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The Effects of the Structural Characteristics of Augmentative and Alternative Communication Display Design on Accuracy and Reaction Time

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ABSTRACT

This research examined how the structural characteristics of AAC display design affect accuracy and reaction time of selecting a target line drawing among participants with and without intellectual disabilities.

Five typically developing participants and seventeen individuals with intellectual disabilities participated. The clinical group included individuals with Down syndrome, autism spectrum disorder, and intellectual disabilities of unknown origin. The participants ranged in age from 6;1 to 18;9. Participants were asked to locate a target from an array of sixteen line-drawings depicting animals. The reaction time and accuracy were recorded across four structural display design conditions. The four conditions included randomly distributed, clustered by quadrant, clustered by column, and clock.

For all participants, the clock condition provided advantages in the speed of locating the desired target when compared to the other conditions. For the individuals with intellectual disabilities, the clock condition also provided increased accuracy when compared to the other conditions. The typically developing individuals showed little variation in accuracy among the conditions.

Clinicians should consider use of the clock condition when considering the structural characteristics of AAC design display. The clock condition positively influences reaction time in typically developing AAC users, and both reaction time and accuracy in AAC users with intellectual disabilities. Additional research would provide a more detailed development of the clinical guidelines for AAC display design.

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Chapter 1

Introduction

The process of communication requires action on the part of the individual wishing to convey his or her thoughts and ideas. For many individuals with disabilities, it is not viable to perform such actions independently. Without the freedom to use their own voices, these individuals depend on some external supplement to aid in their communication processes; these aids and the methods by which they are used are called augmentative and alternative communication (AAC). AAC encompasses any method of communication used for expression other than oral speech. AAC provides individuals with a range of communication support needs with a means of communication (Beukelman & Mirenda 2005).

AAC includes unaided systems such as gestures and body language, as well as aided systems that range from low to high tech. Aided AAC devices require some external piece of equipment. This equipment can be as simple as an alphabet board, or as technological as a personalized computer with dedicated software programs. When constructing any external equipment intended for use as an AAC device many considerations must be taken to ensure optimal design. Selecting the most effective and efficient design features increases the likelihood of overall success. Design features include portability, selection methods, and positioning options, among others. Much research has been conducted to determine the best manner in which to construct an AAC display (Light, Drager, & Nemser, 2004b; Mirenda, 1985; Wagner & Jackson, 2006).

Less research has been focused on examining the visual aspects of design, such as the structural arrangement and color. However, these aspects of design have recently begun to receive more research attention (Wilkinson, Carlin, & Jagaroo, 2006; Wilkinson, Carlin, & Thistle, 2008; Wilkinson & Jagaroo, 2004).

Color Use

The organization of the display may be influenced by aspects such as the color or shape of the symbols. The use of color, either in the foreground or background of the symbol, has been suggested to impact the success of finding a symbol on an AAC display. Wilkinson and colleagues (2008) explored the impact of color on the speed and accuracy of locating a symbol to a matching comparison. The study examined six typically developing preschool children, and 10 children with intellectual disabilities associated with Down syndrome. Each participant completed three experimental conditions across three stimuli types, which were food, clothing and activities. Throughout the six experimental conditions, the layout was manipulated so symbols that share internal color appeared either in clusters or randomly distributed among the array. Within all conditions the participants' speed of responding was faster when symbols that shared internal color (apple, cherry) were presented in a cluster rather than randomly distributed throughout the display. This finding leads to the notion that clustering by color would allow an AAC user to focus on a smaller number of symbols within the display by guiding the search, thus functionally limiting the pool of potential choices to only those that share color with the target.

Separately, color has been linked to a reduction in the cognitive demands of AAC devices. It might be suggested that objects highly associated with a specific color, such as a cherry, may be located more easily on a display when compared to objects linked to an array of color patterns, such as a hat. This notion does not always hold true (Biederman & Ju, 1988; Wurm, Legge, Isenberg, & Luebker, 1993), but it has been found that within the severely disabled population, similarities between object color and the color of a symbol may increase symbol recognition (Mineo Mollica, 2003; Mirenda & Locke, 1989; Stephenson, 2007). Finally, color has also been researched in terms of its appeal. It has been speculated that individuals are more likely to increase use of an AAC device if they possess positive feelings in terms of the overall appeal of that device (Light et al., 2004b).

There are many symbols in which internal color cannot be controlled. In such cases, other dimensions of color have been explored. One obvious dimension is background color. Thistle and Wilkinson (2009) expanded on the idea of background color by studying preschool children without disabilities. They found that when the symbol itself remained white and only the background was colored latency of response took longer. Careful consideration must be used when determining the use and effectiveness of both foreground and background coloring.

Spatial Arrangement

The arrangement of the display is another design aspect to consider when constructing an AAC. In addition to considering which content to include, Light et al. 2004 stressed the importance of the manner in which the content is organized and presented on the display. However, virtually nothing is known neither about how clinicians are constructing displays currently, nor about whether different display designs would actually impact behaviors relevant to AAC use.

In one of the only relevant studies, McFadd and Wilkinson (2010) explored how SLPs are currently designing systems by asking six speech language pathologists to describe their decision making process while creating an aided AAC display. The symbol content selected varied among the clinicians, but all clinicians who selected non-object words separated food items from social-regulatory type words, placing fruits and vegetables together. Although the clinicians all clustered symbols into groups, the manner in which each cluster was organized on the display varied among the clinicians. This variation presents an interesting question about what basis clinicians who construct AAC displays regularly follow when organizing and presenting symbols on a display. The current research explores this question in more detail.

Selection Methods

Other research has focused on the implications of two selection methods commonly used in AAC, with respect to the individual's accuracy and speed of use (Horn & Jones, 1996; Szeto, Allen, & Littrell, 1993). In typically developing children, selecting symbols directly with a finger, head pointer, or other type of stylus (direct selection) places less of a demand on the child when compared to scanning (Ratcliff, 1994). Scanning refers to a selection method in which each symbol is highlighted in a distinct pattern. The individual using the device must then wait for the desired symbol to be highlighted. Once highlighted the individual indirectly selects the intended message

(Peterson, Reichle & Johnson, 2000). Direct selection requires the individual to independently locate the desired target or message. It is the fastest of the selection methods, with a production rate 6 to 25 words per minute (Peterson, Reichle & Johnson, 2000), but can only be utilized if the individual possesses the appropriate and necessary motor skills. Direct selection is also the least difficult of the input selection methods, requiring less concentration, and therefore less work on an individual's working memory (Mizuko, Reichle, Ratcliff & Esser, 1994).

Electronic scanning falls under the umbrella of an aided AAC. The individual is dependent on an external aid. Through highlighting and/or pointing the individual must wait until the desire message is reached to indicate activation. The message may also be presented verbally. The selection method of electronic scanning is not as fast, 5 to 10 words per minute (Peterson, Reichle & Johnson, 2000), but can be utilized when the individual does not possess sufficient motor skills to independently activate the desired message. Scanning has the potential to require high concentration thus requiring more work on the individual's memory. In some situations this may lessen motivation. If the symbol is located towards the end of the scanning process, the individual might forget his/her desired message or simply lose interest before the symbol is reached.

The second of the two selection techniques discussed, scanning, can be presented in a variety of ways. The displays used in scanning are somewhat different from those used in direct selection, but as I will argue are relevant to consider in the display construction within either access method.

Linear scanning describes a process in which each individual item is highlighted, one-by-one and in a row-column grid, until the desired message is selected. Linear scanning is considered the easiest of the scanning methods due to its tendency to require less memory as well as physical demands. The individual is not required to find and remember the location of the intended symbol beforehand. Rather, he/she can simply follow the highlighting until the intended message is reached. Although less cognitively challenging, linear scanning is the slowest of the scanning methods.

A second scanning method, row-column scanning, describes a process in which each row or column is highlighted until the row with the intended item is selected. Then, each item in the selected row is highlighted until the desired item is reached. Row-column scanning is less time-consuming but place more demands on an individual's memory. In this selected method, the individual must locate the desired symbol, before highlighting begins, in order to select the necessary row. Due to the increased cognitive and physical demand, the individual must be very attentive. In some circumstances, this may cause a decrease in the individual's motivation. In contrast, this increase demand may also heighten motivation (Peterson, Reichle & Johnson, 2000).

The final scanning method in question, circular or 360 scanning, describes the process in which each symbol organized in a circular fashion is highlighted until the desired item is selected. This method of scanning has received little attention in research. It has been discussed that this form of scanning is comparable to linear scanning and thus requires similar cognitive and physical demands. In addition to this similarity, circular or 360 scanning, may reduce speed depending mainly on the size of the circular display. Still, because there are no symbols in the center of the display clinicians may be reluctant to use circular scanning because they feel it does not optimize the space available.

Although circular scanning is considered among the easiest scanning methods to learn, it does limit the number of symbols that can be presented (Glennen & DeCoste).

Research goals

The layouts created for linear and row-column scanning are also applied within the direct selection method. The 360 layout is currently almost exclusively limited to the scanning selection method, and not applied within direct selection. As discussed above, however, the 360 layout presents potential benefits within scanning. The current research sought to determine if the 360 pattern would present similar benefits and implications within direct selection.

The results of McFadd and Wilkinson (2010), discussed above, suggested that clinicians do in fact have similar goals, such as symbol selection and clustering of common items. It is in applying these goals that dissimilarities in realizing the physical presentation of the display occur. The clinicians participating in the study varied by either organizing the common symbol clusters by row, or by column. It is debatable which of the two commonly used patterns is superior. Furthermore, the option of organizing the symbols in a 360 pattern was not considered. Thus, the current research intended to expand on the findings that suggest such features of display affect the performance, in terms of both accuracy and latency, within the selection technique of scanning, and determine through further research if similar features of display also affect performance within the selection technique of direct selection.

Specifically, the research sought to examine whether there might be differences in responding under display organizations in which symbols are clustered by (a) column, in which symbols of the same category are organized and presented in the same vertical columns on the display; (b) quadrant, in which symbols of the same category are clustered in groups of four, with each cluster presented in a corner quadrant on the display; (c) 360, in which the symbols are presented in a circle design. Symbols of the same category are organized along the same perimeter of the design (e.g across the top, bottom, or left or right side of the display); or (e) in a random arrangement, in which symbols are not organized in a categorical manner; rather each symbol is randomly distributed among the array. Each display, with the exclusion of randomly distributed, presents the symbol in a taxonomical manner. The varying display organizations are expected to affect an individual's accuracy and latency within symbol selection.

Chapter 2

Method

Participants

Consent forms were obtained from 17 participants with intellectual disabilities with significant communication support needs. The intellectual disabilities included Down syndrome, autism spectrum disorder, and intellectual disabilities of unknown origin. Consent forms were also obtained from 5 typically developing participants, thus resulting in a total of 22 subjects on whom this study will report. The 22 subjects ranged in age from 6;1 to 18; 9. The use of adolescents ensured the subjects' need for communication supports.

The raw and standard scores were recorded for each of the 22 participants. The mean standard score of the PVVT for the participants with intellectual disabilities was 52. The mean raw score for participants with intellectual disabilities was 108. The mean standardized score of the PPVT for the typically developing participants was 126. The mean raw score for the typically developing participants was 172.

All of the typically developing subjects who provided data performed within the expected age ranges on the Peabody-Picture Vocabulary Test, a standardized test of receptive vocabulary. None of the participants were found to have hearing or vision impairments according to parent and/or teacher report. Sensory function was corrected such that each subject was able to complete the computer task at hand. The mean chronological age of the participants was 13;11. Twelve participants were female, while ten were male.

Table 2-1

Subject Code	Diagnostic Status	Gender	Chron Age	Raw Score	Standard Score	% ranking	Age Equivlent
CAB	UND	M	14;10	120	75	5th	9;2
KYR	DD	F	18;9	70	21	<1st	4;4
GFA	DD	F	15;11	65	40	1st	5;0
LTJ	UND	F	16;4	58	20	<1st	3;9
SNN	UND	M	15;0	117	57	2nd	7;1
MGL	UND	F	15;10	139	69	2nd	8;9
ZKW	DD	M	13;3	134	73	4th	8;2
JJN	ASD	M	14;11	145	73	4th	8;11
RPT	DS	M	18;2	102	40	<1st	2;11
ASC	DS	M	16;7	98	40	<1st	6;0
RCO	DS	M	15;1	42	20	<1st	3;0
BTC	ASD	M	12;3	89	39	<1st	5;5
GBM	ASD	F	11;3	87	55	1st	5;5
JNG	UND	F	14;6	88	40	1st	5;4
HDD	UND	F	22;1	108	42	<1st	8;0
OVA	ASD	F	15;8	46	20	<1st	3;4
NIH	UND	M	19;7	128	56	2nd	6;7
MGG	TD	F	6;1	133	123	94th	8;1
NRD	TD	F	9;6	163	112	81st	11;3
NIP	TD	F	10;2	173	116	86th	12;1
AGY	TD	F	N/A	179	123	94th	13;10
CLG	TD	M	10;6	211	157	>99.9th	24;11

- Note: N/A= information not available

Materials

The participants were presented with a variety of AAC displays. Each display featured an array of 16 line drawings depicting animals. Animals were chosen because of their familiarity and recognition. The animals were clustered into four categorized groups including insects, land animals, birds, and ocean dwellers. The groups were arranged by column, in quadrant clusters, in a 360 display with one category occupying each perimeter, and in a randomized order.

Figure 2–1 Column Condition

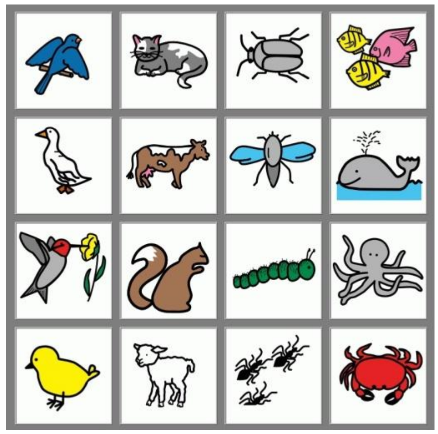


Figure 2–2 Quadrant Condition

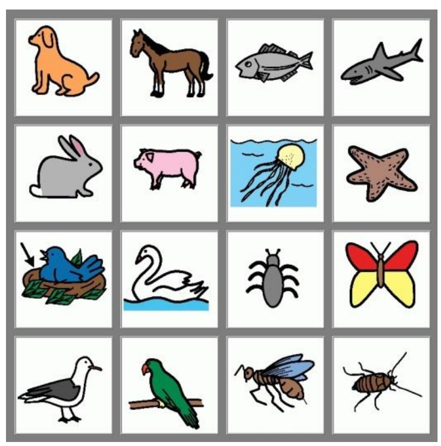
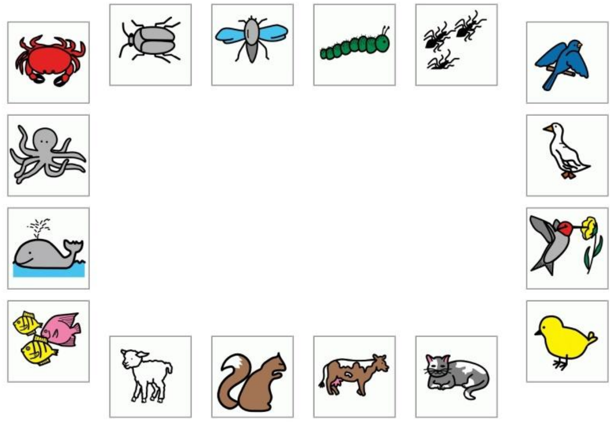


Figure 2-3 Clock Condition



Procedures

The current study was performed using a computer program entitled MTS2 (Wallace, 2010, from Dube, 1991), in which a variety of simulated AAC displays were created. The displays were presented on a 20 inch iMac. The participants worked on the computer, using a mouse to make selections. The participants were shown a photograph in the center of the computer screen. Upon clicking the photograph, it disappeared and was replaced by a display of 16 line-drawing symbols, organized in one of the four taxonomical arrangements discussed above. The arrangements were presented in a randomized order. The participant was expected to locate and click on the symbol they believed to be corresponding to the one previously presented.

Each symbol was correct on one trial, thus each session consisted of 16 trials. The order of which symbol was targeted as correct varied from session to session. Auditory reinforcement was provided in the form of a “herald” sound when the correct symbol was selected. If the participant selected an incorrect symbol, no sound was made. The computer moved automatically though the task.

Throughout the actual assessment, the administrator did not provide direct assistance. If asked for help, the administrator would simply respond “I cannot remember.” or “Which one do you think it was?” Positive reinforcement was built in through the use of the “herald” sound upon correct selection. The administrator was permitted to provide sporadic encouragement, but no specific information.

Pre-assessment

Each subject participated in a pre-exposure session. Throughout this session, the subject was presented with one of the line drawings, such as a line drawing of a swan, in the center of the display. Upon clicking the line drawing, a second display was shown in which photographs of the four different bird choices were presented in the four corners of the display. The presentation during the pre-assessment, with the line drawing as the sample and the photographs as the choices, was the reverse of the actual data collection session in which the photographs were the samples. The pre-assessment was used to prove and confirm sensory function and skills were sufficient to perform the computer task. It also assisted in pre-exposing the participants to the steps taken throughout the actual assessment. Throughout the pre-assessment the administrator was permitted to provide feedback and assistance if needed.

Chapter 3

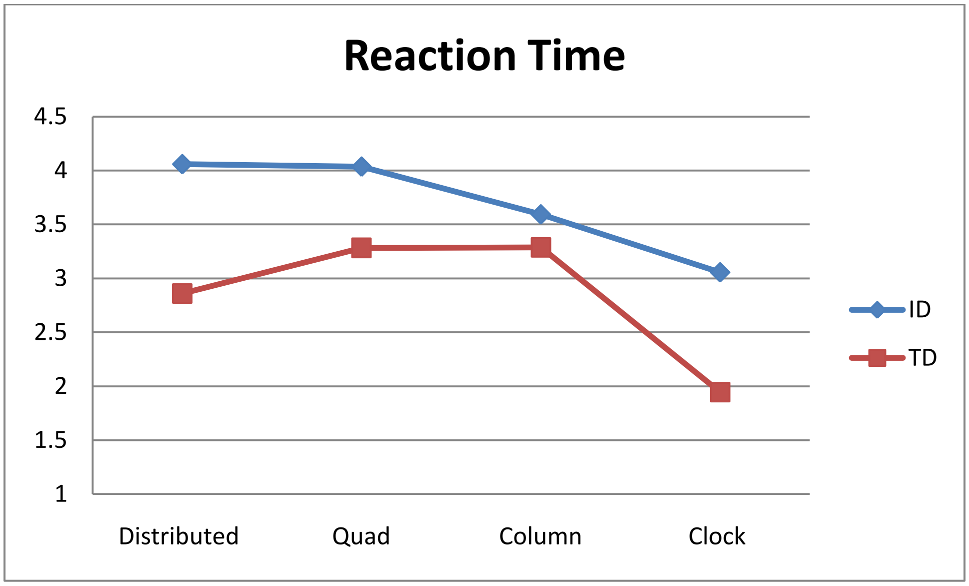
Results

Reaction Time

MTS2 recorded the reaction time beginning when the initial photograph was clicked on, cuing the array of 16 line-drawing symbols to appear, and ending when the participant clicked on a line-drawing within the array. Data analysis was completed on the median reaction time among the participants. The median was used, rather than the mean, to control the influence of single trials with excessively long reaction times which may have occurred if the participant became distraction at some point within the trial (see Wilkinson et al., 2006).

Figure 3-1 presents the average for reaction time for the participants. The blue line represents the participants with intellectual disabilities. The red line represents the participants who were typically developing. When discussing reaction time it is important to remember that a lower score depicts a smaller amount of time and thus represents the more desirable outcome.

Figure 3-1



The table demonstrates the general trend for the reaction time to decrease most for the clock condition. This reflects the most desirable outcome in which the participants took the shortest amount of time to select the correct target. For the participants with intellectual disabilities, the reaction time was highest for the distributed condition and gradually decreased across conditions. For the typically developing participants, the reaction time was highest for the column display and dropped considerably for the clock display.

Accuracy

Accuracy was recorded after the participant selected the line-drawing he/she believed to match the photograph itially shown. Figure 3-2 presents the mean of accuracy for the participants. The blue line represents the participants with intellectual disabilities. The red line represents the participants who are typically developing. When discussing accuracy it is important to remember, unlike reaction time a higher mean represents more correct responses and thus is the more desirable outcome.

Figure 3-2

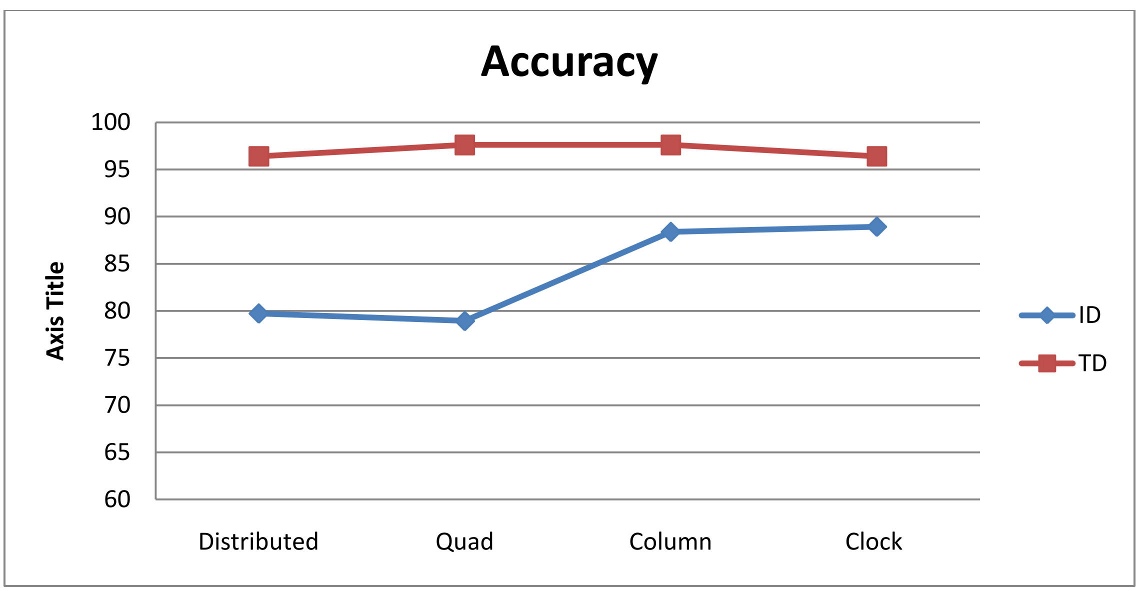


Figure 2-1 displays the accuracy across all conditions for all participants. For the participants with intellectual disabilities, the table demonstrates the general trend for the accuracy to increase for both the column and clock conditions. This increase in accuracy demonstrates more correct responses within these conditions. The typically developing participants show minimal difference across conditions, but do demonstrate a slight increase in accuracy for both the quadrant and column conditions.

Standard Deviation

Table 3-1 Means (Standard Deviation) for each condition.

	Distributed	Quad	Column	Clock
ID	79.7 (13)	78.9 (13)	88.3 (10)	88.9 (10)
TD	96.4 (3)	97.6 (5)	97.6 (3)	96.4 (5)

Statistical analysis has not yet been conducted.

Chapter 4

Discussion

This research suggests that the clock condition provides the most optimal outcome in terms of both reaction time and accuracy. This is especially apparent for the participants with intellectual disabilities. As discussed earlier, little previous research has focused on the clock condition, at least for direct selection access. The minimal research conducted has determined that although circular scanning is considered among the easiest scanning methods to learn, it does limit the number of symbols that can be presented (Glennen & DeCoste). Thus, an unanswered question, which likely must be answered on a child-by-child basis, is whether the improvements in accuracy and reaction time outweigh this constraint.

Significance of Reaction Time

For the participants with intellectual disabilities, the clock condition produced the lowest, most desirable reaction time, as well as the highest, most desirable accuracy. Although the gains in reaction time varied among these participants, on average the gain between the fastest condition (clock condition) and the slowest condition (distributed condition) was approximately 1 second. For typically developing participants, accuracy showed little variation among conditions, but reaction time produced varying outcomes. For these participants, the gain between the fastest condition (clock condition) and the slowest condition (column condition) was approximately 2 seconds. In the context of AAC, such gains are significant for both the user and communication partner (Wilkinson et al., 2008). An AAC user's process of constructing a message typically requires the selection of multiple symbols. Combining a gain of 1 – 2 seconds per symbol would increase the overall rate of communication. For example, a user wishing to construct the phrase "I want cookies and milk," could potentially reduce the message production rate by 5 – 10 seconds. For methods in which the average rate of communication is 15 words or less per minute (Beukelman & Mirenda, 2005), any reduction in message production is beneficial to the AAC user and his/her communication partner.

It is important to note that the use of the clock condition may be one of many strategies used for potential gains in message production rate. This study does not imply its use in isolation will result in the most optimal outcomes. Thus, it is suggested that this condition be used in conjunction with other techniques. Previously conducted research has yielded consistent results proving the benefits of a faster message production rate. Specifically, rate of message production has shown to influence a communication partner's perception of the AAC user he/she is communicating with. Research has demonstrated that the speed of message production in a conversation is a main contributing factor influencing whether or not the AAC user is judged as a competent communication partner (Todman & Rzepecka, 2003.) Jefferson (1989) and Newman (1982) attested that communication problems arise when gaps in communication flow reach a few seconds. Such research emphasizes the importance of message production rate for AAC users.

Significance of Accuracy

As previously stated, little dissimilarity resulted in the accuracy outcomes of the varying conditions among the typically developing participants. For the participants with intellectual disabilities, the clock condition produced the highest, most desirable accuracy outcomes. A difference of 10 was calculated between the mean of the most accurate condition (88.933), and the least accurate condition (78.933).

It is important to note that the current study did not seek to determine which aspects of the clock condition contributed to the increase in accuracy. It can be assumed that a number of aspects affected the participant's ability to select a correct response more often within this condition. Accuracy did not vary within conditions among the typically developing participants. Thus, it can be assumed that the aspects of the clock condition speculated to potentially increase accuracy solely benefited the participant's with intellectual disabilities, but did not negatively affect the typically developing participants.

As discussed previously, the clock condition does limit the number of symbols presented. Initially, this may appear to be a limitation. Upon deeper consideration, it should be considered that a smaller number of symbols places less cognitive demand on an AAC user, and thus may serve as a benefit to some. The limitation of the number of symbols presents another interesting consideration. In the distributed, column, and quadrant conditions, each symbol is arranged with a minimal of three symbols adjacent to it. That is, each symbol is surrounded by three or more symbols on each side. Many AAC users may also possess motor production difficulties (Beukelman & Mirenda, 2005). For these individuals especially, as well as those AAC user's without motor production difficulties, it is less likely an undesired symbol will be accidently selected due to its proximity to the desired target.

Current Limitations and Future Research

The sample population of the current study consisted of 5 typically developing participants and 17 participants with varying intellectual disabilities. Within the intellectually disabled population, questions remain if the effects are consistent among the differing etiologies. Also, the 5 typically developing participants provide insight into the effects of each condition, but the data could be strengthened by the addition of more subjects.

In addition, the current study investigated a specific set of conditions. Within the clock condition, the animals were arranged taxonomically along the perimeter of the display. It is undetermined if this taxonomical arrangement contributed to the success of this particular condition. That is, if the symbols were arranged in a randomly distributed order along the perimeter of the clock condition, would the outcomes have resulted the same? Additional research would be necessary to determine the effects of this taxonomical arrangement.

The current research consisted of simple targets, depicting animals, arranged in a display of 16. Many AAC devices incorporate targets depicting more complex symbols and line drawings, for example those depicting action (e.g. tying a shoe). Additional research remains relevant to determine the effects of symbol complexity. Also, the number of symbols in a display is individualized due to the need of the specific AAC user

(Beukelman & Mirenda, 2005). The exploration of the influence of the display size would provide beneficial information to clinicians constructing AAC displays.

Finally, the current research failed to examine the effect the structural characteristics of the display had on individuals who consistently use an AAC device. The population pool for this study was introduced to the AAC device and immediately observed in the initial stages of its use. It is undetermined if the effects explored are sustained over time as the individual learns and continues to become familiar with the AAC device.

Conclusion

The continuing exploration of the effects of the structural characteristics of AAC display is justified by the findings of the current research. In summary, the clock condition positively influences reaction time in typically developing AAC users, and both reaction time and accuracy in AAC users with intellectual disabilities. Additional research will provide a more detailed development of the clinical guidelines for AAC display design.

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