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The Effects of Symbol Format and Symbol Location on Identification Accuracy

by

Haley L. Jenkins

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Speech Language Pathology

Idaho State University

Spring 2023

Committee Approval

To the Graduate Facility:
The members of the committee appointed to examine the thesis of Haley Jenkins find it satisfactory and recommend that it be accepted.

____
Kris Brock, Ph.D., CCC-SLP
Major Advisor

____
Alycia Cummings, Ph.D., CCC-SLP
Committee Member

____
Susan Tavernier, Ph.D., CNS, RN,
AOCN(R)
Graduate Faculty Representative

Human Subjects Committee Approval

January DATE, 2023
Kristofer Brock
College of Rehabilitation Comm Sciences 1311 E. Central Drive
Meridian, ID 83642

RE: Study Number IRB-FY2022-208 : The Effects of Symbol Format and Symbol Location on Identification Accuracy
Dear Dr. Brock:
Thank you for your responses to a full-board review of the study listed above. Your responses are eligible for expedited review under FDA and DHHS (OHRP) regulations. This is to confirm that I have approved your application.
Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.
You may conduct your study as described in your application effective immediately. The study is subject to renewal on or before May 24, 2023, unless closed before that date.
Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; email humsubj@isu.edu) if you have any questions or require further information.
Sincerely,
Ralph Baergen, PhD, MPH,

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The Effects of Symbol Format and Symbol Location on Identification Accuracy

Thesis Abstract--Idaho State University (2023)

Purpose: SGD interface design such as symbol format and location can increase required operational skills to help reduce device abandonment. The goal of this study was to determine effects of animation within different grid layouts.

Method: Effects on response latency and identification accuracy were examined within a 2 x 2 counterbalanced factorial design and analyzed through a 2 x 2 repeated measures ANOVA for 42 adults without disabilities.

Results: A Tukey's post-hoc analyses showed a medium to large significant interaction for all dependent variables. Specifically, participants had increased accuracy in the LC-A condition, reduced average response latency by 2.36 seconds and increased speed by the 4th trial.

Conclusion: Animation was beneficial in the location-centered grid, increasing accuracy and reducing response time. These findings add to evidence for the benefits of animation to reduce cognitive load, but future research is required to study these effects with other stakeholder populations.

Key Words: Animation; Augmentative and alternative communication; Motor learning principles, Location-centered grid display, Operational competency

The Effects of Symbol Format and Symbol Location on Identification Accuracy

Augmentative and alternative communication (AAC) refers to devices and strategies that rehabilitate, support, or replace natural speech and language secondary to a variety of disorders (e.g., autism spectrum disorder and aphasia) that leave people unable to meet their daily communicative needs (Beukelman & Light, 2020; Dietz et al., 2017; Schlosser et al., 2019). Specific to this study are speech-generating devices (SGDs) that include a dynamic visual interface where graphic symbols representing words can be arranged within a grid display and subsequently activated via direct and indirect selection to construct a syntactically correct message (Beukelman & Light, 2020; Dukhovny & Zhou, 2016). Allen et al. (2017) found that most intervention research for children with complex communication needs included grid displays with static graphic symbols; however, the number of symbols within a grid display varied. This is because children that use SGDs have various comorbidities such as attention or intellectual impairment that make grid display navigation and graphic symbol identification difficult. Creating grid displays that counteract these comorbidities is fundamental for reducing device abandonment rates. To do this, research should intertwine the latest technologies with theories of visual and cognitive processing, and motor learning. Therefore, this study will focus on these constructs with a special emphasis on animation technology and how it can benefit graphic symbol identification within different grid layout displays.

Literature Review

Motor Learning and Grid Displays

Motor learning is the concept that with repeated practice an individual can develop an automatic motor plan to improve symbol navigation and identification accuracy (Dukhovny & Thistle, 2017). One common motor plan that people develop is the ability to type on a keyboard without visual input. Like the keyboard, individuals using SGDs and low-technology AAC systems (e.g., communication books) can establish motor plans if there is consistent symbol location, uninterrupted distributed practice, and independent access to select random symbols (Dukhovny & Thistle, 2019). Dukhovny and Thistle (2019) also explained how applying these principles enhances some aspects of operational competency – notably, the ability to quickly locate and activate symbols with fewer errors to create symbol sequences (Dukhovny & Gahl, 2014; Dukhovny & Thistle, 2019). This automatic plan reduces cognitive working load and allows for cognitive resources to be diverted to more important tasks such as social communication to foster meaningful relationships and symbol sequence construction for academic purposes. However, current research in motor learning and AAC has focused on the concept of consistent and inconsistent symbol location described as "location-centered grid displays" and "size-centered grid displays" during single symbol identification tasks (Dukhovny & Zhou, 2016).

Dukhovny and Zhou (2016) investigated the effects of motor learning on identification accuracy and response time in neurotypical adults. In the size-centered grid condition, participants were trained to identify six graphic symbols in a 2x3 grid array. These six symbols were then randomly distributed into a 40-symbol array along with the 34 untrained foil symbols. In the location-centered grid condition, participants were trained to identify six different symbols that were embedded into consistent locations within the 40-symbol array. The six trained symbols never changed location unlike in the size-centered condition. Results found that participants in the location-centered grid condition had a significantly greater response accuracy (2.33x) and reduced response time (-0.33s) when compared to participants in the size-centered condition. These findings suggest that location-centered designs can be beneficial for increasing identification accuracy and reducing response times even in neurotypical adults. This information highlights the benefits from applying motor learning to SGDs and further emphasizes the need to further study motor learning in SGDs with younger participants and participants with communication disorders.

In one of the few studies that look at motor learning in children, Thistle et al. (2018) investigated the effects of location-centered grids on speed of locating target symbols in neurotypical preschoolers across five sessions. Participants assigned to the location-centered grid condition had a significantly faster response time than those assigned to the sized-centered grid design (Thistle et al., 2018). These results add to the growing body of evidence that suggests consistent symbol location facilitates motor learning and is beneficial for efficient navigation of SGDs (Dukhovny & Zhou, 2016).

In a study that combined symbol location and visual cues, Thistle and Wilkinson (2017) examined the effects of symbol background color cues (white or color) and symbol arrangement (grouped or ungrouped symbol location) on speed and accuracy of constructing multi-symbol sentences in neurotypical children between the ages of 3;0 to 7;11 years old. Results indicated that the condition which contained no background color cues but had grouped symbols had a significant positive effect on younger participants' speed when constructing the multi-symbol sentences (Thistle & Wilkinson, 2017). These findings add to previous research indicating consistent (grouped) symbol location helps individuals build a motor plan to navigate SGD systems. However, there are additional technological tools – animation in the context of this study – that could enhance identification accuracy and response times of graphic symbols depicting verbs. This is because animation has inherent explanatory power through movement, and it captures the learner's attention (Berney & Bétrancourt, 2016).

Underpinnings of Animation and Symbol Format

Animation is frequently described in research as "any application, which generates a series of frames, so that each frame appears as an alteration of the previous one, and where the sequence of frames is determined, either by the designer or the user" (Bétrancourt & Tversky, 2000, p. 5). According to Berney and Bétrancourt (2016), animation is used to serve four purposes: (a) conveying change of a dynamic system over time, (b) gaining attention through motion, (c) demonstrating concrete or abstract procedures (d) and showing completion of a process. The purposes specific to this paper are gaining attention and improving understanding of an abstract process. The stimulus movement effect states that movement is prioritized by our visual–perceptual system (Nealis et al., 1977; Samson et al., 2012). Therefore, animation can direct where children with complex communication needs look first, and previous research argues that verbs should take priority during the search process (Brock et al., 2022; Schlosser et al., 2014; 2019). Animation can also improve the guessability (naming) and identification accuracy of more complex word classes such as verbs because movement is so integral to their meaning (Brock et al., 2022; Schlosser et al., 2012; 2014).

Schlosser et al. (2019) investigated the effects of animation on identification accuracy of verbs in preschool children with mild-to-severe ASD between the ages of 3 and 7 years. Participants were randomly assigned to an animated or static condition. Participants identified Autism Language Program (ALP) animated graphic symbols depicting several verbs within a four-symbol array. Results indicated that animated graphic symbols had a significant positive effect on identification accuracy in children with ASD as compared to the static graphic symbols. These findings suggest that animation can be a helpful tool to improve navigational accuracy, speed, and understanding of symbols used within SGDs.

Similarly, Fujisawa et al. (2011) investigated the effects of animation on comprehension of verbs in students with intellectual disabilities between the ages of 11 and 18 years. In both the control and experimental condition, the students labeled the target symbol that was presented initially as a static symbol. If an error was made in the experimental condition then an animated version of the symbol was shown, while errors in the control condition provided participants with the static symbol again. Results indicated that identification of the static symbols was significantly better in the experimental condition compared to the control condition.

However, it is important to consider the possible negative effects of using animation in AAC technology to make sure they are being minimized. When used incorrectly, animation can increase cognitive demands and can promote a shallow understanding of the concept (Berney & Bétrancourt, 2016; Jones & Scaife, 2000; Lowe, 1999; Mayer & Moreno, 2002; Schnotz & Lowe, 2003). Another limitation is when animation moves too quickly and is paired with lengthy orthographic text. This requires the learner to process both the animation and the text simultaneously which leads to poorer learning outcomes (Berney & Bétrancourt, 2016). To minimize these drawbacks, animation needs to be used specifically as a tool to help facilitate understanding or for drawing attention and not as a new format to replace all static graphic symbols.

In sum, it is imperative to investigate new design features because animation and consistent symbol location have the potential to counteract comorbid impairments in cognition and attention which would result in faster access and better understanding of relevant vocabulary and overall greater operational competency skills. Research of motor learning in AAC has suggested that it helps increase the accuracy of symbol identification and reduce response time by minimizing the cognitive load that is placed on working memory (Dukhovny & Gahl, 2014, Dukhovny & Zhou, 2016; Thistle et al., 2017; Wilkinson et al., 2015). Similarly, several studies have indicated that animated symbols are also facilitative in many language-based outcomes such as naming and identification of single symbols (i.e., verbs and prepositions) as well as identification comprehension and labeling accuracy of five-symbol sequences (Brock et al., 2022; 2023; Fujisawa et al., 2011; Schlosser et al., 2014;

2019). While location-centered layouts have been shown to increase identification accuracy and reduce response times in adults without communication disorders, there are no studies that include symbol format as a variable. Therefore, the primary aim of this study was to determine if animation improved symbol identification accuracy and response latency in location- and size-centered grids.

Methodology

Participants

This study included 42 adults without disabilities who were recruited through two Communication Sciences and Disorders university programs. Participants were between the ages of 18 and 58 years (M = 26.74, SD = 7.74). There were thirty-nine females and three males. Additionally, most participants were white (n = 25) followed by Hispanic (n =8), Asian (n = 7), and Black (n = 2). Participants had no history of intellectual or neurological impairments, had normal or corrected vision and hearing, and were fluent in English.

Power Analysis

An a-priori power analysis was calculated using G*Power 3.1 (Faul et al., 2007). The repeated measures ANOVA power analysis set at alpha = .05 with an expected effect size of .25 and power level of .80 indicated that a sample size of 24 participants was required. A medium effect size was used secondary to the large differences found between animated and static conditions in previous studies (Brock et al., 2022; Harmon et al., 2014; Schlosser et al., 2014, 2019).

Experimenters and Settings

This study was completed in-person in private rooms at two university SLP clinics. The experimenters included two licensed and certified academic SLPs, one SLP graduate student, and two undergraduate students. The trained graduate and undergraduate students administered and scored all experimental procedures (including dependent variables) with 90% accuracy prior to participant data collection as judged by the licensed academic SLPs.

Research Design

A within-subject, 2 x 2 counterbalanced factorial design was used to determine the effects of symbol format (animated and static) and location (size- and location-centered) on the response latency (seconds) and identification accuracy (percentage) of graphic symbols depicting verbs. Each participant took part in all four conditions: animated-location centered, static-location centered, animated-size centered, and static-size centered. All allocations to task conditions were counterbalanced and took place during a single session.

Materials

Verbs

A total of 24 transitive verbs were used in this study: shake, bounce, spin, hug, wave, lift, draw, push, kick, blow, sing, kiss, throw, drop, ride, catch, pull, close, cut, read, eat, hit, open, and cover. The verbs were evenly split into four groups that corresponded to the four experimental conditions. This was done to rule out any learning effects. Paired samples *t*-tests indicated that each experimental condition was equal and not significantly different (*p* value range = .13 to 1.00) with respect to age of acquisition (Kuperman et al., 2012), word frequency (Van Heuven et al., 2014), and imageability (Scott et al., 2019) ratings of the target verbs. In addition, 19 other verbs were used as foils in the experimental identification task. The mean age of acquisition for all verbs was 4.32, while the mean word frequency and imageability ratings were 121.55 and 5.23, respectively.

Graphic Symbols

ALP Animated Graphic Symbols depicting the 24 target and 19 foil verbs were used in this study. Static symbols were taken directly from a frame of the animation and animated graphic symbols were set to a 2-3s loop to control for repeated looping effects (see Schlosser et al., 2014).

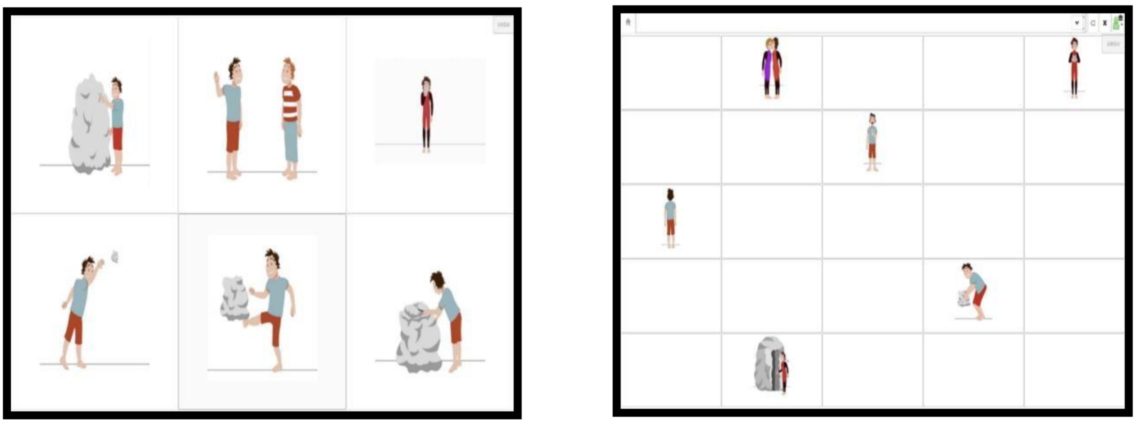
Grid Layouts

This study used two types of grid layouts described by Dukhovny and Zhou (2016): location-centered grid and a size-centered grid. The location-centered grid was consistent with the principles of motor learning; that is, verb symbols were in the same place across all training and experimental trials (see Dukhovny & Zhou, 2016). The size-centered grid included verb symbols that changed location in the experimental trials. Within these grids, the target verbs were presented as either an animated or static symbol and the foils remained as static symbols in all conditions. The foils were static because dozens of simultaneously looping symbols is not conducive to symbol navigation and identification. This is consistent with previous research stating that animation cannot replace static symbols, rather, animation is a tool for learning (Brock et al. 2022; Schlosser et al., 2019).

Training grids were used during the familiarization tasks, with a 2x3 (6 symbols) training grid for the size-centered condition and a 5x5 (25 symbols) training grid for the location-centered condition. Both size- and location-centered training grids only included the 6 target verbs in an animated or static format depending on the condition. This was done to ensure that participants understood the verb symbols and knew which symbols they would be searching for in the experimental grids. See Figure 1 for a visual representation of the training grids.

Figure 1

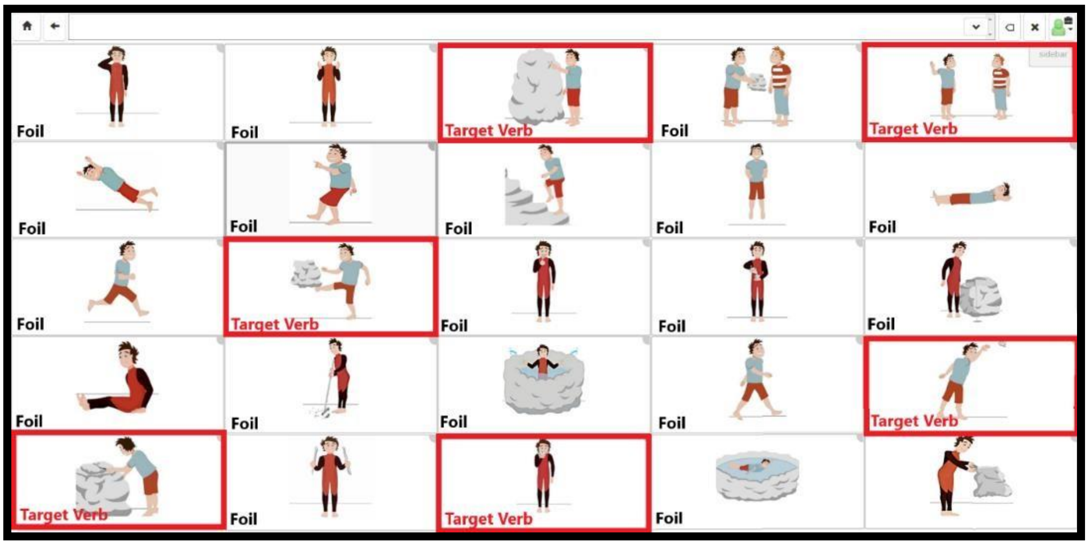
Size-centered and Location-centered Training Grids



Experimental grids were used during the identification task. There were four different 5x5 (25 symbols) experimental grids based on symbol format and grid type: (a) animated graphic symbols in a location-centered grid (b) static graphic symbols in a location-centered grid (c) animated graphic symbols in a size-centered grid and (d) static graphic symbols in a size-centered grid. Each experimental grid included the 6 target verbs and 19 foil verbs. In the size-centered condition, the differences between the 2x3 training and the 5x5 experimental grid represented the change in symbol location that occurs when SLPs do not plan for incorporating new symbol vocabulary (i.e., symbols are not consistently placed). In the location-centered grid, the 5x5 training and experimental grid represented consistent symbol location when the SLP incorporates new vocabulary. Figures 2 and 3 provide a visual representation of all grids across the symbol format conditions.

Figure 2

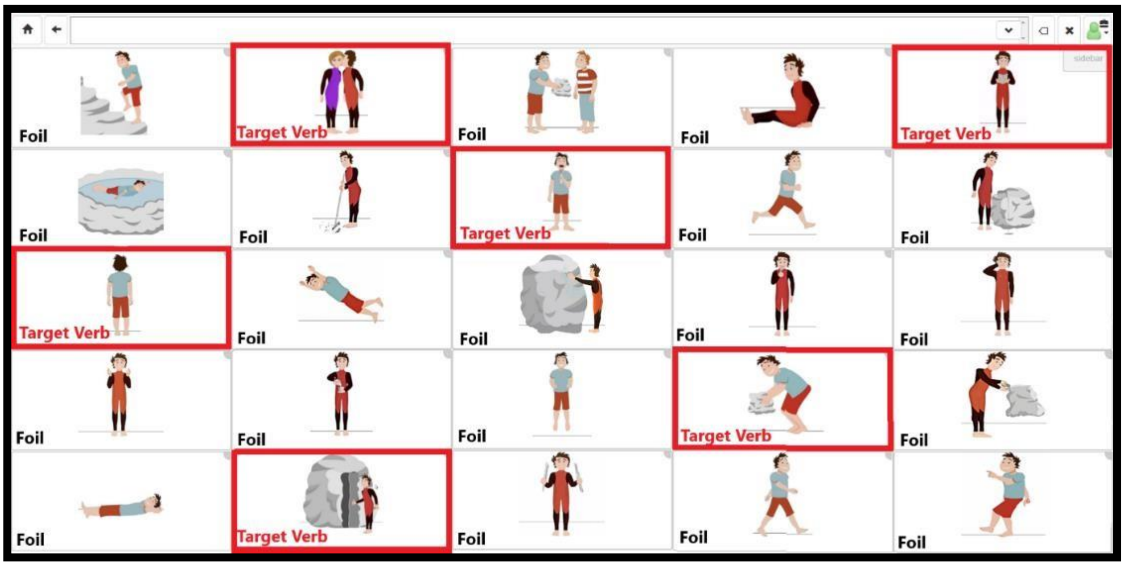
Size-centered Static Experimental Grid Schematic



Note. During the experiment, size-centered grid verbs (foils and targets) were randomly assigned a different location each trial to prevent motor learning given that the primary purpose of the study was to investigate the impact of symbol format on identification accuracy and speed.

Figure 3

Location-centered Static Experimental Grid Schematic



Note. The location-centered grid verbs were consistently placed in the same location for each trial.

The identification task included four trials per target verb for a total of 24 trials. The location of the target verb remained the same in the location-centered grids to facilitate motor learning. In contrast, the location of target and foil verbs in the size-centered grids changed each trial to minimize motor learning while also documenting how symbol format directs navigation and speed. Finally, the location of target verbs was not repeated between the four experimental conditions to minimize learning that could occur between conditions.

Hardware and Software

All tasks occurred on a 20-inch computer that had a touch screen ability and were presented using CoughDrop AAC web-based software. A Go-Pro camera was used to record the computer screen as a back-up in case of technical errors.

Procedures

Familiarization Trials

At the beginning of the 30-minute session, participants learned about AAC, SGDs, and individuals who use graphic symbols to communicate (See Appendix A). Next, the experimenter showed the participants how to select symbols on CoughDrop's web based AAC platform. Then experimenters introduced the participants to the first counterbalanced training grid on the CoughDrop web based AAC site. The order of presentation of the verbs in each condition was randomized once and subsequently presented to all participants in that order. The experimenter auditorily asked participants to identify each of the six target verbs in the training grid by touching the appropriate symbol four times. Each target verb was identified four times for a total of 24 trials (6 verbs x 4 trials). This procedure confirmed the participants' ability to access and identify the target verbs. Failure to identify the correct verb required the experimenter to ask the participant to label the specific verb symbol again to ensure knowledge of the verbs. All participants had 100% identification/labeling accuracy before engaging with the experimental grids.

Experimental Trials

Participants were then introduced to the 5x5 testing grid that included the 6 target verbs from the training grid and 19 foil verb symbols via the CoughDrop AAC website. The order of verb presentation for each counterbalanced condition was randomized once and subsequently presented to all participants in that order. Participants saw a green screen with a button labeled '1' that had an audio recorded direction asking them to locate a specific verb symbol. Participants were then directed to provide either a verbal or non-verbal "ready" signal and then the experimenter clicked the 'thumbs-up' button which audibly produced the word, "start" that initiated the trial and showed the experimental grid with all 25 verb symbols. Synthetic audio feedback (e.g., "Good job!") was presented after the participant selected a symbol. Each verb was presented four times for a total of 24 trials. Verbal reminders of which target verb the participant had to find was provided by the experimenter upon request from the participant. No modeling or affirmative feedback was provided during the experimental grid tasks. A Go-Pro was used to record the session to document accidental symbol selections and provide a back-up in case of technical errors.

Dependent Variables and Measures

The dependent variables for this study were identification accuracy (%), response latency (seconds) and change in response latency from trial 1 to trial 4 (seconds) of correct responses. Identification accuracy included a binary score (0 incorrect or 1 correct). Correct responses were counted as those that occurred before 20 seconds and were correct. Additionally, the first verb identified was the symbol scored to ensure consistency across participants and ensure inter-observer reliability. Response latency was defined as the time between the selection of the ‘thumbs-up’ symbol and selection of a symbol on the experimental grid. Response latency was obtained from the data stored on CoughDrop’s AAC data log. Any reaction time greater than 20 seconds was counted as incorrect and correct selections of any time less than 20 seconds were counted as correct. The change in response latency from trial 1 to trial 4 was measured through subtracting the average response latency of trial 1 from the average time of trial 4 within the same condition.

Reliability

Inter-Observer Agreement

Inter-observer agreement (IOA) data was collected for 30% of participants at random and was scored from the CoughDrop data-logs. Two trained graduate and undergraduate SLP students served as the blinded, independent observer to score the participants’ responses. To determine IOA, the experimenter’s responses were compared to independent observer’s responses. IOA was expressed as a percentage by dividing the number of agreements by the total number of trials and multiplying by 100. For the 30% of the data collected IOA was determined to be 99.6%.

Procedural Integrity

A procedural integrity checklist was created to ensure that the following protocol was followed: (a) consent forms and demographic information were collected (b) the go-pro was set to record (c) participants were introduced to AAC (d) training task, (e) experimental task. Data was collected for 30% of the participants at random and was calculated by dividing the number of steps followed by the total number of steps and multiplied by 100. For 30% of the data collected procedural integrity was determined to be 100%.

Data Analysis

A 2 x 2 repeated measures ANOVA was conducted to determine the effects of symbols format (animated and static) and grid layout (size- and location-centered) on identification accuracy and response latency. Identification accuracy was expressed as a percentage while response latency was measured to the nearest second. Tukey corrected post-hoc analyses were conducted to analyze an interaction between symbol format and grid layout. Effect sizes were also provided to determine the magnitude of the experimental effects. Order and learning effects are not present in this study because each experimental condition used different verbs and randomized symbol placement.

Results

Identification Accuracy

For adult participants, the repeated measures ANOVA revealed a significant main effect for symbol format ($F(1,41) = 12.78$, $p = <.001$, $\eta p^2 = 0.24$) and symbol location ($F(1,41) = 5.04$ $p = 0.03$, $\eta p^2 = 0.11$). Tukey’s post-hoc analyses confirmed that adult participants identified animated symbols and symbols within a location-centered grid layout with more accuracy than static symbols and symbols within a size-centered grid layout (see Table 1). Additionally, there was an interaction between symbol format and location ($F(1,41)$

= 4.28, $p = 0.045$, $\eta p^2 = 0.09$). Specifically, adult participants had increased accuracy in the LC-A condition compared to all other conditions: SC-A, LC-S, and SC-S (see Table 1).

Averaged Response Latency Across Trials

A significant main effect for symbol format ($F(1,41) = 15.18$, $p = <.001$, $\eta p^2 = 0.27$) and symbol location ($F(1,41) = 626.15$ $p = <.001$, $\eta p^2 = 0.94$) was found. Tukey's post-hoc analyses revealed that adult participants had significantly ($p < .001$) reduced response latency with static symbols and symbols within a location-centered grid layout than animated symbols and symbols within a size-centered grid layout, respectively (see Table 1). Additionally, there was a significant interaction between symbol format and location ($F(1,41) = 20.37$, $p = <.001$, $\eta p^2 = 0.33$). The LC-A condition was found to significantly reduce response latency by 2.36 seconds compared to the SC-A condition and by 1.73 seconds compared to the SC-S condition. However, there was no significant response latency difference between the LC-A condition and the LC-S condition (see Table 1).

Change in Response Latency from Trial 1 to Trial 4

There was a significant main effect for symbol format ($F(1,41) = 12.96$, $p = <.001$, $\eta p^2 = 0.25$) and symbol location ($F(1,41) = 13.24$, $p = 0.002$, $\eta p^2 = 0.20$). Post-hoc analyses revealed that target verbs were located significantly faster by the fourth trial when represented as animated symbols ($p < .001$) and in location-centered grid displays ($p = .002$) compared to static symbols in size-centered grid displays, respectively (see Table 1). A significant interaction was found between symbol format and location ($F(1,41) = 20.16$, $p = <.001$, $\eta p^2 = 0.33$). Participants showed a significant ($p < .001$) increase in speed by the fourth trial across all experimental conditions except for the SC-S condition (see Table 1). Lastly, this increase in speed was not statistically significant between the LC-A condition and the LC-S and SC-A conditions.

Table 1

Descriptive Statistics for Symbol Format and Location across all Outcomes Measures

Outcome measure	Symbol format	Location	*M*(SD)
Identification accuracy	Static	Location Centered	96.03(6.54)
		Size Centered	95.83(4.80)
	Animated	Location Centered	99.80(1.30)
		Size Centered	96.43(4.99)
Average response latency	Static	Location Centered	1.55(0.52)
		Size Centered	3.18(0.71)
	Animated	Location Centered	1.45(0.39)
		Size Centered	3.81(0.84)
T1 – T4 response latency change	Static	Location Centered	1.02(0.91)
		Size Centered	-0.23(0.91)
	Animated	Location Centered	0.89(0.71)
		Size Centered	1.02(1.43)

Note. Positive T1 – T4 response latency means indicate faster response latency times on the fourth trial while negative means indicate slower response latency times on the fourth trial.

Discussion

The current study is the first to investigate the effects of symbol format on identification accuracy and response latency within different grid layouts (location-centered; size-centered). Overall, results supported previous findings indicating that location-centered grid layouts improved identification accuracy and reduced response time compared to size-centered grids. Additionally, animation was facilitative and provided a synergistic effect when combined with location-centered grid layouts. However, while these results add to the interface display literature, the data are not ecologically valid as they include typically developing adults. Although the data is promising, it warrants future research in this area.

Symbol Format

Identification Accuracy

Symbol format research focused on animation as a tool to facilitate the understanding of concrete or abstract procedures, manipulating attention, and showing the completion of a process (Brock et al., 2022; Berney and Bétrancourt, 2016; Schlosser et al. 2019). This study, which is consistent with previous research, found that participants identified animated symbols representing verbs with significantly greater accuracy compared to static symbols (Brock et al., 2022; Schlosser et al., 2019). Although in Schlosser and colleagues' (2019) study, autistic children demonstrated a larger change in accuracy between symbol format conditions – which is consistent with the hypothesis that interface design features such as animation may be more pronounced in children with and without disabilities. Moreover, Fujisawa et al. (2011) stated that animated symbols facilitated verb learning, especially in younger neurodivergent children. Overall, data from this study reinforces symbol format research over the last decade – notably, that animation is a tool to improve comprehension and identification single symbols as well as construction of multi-symbol sequences.

Response Latency

Data from this study identified that animated symbols on average do not significantly reduce response latency when compared to static symbols. These data are substantiated by previous work indicating that for animation to not increase cognitive demands they must be repeated in a slow unfolding looping fashion (Berney and Bétrancourt, 2016). Thus, individuals with cognitive impairment who use SGDs are likely to maintain attention for the whole duration of the 3s loop. However, many of the adult participants commented that they had to watch the animated symbols unfold in their entirety because some symbols could look alike as they looped (e.g., CLOSE and OPEN). However, post-hoc analyses revealed that target verbs were located faster by the fourth trial when represented as animated symbols than as static symbols. A potential explanation for this change could be due to the fact that after familiarization with the graphic symbol a participant may be less likely to need to watch the entirely of the loop and instead can rely on the attention gaining feature of animation to quickly identify target verbs. As this learning occurs, it could signal that the animation tool is no longer needed; however, future research is warranted for such a claim.

Symbol Location

Identification Accuracy

Like the current study, results from Dukhovny and Zhou (2016) indicated that the use of location-centered grid displays did significantly increase identification accuracy. In their study, Dukhovny and Zhou reported that, participants were around 2.33 times more likely to get a correct response in the location-centered grids. While the current study contained more adult participants, it had fewer total symbols within a grid (5x5 vs 5x8). With fewer symbols to search between, the current study may have made it easier to find symbols within a size-based grid, impacting the differences between the location and size-centered conditions. Overall, identification accuracy is a quick method for measuring motor learning in both research and clinical settings.

Response Latency

Adult participants from previous research took on average 0.33s longer to identify symbols in the size-centered condition compared to the location-centered condition (Dukhovny & Zhou, 2016). In The current data, the differences were more pronounced with participants selecting a symbol on average 1.99 seconds faster in the location-centered grid than the size-centered condition. Additionally, target verbs were selected faster by the fourth trial in the location-centered condition compared to in size-centered grid displays. This indicated that participants developed a motor plan by the fourth trial.

Finally, Dukhovny and Thistle (2017) identified three stages of motor learning (1), cognitive stage (2), associate phase (3), autonomous stage. Based on anecdotal accounts during administration of the experimental tasks, several participants placed their finger at the exact location of the target verb prior to the graphic becoming visible, indicating an autonomous stage of motor learning had developed.

Symbol Format and Location Interaction

For all three dependent variables, there were significant interactions between symbol format and grid layout. Specifically, the LC-A condition was associated with increased identification accuracy and reduced response latency when compared to the other conditions. The significant difference of accuracy in the LC-A condition compared to all other conditions may likely be due to multiple factors. First, when verbs and prepositions are presented as static symbols they are less transparent because motion-related characteristics are lost, which can make them difficult to understand. For example, the static symbol depicting “sit” may be represented by a person sitting on a chair, and a beginning communicator may interpret the symbol as “chair” (Schlosser et al., 2019.) Animation has the added benefit of movement to help convey change overtime which in turn may reduce the amount of direct instruction or errored selections. More importantly in the context of this study, animation grabs the attention of the learner because the motion perception system is early developing and relatively robust (Braddick et al., 2005). Therefore, the learner has the chance to find the animated symbol faster and attend to the symbol for a longer period of time than the static counterpart. This is due to the fact that learners are required to watch the full animated loop in order to avoid shallow processing. Second, with a location-centered grid layout, the goal is that the client will reach the autonomous stage in which they do not rely on visual search. Rather, the established motor plan for a symbol is an automatic process requiring little conscious effort. The effects of motor learning at this stage means that animation would no longer be beneficial and the symbol should be transitioned to the static counterpart. Although in the earlier stages of motor learning (e.g., cognitive and associative stage) participants are still required to complete a visual search and they rely on visual characteristics of the graphic symbol, which is where animation comes in. At this beginning stage, the visual search process is facilitated by animation’s attention gaining properties consistent with the stimulus movement effect which draws the eyes of the individual to a target verb (Schlosser et al., 2019.) However, once looking at the target, participants often watch the animated symbol loop in its entirety to facilitate understanding of the symbol and reduce shallow comprehension. Then once the graphic symbol became more familiar, the participants no longer had to watch the entirety of the loop and instead could maximize on animation's attention gaining properties, leading to faster response times by the 4th trial.

A possible explanation for the increased speed of selection by the 4th trial is that motor learning occurred in the location-centered grids. This allowed participants to make faster selections because motor schema took over in lieu of a visual search strategy. While the LC-A did produce faster selections (1.45 seconds average) compared to LC-S (1.55 seconds average) this difference was not significant. Additionally, the SC-A condition also produced faster response times by the 4th trial. Since this condition does not rely on motor learning, and the increase in speed by the 4 trial was not seen in the SC-S condition, animation can be assumed to play a role in reduced response time.

Limitations and Future Directions

There are limitations with this current study. The main limitation was that participants consisted of mostly white twenty-year-old college-educated females without disabilities that were tasked with identifying verbs through single symbol selection void of communicative function. Therefore, the results of this paper can only act as preliminary evidence for the effectiveness of using animation as a tool within a location-centered grid layout to increase accuracy and facilitate motor learning. However, previous research has posed that children and adults with disabilities who commonly use SGDs do develop motor plans similar to typically developing peers (Dukhovny & Thistle, 2017; Burtner et al., 2014, Latash, 2007; Thorpe & Valvano, 2002, Dziuk et al., 2007.) Therefore, this study is exploratory in nature for identifying synergistic effects of implementing both symbol format and grid layout designs on motor learning, cognitive processing, and visual processing. Additionally, symbols in this study were displayed using a 20-inch screen and were in a 5x5 grid, therefore the size of symbols present were generally larger than found clinically. Lastly, it is also important to note that response latency was measured on two different campuses and Wi-Fi connectivity may have impacted these data.

Future studies should examine these effects in children with and without developmental disabilities as well as populations who typically use AAC systems. This would provide better clinical insight into how symbol format and grid type impact identification and response latency. Recent work also indicates that animation improves symbol sequence comprehension and labeling (Brock et al., 2022). Therefore, the effects of animation and location-centered grids on symbol sequence construction must be investigated. Additionally, maintenance of motor plans and factors impacting how animation is used as a tool (e.g., duration that an animated symbol is kept before being replaced with static counterpart) should be investigated to develop best practice recommendations.

Clinical Implications

Both animation and location-centered grid have systematic research supporting the benefit of implementing these two SGD interface design features on identification accuracy and response latency. The current study maintains that animation is not meant to replace static symbols entirely, instead it should be used as a tool for introducing new verb or preposition. Two methods for using animation as a tool are the just-in-time (JIT) approach where the animation can be engaged upon swiping across the symbol (Schlosser et al., 2016) or by switching to the static symbol after reaching a specific level of mastery. Based on Dukhovny and Thistle's (2019) discussion on the stages of motor learning, effects of animation would be most apparent during the cognitive and associative stages but would plateau once an individual reaches the autonomous stage. Therefore, animations may be switched to static counterpart symbols when an individual reaches the end of the associative phase or at the autonomous stage of motor learning. However, while this last stage of motor learning was demonstrated by the 4th trial in this study with adult participants with no disabilities, this level of motor learning is uncommon for individuals who use SGDs (Dukhovny & Thistle, 2017).

Clinically, Thistle and Wilson (2015) reported that 32% of SLPs mention motor learning development as a consideration factor while designing grid displays. Additionally, Boster & McCarthy's (2018) paper which reported five out of seven (71%) SLPs used consistent grid layout designs for their clients with autism. After just over a decade, it appears that evidence-based practices regarding location-centered grid layouts and animation are moving toward becoming clinical best practices. However, despite this research progress, symbol format has remained an elusive design feature in clinical practice. A main contributing factor for this delay in clinical application is that most AAC companies do not have the capability to insert animations. Currently, CoughDrop and Avaz allow for animation, but for animation to become a clinically feasible tool, AAC companies need to develop this feature as an option.

Other confounding variables that need to be addressed prior to the application of animation clinically are animation design and looping confounds associated with words that are direct opposites (Brock et al., 2022; Schlosser et al., 2019.) This looping confound can be easily circumvented by turning off the animation for closely linked words. Clinicians should be mindful when introducing new vocabulary to the client to stagger opposite words so that only one will be animated at a given time.

Lastly, the most prominent clinical application for animation within a location-centered grid layout is the potential it has for reducing cognitive resources required for navigating and using SGDs efficiently. The ability to navigate efficiently through the SGD to create symbol sequence is an important skill. However, individuals who use SGDs often have ungrammatical, slow communication which leads to high device abandonment rates before a client can reach the automaticity stage (Dukhovny & Thistle, 2019; Dukhovny & Zhou, 2016; Dukhovny & Gahl, 2014). This study theorizes that facilitation of operational competency would occur through motor learning, with animation's attention-gaining effects increasing speed of acquisition of the initial two stages of motor learning. Therefore, animation and location-centered grid layouts, which significantly increased accuracy and reduced response latency, may facilitate effective and efficient communication for these individuals.

Conclusion

This study is the first to test the effects of symbol format and grid type on identification accuracy and response latency. Animations had a positive effect on identification accuracy within a 5x5 grid and provided a synergistic effect when combined with location-centered grid displays. Animation in a location-centered grid display produced the highest level of identification accuracy compared to all other conditions. While animation did not significantly reduce average response time, it did reduce response latency by the 4th trial compared to the static conditions. These synergistic effects of animation provide preliminary evidence that animation, when used as a tool, could reduce cognitive resources required for communicating by increasing operational competency. Subsequently, these two interface design characteristics could allow children to reach to automatic stage of motor planning more quickly, potentially reducing device abandonment rates.

Data Availability Statement

The dataset from this study is not publicly available as it is being used for external grant submissions.

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Appendix A

Script for Introducing AAC

AAC refers to Augmentative and Alternative communication and is used with individuals who have difficulty communicating using their natural speech and language. It can be used to supplement someone's natural speech or replace it entirely. People that commonly use AAC to help them communicate are people with autism, cerebral palsy, head injuries or aphasia after a stroke and much more. AAC can be simple like gestures or a printed picture board which is what we call No or Low tech AAC. It can be more complex like an app on an iPad that will generate a speech output if someone selects a graphic symbol that represents a word which is considered Hi-tech AAC (ASHA, n.d). This last type of AAC is what is called Speech Generating Devices (SGDs) and is the type that we will be using in this study. We will first show you what it looks like on a computer using the CoughDrop web based AAC software and then we will teach you how to use it for activities in our study. Do you have any questions?