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RESEARCH ARTICLE

Effects of background color and symbol arrangement cues on construction of multi-symbol messages by young children without disabilities: implications for aided AAC design

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ABSTRACT

Children whose speech does not meet their communication needs often benefit from augmentative and alternative communication (AAC). The design of an AAC display may influence the child's ability to communicate effectively. The current study examined how symbol background color cues and symbol arrangement affected construction of multi-symbol messages using line-drawing symbols, by young children with typical development. Participants ($N = 52$) heard a spoken phrase matching a photograph and selected line drawings within a 4×4 array. Friedman two-way ANOVAs evaluated speed and accuracy of multi-symbol message construction under four conditions in which the background color and arrangement of symbols was manipulated. Participants demonstrated significantly faster response times when symbols were arranged by word-class category compared to no symbol arrangement. The majority of children responded faster when symbols had white backgrounds, but this effect failed to reach statistical significance. This study provides preliminary evidence suggesting the importance of symbol arrangement for young children. The findings highlight the need for caution when incorporating background color on displays for young children. Future research is needed to examine the effect of visual cues on children who use AAC and consider additional factors that could influence efficacy of symbol arrangement and background color use.

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Introduction

Many individuals with significant language impairments experience limitations in their ability to use speech to meet all of their communication needs. Augmentative and alternative communication (AAC) consists of a variety of techniques that individuals may rely on when spoken communication is not adequate. Techniques that utilize resources external to the communicator, such as a communication board with visual graphic symbols (hereafter called symbols) or a speech-generating device, are called aided AAC (Beukelman & Mirenda, 2013).

The design of an AAC display relates to the physical layout of the display – where symbols are placed, their size, their color, and so forth. Wilkinson and Jagaroo (2004) have argued that the quality of the display design, and its fit with the visual-cognitive processing of those who use the display, most likely contributes to positive outcomes and the growth of communicative competence. An AAC display that is poorly designed may create unintended barriers to success because a display that is difficult to navigate likely results in more frequent errors, slower access, and general frustration for both the user and communication partners. In contrast, a well-designed display seems likely to facilitate accurate and timely message preparation. Promoting rapid and accurate message preparation is important for individuals who use AAC because such outcomes result in greater perceived competence and higher expectations by teachers and other potential communication partners (Hoag, Bedrosian, McCoy, & Johnson, 2008; Light & Drager, 2008).

A recent online survey (Thistle & Wilkinson, 2015) examined decision making in display design by clinicians working with young children who use AAC. Of the 85 respondents who answered a question about the role of symbol arrangement in display design, 93% (79) rated symbol arrangement as fairly or extremely important. Symbols may be arranged in a variety of ways on a display. For instance, symbol groupings may be based on some commonality between the symbols, which may include part of speech (e.g., nouns grouped together, verbs grouped elsewhere), frequency of use (e.g., high- vs. low-rate symbols), or related event or activity (e.g., trip to the zoo, soccer practice). To date, research examining the arrangement of symbols has focused on perceptual features of the symbols (e.g., internal symbol color, symbol meaning), more so than other display layout considerations such as taxonomic or schematic organizations (Fallon, Light, & Achenbach, 2003).

Wilkinson and colleagues (Wilkinson, Carlin, & Jagaroo, 2006; Wilkinson, Carlin, & Thistle, 2008; Wilkinson & McIlvane, 2013; Wilkinson, O'Neill, & McIlvane, 2014) conducted a series

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of studies with children without disabilities as well as children and adolescents with Down syndrome or autism, examining the effect of arrangement by internal symbol color. Participants in this line of research had age equivalences within the preschool or elementary school-age range on a measure of receptive vocabulary. Clustering like-colored symbols facilitated the speed of locating a symbol both in the behavioral response of selecting the target with mouse or finger (Wilkinson et al., 2006, 2008; Wilkinson & McIlvane, 2013) as well as in visual attention as measured via automated eye tracking technology (Wilkinson et al., 2014). This research suggests that arranging symbols that share internal color together on a grid-based display reduces processing demands, as illustrated by faster search times. Wilkinson and Snell (2011) also demonstrated the benefits of symbol arrangement using a categorical cue as an implicit cue, specifically, the type of emotion (positive or negative). When presenting 30 children with typical development aged 3;8–6;1 (years; months) with displays of emotion symbols, reaction times were faster when emotions of similar type were grouped together, than when there was no grouping. Together, this body of research illustrates that children can take advantage of the perceptual cue provided by arrangement and supports the clinical practice of providing an organization to the display.

The survey of speech-language pathologists (SLPs) conducted by Thistle and Wilkinson (2015) also highlighted that color cueing in the background of symbols on displays is a prevalent clinical practice. All of the clinicians ($n = 112$) reported using background color at least some of the time. The most common rationale was for the background color to provide a syntactic cue, where the color denotes the word class category (i.e., green background for verbs, blue background for adjectives). This is likely a reflection of a common clinical recommendation (Goossens', Crain, & Elder, 1999; Beukelman & Mirenda, 2013). Clinicians also reported using background color to draw the user's attention to specific symbols, and organize the display in support of communication partners' language modeling.

The role of background color cues as a means of highlighting word-class categories reflects the clinical recognition that message preparation involves not just the selection of single symbols in isolation, but also the construction of multi-symbol messages (e.g., sentence formation). Word order can play an important role in sentence formation and has been the target of recent intervention studies (Kent-Walsh, Binger, & Buchanan, 2015). Many high-technology devices require the individual to select symbols in the order in which they are to be spoken. Thus, in some cases the individual may come across a symbol that will be relevant later in the message construction, but is not yet the target (and thus should not yet be selected). This will require that the individual temporarily inhibits attention to that symbol, and thus likely produces demands on various attention and memory processes (Robillard, Mayer-Crittenden, Roy-Charland, Minor-Corriveau, & Bélanger, 2013; Thistle & Wilkinson, 2012, 2013). The logic of background color cueing to highlight syntactic word category is therefore to facilitate or ease the process of producing such multi-symbol messages.

While the use of background color to offer a cue to syntactic category is fairly widespread, the effectiveness of such cues has not received direct empirical study. The only studies to date have examined the role of background color to draw attention to a single target symbol presented within a larger array (Thistle & Wilkinson, 2009; Wilkinson & Coombs, 2010; Wilkinson & Snell, 2011). All of the studies examined the speed and accuracy of visual search for Mayer Johnson Picture Communication Symbols (PCS[1]; Mayer-Johnson, 1992) in children with typical development. A total of 70 children participated across three different studies, which examined whether background color cueing facilitated search for food items (Thistle & Wilkinson, 2009; $n = 30$), emotion symbols (Wilkinson & Snell, 2011; $n = 30$), or animal symbols (Wilkinson & Coombs, 2010; $n = 10$). Contrary to initial expectations, there was no benefit to search from background color cueing, in any of the studies. In fact, background color cues were observed to slow responding for search for a single symbol in all three studies, most particularly in children under the age of 4 years. Children over the age of 4 years showed either no benefit to background color or a mixed outcome. This research illustrates that regardless of the symbol category, younger preschool children (i.e., under 4-years-old) took longer to locate the target when background color was present.

Such results suggest younger children may be more influenced by manipulations of the physical features of visual displays than older children, and that background color is a visual feature that may in fact interfere with speed of responding, especially for children under 4 years old; however, these were all studies in which the search target was a single symbol, and the color cueing reflected semantic features (e.g., the color cues distinguished positive from negative emotions, in Wilkinson & Snell, 2011). The most commonly reported clinical use of background color is to provide a syntactic cue to word class category during multi-symbol sentence formulation, for instance, to facilitate the construction of multi-symbol messages, such as *I LIKE POPCORN*. It is quite possible that the results of studies of search for single symbols, where color serves a semantic cue, do not apply to search for multiple symbols, belonging to different syntactic word classes.

The aim of this study was to determine how symbol arrangement and background color cues affect construction of multi-symbol messages containing symbols representing diverse word-class categories, seeking to answer the following primary research question: First, in the absence of instruction related to the function of background color and symbol arrangement cues, what is the effect of these cues on the speed and accuracy with which children without disabilities can construct multi-symbol messages? Second, do children without disabilities show evidence of learning throughout the task, despite the lack of instruction? Finally, how do the effects differ for children under and over 5-years-old? We anticipated that symbol arrangement would facilitate performance for all participants, regardless of age.

[1]PCS™ Symbols is a product of Mayer-Johnson, LLC. Solana Beach, CA www.mayer-johnson.com

We anticipated that older participants would show no difference in performance regardless of background color cues. We anticipated that younger children would show worse performance with color cues, if the previous work on single-symbol search extended to this context. In summary, we expected similar results to those found in previous research requiring participants to locate a single symbol (Thistle & Wilkinson, 2009; Wilkinson et al., 2006, 2008; Wilkinson & Coombs, 2010; Wilkinson & Snell, 2011; Wilkinson & McIlvane, 2013; Wilkinson et al., 2014)

Method

Participants

Participants with typical development were recruited from daycares and after-school programs in one mid-west and one northeast US state. Parents/guardians of all participants provided informed consent according to the procedures of the University's Office for Research Protections. Due to the exploratory nature of this research, participants were children with typical development. Higginbotham and Bedrosian (1995) discussed the benefits of recruiting individuals with typical development when it was important to control for confounds that may manifest due to heterogeneous populations. The current study represented an initial step toward identifying the effect of specific visual features, while maintaining research control that will enable future research with specific disability populations that may benefit from AAC.

A total of 67 participants met the following inclusion criteria: (a) aged 36 to 95 months (3–7;11 years), (b) receptive vocabulary within normal limits, (c) color vision within normal limits, and (d) no reported sensory or motor limitations that interfered with the child's ability to perform the task. The age range allowed examination of age differences. Of the 67 enrolled participants, 15 (22%) demonstrated less than 50% accuracy across conditions. Given the interest in determining the influence of visual features on selecting multiple symbols to construct an utterance, it was important that the data reflect participants' sequencing of symbols. Correctly sequencing two symbols represented 67% accuracy on one trial, therefore, the 50% cut-off reflected poor performance across multiple trials. Observation of participants demonstrating this low level of accuracy revealed overall difficulty with the task, suggesting that the data did not adequately reflect the target task. Due to this poor performance, these 15 participants' data were not included in reporting or analyses, resulting in a total of 52 included participants.

Participants were primarily from middle class families and approximately 17% represented diverse ethnic and cultural backgrounds. All participants performed within expected age ranges on a standard test of receptive vocabulary, the Peabody Picture Vocabulary Test (PPVT-4; Dunn & Dunn, 2007). Research illustrates that children below the ages of 4–5 years old may respond differently to perceptual cues compared to children over age 5 (Thistle & Wilkinson, 2009; Wilkinson & Coombs, 2010; Wilkinson et al., 2006, 2008). Thus, participants were separated into two groups, those under 5 years old and those over 5 years old. The 20 younger participants ranged in age from 43 to 59 months ($M = 53$). The mean standard score on the PPVT-4 was 121 (range: 90–150). Of the younger participants, 11 (55%) were female. The older group consisted of 32 participants ranging in age from 60 to 89 months ($M = 71$). The mean standard score on the PPVT-4 was 116 (range: 90–140). Of the older participants, 16 (50%) were female.

Materials

All of the participants completed training, pre-test, and experimental sessions using a 29.2 cm touch screen tablet. The tablet screen measured 25.4 cm by 13.9 cm and was propped at a 20-degree angle from 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 visual sample in the form of a digital photograph. The visual sample photograph measured 3.8 cm ×3.8 cm. When the visual sample was touched, the software continued to show the visual sample and also presented the response array, a 4 × 4 grid of PCS symbols. Each symbol in the response array measured 2.4 cm ×2.4 cm. There was 1.5 mm between each symbol in the response array, resulting in an overall grid size of 10.2 cm ×10.2 cm. In addition, three construction placeholders appeared on the response screen. Figure 1 illustrates the software as presented in one experimental trial. The sample included a digitized recording of human speech as an auditory stimulus related to the visual stimulus. The auditory stimulus sentence forms were SVO, SVD, and VOD (e.g., *"He blows the horn," "He blows loudly,"* and *"Blow the horn loudly."*). These recordings were presented through an external speaker connected to the tablet and each stimulus phrase was repeated twice.

Procedures

Participants took part in up to five one-on-one sessions. Data collection took place at the child's day care center, after-school program, home, or the university campus lab. In each location, the exact placement and seating arrangement varied, depending on the resources of the location. Efforts were made to ensure all materials were presented at an adequate volume, participants were comfortable, and distractions were at a minimum. The experiment consisted of four parts: pre-assessment, sequence training, PCS familiarization and pre-test, and experimental tasks.

Pre-assessment

Participants first completed the Color Test by Cassiopeia Information Technologies (2013), an iPad©[2] application of the Ishihara Test for Color Blindness (Awad, Natt, & Pothier, 2007). Participants' receptive vocabulary was measured using the PPVT-4.

Sequence training

[2]The iPad© is a product of Apple Computers Inc., Cupertino, CA www.apple.com

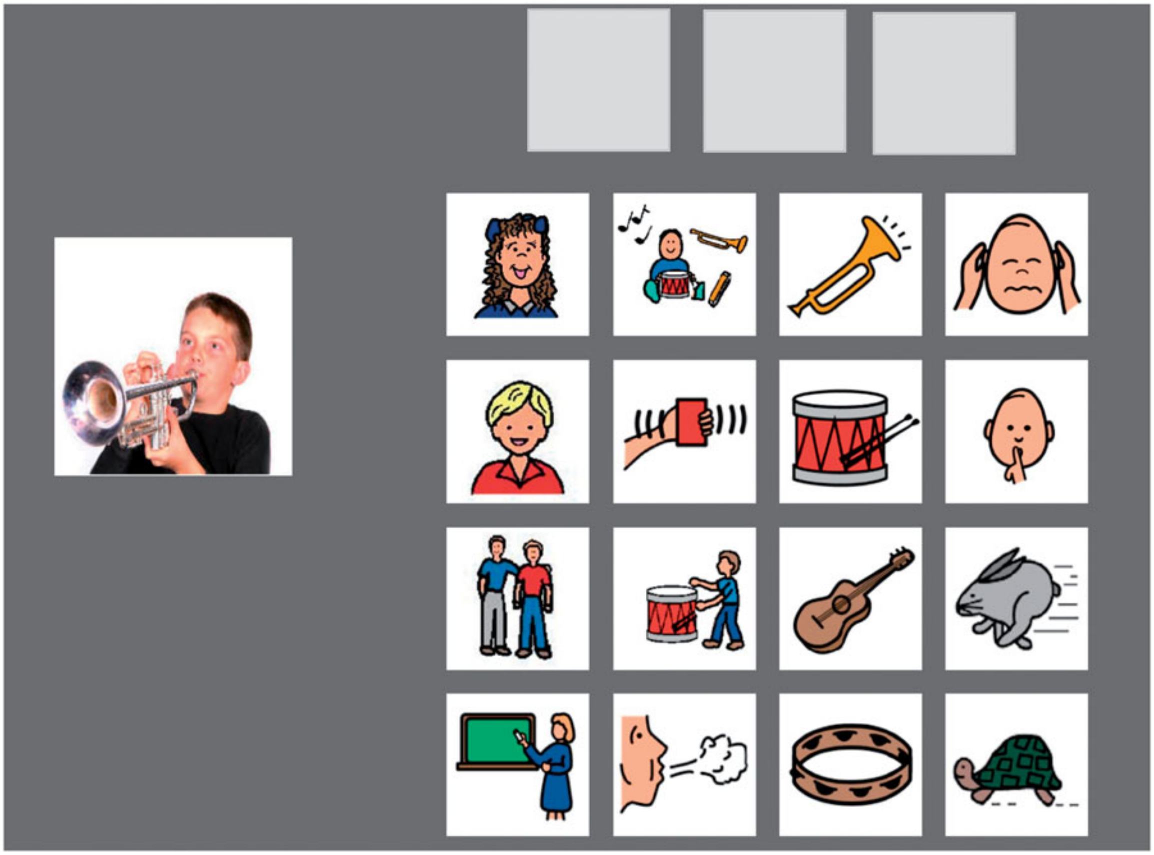

Figure 1. Screen shot of experimental task illustrating the software.

The purpose of the sequence-training task was to familiarize participants with the task of creating multi-symbol messages, in the order that the symbols were presented. During this sequence training, the layout of the display included a digital photograph and 4×4 response grid, similar to the experimental task. However, the stimulus pictures and response array symbols for training were different from those used during the experimental task, so that participants did not gain experience with the specific experimental stimuli. Participants were presented with an auditory and visual stimulus consisting of a digital photograph and three spoken words describing the photograph (e.g., *See the boy, the man, and the girl*). When they touched the stimulus photograph on the tablet, a 4×4 grid of 16 symbols appeared. Participants were asked to locate the three symbols in the grid that matched the spoken words. As part of this familiarization, the length of the sequence was systematically increased (Holcomb, Stromer, & McKay, 1997; Stromer & Mackay, 1993). For each digital photograph stimulus, there were three trials. During the first trial, the participant selected the symbol matching the first stimulus word, during the second trial, the participant selected the symbols matching the first and second stimulus words, and during the third trial, the participant selected all three symbols in the order the stimulus had been presented. For each trial, the researcher provided two repetitions of the stimulus and feedback following selection. The stimulus photographs consisted of digital photographs of children and adults engaged in throwing, biking, digging and jumping activities and did not include arrangement or color cues. The symbols on the response grid were digital photographs of individual people, actions, and objects, rather than PCS symbols, in order to differentiate this task from the experimental task.

PCS familiarization and pretest

Before undergoing the experimental conditions, participants received a brief review of the symbols to become familiar with the PCS symbols used within the experimental tasks. The researcher showed the participants a page of the symbols with white backgrounds. The symbols were grouped by word class arranged in quadrants, rather than columns, to differentiate the array from the experimental task. The researcher pointed to each symbol, labeled the symbol, and provided context for the more abstract symbols (e.g., *The turtle means slow because turtles move slowly*). Immediately after this review, participants completed the PCS pre-test using the touchscreen tablet. An auditory sample, presented through an external speaker connected to the tablet, repeated twice. The participant was instructed to touch the symbol that matched the auditory sample. The response array consisted of a choice of four symbols sharing word class (e.g., drum, horn, guitar, tambourine). The pre-test consisted of 16 trials, resulting in one opportunity to correctly match each symbol. If a participant did not score 100% on the pre-test, the experimenter reviewed the incorrect symbols and re-administered the pre-test. Of the 52 participants,

Figure 2. Symbol arrays used in each experimental condition: (a) white background, grouped symbols, (b) white background, shuffled symbols, (c) color background, shuffled symbols, and (d) color background, grouped symbols.

five (10%) required a review and re-administration of the pretest, at which point they achieved 100%.

Experimental sessions

The experimental sessions consisted of four blocks corresponding to the four possible response arrays shown in Figure 2. The condition in which there was no spatial arrangement cue was called "shuffled," and thus the four conditions were (a) white background, grouped symbols, (b) white background, shuffled symbols, (c) color background, shuffled symbols, and (d) color background, grouped symbols. Each block consisted of 13 experimental trials (one practice trial and 12 data-collection trials), allowing for a variety of sentence forms (subject-verb-object, verb-object-descriptor, subject-verb-descriptor) and multiple opportunities to use each symbol. Blocking the conditions improved ecological validity; the design of an AAC display would not vary from one message construction to another. The order of the conditions was counterbalanced using a Latin square to minimize potential order effects.

For each session, the experimenter placed the tablet in front of the child and instructed the child to use a finger to touch the symbols to repeat what the tablet said. The experimenter modeled the expected response for the first trial of each session. The experimenter provided non-specific encouragement (e.g., *Nice looking*) at regular intervals. Throughout all sessions, the experimenter noted the selections the participant made as well as any behavioral observations that may have been relevant (e.g., participant looked distracted following a noise across the room) on a data collection form.

Procedural reliability

A graduate student in communication sciences and disorders was trained on the procedures of the experiment. The student accompanied the experimenter on 15% of data collection sessions and noted the experimenter's adherence to the procedures. Procedural reliability was calculated by dividing the total number of steps adhered to by the total number of possible steps, multiplied by 100. Separate reliability was calculated for each portion of the data collection procedures: (a) pre-assessment, 96% (72 out of 75), (b) sequence training, 94% (18 out of 19), (c) PCS familiarization, 98% (56 out of 57), and (d) experimental sessions, 100% (171 out of 171).

Accuracy and response time measures

The MTSIII 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 spoken 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 spoken sentence stimuli. 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. Overall accuracy across all trials within each session was calculated by counting the number of correctly selected targets and dividing by 36 (the maximum possible correct targets). 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 to the time that the participant had selected three symbols. Trials were included for response time analysis if the participants selected correctly on two or three of the three possible targets. This cutoff was determined based on historical precedent as well as examination of the data from this study. A criterion of 100% accuracy on this task was considered far too strict, for a number of reasons; (a) using a benchmark of fully error-free performance would be inconsistent with the vast majority of clinical practices, which recognize that occasional errors are to be expected and communicative competence does not require total mastery (Light, 1989), (b) previous research using similar tasks with children without disabilities has demonstrated the substantial difficulty with transposing spoken word to symbols (Poupart, Trudeau, & Sutton, 2013; Sutton, Trudeau, Morford, Rios, & Poirier, 2010), and (c) inspection of the data demonstrated that the criterion of two or three correct selections maximized the number of data points sampled without including trials on which the integrity of the response might be questionable (i.e., trials with zero or only one correct selection).

Data analysis

Analyses utilized the median response time of the trials selected (those with two or three correct selections). The median response time represented a better measure of central tendency than the mean, as it reduced the influence of outliers (see Wilkinson et al., 2006). Data failed to meet assumptions of normality, therefore, nonparametric tests were used to examine the effects of condition for the two age groups.

Results

Figures 3 and 4 illustrate the mean accuracy (Figure 3) and median response time (Figure 4) across conditions, for the younger and older participants. A Shapiro-Wilks test of normal distributions and visual review of the histograms indicated non-normal distribution of the accuracy and response time data. Therefore, for each response variable (accuracy,

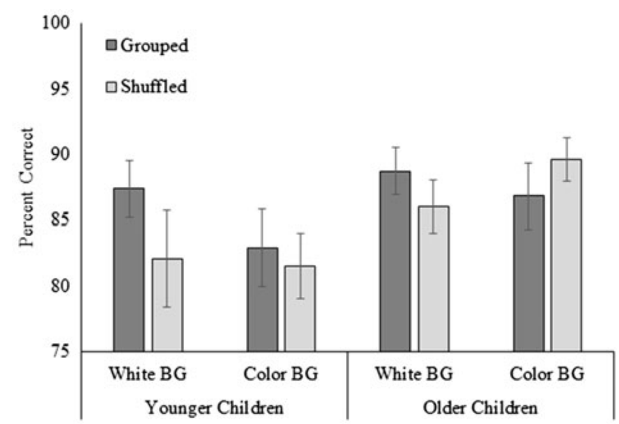

Figure 3. Mean accuracy of responding, by arrangement, color cue, and age with standard error bars. BG = background.

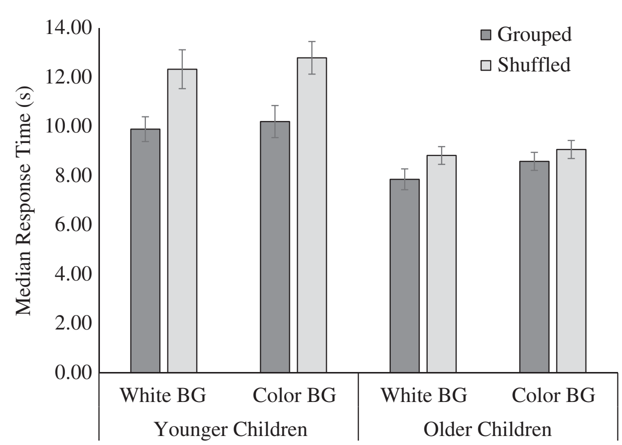

Figure 4. Median latency of responding, by arrangement, color cue, and age with standard error bars. BG = background.

response time) and each age group (younger, older), a Friedman two-way ANOVA by Ranks examined the effect of condition. The analyses revealed no significant effect of condition on accuracy for either age group. Furthermore, for older participants, response time did not differ significantly across the conditions. The response time of younger participants was significantly different across conditions, $\chi^2(3) = 11.58$, $p = .009$. Pairwise comparisons with Bonferroni correction revealed significant differences between the white-group and white-shuffled conditions, $D = 1.15$, $p = .03$, $r = .445$ and the white-group and color-shuffled conditions, $D = -1.25$, $p = .013$, $r = -.484$. This illustrates that younger participants responded faster when symbols with white backgrounds were arranged compared to when shuffled.

To examine learning that may have occurred in the absence of instruction specific to background color and symbol arrangement cues, a split-half analysis was completed. This analysis explored the possibility that experience with the response array could result in faster responding, illustrating learning related to the task in general or specific to the background color and symbol arrangement cues. For each condition, the average response time for the first six trials was compared to the average response time for the second half of the trials. Both age groups demonstrated the same trend: when symbols were grouped, regardless of background color, participants were slightly faster during the second half of trials. When shuffled, participants were faster during the first half of trials with white background symbols and faster during the second half of trials with color background. Figure 5 illustrates the mean response times by arrangement and color in the first and second halves of each session. Wilcoxon Signed Rank tests examined four planned comparisons related to the shuffled arrangement, due to the different pattern of responding evident in Figure 5. One comparison examined the differences between each first half of white-shuffled and color-shuffled, with a significant effect, $z = -3.87$, $p < .001$, with a large effect size ($r = .38$). The second comparison examined the differences between the first and second half of the color-shuffled condition, with a significant effect, $z = -3.12$, $p = .002$, with a large effect size ($r = .30$). The third comparison between each second half of white-shuffled and color-shuffled failed to reach statistical significance. Likewise, the fourth comparison between the first and second half of the white-shuffled condition did not reach statistical significance. When the arrangement was shuffled, responding was significantly slower in the first half of the color condition compared to the first half of the white condition; however, there was significant improvement in response time in the color condition from the first half to the second half of the session. The third comparison suggests that this improvement in the second half was now in line with the other response times, that is, responding in the color condition during the second half was no different than responding in the white condition during the second half.

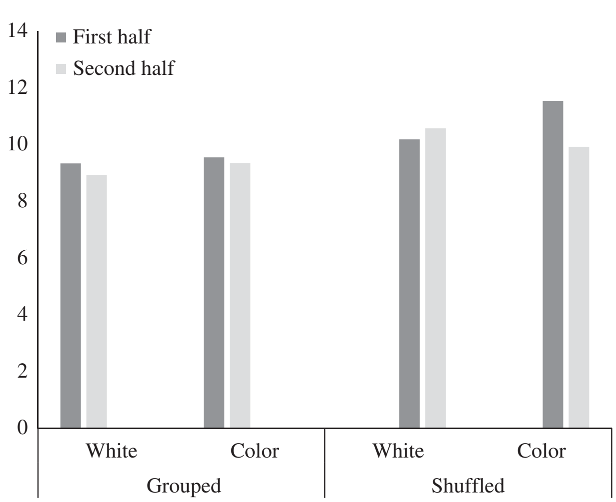

Figure 5. Mean latency of responding by color and arrangement condition in first and second halves of each session.

Discussion

This investigation provides preliminary evidence that, even without instruction, symbol arrangement, but not symbol background color cues, influences construction of multi-symbol messages in children without disabilities. The current study adds to prior work by demonstrating the facilitative effect of symbol arrangement in the context of a multi-symbol message task (e.g., sequencing symbols to repeat a spoken phrase), in which the arrangement reflected part of speech. The results of the color manipulation indicated that background color cuing had no systematic effect on either accuracy or response time, even for this task of constructing multi-symbol messages.

Clinical and scientific implications

Previous research that required participants to locate a single target symbol demonstrated that participants with and without disabilities were faster and more accurate when some type of symbol arrangement was provided, whether that arrangement was by internal symbol color (Wilkinson et al., 2006, 2008; Wilkinson & McIlvane, 2013) or membership within a category (i.e., type of emotion; Wilkinson & Snell, 2011). The current study adds evidence that arranging symbols by word-class category offers similar benefits, by reducing the time taken to construct multi-symbol messages. This decrease in response time is clinically relevant when considered within the context of the task demands of aided AAC. Any reduction in the amount of time it takes to sequence symbols will likely reduce subsequent working memory and attention demands.

A survey of clinicians revealed that 47% (53 out of 112) included background color most or all of the time and that all participants reported using background color at least some of the time (Thistle & Wilkinson, 2015). In many cases, the reason for using background color cues was to aid in multi-symbol message preparation. The current study suggests, however, that such color cues have no systematic effect on accuracy or response time for multi-symbol message preparation in children between the ages of 3 and 7 years. It is important to consider that these results were within the context of a brief task, utilizing a small number of symbols, and in the absence of any instruction to make the function of the visual feature explicit. For the younger group, accuracy was at its highest when the symbols were arranged and placed on white backgrounds (Figure 3), although this visual effect did not reach statistical significance. Likewise, the younger participants demonstrated faster response times when symbols were arranged and placed on white backgrounds (see Figure 4). This finding is consistent with other studies where the task was to find a single symbol (Thistle & Wilkinson, 2009; Wilkinson & Coombs, 2010; Wilkinson & Snell, 2011), and suggests that children do not automatically benefit from the background color coding with arrays of this size, and in a laboratory setting (these issues are considered in a later section).

Consideration of task difficulty

It is important to note that the specific repetition task utilized for this study was not communicative in nature; however, many of the component tasks may be similar to those that would be completed to communicate using aided AAC (e.g., searching for a symbol, selecting the symbol). The task required children to listen to a phrase and hold that phrase in mind while parsing the phrase into individual words, searching for the symbols that represented those words, and then selecting the relevant symbols, in the correct order. Communicating via aided AAC is likely to require many of these tasks as well as additional demands, such as managing the social interaction (cf. Thistle & Wilkinson, 2013).

The difficulty of this sequencing task is consistent with previous research illustrating that young children with typical development have difficulty translating spoken words into symbols (Poupart et al., 2013; Sutton et al., 2010). There were 15 participants who demonstrated poor performance (less than 50% accuracy) across conditions. Due to this poor performance, their data were not included in the analyses. The fact that 15 participants, all younger than 5;2 and without concomitant cognitive or language impairments, were unable to complete the task, highlights the difficulty of a task we expect young children, often with multiple disabilities, to master. Of interest, the excluded participants were of similar age, 3;1–5;2 ($M = 51.4$) and performed similarly on the PPVT-4 as included participants, with an average standard score of 108 (range: 91–124). Success with the current task was not predicated by vocabulary level, as measured in this study. It is possible that other individual factors influenced participants' ability to complete the task and could be important to tease out when considering whether to arrange a display based on parts of speech.

Moreover, among those who did complete the task, young children required 10.5 s to sequence three symbols under the most optimal condition, whereas the older children required 8.5 s. These children had no cognitive, motor, or sensory impairments, possessed several years of linguistic experience, and completed the task in an environment with limited distractions. Furthermore, no navigational skills were required because the symbols were displayed on fixed arrays.

The difficulty our participants had with this task suggests that multi-symbol message preparation using visual symbols may be a difficult task for young children. Although these data do not allow us to determine if the task would be less difficult under more authentic communication conditions, it seems reasonable to suggest that clinicians and communication partners maintain at least an awareness of the potential task difficulty and provide supports to reduce the demands for children who use AAC. At a minimum, communication partners must remember to allow adequate time for a child to construct messages. Possible supports include designing the display to optimize use, such as providing symbol arrangement, making these design strategies explicit, or providing navigation scaffolding if using dynamic page sets. It is therefore imperative that clinicians provide young children with aided AAC displays that maximize efficient and effective visual searches in order to support ease of learning and use.

Limitations and future directions

The inclusion of only children with typical development is a limitation of this study, as the extent to which these results generalize to children who use AAC remains untested. We opted to begin this line of research with children with typical development in order to examine the influence of the design features in a controlled study, with a goal of reducing individual variability. While future research is critical to determine how these results extend to children who may benefit from AAC, this study underscores the importance of conducting such research. First, study is needed to determine whether individuals with disabilities are sensitive to the cue offered by spatial arrangement, that is, how different spatial cues help (or do not help) facilitate responding in individuals who use AAC.

Second, the failure of background color cueing to facilitate multi-symbol message preparation is of critical importance to explore further, in part because it is so commonly used in clinical practice (Thistle & Wilkinson, 2015). Furthermore, the sequencing and familiarization tasks utilized symbols with white backgrounds, which may have primed participants to conditions with white backgrounds. During the sequence-training task, although different symbols were used, the array was similar to the white-shuffled experimental condition. Theoretically, it is possible that this exposure to symbols with backgrounds and no arrangement conferred some benefit; however, if that was the case, the white-shuffled condition should have resulted in the fastest response times. Of note, the split-half analysis revealed significant improvement over the course of the session when the array featured shuffled symbols with background color. It seems likely that the color cue when symbols were shuffled was, at first, distracting. Regardless of whether this was due to a priming effect from the training tasks, or an effect of background color itself, it is important to consider the potential implications of providing a task that is hard to begin with, even if experience with the task may make it easier. Communicating via AAC is difficult (Thistle & Wilkinson, 2013); any upfront demands of the task that make it more difficult may represent a barrier to successful adoption and use of the display.

It is, however, important to delineate whether there are conditions under which background color does facilitate responding. For instance, if individuals with disabilities are more sensitive to physical cues such as background color than children with typical development, it is possible they would benefit from these cues even though children with typical development do not. Alternately, it may be that the color cues only become helpful as array sizes get larger; perhaps color cues may have greater impact on message preparation when an array contains 64 symbols, as compared to only 16. A third possibility is that successful use of the background color cue may require an individual to understand and be able to articulate the arbitrary relation between the color and the word class it represents, recognizing that each color denotes a word class, and that a syntactically accurate sentence consists of different word types. This ability to attend to and manipulate language is called metalinguistics (Bialystok, 1986), and typically emerges around 5–7 years of age. The argument could be made, however, that if a child possesses this level of language, the focus should shift to encoding words and increasing literacy skills, rather than utilizing single-meaning symbols. Controlled study to identify the possible influence of each of these aspects (possible diagnostic contributions, array size, and language skill) would provide additional information and guidance as to whether or not to include background color, and under what circumstances.

This research examined performance on participants' very first exposure to each display. It therefore cannot answer questions about the long-term cost and benefit of visual features. It is possible that background color could facilitate performance after repeated experience with an array, rather than in the short-term as was examined within the current study. If this were to be the case, the short-term disadvantage, or cost, of including background color would need to be weighed against the long-term benefits. In addition, participants received no instruction or training in relation to the symbol arrangement or background color. The current study suggests that background color has the potential to increase the cognitive demands of utilizing the AAC display when implemented without any direct instruction. Perhaps more explicit cueing (e.g., *Look for a yellow word*) would be needed for participants to utilize background color cues. Providing such specific instruction could make the function of the background color more explicit, thus allowing children to take advantage of the cue. Background color cues may also be helpful for communication partners, and has been noted as one reason to color-code displays (Thistle & Wilkinson, 2015). Color cues may provide a visual organization that adults, with extensive linguistic knowledge and experience, may find easier to use to model language, thus scaffolding successful interactions with a child who uses AAC.

This research was conducted under contrived laboratory conditions, rather than within actual communication interactions. We opted for this approach in order to minimize variability that would be introduced by factors such as distraction from other children as well as the demands of natural conversation. It is now critical to examine how the findings translate into naturalistic communication interactions. Does the spatial arrangement cue continue to facilitate message preparation, even during natural conversations? Does background color cueing aid in message preparation when the greater attentional/communication demands are present? Further research is needed to answer these important translational questions.

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