cognitive demands of using an AAC device, only two studies investigated the cognitive factors associated with the use of a SGD (Nicholas et al., 2011; Petroi et al., 2014). Petroi et al. (2014), investigated PWA's ability to identify single symbols on an SGD in the presence or absence of competing stimuli. PWA were most successful in identifying symbols when the AAC display was limited to 8 symbols. Listening conditions did not have a significant effect upon the accuracy of responses in single symbol identification or sentence identification tasks. This finding is in contrast to previous studies that indicate that performance on natural language tasks decreases in divided attention conditions (Arvedson & McNeil, 1986; Murry et al., 1997a; Murry et al., 1997b; Murry et al., 1997c). Petroi et al. (2014), explained their results by stating that cognitive efforts to identify symbols displayed in a grid format across screens may be so challenging that participants with aphasia in their study may have totally ignored the competing task in the divided attention condition.

4.7 SUMMARY

In summary, outcomes from well controlled experimental studies and case studies suggest that AAC intervention options that utilize SGDs facilitate communication in PWA. Gaps in the research included limited data on generalization and maintenance across functional communication behaviors and communication environments. The lack of consistency in design and methodology across studies, and paucity of controlled studies on efficacy and effectiveness of AAC interventions preclude strong predictions about the efficacy of SGD based AAC interventions in PWA. Future research must be devoted to understanding variables that can lead to effective use of AAC strategies and techniques by PWA and across communicative contexts and partners.

V. CONCLUSIONS

This scoping review presented extant literature on the effects of SGD based AAC intervention on selected dependent variables such as functional communication behaviors as well as behaviors related to symbol identification, symbol combination, and navigating the AAC interface. Results indicated that SGD based AAC interventions are effective in facilitating positive change in functional communication measures as well as measures related to effectively accessing and using dedicated SGDs and or mobile communication aids. Additionally, the review indicates a critical need for a greater number of well-controlled studies that evaluate both generalization and maintenance across communicative contexts.

Appendices

APPENDIX A. APPRAISAL SCALE FOR SINGLE-SUBJECT EXPERIMENTAL DESIGN STUDIES*

When to use this scale?: Please use this scale for any single-subject experimental design (SSED) that evaluates the effectiveness of ONE intervention or treatment.

How to use this scale?: Answer all questions with yes or no. Count the number of Yes responses to arrive at the total score.

Origin of the scale: The appraisal items were drawn from the best-practices methodological literature on designing and evaluating SSEDs (Barlow & Hersen, 1979; Gresham, Gansel, & Kuntz; 1993; Kazdin, 1982; Kennedy, 2005; Schlosser, 1999; Schlosser, 2002; Tawney & Gast, 1984), particularly a recent article on the defining features of single-subject research and criteria what constitutes good exemplars of such research (Horner, Carr, Halle, McGee, Odom, & Wolery, 2005). The following items will be used, each to be answered with yes or no.

Appraisal item	Rating
1. Participants, and participant selection, are described with sufficient detail to allow other researchers to select similar participants in future studies. Documentation: p.____ Rationale:	Yes No
2. Critical features of the physical setting are described with sufficient precision to allow for replication. Documentation: p.____ Rationale:	Yes No
3. The dependent variable is sufficiently operationalized. Documentation: p.____ Rationale:	Yes No
4. The dependent variable is being measured repeatedly using sufficient assessment occasions to allow for identification of performance patterns prior to intervention and comparison of performance patterns across conditions/phases (level, trend, variability).	Yes No

Documentation: p.____ Rationale:	
5. Inter-observer agreement meets minimal standards (i.e., IOA = 80%; Kappa = 60%) and is based on >/= 20% of all sessions during each phase/condition. Documentation: p.____ Rationale:	Yes No
6. Baseline data are being compared with data gathered during the intervention phase under the same conditions as baseline Documentation: p.____ Rationale:	Yes No
7. Baseline data are sufficiently consistent before intervention is introduced to allow prediction of future performance. Documentation: p.____ Rationale:	Yes No
8. Experimental control is demonstrated via three demonstrations of the experimental effect (predicted change in the dependent variable varies with the manipulation of the independent variable) at different points in time (a) within a single participant (within-subject replication) or (b) across different participants (between-subject replication). Documentation: p.____ Rationale:	Yes No
9. The independent variable is defined with replicable precision. Documentation: p.____ Rationale:	Yes No
10. Treatment integrity is at an appropriate level given the complexity of the treatment, independently verified, and based on relevant procedural steps in >/= 20% of sessions during each phase/condition. Documentation: p.____ Rationale:	Yes No
Total Number of "Yes" Responses	

*(Schlosser, & Raghavendra, 2003)

APPENDIX B. APPRAISAL SCALE FOR GROUP STUDIES*

When to use this scale?: Please use this scale for any group studies involving (a) randomized controlled trials (RCTs), (b) non-RCTs, and (c) case series.

How to use this scale?: Answer all questions with yes or no. Count the number of Yes responses to arrive at the total score. RCTs may attain a total score out of 12. The maximum score for Non-RCTs is 10 because the first two items are marked "no." The maximum score for case series is 4.

Origin of the scale: This scale is based on the PEDro scale, which, in turn, is based on the Delphi list developed by Verhagen and colleagues (*Journal of Clinical Epidemiology, 51,* 1235-41, 1998). The first item of the PEDRo scale (participant selection) relates to the external validity and thus does not apply to EVIDAAC, which is strictly examining the quality of evidence in terms of its internal validity. Therefore, the first item was eliminated for EVIDAAC purposes. An item each was added for reliability and treatment integrity.

Appraisal Item	**Rating**
1. The participants were randomly allocated to interventions (in a crossover study, participants were randomly allocated to an order in which treatments were received)	Yes No
2. Allocation was concealed.	Yes No
3. The intervention groups were similar at baseline regarding the most important prognostic indicators.	Yes No
4. There was blinding of all participants	Yes No
5. There was blinding of all therapists who administered therapy.	Yes No
6. There was blinding of all assessors who measured at least one key outcome.	Yes No
7. Inter-observer agreement for the dependent measure/s meets minimal standards (i.e., IOA = 80%; Kappa = 60%) and is based on >/= 20% of all sessions during each phase/condition	Yes No
8. Treatment integrity is at an appropriate level given the complexity of the treatment, independently verified, and based on relevant procedural steps in >/= 20% of sessions during each phase/condition.	Yes No
9. Measures of at least one key outcome were obtained from more than 85% of	Yes No

participants originally allocated to groups.	
10. All participants for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat."	Yes No
11. The results of between-intervention group statistical comparisons are reported for at least one key outcome.	Yes No
12. The study provides both point measures and measures of variability for at least one key outcome.	Yes No
Total # of Yes responses	

*(Schlosser, & Raghavendra, 2003)

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