Research Article

The Effect of Symbol Background Color on the Speed of Locating Targets by Adults Without Disabilities: Implications for Augmentative and Alternative Communication Display Design

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Purpose: Previous research with children with and without disabilities has demonstrated that visual–perceptual factors can influence the speech of locating a target on an array. Adults without disabilities often facilitate the learning and use of a child's augmentative and alternative communication system. The current research examined how the presence of symbol background color influenced the speed with which adults without disabilities located target line drawings in 2 studies.
Method: Both studies used a between-subjects design. In the 1st study, 30 adults (ages 18–29 years) located targets in a 16-symbol array. In the 2nd study, 30 adults (ages 18–34 years) located targets in a 60-symbol array. There were 3 conditions in each study: symbol background color, symbol background white with a black border, and symbol background white with a color border.
Results: In the 1st study, reaction times across groups were not significantly different. In the 2nd study, participants in the symbol background color condition were significantly faster than participants in the other conditions, and participants in the symbol background white with black border were significantly slower than participants in the other conditions.
Conclusion: Communication partners may benefit from the presence of background color, especially when supporting children using displays with many symbols.

Children who are unable to use speech to meet their communication needs are at risk of delays in their language and communication, even when provided with augmentative and alternative communication (AAC) strategies (Brady, Thiemann-Bourque, Fleming, & Matthews, 2013; Smith, 2015). AAC may include a range of tools and techniques, often visually based, augmenting and/or replacing spoken utterances. Vocabulary is pictured on a page or on cards that a child can point to or hand to a partner.

One reason children may be at risk for communication delays is that once AAC is provided, there is much a child must learn, both about language and the use of the system. Much like learning spoken language, learning the visual language of AAC requires understanding that the language is made up of symbols. Children learning to speak, however, often have the benefit of frequent models of spoken language. Children learning to use AAC, on the other hand, often only receive models of AAC use during specific instruction time (Barker, Akaba, Brady, & Thiemann-Bourque, 2013). Furthermore, this instruction time may be limited to 1 or 2 hr per week, time that has been allotted for the speech-language pathologist to work with the child. For much of the remaining time, the child is expected to communicate using the visual means of AAC when others are using speech. The current research examines one aspect of AAC display design and how the display design might influence communication partners.

Role of Communication Partners

Communication partners are a source of input for children learning any language, whether that input is spoken or represented visually. For children without disabilities,

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the input matches the expected output; both are speech. However, children who use AAC are likely to receive qualitatively different language models compared to children without disabilities. Specifically, the input is often limited to speech, whereas the output is visual (Smith & Grove, 2003). There is a disparity between models and expectations for children who are learning to use the spoken word compared to children who are learning to use AAC. Children learning to speak are provided with hours of spoken language input and are not expected to produce spoken language during the first year of this input. On the other hand, children who use AAC are rarely provided with models of language using the AAC system (Barker et al., 2013).

Aided language modeling in AAC is an intervention that has shown promise toward reducing the mismatch between input and output (O'Neill, Light, & Pope, 2018). In aided language modeling, the communication partner points to the symbols that correspond to their spoken input, thus providing both spoken and visual input, as well as a model of AAC use. The communication partner's model supports comprehension, demonstrates expressive use of the display, and highlights the display as an acceptable mode of communication (Romski & Sevcik, 1996). Although there are several variations to language modeling (Drager et al., 2006; Goossens, Crain, & Elder, 1999; Romski & Sevcik, 1996), the general principle is that the communication partner uses the AAC display in conjunction with spoken language. Thus, the child hears the communication partner's spoken words and sees the symbols on their display that match those words. Positive outcomes have been reported, including increased vocabulary, improved sentence complexity, and increased participation by children with autism spectrum disorders (Binger & Light, 2007; Drager et al., 2006; Romski & Sevcik, 1996; O'Neill et al., 2018).

Challenges of Aided Language Modeling

Despite recognition of the value of aided language modeling, communication partners rarely provide such models (Barker et al., 2013). For instance, in a survey of teachers of preschoolers with complex communication needs, teachers reported using aided language modeling two to three times per day (Barker et al., 2013). More promising rates were reported by parents when training was provided, although there was a wide range of implementation, from 2 to 26 min of modeling per day (Jonsson, Kristoffersson, Ferm, & Thunberg, 2011). Given the evidence supporting the effectiveness of aided language modeling, why is it so rarely implemented? One possible reason could be simply a lack of awareness. A communication partner may be a parent, a peer, a teacher, or any other individual who interacts with the child who uses AAC. Often, the individual does not know the optimal way to approach, talk to, or support communication with the child who uses AAC (Kent-Walsh & McNaughton, 2005). It is also possible that the relatively low rates of modeling evidenced in previous research (Barker et al., 2013; Jonsson et al., 2011) have improved with recent research supporting aided language modeling (e.g., O'Neill et al., 2018).

Another reason communication partners infrequently model aided language may be related to the display itself. Communication partners augment spoken language using a display that is neither their primary mode of communication nor designed with their needs in mind. For example, the meaning of specific symbols may not be obvious, the size of any text may be too small to be easily read, or the number or organization of the symbols may make it difficult to find desired targets. At a basic level, it is well known that ease or difficulty of visual search for a target can be influenced by the complexity of the array (Rayner, 2009). If the communication partner perceives modeling to be difficult, it is possible they will engage in it less often. Any display should first and foremost be designed to accommodate the needs of the child using it; however, features that do not influence the child's use could be manipulated to capitalize the partner's use.

The first barrier to aided language modeling can be addressed by recognizing the critical role a communication partner plays in supporting AAC and by providing training to that communication partner. Communication partners' knowledge and skills related to AAC interventions, available technologies, and instructional strategies can support or present barriers to participation by children who use AAC (Beukelman & Mirenda, 2013). There is strong evidence for the effectiveness of partner training that includes instruction on aided language modeling. Within this evidence base, a range of communication partners have been studied, including parents and educational aides (Kent-Walsh, Murza, Malani, & Binger, 2015; Senner et al., 2019).

Display Design Considerations

The current study addresses the second potential barrier to aided language modeling by examining one design aspect of a visual display: symbol background color. Previous research has shown that children without disabilities over the age of 4 years benefit from symbol arrangement, but that presence or absence of background color did not result in significantly different accuracy or reaction times (Wilkinson & Coombs, 2010; Wilkinson & Snell, 2011). Furthermore, grouping symbols by word type (e.g., nouns, adjectives) results in faster and more accurate sentence construction by children without disabilities than when the symbols are not grouped (Thistle & Wilkinson, 2017). However, as long as the symbols were grouped by word type, including background color to cue word type (e.g., yellow background for nouns) appeared to reduce response time for some children, although this effect failed to reach statistical significance. Therefore, although symbol arrangement appears to be an important feature to include on a child's display, background color, at best, provided no benefit. Perhaps inclusion of background color would benefit the communication partner by making it easier to find symbols to model, thus potentially increasing the likelihood of modeling, which would then benefit the child's learning of the display.

Thistle and Wilkinson (2015) noted that a handful (11% of the 112 participants) of speech-language pathologists reported using background color coding to facilitate communication partner modeling. Guided search theory (Wolfe, 1994) suggests that perceptual features may reduce the set size from the entire display to just those symbols within a particular color group. For instance, a display consisting of 50 symbols may, in effect, be made smaller by grouping symbols that share some common element (e.g., part of speech, category). Although the physical grouping is important, both the guided search theory and the Gestalt principle of common region (Palmer, 1992; Wagemans et al., 2012) suggest that color can be used to further highlight the groupings. For instance, a common clinical practice is to use background color to denote the part of speech of the symbol (e.g., modified Fitzgerald key; Goossens et al., 1999). According to guided search and the principle of common region, these colors would reduce the need to visually review each symbol, allowing the individual to restrict the search just to those symbols with the assigned color according to the symbol's part of speech.

Research Purpose

It is common in visual search research to equate response time to complexity, where faster response times are indicative of an easier task (Wolfe, 1998). Therefore, the aim of this research was to examine the effect of background color cueing in adults without disabilities as one method of making aided language modeling easier for communication partners. Two studies were conducted to address this aim. Study 1 asked participants to sequence three symbols using a 16-symbol grid. Study 2 utilized a 60-symbol grid to examine if the effect depended on the size of the array. It was hypothesized that perceptual grouping provided by color would result in faster response times.

Study 1

Method

Participants

Thirty participants, ages 18–29 years (M = 21), were recruited to participate in the study from a northwestern university. All participants reported normal or corrected visual acuity, normal color vision, and no motor or sensory limitations. Approximately 13% represented diverse ethnic and cultural backgrounds. Twenty-five (83%) participants were female. The participants provided informed consent following the procedures of the university's institutional review board. Participants who reported prior experience with individuals who communicate using AAC were excluded from the study. It is possible that experience with individuals who use AAC could result in familiarity with a display organized syntactically and color coded to highlight the syntactic categories of the symbols. Thus, excluding participants who reported experience interacting with someone who used AAC to communicate reduced the possible confound such experience could introduce.

Materials

Data collection took place in an office at the university. Participants were seated at a table, with the data collection materials placed on the table in front of them. All participants completed the task using a 25.5-cm touch screen tablet running Windows 8 operating system. The tablet screen measured 13.5 cm × 21.7 cm and was propped at a 45° angle on the table. A Java-based stimulus presentation software program developed for education and research presented all stimuli and recorded responses (MTS-III; Dube, 1991). The software presented a green start button before each trial, measuring 2.8 cm × 2.8 cm. Each trial presentation featured a 16-symbol array of Picture Communication Symbols, with the written word visible under each symbol. Each symbol measured 1.6 cm × 1.6 cm. There was a 0.3-cm space between each symbol in the response array, resulting in an overall size of 7.5 cm × 7.5 cm for the entire grid. When the correct symbol was selected, the software transferred the image to an array of three blank squares located at the top of the screen, each measuring 1.6 cm × 1.6 cm, therefore eliminating the possibility for that symbol to be chosen again in the 16-symbol array.

The symbol array was arranged in the same manner for each trial and condition. The three conditions were (a) color: background color using the modified Fitzgerald key (people were yellow, verbs were green, nouns were orange, and adjectives were blue), (b) border: color coding using the modified Fitzgerald key outlining the border of the symbol only, and (c) white: color symbol placed on a white background with a thin black border.

Sentence stimuli were presented one at a time and were printed with black ink on standard white paper. Each piece of paper was covered with a page protector and placed inside a three-ring binder. The sentences were presented with the target words bolded and underlined (e.g., The **boy** **reads** the **book**).

Procedure

Participants were randomly selected to complete the experimental trial with the color, border, or white background, resulting in three groups of participants. An independent t test revealed no significant difference in age across all groups. Participants took part in one session lasting 5–10 min. For each trial, participants viewed the stimulus sentence, selected start to begin the software, and selected the symbols that corresponded to the target words in the stimulus sentence. Each condition consisted of 14 trials: The experimenter modeled the task on one trial and the participant completed the remaining 13 trials. The first of these 13 trials was considered a practice trial and was discarded from data analysis for all participants.

Procedural Reliability

An undergraduate student in communication sciences and disorders was trained on the procedures of the experiment. The student observed the experimenter during 21% of data collection sessions and noted the experimenter's adherence to the procedures. Reliability was calculated at 100%.

Accuracy and Response Time Measures

The MTS-III software recorded the symbols selected and the response time for each symbol selection within each experimental trial. An accurate response consisted of the selection of the correct symbol in the correct order given the written sentence stimuli. An inaccurate response occurred if a participant selected a symbol out of the sequential order or a symbol that was not included in the sentence stimuli. A trial was noted as incorrect if any of the three target symbols were incorrectly selected. For all data collection sessions, the researcher noted the participant's selection on a data collection form. Upon session completion, the accuracy measured by the software was compared to the accuracy noted by the researcher to ensure the accuracy of the software recording. Accuracy was calculated by counting the number of correct trials and dividing by 12 (the number of trials). The percent correct selection was calculated by multiplying this number by 100.

Response time was defined as the time to construct the entire three-symbol message, measured as the period between the onset of presentation of the 16-symbol array and the time that the participant had selected three symbols. Only correct trials were included for response time analysis.

Data Analysis

Overall, participants performed at ceiling levels, with an average of 97% accuracy; therefore, no analysis of accuracy was conducted. A one-way analysis of variance (ANOVA) measured the effect of condition (border, color, white) on response time. A mixed between-subjects/within-subject ANOVA measured the effect of time within each condition (comparing response times on the first half of trials to the second half of trials). If participants demonstrated faster response times across the second half of trials, then that could indicate learning above and beyond any effect of background color. Post hoc paired *t* tests, with a Bonferroni correction to control Type I error, were conducted to investigate pairwise differences between statistically significant effects.

Results

Across all conditions, participants averaged 97.8% (range: 83%–100%) accuracy. In fact, only seven participants achieved less than 100% accuracy, with one making two errors and six making one error across the 12 trials. This ceiling effect illustrated the overall ease of the task, and further analysis was deemed unnecessary.

A one-way ANOVA revealed no statistically significant effects of condition, $F(2, 29) = 0.245$, $p = .785$. A mixed between-subjects/within-subject ANOVA comparing the response times of the first six trials to the response times of the second six trials for each condition was conducted. The analysis revealed a significant main effect of time where response time was faster during the second half of trials than during the first half, $F(1, 27) = 7.416$, $p = .011$, $\eta^2 = .215$. Planned *t* tests revealed a significant difference between the first (4.98 s) and the second (4.48 s) half of the white condition, $t(9) = 2.49$, $p = .034$. There was no significant difference between the first and the second half of trials under either the color or the border condition.

Study 2

Given the lack of effect of background color in the 16-symbol array, a follow-up study was conducted to examine the effect of background color when searching a larger array, specifically 60 symbols. It is possible that the size of the array influences the perceptual grouping that background color could lend.

Method

Participants

Thirty participants, ages 18–34 years ($M = 20$), were recruited to participate in the study from a midwestern university. All participants reported normal or corrected visual acuity, normal color vision, and no motor or sensory limitations. Approximately 7% represented diverse ethnic and cultural backgrounds. Seventeen (57%) participants were female. The participants provided informed consent following the procedures of the university's institutional review board. As with Study 1, participants who reported prior experience with individuals who communicate using AAC were excluded from the study.

Materials

Data collection took place in an office at the university, and the procedural setup was similar to that of Study 1, using the same hardware and software to present the task and measure responses. However, the stimulus sentences and response array were different in order to examine the effect of the size of the array. Each trial presentation featured a 60-symbol array of Picture Communication Symbols (five rows of 12 symbols), with the written word visible under each symbol. Each symbol measured 1.6 cm × 1.6 cm. There was a 0.1-cm space between each symbol in the response array, resulting in an overall size of 8.7 cm × 20.9 cm for the entire grid. When the correct symbol was selected, the software transferred the image to an array of three blank squares, each measuring 1.6 cm × 1.6 cm, therefore eliminating the possibility for that symbol to be chosen again in the 60-symbol array.

The symbol array was arranged in the same manner for each trial and condition. The three conditions were the same as in Study 1: (a) color: background color using the modified Fitzgerald key, (b) border: color coding using the modified Fitzgerald key outlining the border of the symbol only, and (c) white: color symbol placed on a white background with a thin black border.

Sentence stimuli were presented one at a time and were printed with black ink on standard white paper. Each piece of paper was covered with a page protector and placed inside a three-ring binder. The sentences were presented with the target words bolded and underlined (e.g., The **farmer** **drinks** the **water**).

Procedure

Participants were randomly selected to complete the experimental trial with the color, border, or white background. An independent *t* test revealed no significant difference in age across groups. The structure of data collection sessions and trials was the same as in Study 1.

Procedural Reliability

Procedural reliability was conducted similarly as with Study 1 for 20% of data collection sessions. Reliability was calculated at 97.1%.

Accuracy and Response Time Measures

Accuracy and response time measures were collected similarly as with Study 1.

Data Analysis

Data analysis procedures were conducted similarly as with Study 1. A one-way ANOVA measured the effect of condition (border, color, white) on response time. A mixed between-subjects/within-subject ANOVA measured the effect of time within each condition (comparing response times on the first half of trials to the second half of trials). If participants demonstrated faster response times across the second half of trials, then that could indicate learning above and beyond any effect of background color. Post hoc paired *t* tests, with a Bonferroni correction to control Type I error, were conducted to investigate pairwise differences between statistically significant effects.

Results

Across all conditions, participants averaged 98.4% (range = 92%–100%) accuracy. This ceiling effect illustrated the overall ease of the task, and further analysis was deemed unnecessary.

A one-way ANOVA revealed a statistically significant effect of condition, $F(2, 29) = 20.935$, $p < .001$, with a large effect size ($\eta^2 = .608$). Post hoc analyses using the Bonferroni correction indicated that the average response time was significantly faster in the background color condition ($M = 9.29$, $SD = 1.45$) than in border ($M = 12.39$, $SD = 1.67$), $p = .003$, and white conditions ($M = 14.78$, $SD = 2.43$), $p < .001$. The average response time in the border condition was significantly faster than in the white condition, $p = .028$. Figure 1 presents the mean response times for each condition.

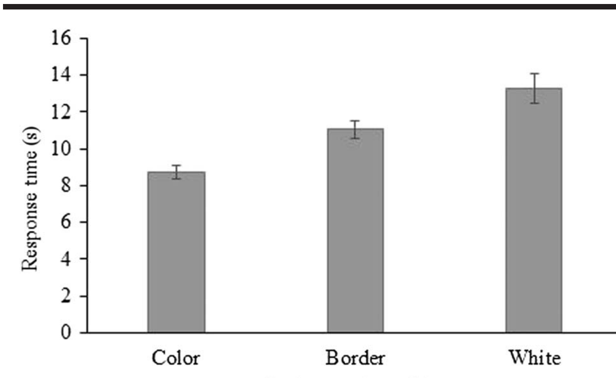
A mixed between-subjects/within-subject ANOVA comparing the response times of the first six trials to the response times of the second six trials for each condition was conducted. No statistically significant differences between the first and second halves emerged for any condition.

Discussion

The current results show that for adults, background color cues on a large array provided a distinct advantage, as measured by faster response times to sequence multiple symbols. Border color also resulted in faster response times compared to the white background condition. These results suggest that AAC displays that utilize color coding to highlight the parts of speech of the symbols may provide clear benefits for adults. The results also illustrate that the size of the array influences the effect of background color. When using a 16-symbol array, background color had no effect on adults' response times, similar to previous research that failed to show significant benefits of background color cueing for children (Thistle & Wilkinson, 2017). Of note, when using the 16-symbol array, participants under the white condition were significantly faster in the second half of trials. This illustrates an initial and early advantage of color where response times were as efficient from the first search to the last search, whereas when the background was white, participants took longer initially. This suggests that with small array sizes, background color may provide no lasting benefit for adults; however, with larger array sizes, background color may aid visual search.

Consistent with previous studies with children with and without disabilities (Thistle & Wilkinson, 2009, 2017;

Figure 1. Mean response time with standard error bars for each condition.



Wilkinson, Carlin, & Thistle, 2008; Wilkinson & McIlvane, 2013), the current study illustrates the importance of considering visual–perceptual characteristics of the AAC display. Visual attention processing research highlights the effects of the complexity of a visual array that are in line with the response data reported here. Specifically, finding a target in an array with many symbols is a harder task, resulting in longer search times, than finding a target in a simpler array (Rayner, 2009). However, research also illustrates that visual features of an array can influence the complexity, such as the grouping that occurs through the principle of common region (Palmer, 1992; Wagemans et al., 2012). The current study illustrates the effect of complexity, where participants took longer to sequence three symbols when using the 60-symbol array than those using the 16-symbol array. The background color provided grouping that reduced the complexity of the display as seen in faster response times when color was present.

It is possible that the facilitative effect for adults may ultimately benefit children if this effect supports aided language modeling. Aided language modeling in AAC is an intervention that has shown promise toward reducing the mismatch between input (spoken) and output (visual) inherent in aided AAC use (Smith & Grove, 2003). However, rates of aided language modeling reported by communication partners are low (Barker et al., 2013). One potential reason for the low rates is the complexity of coordinating a visual search for target symbols with spoken output. Furthermore, depending on the relationship, the communication partner may not have familiarity with the child's display, or may be providing modeling for multiple children, each with a different display. In the current study, both full symbol background color and color borders increased the speed with which participants located symbols. As long as the color does not detract from the child's success of using the system, a clinical implication of the current study is to include color to support the communication partner. Communication partners may be more likely to provide aided language modeling when the display includes features that guide the visual search.

Limitations and Future Directions

The goal of AAC is to support effective communication, which is a task much more complex than the experimental task utilized in this study. Although the task included some of the components required during aided language modeling (e.g., locating symbols), to adequately control responding, some ecological validity was lost, notably the complexity of speaking while searching for and selecting corresponding symbols. Future research should examine the effect of background color on aided language modeling in more realistic settings. Such a study could examine the rates of aided language modeling performed by a communication partner with different displays/children to determine if there are differences in rates or ease of using the display to model spoken language, given displays with and without background color. Future research should also examine the effect of background color on children who use larger displays. Previous research showed a trend of slower response times when backgrounds were colored compared to white, but this was limited to a small, 16-symbol array (Thistle & Wilkinson, 2017). It is possible that children would show a different pattern of responding when using larger displays.

Conclusion

The results of the current study suggest background color may benefit adult communication partners, but should also be a caution to clinicians who assume that because the background color cues benefit them, as adults, it will similarly benefit the children who use it. However, it may also be that color cues are most important with larger arrays. It is possible that the size of the array, rather than the background color, influenced the young children's responses in Thistle and Wilkinson's (2017) study. For the adults, background and border color cues facilitated search of a 60-symbol array, but response times were comparable across all conditions using the 16-symbol array. The current findings offer further evidence that principles of visual attention processing may be important considerations when designing AAC displays (Wilkinson & Jagaroo, 2004). Although previous research has examined a variety of design manipulations with children with and without disabilities (Thistle & Wilkinson, 2009, 2017; Wilkinson et al., 2008; Wilkinson & McIlvane, 2013), the current research extends to adults in order to consider the communication partner. Communication partners can play a vital role in supporting the learning and use of AAC (Beukelman & Mirenda, 2013).

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