THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF COMMUNICATION SCIENCES AND DISORDERS

Effects of Spatial Arrangement on Visual Search in Grid-based AAC by Adults without Disabilities

EMILY LEVAN
SPRING 2021

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree in Communication Sciences and Disorders
with honors in Communication Sciences and Disorders

Reviewed and approved* by the following:

Krista Wilkinson
Professor of Communication Sciences and Disorders
Thesis Supervisor

Carol Miller
Professor of Communication Sciences and Disorders
Honors Adviser

* Electronic approvals are on file.

ABSTRACT

The current study aimed to answer the question, “how can the principles of spatial arrangement be used to maintain less visual crowding while filling in the white spaces on a grid-based AAC display?” Specifically, it sought to determine whether spatial arrangements that reduce visual crowding by manipulating the size and spatial of symbols on an array might facilitate search. Twenty-five typically developing participants, ranging in age from 18 to 30-years-old, participated. After presenting a photograph on a screen followed by a verbal prompt, the participants were asked to locate a symbol on one of four display design conditions. The conditions were labeled SOC, CSR, SAC, and PermAr. Each of the four possible layout conditions had something altered to it, whether it was symbol size, the clustering of symbols, or a combination of both. Participant’s eye gaze transitions from the target symbol was recorded across these four conditions. For the majority of participants, their visual attention stayed fixated on the target or transitioned to a grammatically related symbol when presented with the perimeter design display, called the PermAr. Moreover, PermAr exhibited the least amount of participants to transition their gaze to a distracter (irrelevant symbol) from the target symbol when compared to the other conditions. Clinicians should consider utilizing a perimeter display that utilizes a ‘perimeter arrangement’ to separate the grammatical categories. Often clinicians maximize the number of symbols on AAC grid-based displays to increase the vocabulary inventory which causes visual crowding. The perimeter display reduced visual crowding and narrowed AAC user's visual attention which made it easier to find the target symbol. Further research will require expansion to individuals who would be actual users of AAC.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This research was supported by grant number NICHD 1R01HD08338 awarded to Krista Wilkinson, PI. These findings and conclusions do not necessarily reflect the view of the funding agency. I would like to express my deep gratitude to my research supervisor, Dr. Wilkinson, for her patient guidance, enthusiastic encouragement, and useful critiques of this research work. I would also like to thank my honors advisor, Dr. Miller, for her advice and assistance in keeping my progress on schedule. Finally, I wish to thank my family for their support and encouragement throughout my study.

Chapter 1

Introduction

What enters a person's mind when they hear the word communication? Possibly, they think of someone giving a speech like Martin Luther King Jr. Or maybe they think of texting, calling, or emailing. In truth, these are all true examples of communication. Communication is the transmission of information between two or more people. People communicate to express wants and needs, share ideas, form social closeness, and to have fun. Many individuals with disabilities experience limitations in their ability to accomplish such actions independently through the use of speech; they have what is called "complex communication needs" (CCN). Beukelman and Light (2020, p. 4) expressed that "without understandable speech, people with complex communication needs face severe restrictions in their communication, participation, and inclusion and in all aspects of life—education, medical care, employment, family, and community involvement—unless they are provided with other communication supports."

Augmentative and Alternative Communication

"The development of augmentative and alternative communication, or AAC, offers the potential to enhance the communication effectiveness of people with complex communication needs" (Beukelman & Light, 2020, p. 4). As reviewed by the American Speech-Language-Hearing Association (ASHA), AAC is made up of tools and interventions that involve any method of communication used for expression other than oral speech. Everyone uses AAC in various forms each day. For instance, people utilize AAC when exhibiting facial expressions or gestures in place of talking. Even writing a note and passing it to a friend is another way to communicate without oral speech. People with severe speech or language problems may use it all the time, or only use the AAC for longer sentences or when conversing with people they do not know well (ASHA, n.d.).

Unaided vs. Aided AAC

There is a whole range of AAC systems that are developed to meet each individual's needs. These systems include both unaided and aided options. Unaided AAC systems do not require anything, except the body. These include gestures, body language, facial expressions, and vocalizations and speech approximations. In contrast, aided AAC requires some sort of external piece of equipment or technology. There are two types of aided AAC: low-tech and high-tech. The low-tech option is simple technology, such as communication boards and picture exchange systems. The high-tech option refers to computerized-based technologies, like speech-generating devices (SGDs) that use synthesized speech to speak for an individual. Some of the SGDs have the option to speak in different languages (ASHA, n.d.). Stephen Hawking, the world-famous physicist, utilized a speech-generating device that enabled him to produce speech through the computer. According to Vinay (2018), in order for Hawking to deliver information to his computer, he used an "infrared switch installed on his spectacles that caught the slightest of twitches in his cheek" (p. 2). Beukelman and Light (2020) highlight that "approximately 5 million Americans and 97 million persons worldwide may benefit from AAC to enhance their communication and increase their participation in their communities" (p. 6).

Display Design

Some aided AAC systems make use of auditory forms of language representation (e.g., auditory scanning), but most aided AAC systems rely on a visual modality (e.g., letters, words, or pictures). Since the means for communication is visual, the success of AAC intervention will depend on the effectiveness and efficacy with which the information is presented in the display (see, e.g., Wilkinson, Light, & Drager, 2012). Wilkinson and Jagaroo (2004) argued that the design of an aided AAC display pertains to the physical layout of the display: where symbols are arranged, their size, their color, and so forth. When an AAC display is poorly designed, it may cause confusion and limit successful communication. Furthermore, a display that is difficult to navigate causes more frequent errors, slower access, and frustration for the patient. Thus, the client often chooses not to use their device and finds a less conventional means to communicate. Wilkinson et al (2012) claim that it is crucial to appropriately design an AAC display that fits a user's needs. This is based on the visual-cognitive processing--how a user attends, perceives, and makes sense of the visual information on the display. A well-designed display helps the client create messages accurately and rapidly, which results in a greater perceived competence and higher expectations by communication partners.

Wilkinson and Jagaroo (2004) reviewed the literature in cognitive science and visual cognitive neurosciences, to determine what visual-perceptual dimensions affect attention, memory, and other cognitive processes. I will review several studies that have examined the role of symbol structure (color) and spatial layout (symbol location). These two dimensions were chosen because research in cognitive science and visual cognitive neurosciences reveals that visual and spatial function are prominent functional domains of the human brain. Therefore, both dimensions can be powerful influences on visual and cognitive processing outcomes and will have an effect on the types of clinical materials used in aided AAC.

Wilkinson, Carlin, and Thistle (2008) examined whether visual search by children with typical development was affected by the location of symbols within a display when there were subgroups of like-colored symbols. For instance, when a 16- symbol grid display consists of four blue items, four red items, four yellow items, and four green items, does it matter if like-colored symbols are clustered together, in small groups, or rather distributed throughout the display? Their study found that clustering symbols that shared a color facilitates search and reduces attention to distractors in children with typical development.

Further studies focused their research on the visual search patterns of individuals with Down Syndrome (DS) and Autism Spectrum Disorder (ASD) (Wilkinson & Madel, 2019; Wilkinson & Mcllvane, 2013). Automated eye tracking technologies were used to examine the eye gaze behavior during visual search. These eye tracking technologies recorded the participant's point of gaze during search using infrared light reflected from their eyes (see Wilkinson & Mitchell, 2014, for a description of eye tracking technologies as related to AAC research). Both studies found that participants with DS and ASD were able to find the target symbol more accurately and able to select the target symbol faster when the like-internal colored symbols were clustered together on the display in comparison to the distributed layout. Also, they fixated less on distractors in the clustered condition, which is beneficial for the future because these individuals may be prone to distractors (Wilkinson & Madel, 2019; Wilkinson & Mcllvane, 2013). These findings support the idea that design matters and small changes to the way clinicians organize the display on the aided AAC will result in substantial differences in speed and accuracy of finding a target.

Wilkinson and Snell (2011) noted that communication about feelings is a core element in human interaction; therefore, the aided AAC systems must incorporate symbols representing these concepts into the displays. However, there are a lot of challenges when it comes to trying to represent emotions with static picture symbols. Moreover, individuals with disabilities have difficulties in identifying symbols representing emotions. Manipulations of symbol internal color were inappropriate for this representation because emotion symbols are represented by faces, and the internal color of the face cannot be changed without making it abnormal (i.e., blue faces or red faces). Instead, they examined background color cuing and spatial arrangement to help children identify symbols of various emotions.

In order to do this, they created four display types that were identical in stimuli, but varied in the number of cues (no cue, spatial, color, or both). The first exhibited neither the color cue (white background) nor spatial cue, while the second displayed both. In contrast, the alternative two displays presented one cue each, the spatial or color cue, respectively. Participants were 30 children with typical development. Response times to find targeted symbols were shorter when a spatial cue was added, but only when the symbols had white backgrounds. This suggests that the background color cue had no effect and did not facilitate response. This study highlights that structural design characteristics of the visual display itself are a potentially important feature that might contribute to greater fluency with an aided AAC. Consequently, when clinicians cannot cluster by symbol internal color, spatial cues alone can be effective.

Visual Clutter/Crowding

Although humans have the capacity to observe a detailed visual world, the ability to identify individual objects is limited when there is clutter--a phenomenon known as *visual crowding*. “Clutter is the state in which excess items, or their representation or organization, lead to a degradation of performance at some task” (Rosenholtz et al., 2007, p. 8). Generally, crowding is a breakdown of object recognition. Pelli and Tillman (2008) state that object recognition means calling a chair a chair regardless of variations in style, viewpoint, and surrounding clutter. The term crowding dominates in the periphery, which means that observers “have difficulty performing a peripheral task, such as accurately identifying or discriminating a target, when that target is surrounded by flankers” (Keshvari & Rosenholtz, 2016, p. 2). A flanker is identified as a neighboring object that surrounds the target.

Figure 1 portrays the influence of neighboring objects on visual discrimination. When focusing on the plus sign, the letter E on the right side is easily read, while the same letter E in the word “BED” is quite difficult. Crowding impairs identification, not detection. Therefore, crowding does not simply make the target disappear, but rather impairs the ability to identify, count, and locate objects (Pelli & Tillman, 2008).

Research has revealed that crowding is not restricted to only letters, but occurs with a wide range of objects including shapes and faces (Levi, 2011). Crowding not only impairs object recognition, but Bulakowski, Post, and Whitney (2011), discovered that crowding has a damaging effect on other various perceptual tasks, such as: limiting object perception, eye and hand movements, visual research, and reading speed.

Figure 1: Visual Crowding

Under certain circumstances, crowding may be reduced or eliminated completely. For instance, when targets and flankers are contrasting in shape, size, or color, the target "jumps out" and crowding is diminished (Levi, 2011). Based on this information, it would be beneficial to consider methods for enhancing perception by reducing clutter/crowding.

Effects of visual crowding on AAC design layouts

Wilkinson and Jagaroo (2004) proposed that principles of visual cognitive processing might offer suggestions for the design of AAC displays. They identified four areas of visual cognition that could perhaps impact how people interact with these displays: (a) organization, that is either grids (row-column configuration) or integrated within natural scenes; (b) symbol color and contrast; (c) symbol arrangement; and (d) symmetry and axial orientation.

Organization. Traditionally, symbols have been organized into grid-based visual symbol arrays, in that particular symbols occupy individual spaces at regular intervals. Yet, individuals are also presented with an alternative visual symbol array called the visual scene display (VSD), which can either be schematic (drawn) or photographic. In this type of display, individual symbols are programmed onto an everyday-occurring contextual scene. For a better understanding, Wilkinson and Jagaroo (2004) illustrate how the symbol for the word "milk" would be displayed as sitting on the table in the kitchen. The grid display poses various advantages that assist both perception and retrieval of each individual cell and their values. For instance, stimuli are individually placed into squares that are isolated in physical space, which encourages attention to be brought to each cell. Alternatively, in a naturalistic scene the identity of an "object and its semantic associations are integrally tied to other objects in the scene and the holistic context carried by the scene" (Wilkinson & Jagaroo, 2004, p. 126).

Color and Contrast. According to the principles of visual cognition, color and contrast are two primary factors that impact perception, learning, and recall of AAC symbols. Specifically, for VSDs, color brings out contrasts between objects and highlights the features. Color takes on a different role for grid displays due to the lack of context presented within the symbols. The absence of background context causes grids to organize symbols together based on similar surface colors. Consequently, when non-relevant colors are presented it can create distractions or hinder the discrimination of symbols with similar surface color. In regards to this information, Wilkinson and Jagaroo (2004) asked: "What are the best permutations for color/form combinations in AAC display" (p. 132)?

Symbol Arrangement. There is research that explores the most effective methods for organizing vocabulary. The placement of symbols in space directly affects how well the item is perceived or remembered. Wilkinson and Jagaroo (2004) mention a variety of strategies to arrange a simple display, such as: activity (snacks, hide-and-seek), themes (holiday, birthday party), or word type (people, food). Additionally, individual pages of a display can be organized "by row (food on the top row followed by drinks and utensils), preference (highly preferred or most salient at the top), or word-class category (subjects on the left side, action labels in the center, direct objects on the right)" (Wilkinson & Jagaroo, 2004, p. 128). Perhaps, the principles of visual cognition can impact the way symbols are arranged on a display. Wilkinson & Jagaroo (2004) state that “perception and recall of faces and emotion information, as well as geometrically regular forms, are enhanced when stimuli appear in the left visual field” (p. 129). The right visual field is responsible for processing fewer abstract stimuli.

Symmetry and Axial Orientation. When creating a grid-based or a schematic scene-based AAC display, it is important to appropriately construct and align the symbols. For this purpose, professionals need to create a better understanding of the principles of symmetry and axial orientation for AAC designs. Wilkinson and Jagaroo (2004) note that “symmetry and axial orientation refer to the structure of a stimulus itself (symmetry) and how it is aligned (axial orientation)” (p. 132). When one side of a stimulus is a mirror image or reflection of the other side- also known as having equal halves- we can identify the symbol as symmetric. For instance, the letter “T” is an example of a symmetric stimulus. Axial orientation expresses the position or orientation of an object’s main axes in planar space (Wilkinson & Jagaroo, 2004). For instance, the accepted orientation for the letter “E” is positioned straight up. To deviate from the accepted orientation, this letter would be rotated slightly or rotated a full 90 degrees. In this case, the letter is less recognizable which hinders the time it takes to discern the letter. Hence, axial orientation makes a significant contribution to interpretation of visual stimuli (Wilkinson & Jagaroo, 2004).

This current research is specifically focused on symbol/spatial arrangement. Spatial arrangement crucially affects the recognition of a visual symbol, as exemplified by the phenomenon visual crowding. Thus, spatial arrangement can be applied to reduce crowding completely. To observe the effects of arrangement, one promising avenue involves eye-tracking technologies.

Eye-tracking technologies

As a person views or interacts with a visual image on an aided AAC device, research-based eye tracking technologies can be used to automatically track the point of an individual's gaze. According to Wilkinson and Mitchell (2014), these technologies "record the orientation of the individual's eyes in a series of samples taken at rapid intervals through measurements of infrared light reflected from the cornea (the curved portion of the eyeball) and the pupil, and as a function of the distance of the eyes from the monitor" (p. 1). There are various models of eye-tracking technologies available such as, Tobii Technology, SensoMotoric Instruments, Applied Science Laboratory, and ISCAN.

Karatekin (2007) states that "eye tracking provides a non-invasive method for elucidating a wide variety of cognitive processes, from visual-spatial attention to object recognition to object perception, memory, and language" (p. 284). Based on sampling data, researchers can observe what areas within the visual image were viewed or ignored, in what order, how many times, and for how long (latency). These dependent variables can be compared within individuals or across groups of individuals. Wilkinson and Mitchell (2014) emphasize that eye-tracking technologies will be beneficial for inspecting how individuals with developmental or acquired communication disabilities may respond to aided AAC systems. In addition, this technology can distinguish how search is affected by the different symbol/spatial arrangements based on the variations in search behavior.

A series of ongoing eye-tracking studies have begun to examine whether variations in spatial location and grouping of similar symbols affect performance of visual search. In one study (Wilkinson, Liang, & McIlvane, 2018; Wilkinson, Qian, & Gilmore, in preparation) participants were presented with four differing layout designs. There were 24 total participants;

twelve participants with Down syndrome and twelve with typical development matched on receptive vocabulary age estimate. The first display was called “standard of care” which is known as the traditional row column grid display. This display arranged the grammatical categories from left-to-right (subjects to the left, followed by actions, objects, descriptors, etc.) with symbols fairly close together to maximize the number available. The second grid display titled “wide” was another example of a grid display that exhibits the traditional row column arrangement. However, the symbols were more spaced out. The last two displays, “corners” and “perimeter,” both illustrate an arrangement with spatial cueing. For the “corners” display, the grammatical categories of interest were divided into four groups placed in each corner. The “perimeter’ display used a ‘clock’ arrangement to separate the grammatical categories.

Figure 2 illustrates representative gaze patterns for one individual with Down Syndrome and one with typical development. The findings indicated that there are more diffuse fixations with the “standard of care” and “wide” grid display. The “standard of care” has the most scattered fixations. On the other hand, “corners” and “perimeter” promoted narrow attention toward the targeted grammatical category (and away from irrelevant) during search. The “perimeter” grid display had the most efficient visual search behavior.

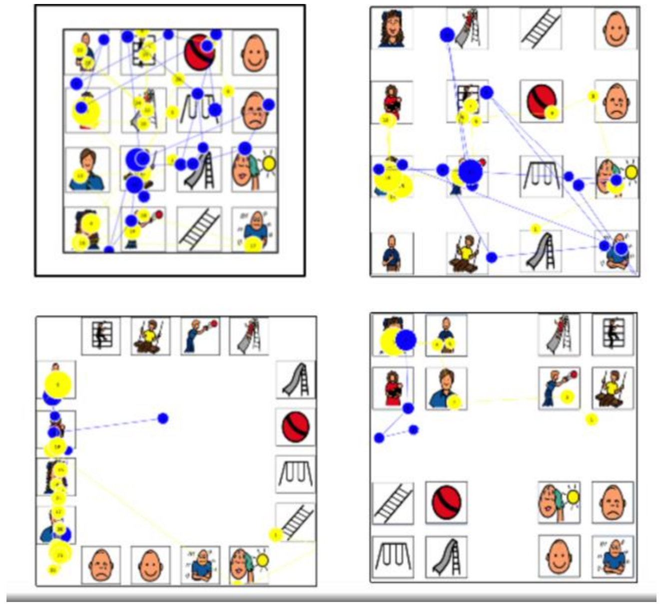

Figure 2: Effects of Spatial Cues

In conclusion, the efficient use of space is key to facilitating search on AAC grids. The spatially clustered displays take advantage of white space between the clusters to narrow attention. Light et al. (2019) also point out that these arrangements are likely most crucial for individuals who are new to a grid display(s). Once the layout becomes familiar, the spatial cues may be less important, and it may be possible to begin adding vocabulary into the white spaces, thus providing access to more vocabulary. All in all, design matters and it matters for everyone.

Research Purpose

Although Wilkinson et al (2018, in preparation) illustrated that spatial arrangement can facilitate visual search, the amount of white space in the "corners" and "perimeter" conditions means that there is room for additional vocabulary. Clinicians seek to ensure as much vocabulary as possible on AAC displays. The purpose of this study was to determine how the principles of spatial arrangement can be used to maintain less visual crowding while filling in the white spaces. Specifically, I sought to determine whether spatial arrangements that reduce visual crowding by manipulating the size and spatial arrangement of symbols on an array might facilitate search. While these displays all contain exactly the same vocabulary, they systematically differ from one another along three dimensions; (1) the size of the symbols, relative to one another; (2) the arrangement of symbols within three broad grammatical categories, that is, subjects, actions and objects, and emotions; and (3) whether the grid is symmetrical or in a perimeter layout. The four conditions presented to participants are illustrated in Figure 3 and the specific changes within each one are summarized in Table 1 and described in detail below. Each of the four possible layout conditions had something altered to it, whether it was symbol size, the clustering of symbols, or a combination of both. The small changes made to each condition will help researchers determine the optimal layout for efficient visual search.

Research Conditions

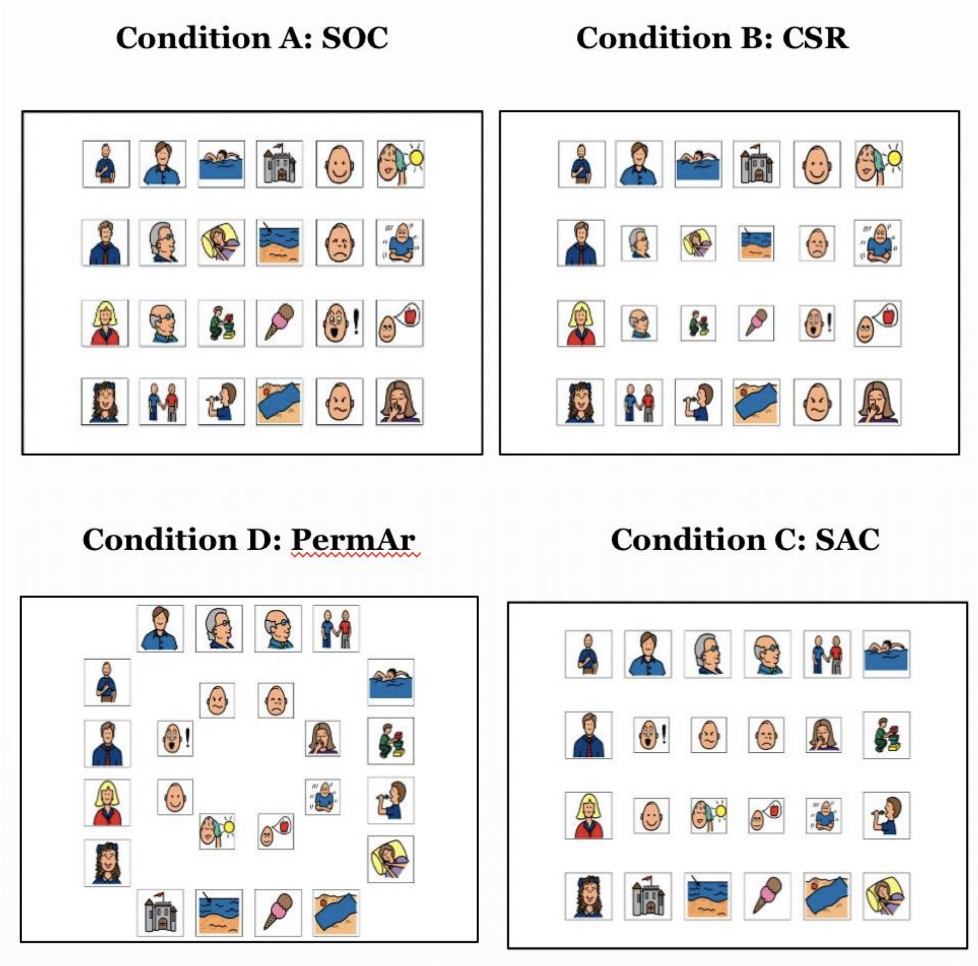

Figure 3: Grid-display Layout Conditions

Table 1: Grid-Display Alterations

	Symbol size	Symbol arrangement by grammatical class	Grid type
SOC	All symbols are equal size	Left-to-right	Symmetrical grid
CSR	Smaller central symbols	Left-to-right	Symmetrical grid
SAC	Smaller central symbols	Edges to center	Symmetrical grid
PermAr	Smaller central symbols	Edges to center	Perimeter layout

The first design layout is called the “Standard of Care” (SOC). This layout organized the symbols in the typical row column grid display and had each symbol equal in size. The symbols are placed in grammatical categories moving from left to right, like when reading or writing a sentence. The subjects are grouped in the left column, followed by actions and objects, and emotions.

The next layout design shown is called “CSR.” The layout for CSR is very similar to SOC because it is portrayed as a grid display and the grammatical categories are organized left-to-right. However, the symbols in the center are smaller in size. The placement of large symbols on the periphery (sides) and smaller symbols in the center of the display minimizes visual crowding. Since the targets and flankers are contrasting in size it allows the target to “stand out” and individuals response times will be faster and more accurate.

Following CSR, is the “SAC” layout. Like the others presented, this design exhibits the traditional row column arrangement and the symbols in the center are smaller. However, the grammatical categories are not arranged left-to-right. The SAC layout organizes the grammatical categories spatially with the emotions clustered in the center. As Light et al. (2019) pointed out “spatial cues may serve as a means to narrow attention toward relevant (and away from irrelevant) symbols during search” (p. 18). As demonstrated in the Light et al. (2019) study, individuals with Down syndrome and children with typical development (matched for vocabulary) exhibited more visual fixations towards relevant (target) symbols and less fixations on non-relevant (flanker) symbols. Therefore, designing grammatical categories spatially rather than left-to-right would be a more effective layout, and clustering smaller symbols in the center reduces crowding, allowing symbols to better stand out to create more efficient visual searches.

Finally, the last design layout mentioned is "PermAr." This type of layout is very different from the others mentioned above. The PermAr utilizes a perimeter arrangement for the grammatical categories. The categories are placed in a clockwise direction with the emotion symbols, which are smaller, gathered in the middle. From the previous study, the "perimeter" spatial arrangement created the most efficient eye gaze to the targeted grammatical category. Plus, the presence of empty space on the display promotes narrow attention. When the smaller symbols are grouped in the center, with the larger symbols placed in the periphery it reduces or removes visual crowding all together. Thus, it has a positive effect on perceptual tasks, such as: object perception, visual research, and reading speed. The PermAr design layout utilizes all these essential variables to make it the best visual support and number one option for individuals to use.

Chapter 2

Methods

Participants

A total of 25 total participants from Penn State University Department of Psychology Subject Pool underwent study; of them, 16 (64%) were female. The mean age was 19;10 (years; months) with a range from 18 to 30 years (18; 2 to 30; 8). The majority of participants reported typically developing with corrected visual activity, normal color vision, and no motor or sensory limitation. We started with people without disabilities as a means to limit the potential influence of other factors, such as physical and intellectual disabilities (Wilkinson & Coombs, 2015). The participants provided informed consent consistent with the procedures of the university's institutional review board.

General Procedures

The Tobii T60 provides a seventeen-inch screen monitor with an integrated camera-based eye tracker system. The T60 conducts binocular tracking, which means it tracks both eyes simultaneously, at 60 Hz. Also, it combines both bright and dark pupil tracking. The T60 communicates via a Tobii Eye Tracker (TET) server which is located within the monitor. The TET is responsible for "performing image processing on the camera video feeds and for mapping from image parameters to screen coordinates" (Weigle & Banks, 2008, p. 4).

Figure 4: Tobii T60 Eye Tracker System

Tobii Studio software is a program for recording and analyzing eye gaze data (Tobii Technology, 2012). This software supports a large variety of stimuli and permits both multiple and different stimulus types to be combined in one single recording. Tobii Technology advertises that this software displays a "holistic view of behavior by integrating recording of eye tracking data with user video, sound, keystrokes, mouse clicks, questionnaires, and other data sources in a single solution" (Tobii Technology, 2012, p. 4). The eye tracking data can be utilized for comparison, interpretation, and presentation.

Calibration Procedure

The accuracy of the Tobii eye tracking technology depends on the quality of the calibration. For this study, the 2.0 calibration was operated on each participant. This calibration played animated gifs/short videos instead of fixation points. The calibration, on the Tobii T60, presented a video of SpongeBob in the upper left corner and then another one in the bottom right corner. The calibration allowed the program to recognize a participant's eye gaze behavior.

Experimental Procedure

The subject was presented with a photograph on the screen, followed by a spoken prompt that described the image in one word. For instance, a picture of a woman yawning appeared and then was followed by the spoken word "tired." After that, one of the four layout conditions illustrated in Figure 3 and summarized in Table 1 (SOC, CSR, SAC, PermAr) was randomly selected and shown on the screen. The subject chose the symbol that best represented the picture and verbal prompt mentioned beforehand.

Data Processing and Analysis

Data collection occurred at a laboratory in the Ford Building on Penn State University's campus. While recording, the Tobii Eye tracking technology collected raw eye movement data points that corresponded to the sample rate of 60 Hz (every 16 ms). Each data point was identified with a timestamp and "X, Y" coordinates, and sent to Tobii Studio. The software then processed further into fixations and overlaid on a video recording of the stimuli utilized in the test (Eye movement classification, 2015).

The transitions from the target symbol were the dependent variable. A program was written to calculate each transition from fixation to fixation, beginning when one of the four experimental layout conditions became visible to the participant. It was recorded when the participant transitioned their eye gaze from the target symbol to a grammatically related symbol, a distracter (irrelevant symbol), white space, or stayed fixated on the target symbol. Note that the target-related symbol refers to the same grammatical category as the target symbol. For instance, if the target was a "subject" the target-related symbol would be a "subject" as well. The distracter refers to a symbol that is irrelevant (a different grammatical category) to the target symbol. Data analyses were completed on the mean of transitions from the target symbol.

Chapter 3

Results

Figure 5 shows the mean percent of transitions from the target symbol to: (1) target or target-related symbol, (2) distracter, and (3) white space for each layout condition.

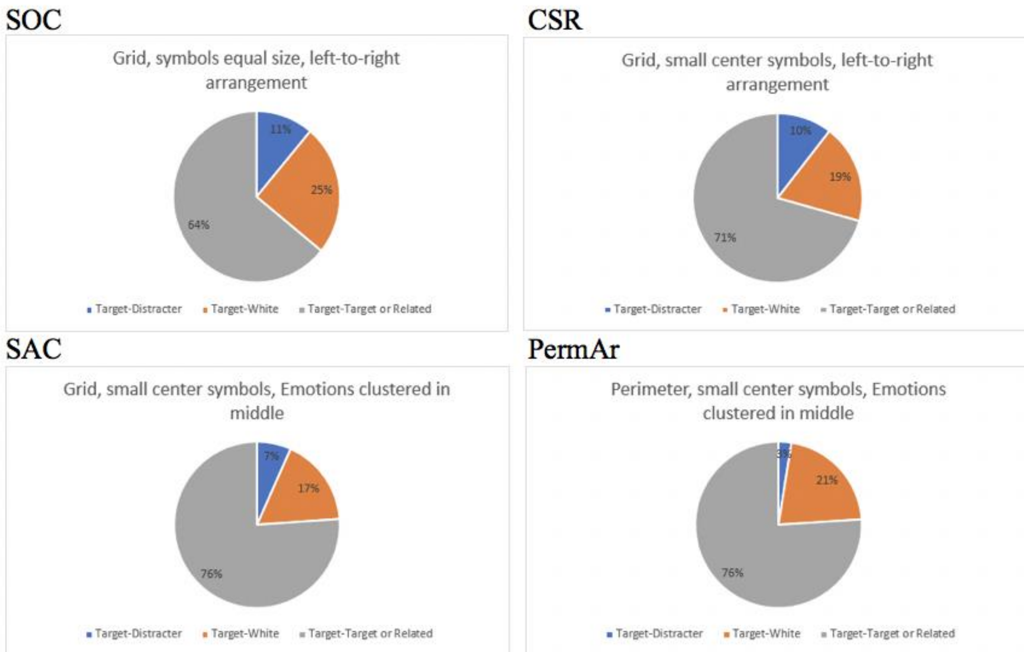

Figure 5: Mean percent of transitions from the target symbol to: 1) target or target-related symbol, 2) distracter, and 3) white space

Figure 6 presents the percentage of participants who transitioned from target symbol to a distracter for each layout condition.

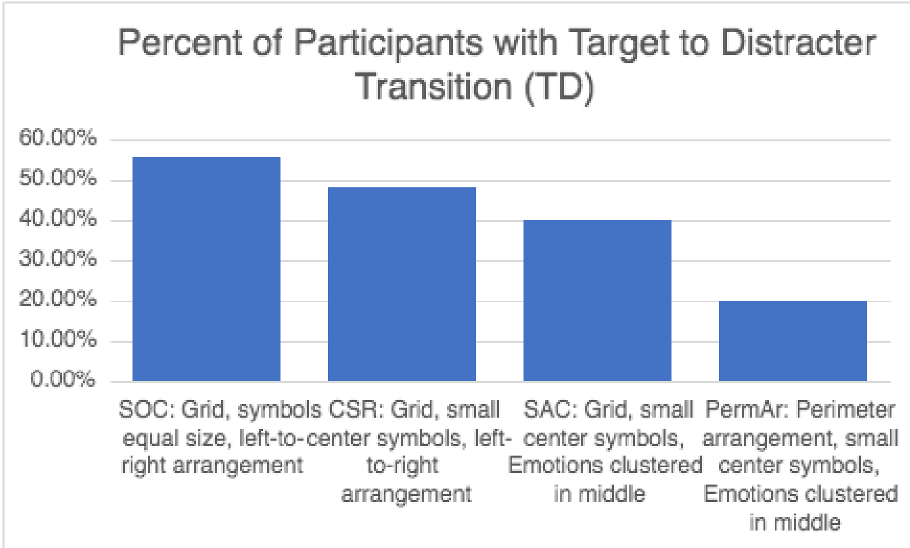

Figure 6: Percent of participants to transition their eye gaze from the target symbol to a distracter symbol

As presented from Figure 5, the majority of participants (a mean of 76%) stayed fixated on the target or transitioned to a grammatically related symbol when presented the SAC and PermAR layout. However, this eye gaze behavior was not the same when the participants were presented the SOC and LP layout. There was a definite decline of fixations on the target or transitions to a grammatically related symbol. There were 25% of participants who transitioned their eye gaze from the target symbol to white space when presented the SOC layout. It was assumed that more participants would transition to the white space when presented the PermAr layout. However, only 21% of participants fixated on the white space when PermAr layout was displayed.

As shown in Figure 6, the PermAr layout exhibited the fewest participants (20%) to transition their attention to a distracter from the target symbol, compared to the SOC layout in which over half of the participants (56%) transitioned their attention to a distracter from the target symbol.

Chapter 4

Discussion

Structural design characteristics of the visual display on an aided AAC device can be important features that contribute to efficient visual search (Wilkinson & Snell, 2011). One design characteristic relates to visual crowding, which is a phenomenon that is defined as the inability to identify, count, and locate individual objects when surrounded by flankers (neighboring objects). This research evaluated whether crowding could be reduced by manipulating spatial arrangement and relative size of symbols. Based on the results, simply changing the symbol size, the clustering of symbols, and/or a combination of both reduced or eliminated visual crowding. Thus, it allowed the target symbol to "stand out" to the participants which lead to a more efficient and effective visual search.

Reducing visual clutter improves search

The research implemented four experimental layout conditions labeled SOC, CSR, SAC, and PermAr. In many current perceptions of AAC displays, symbols are arranged in symmetrical row-column grid arrangements, often from left to right by grammatical class. This typical grid-display is known as Standard of Care (SOC). As research clearly demonstrated, alterations on design of aided AAC displays had an impact on an individual's visual search. Thus, each other layout had something altered to it, whether it was symbol size, arrangement of symbols, or a combination of both. These changes to each condition helped researchers determine the most optimal layout for visual search.

Even with a typical row column grid display, a small change to the layout will noticeably improve one's eye gaze behavior; the condition CSR was a great example of this. CSR exhibited some improvements in visual search compared to the SOC. For example, the transition from target to target or a related symbol went up 7% from the SOC layout. The only modification made to this condition was the size of the symbols. The larger symbols were placed on the periphery (sides) and smaller symbols in the center of the display. Based on previous findings, when targets and flankers are contrasting in size, the target "jumps out" and crowding is diminished.

An even greater improvement in visual search occurred with the SAC layout. The transition from target to target or related symbol increased to 12% from the SOC layout. This layout organized the grammatical categories spatially with the emotions smaller in size and clustered in the center. The spatial arrangement creates a more accurate and appropriate search because the participants' attention is narrowed towards relevant (and away from irrelevant) symbols. Most participants stayed fixated on the target or transitioned their gaze to a grammatically similar symbol.

The last layout condition presented to each participant was known as PermAr, which presented the most efficient visual search. The PermAr utilized a perimeter arrangement for the grammatical categories, which means they were placed in a clockwise direction. The emotion symbols, which are smaller, gathered in the center. These results supported previous research which stated that the PermAr layout promoted the most effective eye gaze behavior. This condition had the fewest participants to transition their attention to a distracter from the target symbol. Research has shown that only 3% of participants transitioned their eye gaze to a distracter. In contrast, 7-11% of participants turned their attention to a distracter when they assessed the other layout conditions. PermAr exhibited a great amount of white space compared to the other conditions. Because of this, it likely reduced visual crowding and helped narrow the attention which made it easier to find the target symbol.

Clinical Implications

Currently, clinicians often try to maximize the number of symbols on AAC displays, in order to offer as many vocabulary items as possible. However, this strategy likely causes visual crowding. In order for there to be less visual crowding and improvements with eye gaze behavior, it is beneficial to use a perimeter display that utilizes a 'perimeter arrangement' to separate the grammatical categories. Even though there is a lot of empty space with the clock arrangement, as Light et al. (2019) pointed out, once the layout becomes familiar, the spatial cues may be less important, and it may be possible to begin adding vocabulary into the white spaces. Thus, clinicians can take advantage of the white space by clustering smaller-sized symbols in the center. This results in providing access to more vocabulary. Communication outcomes for each individual will be influenced by the design of the aided AAC system itself. Careful construction of the physical "space" is critical to maximize its utility for the individual. This validates the idea that each clinician has the power to create displays that promote the most efficient eye gaze behavior.

Future Research Directions/Limitations of Current Research

This research requires expansion to individuals who would be actual users of AAC. For this current study, we began with college students who did not have disabilities and were not daily users of AAC. We opted to begin this line of research with individuals with typical development because the task was challenging and people with disabilities would probably struggle. Clearly, however, future studies need to replicate these findings with individuals with disabilities, who might benefit from aided AAC interventions.

Second, the study was controlled through a mouse. This is a limitation because most AAC devices do not use a mouse. However the "mouse is a common navigational input device that may be used by young children with complex communication needs to access computer technologies (Costigan, Light & Newell, 2012)." This study found that display features such as target size and angle of approach affected the accuracy and efficiency of young children in selecting targets with the mouse. Upcoming research needs to make use of something more ecologically valid in order to gain evidence that would suggest patterns are the same.

Another limitation is the research was conducted under devised laboratory conditions and procedures, so there was no actual communication occurring during the task. We chose to do this approach in order to reduce variability that would be caused by factors such as distractions from other individuals along with the demands of natural conversation. For the future, it is critical to examine how the findings would interpret into naturalistic communication interaction.

The last limitation is that some current technologies do not allow for specific display customizations on aided AAC devices. If a clinician is unable to create an AAC display that fits the user's needs, this could cause confusion, slower access, frustration, and unsuccessful communication. Therefore, for the future, researchers should work with manufacturers to ensure that the technologies allow for this type of customization.

BIBLIOGRAPHY

American Speech-Language-Hearing Association. Augmentative and Alternative Communication (AAC). https://www.asha.org/public/speech/disorders/aac/.

Beukelman, D. R., & Light, J. C. (2020). *Augmentative & alternative communication supporting children and adults with complex communication needs*. Baltimore, MD: Paul H. Brookes Publishing.

Bulakowski, P. F., Post, R. B., & Whitney, D. (2011). Reexamining the possible benefits of visual crowding: dissociating crowding from ensemble percepts. *Attention, Perception, & Psychophysics*, *73*(4), 1003–1009. https://doi.org/10.3758/s13414-010-0086-2

Eye movement classification. Read the article. (2015, August 14). https://www.tobiipro.com/learn-and-support/learn/steps-in-an-eye-tracking-study/data/how-are-fixations-defined-when-analyzing-eye-tracking-data/.

Karatekin, C. (2007). Eye tracking studies of normative and atypical development. *Developmental Review*, *27*(3), 283–348. https://doi.org/10.1016/j.dr.2007.06.006

Keshvari, S., & Rosenholtz, R. (2016). Pooling of continuous features provides a unifying account of crowding. *Journal of Vision*, *16*(3), 39. https://doi.org/10.1167/16.3.39

Levi, D. M. (2011). Visual crowding. *Current Biology*, *21*(18). https://doi.org/10.1016/j.cub.2011.07.025

Light, J., Wilkinson, K. M., Thiessen, A., Beukelman, D. R., & Fager, S. K. (2019). Designing effective aac displays for individuals with developmental or acquired disabilities: State of the science and future research directions. *Augmentative and Alternative Communication*, *35*(1), 42–55. https://doi.org/10.1080/07434618.2018.1558283

Pelli, D. G., & Tillman, K. A. (2008). The uncrowded window of object recognition. *Nature Neuroscience*, *11*(10), 1129–1135. https://doi.org/10.1038/nn.2187

Qian, Y., Wilkinson, K., & Gilmore, R. (2019). The effect of spatial organization in the design of visual supports for adults with communicative disorders. *Journal of Vision*, *19*(10). https://doi.org/10.1167/19.10.310b

Rosenholtz, R., Li, Y., & Nakano, L. (2007, January 2). *Measuring visual clutter*. Journal of Vision. https://jov.arvojournals.org/article.aspx?articleid=2122001#133662559.

Thistle, J. J., & Wilkinson, K. (2017). Effects of background color and symbol arrangement cues on construction of multi-symbol messages by young children without disabilities: implications for aided AAC design. *Augmentative and Alternative Communication*, *33*(3), 160–169. https://doi.org/10.1080/07434618.2017.1336571

Tobii Technology. (2012, December 12). *Product Description Overview.* https://www.tobiipro.com/siteassets/tobii-pro/product-descriptions/tobii-pro-studio-product-description.pdf/?v=3.2

Vinay, A. (2018, March 14). *Here's How Stephen Hawking Used His Cheek Muscle To Communicate With The World*. ScoopWhoop. https://www.scoopwhoop.com/how-did-stephen-hawking-communicate/.

Weigle, C., & Banks, D. C. (2008, January 28). *Analysis of eye-tracking experiments performed on a Tobii T60*. Search the world's largest collection of optics and photonics applied research. https://www.spiedigitallibrary.org/conference-proceedings-of-spie/6809/1/Analysis-of-eye-tracking-experiments-performed-on-a-Tobii-T60/10.1117/12.768424.full.

Wilkinson, K., Carlin, M., & Thistle, J. (2008). The Role of Color Cues in Facilitating Accurate and Rapid Location of Aided Symbols by Children With and Without Down Syndrome. *American Journal of Speech-Language Pathology*, *17*(2), 179–193. https://doi.org/10.1044/1058-0360(2008/018)

Wilkinson, K. M., & Coombs, B. (2010, September). *Preliminary Exploration of the Effect of Background Color on the Speed and Accuracy of Search for an Aided Symbol Target by Typically Developing Preschoolers*. Early childhood services (San Diego, Calif.). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4599784/.

Wilkinson, K. M., & Jagaroo, V. (2004). Contributions of Principles of Visual Cognitive Science to AAC System Display Design. *Augmentative and Alternative Communication*, *20*(3), 123–136. https://doi.org/10.1080/07434610410001699717

Wilkinson, K. M., Liang, J., & McIlvane, W. J., (2018). *Sequential analysis of how visual-perceptual features affect visual attention to symbols in individuals with Down syndrome.*

Poster session presented at the annual Gatlinburg Conference on Research and Theory in Mental Retardation/Developmental Disabilities, San Diego, CA (April).

Wilkinson, K. M., Light, J., & Drager, K. (2012). Considerations for the Composition of Visual Scene Displays: Potential Contributions of Information from Visual and Cognitive Sciences. *Augmentative and Alternative Communication*, *28*(3), 137–147. https://doi.org/10.3109/07434618.2012.704522

Wilkinson, K. M., & Madel, M. (2019). Eye Tracking Measures Reveal How Changes in the Design of Displays for Augmentative and Alternative Communication Influence Visual Search in Individuals With Down Syndrome or Autism Spectrum Disorder. *American Journal of Speech-Language Pathology*, *28*(4), 1649–1658. https://doi.org/10.1044/2019_ajslp-19-0006

Wilkinson, K. M., & McIlvane, W. J. (2013). Perceptual Factors Influence Visual Search for Meaningful Symbols in Individuals With Intellectual Disabilities and Down Syndrome or Autism Spectrum Disorders. *American Journal on Intellectual and Developmental Disabilities*, *118*(5), 353–364. https://doi.org/10.1352/1944-7558-118.5.353

Wilkinson, K. M., & Mitchell, T. (2014). Eye Tracking Research to Answer Questions about Augmentative and Alternative Communication Assessment and Intervention. *Augmentative and Alternative Communication*, *30*(2), 106–119. https://doi.org/10.3109/07434618.2014.904435

Wilkinson, K. M., & Snell, J. (2011). Facilitating Children’s Ability to Distinguish Symbols for Emotions: The Effects of Background Color Cues and Spatial Arrangement of Symbols on Accuracy and Speed of Search. *American Journal of Speech-Language Pathology*, *20*(4), 288–301. https://doi.org/10.1044/1058-0360(2011/10-0065)

Wilkinson, K. M., Qian, Y., & Gilmore, R. (in preparation). Judicious arrangement of symbols on an AAC display optimizes visual attention and speed of responding by individuals with and without Down syndrome. *American Journal on Intellectual and Developmental Disabilities.*

Academic Vita of Emily LeVan

emilyalevan@icloud.com

EDUCATION

Bachelor of Science in Communication Sciences and Disorders | The Pennsylvania State University

Major: Communication Sciences and Disorders
Minor: Special Education

AWARDS AND HONORS

- Pennsylvania State University Schreyer Honors Scholar
- Dean's Honors
- The President's Freshman Award
- The President's Sparks Award
- The Evan Pugh Scholar Award

RELATED EXPERIENCE

The Laboratory of the Study of Visual Supports in Communication and Education, Undergraduate Researcher

- Collected and analyzed data from participants with typical development and participants diagnosed with Down Syndrome
- Debriefed subjects
- Reviewed literature
- Developed a thesis paper concerning the most optimal ways to arrange visual-graphic symbols on communication displays for individuals with developmental and intellectual disabilities

CSD Undergraduate Virtual Research Event

- Created a pre-recorded 60 second summary of my research
- Designed a poster on my research
- Discussed and answered questions about my research with people who attended the event

Observation Hours with a Speech Language Pathologist in Multiple Settings

- School setting (ages 9-13), St. Joseph's Hospital (inpatient and outpatient therapy), and Speech, Language, & Hearing Clinic at Penn State

WORK EXPERIENCE/EMPLOYMENT

Assistant Teacher, Tiny Thinkers Academy | Berks County, PA

- Created a safe and nurturing environment for all children at children's daycare center
- Communicated with children's parents about daily activities, behaviors, and related issues
- Developed and administered activities to keep children engaged and to promote gross and fine motor skills
- Consulted with my supervisor and other teachers to best help the children

Group Fitness Instructor, ACE Fitness | University Park, PA

- Designed structured and innovative fitness plans to be executed in small to large group atmospheres
- Cultivated positive relationships with class participants by teaching a variety of challenging and entertaining group fitness classes
- Encouraged members to reach their fitness and wellness goals and served as a point of reference for fitness expertise within classes

Learning Assistant, Psych 100 | University Park, PA

- Scheduled meetings and communicated regularly with professor, other learning assistants, and students taking the course
- Assisted with grading blog assignments
- Monitored review sessions and answered students' questions

ACTIVITIES

NSSLHA (National Student Speech-Language Hearing Association) Member

- Network with future speech-language pathologists
- Provided with volunteer opportunities

Penn State Dance MaraTHON Committee Member

- Raised money to support the Four Diamonds Fund
- Interacted with and educated donors about THON's mission