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The Effects of Interface Display and Cognitive Function on Story Retell in People without Aphasia

by

Mallary Owen

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the Department of Communication Sciences and Disorders

Idaho State University

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To the Graduate Faculty: The members of the committee appointed to examine the thesis of Mallary Owen find it satisfactory and recommend that it be accepted.

Dr Kristofer Brock, Major Advisor

Dr Victoria Scharp, Committee Member

Dr Kristina Blaiser, Committee Member

Dr Elizabeth Horn, Graduate Faculty Representative

IDAHO STATE UNIVERSITY
HUMAN SUBJECTS COMMITTEE
NOTICE OF ACTION

December 9, 2020

Kristofer Brock
College of Rehabilitation Comm Sciences

RE: Study Number IRB-FY2020-276: The Effects of Interface Display and Cognitive Function on Story Retell in People with Aphasia

Dear Dr. Brock:

I have reviewed your application for revision of the study listed above. The requested revision involveschanging Recruitment Strategies.

You are granted permission to conduct your study as revised effective immediately. The date for renewal remainsunchanged at 7/28/21, unless closed before that date.

Please note that any further changes to the study must be promptly reported and approved. Contact Tom Bailey(208-828-2179; email humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen,
PhD, MPH, CIP
Human Subjects
Chair

Acknowledgements

I wish to extend my sincere appreciation to my supervisor, Dr. Kristofer Brock, for his invaluable advice, continuous support, and patience during the research process. I would also like to acknowledge the unwavering support and love of my fiancée, James, and my sister, Hillary. Without their enthusiasm and input, this project could not have been achieved.

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The Effects of Interface Display and Cognitive Function on Story Retell in People without Aphasia

Thesis Abstract--Idaho State University (2021)

Augmentative and alternative communication (AAC) systems may impose increased cognitive demands on adults with aphasia resulting in poor communication outcomes. In addition, interface displays differentially impact the cognitive and linguistic systems of persons with aphasia. Therefore, the primary purpose of this investigation was to determine how interface displays (grid and scene) impacted navigation accuracy and efficiency (response latency) and discourse outcomes (e.g., syntactic complexity) from a story retell. The secondary purpose was to predict the optimal interface display from various standardized and non-standardized cognitive assessments. A within-subjects design was used for the study. As a pilot project, only eight neurotypical adults completed a series of standardized and nonstandardized cognitive assessments followed by a navigation and story retell task in both the grid and scene interface display conditions. Paired samples *t*-tests revealed that navigation accuracy was significantly higher in the scene display condition. Similarly, response latency was significantly shorter in the scene display condition. There were no differences on any discourse outcome measure between the two conditions. Finally, linear regression analyses indicated that various cognitive linguistic-scores may predict an optimal interface display. Clinical implications of these findings will be discussed.

Keywords: AAC; Aphasia; Cognition; Interface Display; Operational Competence

The Effects of Interface Display and Cognitive Function on Story Retell in People without Aphasia

Persons with chronic, severe nonfluent aphasia are a fast-growing population within the United States, with estimates of over 2 million people living with aphasia (National Stroke Association, 2016). Persons with aphasia experience deficits with language, which manifest as difficulty with either receptive language, expressive language, or both in any modality of language (i.e., reading, comprehension, writing, speaking; Hallowell, 2017). This deficit in language is a loss in the ability to access linguistic representation of stored concepts (McNeil & Pratt, 2001), which implies that aphasia is a processing disorder rather than a disorder of linguistic knowledge or rule governance. One emerging intervention that taps into the stored linguistic knowledge of persons with aphasia includes augmentative and alternative communication (AAC) systems that supplement or replace natural spoken language (Koul, 2011). These AAC systems typically include two standard interface displays: grid displays and scene displays. Grid displays use semantically-based hierarchical organization where graphic symbols are embedded into folders (similar to how people store files on a computer). Scene displays, in contrast, are episodically-based using photographs that are chronologically organized.

AAC systems are still dependent on the linguistic system (requiring users to develop sufficient knowledge and skills of the new linguistic code; Light & McNaughton, 2014), with an emphasis on visual processing to support language by using visual images to represent words and phrases. Dietz and colleagues (2018) suggested that intersystemic reorganization (proposed by Luria, 1972), where a weak system can be strengthened when paired with an intact system, takes place during AAC interventions. That is, adults with aphasia use AAC to augment spoken language recovery using the intact visual system to improve the damaged linguistic system. However, due to the variable linguistic deficits of adults with aphasia, researchers have linked high-level executive functions (a domain of cognition) to have an impact on functional communication, defined as "the ability to receive or to convey a message, regardless of the mode, to communicate effectively and independently" (Frattali et al., 1995 p.12; Fredriksson et al. 2006; McNeil, 1981 & McNeil et al., 1991; Miyake & Friedman, 2012; Purdy, 2002). Because of the potential impact cognitive abilities may have on AAC intervention, the cognitive and linguistic profiles of people with aphasia should be identified in order to match their strengths and weaknesses with the most appropriate AAC system and interface display. Moreover, AAC strategies and techniques are not a panacea for speech and language impairments, and often impose additional demands on executive functions, specifically working memory and cognitive flexibility (e.g., switching between linguistic modalities), which can lead to difficulty in device mastery, such as inaccurate navigation of the device, causing communication breakdowns (Brock et al., 2017; Petroi et al., 2014; Wallace et al., 2010). AAC researchers have sought to investigate the effects of AAC interface display on a multitude of variables in persons with aphasia, such as navigation accuracy and various linguistic output variables (Brock et al., 2017; Dietz et al., 2014; Wallace et al., 2010). However, there is limited empirical research investigating if any specific cognitive domains are associated with AAC use in persons with aphasia. Therefore, it is important to examine executive functions of persons with aphasia and neurotypical adults as it relates to AAC operational (e.g., navigation) and linguistic (e.g., story retell) competencies.

Interface Displays, Cognition, and Discourse?

Before discussing cognition and communication, it is important to understand how the grid and scene displays organize symbols for message production. Generally, grid displays use commercially-available cartoon line drawings to depict words and messages that are organized like computer files, taxonomically, with superordinate categories and subordinate categories embedded across several screens. To create a message, the person with aphasia selects a superordinate category (e.g., animals) from the home screen, and several subordinate categories appear on the second screen (e.g., farm animals). Thus, while many symbols are "hidden," people with aphasia can generate novel multi-symbol messages. In contrast, scene displays utilize photographs that are organized schematically or chronologically that can be accompanied by orthographic text. These displays may also include a navigation ring with a small collection of static exemplar photographs that surround the edge of the display and are visible on each page of the interface (Brock et al., 2017). These contextually relevant photographs allow adults with aphasia to recognize the embedded semantic associations that portray the relationship between people, places, and activities (Brock et al., 2017; Koul, 2011; McKelvey et al., 2007), which facilitates multimodal message creation and the enhanced perception of communicative competence from unfamiliar listeners (Brock et al. 2017; 2019; under review; Dietz et al., 2014; 2018). However, novel graphic symbol message production is difficult because scene displays are specific to a situation or story.

Fridriksson and colleagues (2006) discussed the role of executive functions (e.g., working memory, inhibition, shifting) in communicative success by outlining some of the demands required to hold a conversation: (a) retaining what the conversation partner said, (b) the ability to plan a response, and (c) a potential need to inhibit an inappropriate response. With aided AAC systems, additional demands are also present such as navigation, inhibiting the selection of a symbol, and deciding which modality to use for communication. Therefore, if executive functioning is impaired in adults with aphasia, then functional communication can be impacted beyond the severity of the language impairment (Fridriksson et al., 2006). It remains unclear how the two most popular interface displays (grid and scene displays) impact cognition and communication.

Successful use of both display types may rely on executive functioning, adequate attention, and working memory resources (Nicholas & Connor, 2017). Attention allows individuals to shift focus from one task to another as well as attend to stimuli in the environment. In adults with aphasia, allocation of attentional resources may be inefficient (McNeil et al., 1991). If AAC systems are introduced, it is possible that attention capacity is further divided between communication, navigation, and symbol comprehension, among other constructs, and therefore, an interface design must be selected to mitigate the limited capacity system.

Purdy and Dietz (2010) outlined the impact of cognitive impairments on communication outcomes for persons with aphasia. They proposed that grid displays may adversely affect the successful operation of the AAC system by this population for several reasons. Most notably, taxonomic grids organize language semantically through the use of superordinate and subordinate folders, which is problematic given the semantic and syntactic deficits of individuals with aphasia. In contrast, scene displays provide high-context photographs that are surrounded by a navigation ring; therefore, most symbols are within view and not embedded into a folder like the grid symbols. In addition, high-context photographs can establish the context for conversational interactions (Hux et al., 2010). While both scene and grid displays store symbols on one or more levels, requiring a person with aphasia to retain information in their working memory (see Baddeley, 2000; Wilkinson, 2013), scene displays may have an advantage. Specifically, scene displays adhere to the intersystemic reorganization principle (Luria, 1972) that allows people with aphasia to use other intact systems, such as recognition memory and visual-perceptual abilities (Fox & Fried-Oken, 1996), to reduce the cognitive demands required to process information and subsequently communicate. For example, a scene display's photographic content and simple navigation interface may decrease the burden placed on these limited capacity systems, thereby allocating additional cognitive resources to communication outcomes (Brock et al. 2017; Dietz et al., 2014; Light & McNaughton, 2012; Wilkinson et al., 2012). By reducing the demands on working memory, attention, and executive functions, people with aphasia may allocate more resources to effective navigation of the AAC system, create syntactically complex multimodal messages (natural speech + symbol messages), take more conversational turns, and repair or prevent conversational breakdowns. While interface displays differentially impact these cognitive systems, the majority of AAC research has focused word- and sentence-level communication tasks.

To become a competent communicator, individuals must move beyond semantic-level and even sentence-level interventions such as Semantic Feature Analysis (Boyle & Coelho, 1995) and Verb Network Strengthening Treatment (Edmonds et al., 2009). AAC intervention should focus on service delivery in natural environments that incorporates more complex language such as discourse (Light & McNaughton, 2015). Discourse analysis can be used to assess language ability in adults with aphasia in a more naturalistic and ecologically valid domain (i.e., connected speech; Stark, 2019). Discourse can be described as the way language in use is structured above the sentence level and includes a wide variety of speech acts such as storytelling, providing directions, and conversation (Armstrong, 2000). Discourse can be analyzed on a micro (e.g., type-token ratio) and macro-linguistic (e.g., main concept analysis) level with the ultimate goal of quantifying the amount of information that is relayed by the speaker. Brock et al. (2017) utilized various discourse analyses to investigate the effects of interface displays (grid and scene displays) on several communicative outcome variables (e.g., conceptual complexity and communication turns) with two persons with aphasia. The results of this case study found that the participants had more accurate navigation and more syntactically complex multi-modal utterances in the scene display condition than in the grid display condition. These quantitative results were corroborated by 168 participants in two studies that included lay persons, undergraduate and graduate students in communication sciences, and caregivers of persons with aphasia (Brock et al., 2019; under review). The participants used the Communicative Competence Scale to rate the communicative effectiveness of a participant with aphasia, and they agreed that the individual was a better communicator using the scene display when compared to the grid display.

AAC intervention is used not only to provide alternative means to communication, but also to augment spoken language recovery (Dietz et al., 2018). In adults with aphasia, intervention is also centered on recuperation of pre-stroke language capacity (Dietz et al., 2018; Hersh, 1998; Simmons-Mackie, 1998; Weissling & Prentice, 2010). Dietz and colleagues (2018) investigated the effects of an AAC intervention to recover language function. The researchers allocated participants to an AAC intervention condition or a standard spoken intervention condition. Through fMRI and behavioral outcome data, they found that each intervention promoted neural reorganization and improved language function; however, the participants in the AAC condition had better spoken discourse outcomes (e.g., T-units and counted words) than participants in the spoken language treatment condition post-intervention. The fMRI data also suggested that participants in the AAC intervention had strengthened connections between visual processing cortices and long-term memory, resulting in a coupling between the semantic system and the frontal expressive language regions of the brain. Thus, AAC intervention should be considered a viable treatment option at the onset of aphasia to induce language recovery rather than a last resort intervention. While seminal, Dietz et al. only used a discourse task which cannot provide necessary information regarding the interplay between cognitive demands, AAC system use, and the interaction between varying linguistic components required for discourse (e.g., morphology, syntax and semantics; Bryant et al., 2016; Marinelli et al., 2017). Research indicates that cognitive ability and AAC interface design influences discourse production and general communication (Frankel et al., 2007). Therefore, it is important to understand the cognitive (e.g., executive functioning) and linguistic profiles of people with aphasia in order to match their strengths and weaknesses with the most appropriate AAC interface display at the outset of intervention.

Predicting Optimal AAC Interfaces

AAC strategies may impose additional demands on various limited-capacity cognitive systems because using these strategies can be a multi-task demand (e.g., communication, display navigation, and inhibition; Purdy & Dietz, 2010). At present, there is a paucity of research investigating which executive functions (e.g., attention and working memory) might be the best predictors for selecting an AAC interface display that not only enhances navigation but also spoken discourse. This is important because knowing how cognitive functions may impact operational success of the device could help guide clinicians during the assessment process.

Current research supports the link between cognitive and linguistic performance demonstrating the possibility to predict the cognitive profile of patients with severe aphasia on the basis of linguistic impairments (e.g., Hinckley & Nash, 2007). In a study investigating cognitive profiles in persons with aphasia, Marinelli and colleagues (2017) found that the 189 participants fell into one of three categories: mild to no, moderate, and severe cognitive deficits. The cognitive profiles were based on a standardized cognitive battery (i.e., Cognitive Test

Battery for Global Aphasia; Marinelli et al., 2009) that measured attention, memory, executive function, visual-spatial ability, and visual-auditory recognition. Additionally, the authors administered the Aachen Aphasia Test (Luzzatti et al., 1996) to determine the relationship between cognition and language. Each of the three groups had varying cognitive deficits; of particular interest to the current study are deficits in visual-spatial ability and executive functions. Two-thirds of participants in the moderately impaired group showed moderately impaired visual-spatial ability and had deficits in executive functions-logical reasoning. Participants in the severe group had severe deficits in all cognitive domains with the exception of visual-spatial ability, most of which showed moderate impairment. The results from the Achen Aphasia Test explained 43% of the variance in cognitive performance, with naming, comprehension, and reading-spelling skills as significant predictors. Specifically, the mild to no cognitive deficit group outperformed the other two groups in these domains, with longitudinal data supporting the initial results. These findings support the hypothesis that the level of linguistic deficit is connected to the cognitive deficit severity. In sum, adults with aphasia who have different cognitive-linguistic profiles will likely have different rehabilitation outcomes, making the assessment process and clinical decision that much more important. With respect to aided interventions, AAC interface displays may impose additional demands on individuals with aphasia who already have cognitive impairments, subsequently and differentially impacting communication outcomes.

There is limited empirical research investigating if any specific cognitive domains or profiles are associated with AAC use in adults with aphasia. Therefore, it is necessary to discuss literature outside of this clinical population. Wallace et al. (2010) investigated the effects of cognitive flexibility, image contextualization (i.e., no, low, and high context) and prompt type (i.e., matching informative and uninformative) on navigation of a dynamic screen AAC interface with survivors of severe traumatic brain injury (TBI). A total of 18 participants were separated into two groups dependent on their Symbol Trails score (pass/fail) from the *CLQT*. Participants who did not meet criterion on the Symbol Trails subtest were significantly less accurate when navigating the AAC interface, with no significant main effect for accuracy across image conditions. Notable limitations included the use of a single, decontextualized grid display without a communication outcome, making it difficult to predict navigation accuracy in real life applications (e.g., conversation). Additionally, measures of cognitive flexibility were dependent solely on the participants' results on the Symbol Trails subtest.

Overall, AAC systems may impose increased cognitive demands on adults with aphasia resulting in poorer communication outcomes. However, interface displays differentially impact the cognitive and linguistic systems of persons with aphasia with the literature indicating that scene displays may relieve the burden on some cognitive abilities. There is limited research investigating which cognitive and linguistic abilities, if any, are impacted or supported by grid or scene interface displays. Therefore, the purpose of the current study is two-fold. First, the primary aim is to determine how well performance on a cognitive battery of assessments can predict navigation accuracy and efficiency of an AAC device with either a grid or scene interface display in neurotypical adults. The secondary aim is to investigate the influence of interface display scheme on production of linguistic complexity during a discourse task (Cinderella Story Retell) with a novel communication partner.

The specific research questions for the study were: (a) do participants with higher scores on assessments of various cognitive skills (e.g., attention, executive functions, working memory) have higher levels of navigation accuracy in either or both grid and scene interface display? (b)

Will there be a significant difference in response times in either the grid or scene interface display? (c) During a discourse task, will participants produce significantly more complex utterances in the scene or grid interface display?

Method

Participants

Eight English-speaking neurotypical adults were recruited. Participants met the following inclusion criteria: (a) over the age of 50, (b) English as a first language, (c) normal cognition as indicated by the standardized assessment batteries used within the study, (d) no uncorrected vision or hearing impairments, (e) no other neurological diseases or disorders, and (f) physical and motoric capability to utilize a computer mouse/mouse pad. Participants were also required to have Wi-Fi access, computer/laptop with video camera access, and a printer.

Research Design

The investigators used a within-subjects design to investigate the effects of interface display (grid and scene) on the following dependent variables: (a) percent accuracy of target word selection, (b) response latency of correctly selected targets, and (c) discourse analyses (main concept analysis and conceptual complexity units). The interface display variable was counterbalanced across participants to mitigate order effects.

Materials

Cognitive Assessments

A comprehensive battery of assessments was used to investigate cognitive functions in all participants and was administered in approximately 60 minutes. Although not explicitly non-linguistic, many of the selected evaluations that measure executive functions avoid the requirement of language processing (Nicholas & Connor, 2017), thus reducing the impact of impaired linguistic abilities. The *Cognitive Linguistic Quick Test* (CLQT; Helm-Estabrooks, 2001) was used to assess strengths and weaknesses in five cognitive domains: attention, memory, executive functions, language, and visuospatial skills. The Corsi Block test (Lezak 1983) was used to assess visual-spatial working memory. The *Hayling Sentence Completion Test* (Burgess and Shallice, 1997), a clinical assessment of executive functioning, was used to measure response initiation and suppression.

Table 1

Cognitive Assessment Batteries and Tasks by Domain

Tasks and Assessments	**Cognitive Domains**							
	Attention	Memory	Executive Function	Language	Visuospatial Skills	Cognitive Flexibility	Response Suppression	Psychomotor Speed
CLQT Subtests:								
Personal Facts		■		■				
Symbol Cancellation	■		■					
Confrontation Naming				■				
Clock Drawing	■	■	■	■	■			
Story Retelling	■	■		■				
Symbol Trails	■		■		■	■		
Generative Naming		■	■	■				
Design Memory	■	■			■			
Mazes	■		■		■			
Design Generation	■		■		■			
Corsi Block Test					■			
Tower of London Task			■			■		
Hayling Sentence Completion				■			■	
Coin Rotation Task								■
Stroop Color & Word Test			■	■		■	■	

The Tower of London task (Shallice, 1982) was used to assess goal-directed planning behavior (Purdy, 2002). The Coin Rotation task (Levine, Milberg, & Stuss, 1992) measured psychomotor processing speed. The Stroop Color and Word Test (Stroop, 1935) was used as a measure of inhibition.

AAC Device

A 15inch Dell Inspiron 2-in-1 laptop, equipped with Compass software (Tobii Dynavox, 2020) was used to create the interface displays. The Dell laptop included a 512GB solid state drive with 16GB of RAM and an Intel i7 core processor. Compass software was chosen for his study because it is widely used, commercially available, and includes the ability to create a variety of interface displays.

Grid

The grid displays included 128 Picture Communication Symbols graphic symbols within a three-level hierarchical grid. The grid displays home screens included the five following superordinate categories: Cinderella story, objects, places, descriptions, feelings. These categories were selected based on agreed themes and subjects of the Cinderella story. Participants selected a target symbol via mouse click, which was then displayed in a message window. Each page included a "clear" symbol to delete messages from the message window as well as a "Go Back" symbol to navigate between the categories.

Scene

The scene displays included color photographs from the Cinderella story, with original images used from Walt Disney's Cinderella (Grimes, 2005). A total of 5 exemplar photographs surrounded the border of the display. Once an exemplar photograph was activated via touchscreen, a page with two photographs related to the selected scene appeared. Finally, navigational components included a 'go back' button that allowed participants to return to the previous screen.

Procedures

All experimental procedures, from consent to completion of the study, were completed through video conferencing. Video conferencing was used secondary to COVID-19 regulations.

For each experimental test or task, specific modifications were made to ensure reliable and valid data collection via video conferencing. General video conference procedures are discussed in the following sections.

Standardized Assessment

Data were collected at via video conferencing with the clients at their home. Prior to the experiment, the cognitive battery of assessments, as previously outlined in the Cognitive Assessments section, were administered to all participants on day 1.

Navigation task. The experiment was completed over the course of two days, separated by at least one week but not more than three weeks. On day 2, the experimenter familiarized participants with the AAC system. The experimenter demonstrated device operation (see Appendix A for specific detail), including navigation in and out of folders/scenes (operational competence), symbol message generation (linguistic competence), and two communication repair strategies (i.e., repetition and rephrase using multimodal communication; strategic competence). This minimal training was provided to all participants in an attempt to replicate what happens to adults with aphasia when natural speech outcomes have reached a plateau or if insurance will not pay for additional services. That is, with limited AAC training, many adults with aphasia are expected to exhibit communication competence, and perhaps aspects of competence are achievable or different between interface displays.

Participants then began the navigation task. Each participant was provided with visual and verbal directions (see Appendix A) on how to complete the task. Once assent was given and the participants understood the task directions, two familiarization trials were

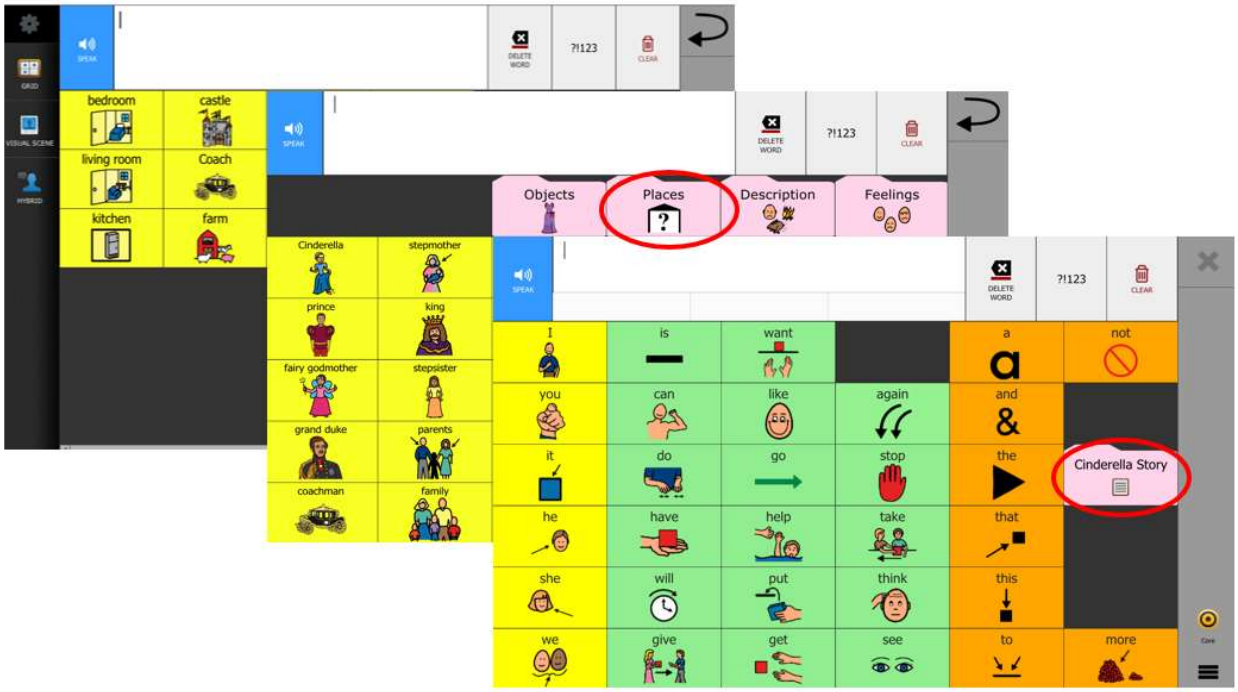

Figure 1. This figure depicts the grid display. The home screen contains the superordinate categories and can be selected in order to move to a subordinate category or level. In this example the superordinate category *Cinderella Story* was selected to display the subordinate level 2. Then, the folder *Places* was selected to display level 3.

provided. Specifically, the experimenter shared the computer screen with the Compass program with the participant and ensured all buttons were visible. The researcher gave remote control of the Compass program to the participant. Next, the experimenter began digitally recording the session and said, "We are going to play a computer game, and I will ask you to find a specific symbol of a picture depicting a word." Next, participants were told "You will have 60 seconds to find that word on this computer. You will hear a 'ding' that signals when you are allowed to begin." Then participants were told "Once you find the picture, you must touch it with your computer mouse. If you cannot find the symbol or picture, please keep looking for the entire 60 seconds." Assent was confirmed by asking the participants, "Are you ready to play the game?"

An affirmative response was followed with the first familiarization trial, and the experimenter stated, "Please find the symbol for ____."

Figure 2. This figure depicts the visual scene display interface. For the current study, pictures from Cinderella were used in place of personally relevant photographs.

Within the grid display condition, familiarization trial one required the participants to locate a symbol on level 2 (i.e., target word located on the second screen), while familiarization trial 2 required the participants to navigate to level 3 (i.e., target located on the third screen). This ensured that participants could navigate to the deepest levels within the grid display. Figure 1 depicts an example of the organization and content within each level. Similarly, the scene display condition had two familiarization trials that required participants to locate a specific photograph depicting a scene (see Figure 2 for the scene display organization). Participants received feedback regarding the accuracy of their response. Additionally, all participants required 100% on the familiarization task before engaging in the experiment. Familiarization trials were repeated as many times as necessary for task comprehension.

Once the participants reached the 100% criterion, the experimental navigation task commenced. The directions were the same as the familiarization trials except that non-affirmative feedback was provided (e.g., “You’re doing great.”) to maintain motivation. The grid experimental condition included 24 trials and the scene condition included 16 trials. Finally, the interface display presentation order was randomized to control for order effect.

Discourse task. After the navigation task, which provided additional experience with AAC system operation, all participants were encouraged to use the interface displays to retell the Cinderella story. First, the experimenter turned on the digital recorder, and participants were provided 5 minutes to read through the Cinderella story. The orthographic text was hidden in the book, and participants relied solely on the pictures. Second, the experimenter asked the participants if they had any questions about the book. Then the experimenter instructed that the participants would have a maximum of 10 minutes to retell the Cinderella story. Participants were encouraged to include as much detail as possible in any communicative modality (e.g., gesture, speech, AAC system). Participants were provided the opportunity to ask any clarifying questions about the procedure before the discourse task commenced. Once assent and task comprehension were confirmed, the participants engaged in the discourse task. See Appendix B for specific discourse directions.

Design

A 2 x2 mixed factorial design was used. A mixed design was selected to increase the power of the study through the within-subjects variable. Practice effects for the interface display variable were mitigated through counterbalancing the order in which the displays were presented. However, the navigation task always preceded the discourse task to reflect the minimal training many adults with aphasia receive after obtaining an AAC system. Finally, all experimental conditions were digitally recorded to analyze accurate symbol navigation and response latency. Additionally, the video recording captured symbols, gestures, and speech used by participants during the discourse task.

Dependent Variables

Navigation Accuracy and Response Latency

The dependent variables included percent accuracy of symbol selection and response latency for accurate symbol selection in the navigation task. Symbol selection was considered accurate if the participant correctly touched the symbol stimuli on the first attempt. Response latency (ms) was measured by calculating the time between the audible "ding" and the participants' physical touch (or mouse click) of a symbol on the computer screen. Response latency was analyzed for correct symbol selection only.

Macrolinguistic Discourse Variables

Participant discourse productions were video recorded and transcribed by the experimenters. An utterance was defined as continuous communication followed by a break in communication output that lasted for a 1-s period of silence or a change in topic was noted. Macrolinguistic analysis included main concept analysis (Richardson & Dalton, 2015) and conceptual complexity (Blank & Franklin, 1980). Utilizing main concept analysis allows researchers to quantify the "degree to which speakers are able to communicate the overall gist of an event" (Richardson & Dalton p.45, 2015). Conceptual complexity has been used previously by researchers investigating the messages of people with aphasia when there are no standardized picture stimuli (Brock et al., 2017; Hux et al., 2010). Additionally, conceptual complexity approximates syntactic complexity for people who have limited residual natural spoken language. It is particularly useful for participants who use a combination of verbal and nonverbal language. Due to the nature of the linguistic deficits in adults with severe non-fluent aphasia, microlinguistic measures were not included in the analysis. Most microlinguistic measures, such as Moving Average Type Token Ratio (MATTR) and lexical diversity, are more appropriate for populations with very mild aphasia (Cunningham & Haley, 2019) or with speech samples containing more than 50 words (Fergadiotis et al., 2013).

Data Analysis

Navigation Task Data Analysis

The researchers conducted a mixed two-way ANOVA. Navigation accuracy was calculated by the adding the total number of correct responses and dividing that by the total number of trials. For response latency, digital video recordings were inserted into Camtasia® and analyzed by calculating the time between the audible “ding” to begin a trial and the mouse click of a symbol on the computer screen.

Main Concept Analysis

Main concept analysis (MCA) measures how well an individual conveys the essential elements of a story (Dalton & Richardson, 2019). Dalton and Richardson define a main concept as an utterance (containing one main verb, its constituent nouns, and any associated clauses), which is scored based on accuracy (all essential information is correct) and completeness (all essential information is present). If the main concept (MC) was produced, then it received one of four codes: accurate and complete (AC); accurate and incomplete (AI); inaccurate but complete (IC); and inaccurate and incomplete (II). If the MC was absent then it was coded as AB. Based on the 2016 study by Richardson and Dalton, they outline 34 main concepts contained in the Cinderella story. Each main concept contains essential information as well as examples of alternative productions. An example of a main concept from the study is “Stepmother/stepsisters were mean to Cinderella”.

Conceptual Complexity

Conceptual complexity allows researchers to quantify utterance complexity for the participants with aphasia without using a standardized picture. Conceptual complexity was coded into four levels: (a) matching experience (least complex); (b) selective analysis of experience; (c) reordering experience; and (d) reasoning about experience (Blank & Franklin, 1980). Utterances at the matching experience level included the identification of global objects, people, and events through the sense organs. Utterances at the selective analysis level consisted of specific aspects of global objects, people, and events that are conveyed through visual, tactile, and auditory information. Utterances at the reordering of experience level consisted of concept sequencing, metalinguistics, generalizations, and conditional relations. Utterances at the reasoning about experience level required problem-solving and information integration. Frequencies were calculated for the number of utterances at each conceptual complexity level.

Analysis for all Discourse Metrics

Separate, mixed two-way ANOVAs were conducted for each discourse metric discussed above. In spite of the multiple dependent discourse variables, a MANOVA was not selected for this study because of the nature of our univariate research questions. As Huberty and Morris describe (1989), for multiple ANOVAs to be viable, the research must be exploratory and unconcerned with the aggregated contribution the outcome variables have on one another. This is the case for the current study. We are concerned with finding metrics that provide insight into which interface display is the most appropriate for specific adults with aphasia. Future research can either replicate this study and its univariate analyses or increase the sample size to conduct a MANOVA. Additionally, each discourse metric (i.e., MCA, conceptual complexity) is conceptually independent, meaning that each discourse metric has a specific meaning that can be understood without being associated with another metric (Huberty & Morris, 1989). Moreover, these discourse metrics have been used in univariate contexts within previous studies before (Kong, 2009; Richardson & Dalton, 2016), allowing the separate ANOVAs to replicate previous research.

A 2 x 2 repeated measures ANOVA was performed to determine the effects of interface display (grid vs. scene) and navigation level (level 1 vs. level 2) on navigation accuracy and response latency. As noted previously, the grid display included three levels of display pages while the scene display only included two levels. Therefore, a 2 x 3 repeated measures ANOVA could not be completed. However, the grid included seven trials in level 1 and eight trials in the level 2 while the scene included 6 of trials in level 1 and ten trials in level 2. Given the similar number of trials in each level, the comparison is valid.

A one-way ANOVA was conducted to examine the effects of grid display level (1, 2, 3) on navigation accuracy and response latency. Additionally, several Pearson product-moment correlational analyses were conducted to explore potential relationships between various cognitive-linguistic assessments and the dependent variables. Finally, linear regressions were conducted to explore whether any standardized or non-standardized assessment tasks predicted the participants' ability to navigate to symbols and retell the story; the goal being to select an optimal interface display for the individual based on commonly administered tests.

Reliability

Inter-rater reliability was implemented for 20% of the total participants. An unblinded, second researcher viewed and independently scored all assessments and tasks completed (i.e., aphasia and cognitive assessment scoring, navigation accuracy, response latency for correctly selected stimuli, and transcription). The inter-rater reliability scores were as follows: 100%

accuracy for navigation accuracy, 100% accuracy for response latency, and 100% accuracy for transcription. Procedural integrity data, collected for 20% of the participants, indicated that the procedures were implemented correctly 98% of the time.

Results

Navigation Accuracy

Two paired samples *t*-tests (two-tailed) were conducted to determine the effects of interface display on overall navigation accuracy. There was a significant difference between the interface display (t (8) = 2.6, p = .035, Cohen's d = .92), with participants navigating to targets in the scene display more accurately (M = 98.4, SD = 2.89) than the grid display (M = 92.4, SD = 5.57). Participants had higher overall higher navigation accuracy at each level of the scene display when compared to the grid display. Interestingly, navigation accuracy was lowest in level 1of the grid display condition, followed by level 3, and a marginal improvement in accuracy at level 2 (see Table 2).

For a more detailed analysis, a 2x2 repeated measures ANOVA was conducted to examine the effects of interface display (grid and scene) and navigation levels (Level 1 and Level 2) on navigation accuracy. Results indicated a significant difference between interface display types (F (1,7) = 9.39, p = .018, η^2p = .573) and between navigation levels (F (1,7) = 7.66, p = .028, η^2p = .522). Participants using a scene interface display had higher levels of accuracy than in the grid display condition. Additionally, there was a significant interaction between interface display and navigation level (F (1,7) = 10.23, p = .015, η^2p = .594). Specifically, participants navigated significantly more accurately to target symbols in the level 1 (p = .005) and level 2 (p = .009) scene display condition than the level 1 grid display condition. Finally, participants had significantly higher levels of accuracy in level 2 of the grid display than in level 1 of the grid display (p = .005).

Table 2

Navigational Accuracy Outcomes Across Interface Displays and Levels

Level	Display type	Accuracy *M*(SD)	Latency* *M*(SD)
1	Grid	85.7 (10.8)	6.62 (4.01)
	Scene	100 (0.0)	2.84 (1.5)
2	Grid	96.9 (5.79)	12.9 (5.23)
	Scene	98.8 (3.54)	10.8 (4.22)
3	Grid	93.8 (9.45)	15.5 (4.14)
	Scene	NA	NA

Note. * = Latency in seconds. There was no third level navigation in the scene display.

Finally, to replicate previous work from Pertroi et al., (2014), a one-way ANOVA was conducted to examine the effects of grid display level (levels 1, 2, and 3) on navigation accuracy. Results indicated a significant difference between the levels (F (1,7) = 3.67, p = .05, η^2p = .34). The post-hoc analysis indicated that level 1 navigation accuracy was significantly worse than level 2 (p = .005); however, no other significant differences were found.

Response Latency

A paired samples *t*-tests (two-tailed) was conducted to determine the effects of interface display on response latency measured in seconds. Results indicated a significant response latency difference (t (8) = -3.64, p = .008) between the two displays, with the scene display condition being faster (M = 8.41, SD = 3.38) than the grid display (M = 12.06, SD = 2.94).

For a more detailed analysis, a 2x2 repeated measures ANOVA was conducted to examine the effects of interface display (grid and scene) and navigation levels (Level 1 and Level 2) on response latency. Results indicated a significant difference between interface display types (F (1,7) = 6.71, p = .036, η^2p = .489) and levels with respect to response time (F (1,7) =

18.50, p = .004, η^2p = .726). Participants using a scene display had shorter response times when compared to the grid display condition. There was not a significant interaction between interface display and response time in levels (F (1,7) = 1.863, p = .214, η^2p = .21). However, the post-hoc comparisons indicated significant differences between some levels of the interface displays. Specifically, level 1 scene display response times were significantly shorter than the level 2 grid display response times. Additionally, level 2 scene display response times were significantly longer than the level 1 scene display times. Refer to Table 2 for further details.

Finally, to replicate previous work from Pertroi et al., (2014), a one-way ANOVA was conducted to examine the effects of grid display level on response latency. Results further indicated a significant interaction between grid display levels and response time (F (2, 14) = 9.21, p = .003, η^2p = .568). Specifically, participant response times were significantly shorter in level 2 and level 3 of the grid display than in level 1 of the grid display (see Table 3).

Discourse Analysis

During the discourse task, neurotypical adults did not navigate to any symbols located on the grid display. Thus, this condition was relabeled as a natural spoken language condition. Paired sample *t*-tests (two-tailed) were conducted to determine the effects of device display on discourse task length and complexity. The effect of interface display on discourse length was approaching significance, (t (8) = 1.9, p = .099, Cohen's d = .67), with participants having shorter discourse length (seconds) in the scene display condition (M = 269.13, SD = 127.1) than the natural spoken language condition (M = 315.75, SD = 92.85). Conceptual complexity was also approaching significance (t (8), = 2.298, p = .055, Cohen d = .81) with participants in the natural spoken language condition producing more conceptually complex utterances (M = 96.13, SD = 30.37) than in the scene display condition (M = 78.75, SD = 24.86). Given the exploratory

Table 5

Discourse outcomes	Interface display	Score *M*(*SD*)
Conceptual Complexity Levels		
Matching experience	Grid	3.13 (4.26)
	Scene	1.38 (1.69)
Selective analysis	Grid	14.5 (10.57)
	Scene	15.5 (9.9)
Reordering experience	Grid	48 (20.16)
	Scene	36.38 (12.97)
Reasoning about experience	Grid	30.5 (17.75)
	Scene	25.5 (13)
Main Concept Average	Grid	3.96 (.42)
	Scene	3.79 (.48)

nature of the current research, we conducted an additional series of paired samples *t*-tests across the four conceptual complexity levels. The effect of interface display on the Reordering of Experiences Level (ROEL) was approaching significance, with participants in the grid display condition producing more ROEL level utterances than in the scene display condition. Refer to Table 5 for further details. Results indicate a negligible difference in MCA production between scene display and natural spoken language conditions.

Correlation and Regression Analyses

Several Pearson product-moment correlational analyses were conducted to explore potential relationships between various cognitive-linguistic assessments and the dependent variables (see Table 3). There was a significant negative correlation between CLQT design generation and scene display conceptual complexity average (r (6) = -.792, p = .034). Next, a significant positive correlation was observed between the CLQT generative naming task and the natural spoken language conceptual complexity average (*r* (6) = .873, *p* = .010). There was also a significant positive correlation between the CLQT Story Retell task and natural spoken language conceptual complexity average (*r* (6) = .831, *p* = .021). Finally, there was a significant positive correlation between CLQT Attention scores and natural spoken language conceptual complexity average (*r* (6) = .769, *p* = .043). All other correlations were not significant and not reported in the table.

Several linear regressions were conducted to predict the best interface display from the participants' various cognitive-linguistic skills or scores. The Tower of London, Stroop Interference Factor, CLQT Symbol Trails, and CLQT Generative Naming explained a significant amount of the variance in grid response latency (F (2, 4) = 22.56, p = .04, R^2 = .98, adjusted R^2 = .93). The individual predictors were examined further and indicated that the Tower of London (t = 3.83, p = .051), Stroop Interference Factor (t = -3.51, p = ..017), and Symbol Trails subtest (t = 4.39, p = .048) were significant predictors in the model. The regression coefficients can be found in Table 4 and indicated that an increase in these cognitive assessment scores results in a shorter response latency by about 1.00 s and .40 s respectively. However, an increase in Symbol Trail scores results in an increase in response latency by about 2.62 s.

Next, the CLQT Executive Function, Visuospatial, and Memory scores explained a significant amount of the variance in scene navigation accuracy (F (1,8), p = .076, R^2 = .87, adjusted R^2 = .74). The individual predictors were examined further and indicated that CLQT Memory (t = 4.19, p = .025) was a significant predictor in the model and CLQT Executive Functions approached significance (t = -2.17, p = .071) were. The regression coefficients indicated that an increase in the Visuospatial and Memory cognitive assessment scores results in a .45- and .35-point increase to accuracy scores. However, an increase in Executive Function scores may result in a reduction in accuracy scores by about 1.17 points.

Similarly, The CLQT Generative Naming, Story Retell, and Attention index score explained a significant amount of the variance in conceptual complexity average in the natural spoken language condition (F (1,8), p = .007, R^2 = .975, adjusted R^2 = .950) (See Table 4). Overall, the CLQT Story Retell (t = 5.00, p = .01) was a significant predictor in the model while CLQT Attention approached significance (t = 2.79, p = .06). The regression coefficients indicated that an increase in these cognitive assessment scores results in a .25-point increase in natural spoken language average complexity.

Table 3

Correlations of Cognitive Assessments and Interface Conceptual Complexity

	Experimental outcomes			
Assessment tasks	Grid conceptual complexity	Scene conceptual complexity	MCA score scene display	Scene display latency
CLQT Design Generation	.43	-.79*	.57	-.08
CLQT Generative Naming	.87*	.15	.67	-.27
CLQT Story Retell	.83*	.48	.08	-.58
CLQT Symbol Trails	.22	-.25	.83*	.21
CLQT Attention	.77*	-.16	.86*	-.27
CLQT Executive Functions	.62	-.37	.84*	-.1

TOL	.52	-.21	.19	-.71*

Note. CLQT = Cognitive-Linguistic Quick Test; TOL = Tower of London; *$p < .05$, **$p < .01$

Table 4

Regression Coefficients and Percentage of Variance Explained

Predictor variables	Outcome variables	R	R^2	b	t	p value	95% CI
Model 1	Grid response latency	.99	.98	-	-	.04	-
TOL		-	-	-1.00	-4.90	.03	[-1.15, -.07]
Stroop IF		-	-	-.40	-8.15	.01	[-1.63, -.50]
CLQT Symbol Trails		-	-	2.62	4.39	.04	[-.95, .29]
CLQT Generative Naming		-	-	-1.08	-2.30	.14	[.01, 1.26]
Model 2	Scene navigation accuracy	.93	.87	-	-	.07	-
CLQT Executive Function		-	-	-1.17	-2.74	.07	[-2.84, .21]
CLQT Visuospatial		-	-	.45	2.25	.11	[-.41, 2.39]
CLQT Memory		-	-	.35	4.19	.02	[.25, 1.85]
Model 3	Grid conceptual complexity	.99	.98	-	-	.007	-
CLQT Generative Naming		-	-	-.18	-1.07	.36	[-1.58, .78]
CLQT Story Retell		-	-	.20	5.00	.01	[.28, 1.28]
CLQT Attention		-	-	.05	2.79	.06	[-.12, 1.88]

Note. TOL = Tower of London; Stroop IF = Stroop Interference Task; CLQT = Cognitive Linguistic Quick Test.

Discussion

The purpose of this research was to (a) determine how well performance on an assessment of cognitive skills (e.g., cognitive flexibility, executive functions, working memory) can predict navigation accuracy of an AAC device with either a grid or scene interface display in neurotypical adults and (b) to investigate the influence of interface display scheme on production of linguistic complexity during a discourse task with a novel communication partner. There were four major findings that emerged from this research. First, interface display (grid and scene) had a significant effect on participant navigation accuracy. Second, display type had a significant effect on navigation efficiency. Third, the scene display condition did not impact production of linguistic complexity during a discourse task. Finally, performance on certain cognitive-linguistic assessments has the potential to predict the success a neurotypical adult will experience navigating within a grid and scene display.

Navigation Accuracy

System navigation is an important contributor to effective communication when people rely on AAC to communicate. Consistent with previous research (e.g., Brock et al., 2017; Wallace & Hux, 2010), participants in the current study navigated more accurately to targets in all levels of the scene interface display condition than the grid display. This can be attributed to the relatively transparent high context photographs used in combination with their organization (e.g., story grammar framework) in the scene display (Brock 2019; Wallace & Hux, 2010). Furthermore, the grid display contained more symbols than the scene display and required additional navigation in order to be located (i.e., symbols displayed on three different levels versus two).

Interestingly, navigation accuracy in level 1 of the grid display was the least accurate. Level 1 of the grid display contained core vocabulary words (e.g., articles, pronouns, prepositions) that are typically represented by less iconic symbols. This lack of iconicity may have impacted participants' navigation to target words on this level, suggesting that more explicit training of symbols on this level would be recommended.

Response Latency

Conversational efficiency is an important component when becoming a competent communicator (Light & McNaughton, 2014). Communication partners may perceive a higher or lower level of competence based on the speed of communication (Beck at al., 2002). Results indicated that scene displays may facilitate higher levels of operational competence, allowing participants to more effectively navigate the device to a given target. These findings align with previous research demonstrating that contextualized photographs significantly increase navigation accuracy (Brock et al., 2017) and navigation speeds (Wallace et al., 2010) compared to non-contextualized images. This can be linked to the organization of the displays as well as the symbols used. Scene displays typically organize contextualized photographs schematically or chronologically, which may have facilitated more efficient retrieval of targets. In addition, people process information in contextualized photographs with greater automaticity (Wilkinson & Jagaroo, 2004). In contrast, the organization of grid displays may impose additional processing times due to the greater number of symbols per page as well as the taxonomic organization (Brock et al., 2017).

Story retell times were also shorter in the scene display than in the grid display condition, indicating that the scene display interface helped participants more efficiently communicate key points without compromising story complexity or retell accuracy. This is important for two reasons. First, as previous research has indicated, perceptions of communicative competence can have a profound impact on whether or not communication partners will engage or maintain not only a conversation but AAC use with an individual using an AAC device (Brock et al., in press;

Jonhson et al., 2006). Second, the contextualized photographs in the scene display may have allowed participants to allocate cognitive resources to the discourse task, increasing their efficiency in communicating the main concepts of the Cinderella story. Various linguistic deficits in adults with aphasia “can be explained by a deficit of resource capacity or a reduced ability to allocate attentional resources” (Marinelli at el. 2017, p.11; Murray et al., 1997), highlighting the importance of preserving attentional resources. The attention framework of aphasia proposes that attention, arousal, and language are interdependent (McNeil et al., 1991) and that adults with aphasia may have subtle deficits in some or all of these areas. The demand on attentional resources for navigation may have been mitigated by the scene display (Brock et al., 2017). However, participants did not demonstrate higher levels of conceptual complexity or production of main concepts in the scene display condition.

Discourse Outcomes

Neurotypical adults in the current study found no utility in the grid display device and did not navigate to any symbols during the story retell task. This may be due to the limited information that graphic symbols provide. For example, selecting a single graphic symbol has the potential for several intended messages (e.g., selecting the symbol for “midnight”, which could mean “you have to be home by midnight” or “the clock struck midnight”, etc.). Thus, the grid display condition was more akin to a natural spoken language condition. There were no significant differences in conceptual complexity of utterances or production of main concepts between the natural spoken language condition and the scene display condition. This indicates that the scene display did not decrease participants’ ability to produce complex utterances and did not impose any additional difficulty in communicating necessary information to convey key aspects of a story.

While these are promising outcomes, the type of discourse task may have impacted production of complex utterances (Stark, 2019). Findings from Stark (2019) suggests that discourse type is sensitive to production of specific aspects of spoken language (e.g., propositional density, verbs per utterance, noun to verb ratio, etc.), with narrative discourse being most sensitive to depth of vocabulary and content richness. These differences between discourse tasks highlight the importance of including more than one discourse elicitation method in future research. With respect to conceptual complexity, the Cinderella story provides participants with limited opportunities for production of higher levels of conceptual complexity (e.g., Level 4 RAEL: "The king wanted his son to marry so he sent out invitations") with level 3 (ROEL) being the most commonly produced.

Predicting an Optimal Interface Display

Many of the cognitive assessments were significantly correlated with (see Table 3) conceptual complexity, main concept analysis, and navigation response latency in each interface condition. The majority of correlations were related to discourse outcomes, with the Tower of London task being the only assessment to be negatively correlated with scene response latency. The positive correlation between CLQT Attention scores and conceptual complexity average in the grid/natural spoken language condition suggests attention may be an indicator of success (e.g., increase complex utterances). This, coupled with the navigation efficiency findings, suggests that attention resources may be essential to successful story retell. The positive correlation between the Story Retell task from the CLQT and natural spoken language complexity average suggests that the Story Retell task may be a viable predictor variable of naturally spoken syntactic complexity in a similar discourse task. The CLQT Design Generation subtest helps assess executive skills related to productivity, self-monitoring, and ability to vary responses rapidly. The negative correlation observed between the CLQT Design Generation subtest and the scene display conceptual complexity average suggests that participants who had more difficulty generating abstract designs without support would benefit from the additional contextual support of the scene interface display. The CLQT Generative Naming subtest assesses word retrieval skills. The positive correlation between this subtest and the natural spoken language condition indicates that participants' ability to produce words without contextual support may lead to successful discourse when using a grid interface display. Various CLQT subtests and index scores were positively correlated with the MCA average in the scene display. These were the Symbol Trails subtest (a measure of cognitive flexibility), the Executive Function and Attention index scores. This may suggest that adults with aphasia who experience deficits in this area may benefit from the support of the scene interface display, but additional participants with and without aphasia are required. These results suggest that there are several potential predictor variables that could assist clinicians in selecting an optimal interface display; however, a larger sample size is required.

Regardless of sample size, linear regression models were created because selecting assessments that are able to predict operational competence (e.g., navigation accuracy and response latency) based on performance may help clinicians reduce the time spent on the lengthy AAC assessment process. In the first model, increased scores from the Tower of London task (a measure of executive function and cognitive flexibility) and the Stroop Interference Factor (a measure of executive function, cognitive flexibility, and response suppression) may predict shorter response latency times in grid interface devices. Thus, if an adult with aphasia has relatively intact executive functions and cognitive flexibility they may have increased efficiency when navigating a grid interface display.

In the second model, the Executive Function, Visuospatial Skills, and Memory index scores from the CLQT may predict navigation accuracy in scene interface devices. As suggested by Wallace et al. (2010), cognitive abilities are linked to navigational ability. A person with deficits in the Visuospatial and Memory abilities may benefit from a scene display. For example, the high context photographs in the scene display may help to elicit a stronger activation of the visual sketchpad (Baddeley, 2000; Dietz et al., 2014). By reducing the burden on these cognitive abilities, more resources can be allocated to effective navigation of the AAC device, including an increase in navigation accuracy. This suggests that scene interface displays would be recommended for those who receive both high and low scores on these subtests. However, each model contained results that conflict with previous research. For example, in model 2, as Executive Function points increase, scene navigation accuracy would be expected to decrease. Thus, while the findings of the current study are promising, further research is necessary. Limitations will be discussed further in the following section.

In sum, linear regression analyses may allow researchers to predict how successfully persons with aphasia will operate and use different interface displays for communication purposes. Subsequently, clinicians can utilize these data to streamline the AAC assessment process, which is a rather long and difficult process. As Johnson et al. (2006) outlined, long-term AAC system success requires clinicians to account for several AAC system characteristics (e.g., interface display) as well as the preferences of the client. Successful assessments can lead to a recommendation of an appropriate AAC system that either prevents or mitigates system abandonment. Therefore, predicting outcomes from various cognitive assessments may help ensure that the AAC assessment process is more efficient and prevents system abandonment by individuals with aphasia.

Limitations

There are several limitations associated with this study. First, the smaller sample size of neurotypical participants limits the application of results to the general population of those with aphasia. Due to the COVID-19 pandemic, no adults with aphasia could be recruited for participation in the experiment. Second, data collection occurred remotely, likely impacting participant response times. Similarly, type of participant technology (e.g., computers and hard drives) could not be controlled. Some participants either used a laptop mouse pad or a computer mouse during the navigation task, which may have impacted response times to an unknown degree. Many of the cognitive assessments have not been standardized for use via video conferencing. Third, as previously outlined, the type of discourse task selected may have impacted production of conceptual complexity. As Stark (2019) noted, narrative discourse relies more on memory and aspects of executive function (e.g., planning and organization) than visual aspects, suggesting that scene displays may mitigate potential deficits in executive function, allowing them to focus on communication. Fourth, neurotypical adults did not use the grid display to aid in story retell, so results related to complexity of discourse may not be directly related to the grid display condition. However, this does provide some justification regarding the need to make grids simpler to use for communication. Finally, data analyses included parametric statistics that are typically reserved for sample sizes much larger than the current study. Additionally, correlational analyses were conducted, which cannot establish any conclusive relationships among the variables. Although linear regression analysis was utilized, this is typically reserved for larger sample sizes (e.g., 50 participants) and thus need to be interpreted with caution.

Clinical Implications

Although AAC treatment is intended to develop competent communicators, adults with aphasia are often provided with a limited amount of support, potentially related to the frequently large clinical caseloads (Hoffman et al., 2013). In addition, this support is typically focused on operational competence such as navigation of the device. Because of this "out of the box" mindset, a clinician's ability to predict level of success with display type based on the user's performance through a set of cognitive-linguistic standardized and non-standardized assessments would help to facilitate operational competence, allowing clinicians to focus treatment on linguistic, social, and strategic competencies, potentially decreasing the length of overall treatment required. Findings from the investigation suggest difficulty with productivity and self-monitoring may be mitigated with a scene interface display device. In the current study, neurotypical adults benefitted from the organization and contextualized photographs in the scene display, achieving higher levels of operational competence (navigation efficiency and accuracy), suggesting that adults who have experienced stroke with subsequent aphasia, would also benefit from the additional supports of the scene interface display. Additionally, results suggested that scene displays may not impose any additional demands on the limited capacity systems that, in turn, would negatively impact linguistic competence in neurotypical adults completing a discourse task. Thus, it is possible that the same may be true for adults with aphasia.

Future Research

Overall, more participants should be included in future research in order to more accurately represent the general population. A higher participant pool also allows for use of more robust data analysis measures (e.g., linear regressions). Additionally, a larger number of participants may allow researchers to identify varying cognitive profiles that highlight specific cognitive functions associated with competent communication using an AAC with either a grid or scene interface display. These findings should be replicated with adults with aphasia. The current study selected the Cinderella Story due to available standardized analysis of the discourse (e.g., MCA); however, for ecological validity, future discourse tasks should include more natural discourse, such as conversation. To provide a more accurate discourse comparison, participants without aphasia should be required to create messages using only an AAC device and gestures versus their typical speech output. It may be beneficial to include a device rating questionnaire for participants to complete following both experimental conditions to investigate their opinions related to both devices (e.g., which device did they prefer). Finally, instructions for grid core vocabulary located on level 1 can be varied and compared in order to investigate the impact instruction may have on navigation accuracy and efficiency.

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Appendix A

Navigation Task Prompt

- We are going to play a computer game, and I will ask you to find a specific symbol of a picture depicting a word.
- You will have 60 seconds to find that word on this computer.
- Once you find the picture, you must touch it with your finger. If you cannot find the symbol or picture, please keep looking for the entire 60 seconds.
- Are you ready to play the game?

Appendix B

Discourse Task Directions

The following directions are from the AphasiaBank Protocol (MacWhinney, Fromm, Forbes, & Holland, 2011).

- Now I am going to ask you to tell a story. Have you ever heard the story of Cinderella?
- Do you remember much about it? These pictures might remind you of how it does.
- Take a look at the pictures and then I'll put the book away, and you will have 10 minutes to tell me the story in your own words. *Allow participant to look through the book (assist with page turning if needed)*
- *If necessary, prompt*: Now tell me as much of the story of Cinderella as you can.
- You can use any detail you know about the story, and you are encouraged to use words, gestures, and the computer to help you tell it.
- Do you have any questions?
- *If the participant gives less than a 3 minute retell, or seems to falter, allow 10 seconds, then prompt:* What happened next? *or* Go on
- *Continue until participant concludes the story or it is clear they have finished.*

Appendix C

Zoom Conference Instructions for Caregiver

First, below is information about how this research will be completed using Zoom Video Conferencing. It is important that you download the Zoom software and are familiar with it. There are basic tutorials at https://support.zoom.us/hc/en-us, and you can always ask me for assistance. Second, it is important that you refrain from helping the participant respond to the questions/prompts they are given. This is vital to ensure that the results yielded from this experiment are valid.

You will need a computer/laptop for Zoom. Make sure that the Zoom device has the video enabled and audio enabled. You will also need a smartphone device to record your loved one during data collection. Please silence your smartphone and enable "Airplane Mode" to disable any push notifications, texts, or calls.

Prior to our meeting, please gather all of the necessary items, located in **blue**

Day 1 Standardized Testing and Cognitive Tasks

This meeting will last for approximately 90 minutes. The researcher will be recording today's session using Zoom. Additionally, you will be recording the session from your end using your smartphone. Please ensure that the smartphone is in silent mode and in airplane mode for the duration of this session. At the end of each task please stop the video until the researcher requests you to begin recording the next task. These video recordings will be shared with no one except for myself and my research mentor Dr. Kristofer Brock.

The participant will be asked to complete 6 cognitive tasks and one language test. For the majority of the tasks the researcher will share their computer screen with you. During certain tasks the participant will be given remote control of the researcher's screen in order to participate. When necessary, the participant will be instructed to use the computer mouse to make selections. Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left hand corner. Then click and drag that box out of view.

Some tasks will be longer than others. The participant will be allowed to take breaks in between tasks if needed, but it is important that once a task is started that it is completed. Please refrain from providing any support to the participant.

Task 1 Western Aphasia Battery-Revised *30-45 min*:

Items you will need:

- **Pencil**
- **Cup**
- **Flower**
- **Comb**
- **Screwdriver**
- **Ball**
- **Knife**
- **Safety Pin**
- **Hammer**
- **Toothbrush**
- **Eraser**
- **Padlock**
- **Key**
- **Paper Clip**
- **Watch**
- **Rubber Band**
- **Spoon**
- **Cellophane Tape**
- **Fork**

The majority of this task will be completed on the computer. The participant will be given remote control of the researcher's screen in order to participate. When necessary, the participant will be instructed to use the computer mouse to make selections. Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left hand corner. Then click and drag that box out of view.

For one of the tasks the researcher will instruct you how, when and in what order to place the gathered items. Please record the participant from behind, with a clear view of the computer screen. If the participant is asked to point to an item the video recording should clearly show which item they selected.

Task 2 Cognitive Linguistic Quick Test *15-30 min*:

Items you will need:

- **Print out of the CLQT Response Booklet**

The majority of this task will be completed on the computer, with some tasks that will require the participant to write or draw in the response booklet. The participant will be given remote control of the researcher's screen in order to participate. When necessary, the participant will be instructed to use the computer mouse to make selections. Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left hand corner. Then click and drag that box out of view.

When the participant is completing tasks on the computer, please record them from behind, with a clear view of the computer screen. If the participant is asked to point to an item the video recording should clearly show which item they selected.

Task 3 Corsi Block Test *5-10 min*:

This task will be completed on the computer and the participant will need to use a mouse. Please record the participant from behind, with a clear view of the computer screen. If the participant is asked to point to an item the video recording should clearly show which item they selected. For this task the participant will see 9 blocks. Some will “light” up (yellow) in a sequence. Once you hear “go”, you need to click the same blocks in the same sequence. The sequences will become increasingly longer. When ready, press the space bar.

Task 4 Tower of London Task *5-10 min*:

This task will be completed on the computer and the participant will need to use a mouse. The participant will be given remote control of the researcher’s screen in order to participate. When necessary, the participant will be instructed to use the computer mouse to make selections. Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the “ – “ icon in the top left hand corner. Then click and drag that box out of view.

Please record the participant from behind, with a clear view of the computer screen. If the participant is asked to point to an item the video recording should clearly show which item they selected. The participant will be asked to complete a series of moves in order to match their stack of blocks to the pattern displayed at the top of the screen.

Task 5 Hayling Sentence Completion Test *5-10 min*:

In this task the participant will be asked to respond to sentences spoken by the researcher. If the research is unable to understand them, they may ask you to repeat what the participant said. Please be sure to repeat exactly what the participant said. Please refrain from providing any prompts or support.

Task 6 Coin Rotation Task *5 min*:

Items you will need:

- **A Quarter**

Please clearly record the participants hand that is manipulating the coin. Using only 1 hand, turn the coin 180 degrees using only your thumb, index, and middle fingers. Please watch the researcher demonstrate. You will have 10 seconds to complete as many turns as you can.

Task 7 Stroop Color and Word Test:

For this task the participant will be asked to name words or colors aloud from a list presented on the computer screen. Please record the participant from behind, with a clear view of the computer screen. If the participant is asked to point to an item the video recording should clearly show which item they selected.

UPLOAD VIDEO: After the task is completed, please upload your recording to Box, which is a HIPPA and FERPA secure cloud-based storage service. The researcher will send you a personal Box link for this upload. No one else will be able to access this Box link except for the researcher and Dr. Kristofer Brock.

UPLOAD DOCUMENTS: After the task is completed, please take photographs of each page of the CLQT response booklet. Photographs should be well lit and include the entire page. Please upload photographs of the CLQT response booklet to Box.

Day 2 and 3 Navigation Task and Story Retell

This meeting will last between 20-30 minutes. The researcher will once again be recording this Zoom session. You will also need the following required items:

- smartphone for recording the Zoom session and the participant
- a laptop or desktop to connect to the Zoom session

Please use your phone to record the research participant during today's meeting. Your phone should be set to silent and in airplane mode. You will need a laptop or desktop to connect to the Zoom meeting. When recording please make sure we can see (1) the hand that the participant uses to select items on the screen and (2) the entire computer screen. Please ensure that the participants voice is able to be heard in the recording by keeping the camera close to the individual.

Navigation Task:

For this task please record the participant from behind with a clear view of the computer screen and the selections that they make. The participant will need access to a mouse. **The participant will be given remote control of the researcher's screen in order to participate. Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left hand corner. Then click and drag that box out of view.**

We are going to play a computer game. The researcher will ask you to find a specific symbol of a picture depicting a word. You will have 60 seconds to find that word on this computer. You will hear a 'ding' that signals when you are allowed to begin. Once you find the picture, you must click with the mouse. If you cannot find the symbol or picture, please keep looking for the entire 60 seconds. Are you ready to play the game?

Story Retell Task:

For this task please record the participant from behind with a clear view of the computer screen and the selections that they make.

For the next task you will be asked to retell the story of Cinderella. Have you ever heard the story of Cinderella? Do you remember much about it? These pictures might remind you of how it goes. Please take a look and scroll through the pictures on the screen. When you are finished the researcher will put them away. You will have 10 minutes to tell the story in your own words. Tell the researcher as much of the story of Cinderella as you can. You can use any detail you know about the story, and you are encouraged to use words, gestures, and the computer to help you tell it.

UPLOAD VIDEO: After the task is completed, please upload your recording to Box, which is a HIPPA and FERPA secure cloud-based storage service. The researcher will send you a personal Box link for this upload. No one else will be able to access this Box link except for the researcher and Dr. Kristofer Brock.