Abstract: The purpose of this study was to evaluate the effects of different speech-generating device displays and vocabulary organizations on the acquisition of multi-step requesting responses in children with autism spectrum disorder (ASD). Four young children with ASD were taught to use an iPad® application to make requests using both a taxonomically-organized grid display and a schematically organized visual scene display or hybrid. The conditions were compared using a multielement design. Time delay and least-to-most prompting were used to teach responses in both conditions. Three participants met mastery criterion for acquiring requests with the schematic display but did not meet criterion requesting with the taxonomic display. A fourth participant learned to make requests with both displays but showed generalization only with the schematic display. Error analyses indicated there were different types of errors made across conditions, which may suggest the need to tailor intervention methods to specific displays. Implications for the design of AAC displays, assessment, and interventions are discussed.

Children with autism spectrum disorder (ASD) who have limited to no vocal speech (estimated to be around 20% of this population; Armstrong & Jokel, 2012) are often considered candidates for augmentative and alternative communication (AAC). Research suggests that although individuals with ASD may acquire a variety of AAC systems including manual sign, non-electronic picture-based systems, and speech generating devices (SGDs), SGD acquisition is often efficient and frequently a preferred method of communication (Gevarter et al., 2013). Until recently, the use of SGDs for young children with ASD may have been limited, but easily accessible, inexpensive, portable SGD systems are now available via AAC applications on multimedia devices such as the Apple iPad® and iPhone® (Shane et al., 2012).

Traditional SGDs have often utilized grid-based displays, where vocabulary items are presented as graphic symbol buttons (programmed with voice output) in rows and columns (Drager et al., 2004; Drager, Light, Speltz, Fallon, & Jeffries, 2003). Dynamic grids allow for navigation through multiple pages and are often organized taxonomically with category folders (e.g., FOOD) that link to additional grids with related vocabulary (Drager et al., 2004). In contrast, visual scene displays (VSDs) utilize embedded voice output hotspots within a visual representation (e.g., photographic image) of a scene, context, or location (Drager et al., 2004; Light et al., 2004). VSDs can be organized schematically, with smaller images of scenes on a main page that link to larger images of individual scenes with embedded hotspots. A hybrid display incorpo-
rates grid and VSD elements (e.g., row of symbols within a VSD).

Research suggests that developmental and cognitive factors may predict success with these different SGD formats. For instance, 2-to-3-year-old typically developing children were found to be more accurate at locating vocabulary with schematic VSDs than with schematic or taxonomic grids (Drager et al., 2003; Drager et al., 2004). Advantages were not replicated with 4 and 5 year olds (Light et al., 2004). Robillard, Mayer-Crittenden, Roy-Charland, Minor-Corriiveau, and Bélanger (2013) found that for 4-to-6-year-old typically developing children, age and cognitive abilities predicted successful navigation with a taxonomic grid. Given that taxonomic grid use may require more advanced skills, researchers have suggested that VSDs may be appropriate for young children with ASD who may benefit from the contextual supports (Drager et al., 2004; Drager et al., 2003). As ASD is often associated with developmental delay (Armstrong & Jokel, 2012), VSDs may also be beneficial for older children with ASD as well.

Although a variety of VSD and grid-based AAC applications are available, in a recent review of AAC application studies for individuals with ASD, all 17 included studies examined grid-based applications (Lorah, Parnell, Whitby, & Hantula, 2015). Most studies have involved single step requesting sequences (e.g., selecting preferred items from one page of symbols), and only a few have examined requesting that requires navigation (e.g., Achmadi et al., 2012; Strasberger & Ferreri, 2014; Waddington et al., 2014). Studies support the efficacy of systematic behaviorally-based instructional packages (e.g., time delay with least to most prompting or graduated guidance) but are limited in their exploration of category folder selection from an array of choices and the use of correspondence checks (Frost & Bondy, 2002) which assess whether an AAC response is associated with an actual desire for an item or activity.

There is considerably less research exploring the use of VSDs or hybrids for individuals with ASD. Drager et al. (2005) reported on four case studies of young children with ASD who increased social interactions and vocabulary use after the implementation of a multimodal AAC intervention that included VSDs. Unfortunately, the lack of experimental control limits conclusions. Ganz et al. (2015) found that one of two participants with ASD made more communicative responses using a VSD-based SGD than with a non-electronic symbol-based exchange system. In a study involving young typically developing children and those with complex communication needs or CNN (including one child with ASD), Wood Jackson, Wahlquist, and Marquis (2011) compared differences between static grid and VSD SGDs during storybook reading. Results were mixed but suggested that individuals with CNN may respond differently than typical peers for certain outcomes (e.g., children with CNN were significantly more likely to use the grid to answer open-ended questions, but showed a slight accuracy advantage [not significant] with a VSD for close-ended questions). Gevarter et al. (2014a) taught participants to make requests for single items using different SGD display formats. These formats included a voice output hotspot embedded in a photographic image of a single item (e.g., pressing a photo-image of a slinky on a table led to an output of "slinky"), a single symbol button voice output area (e.g., pressing a graphic symbol of slinky led to an output of "slinky"), and a single symbol button voice output area presented within a photograph (e.g., pressing the graphic symbol for slinky placed below a photograph of a slinky on a table led to output of "slinky"). Two participants had the most success when the voice output hotspot was embedded within a photo-image. These displays could be seen as pre-cursors to VSDs, grids and hybrids, but did not entail the variety of elements necessary for advanced communication. In a follow-up set of studies, involving six participants, Gevarter et al. (2017, 2014b) found that different displays influenced the acquisition of requests made amongst a choice of four preferred items. Displays compared included: (a) a grid display with symbols, (b) a photo-image with embedded voice-output hotspots, (c) a hybrid photo-image with embedded voice-outputs and symbol hotspots, and (c) a hybrid pop-up grid (photo image of items with a hotspot that opened a pop-up grid of symbols). Although the photo-image with embedded hotspots had elements similar to a VSD, preferred items were not depicted in a larger scene-based con-
text. Navigation through pages was not required. Four of the six participants mastered requests in fields of four preferred items, with the photo-image with embedded hotspots being the most advantageous for three and the hybrid pop-up grid being most beneficial for the fourth (see Gevarter et al., 2017, for examples of displays). Error analysis (e.g., coding and monitoring types of errors made) was employed. Error analysis has been used in academic interventions for individuals with disabilities (Gable & Hendrickson, 1990) and, in some cases, in AAC research (see Fallon, Light, McNaughton, Drager, & Hammer, 2004). In the Gevarter et al. (2017) study, error analysis suggested that some errors were more or less common with specific displays.

Although there is likely not one AAC system that is appropriate for all individuals with ASD, in the absence of definitive rules for how to select a system, single subject designs can provide individualized comparisons (Gevarter et al., 2013). Direct comparisons of SGD formats are essential for the further development of research-based procedures that enable individualized AAC assessment and interventions for more advanced skills. Therefore, the primary research aim of this study was to determine whether the acquisition of navigation-based SGD requesting skills, taught via a systematic instructional package, amongst children with ASD is differentially affected by the use of taxonomic grid displays versus schematically organized VSD or hybrids.

Method

Participants

Four children with ASD who had received independent diagnoses from local disability service agencies (primary source of recruitment) participated. Addie was a 4-year-old African American male with whom the study was initially piloted as part of dissertation proposal. Donna was a 4-year-old Caucasian female, Quinn an 8-year-old Caucasian male, and Ricardo a 6-year-old Mexican American male. Although Quinn was older than participants in prior research involving VSDs, he was included because his severe ASD symptoms and challenging behaviors had prevented practitioners from introducing an SGD. Table 1 reports participants’ communication scores, ASD severity ratings, and prior use of AAC and play-based touchscreen devices. Information was gathered via parent and therapist interview and direct observation. Participants had to have mastered non-navigational requests for preferred items in fields of four using both a grid display and either a photo-image with embedded voice-output hotspots or a hybrid format (e.g., photo image with a pop-up grid) during one of a prior set of studies (see Gevarter et al. 2017 for initial participation requirements and prerequisite display descriptions).

Setting and Interventionists

Sessions occurred in two rooms and an outdoor space of participants’ homes, selected based upon the differential availability of preferred toy items in each setting (e.g., kitchen table-top toys versus bedroom floor toys). Locations included kitchens, living rooms, and bedrooms (intervention), as well as backyards and balconies (generalization). Interventionists (including the lead author) were graduate students in special education at the time of the study. The lead author trained all interventionists via modeling, review, and role play of procedural steps.

Experimental Design and Sessions

A multielement design (Sidman, 1960), which does not require a baseline, was implemented for each participant. The independent variable was the difference in display formats and organizational systems, and the dependent variable was correct responding (i.e., making an independent request using the SGD that corresponded to an item desired (see Response Definitions for more detail). Although a baseline phase can help in monitoring carryover effects, given that all participants had prior experience using SGDs for non-navigational requests, there was a concern that learning could occur through practice alone and thus baseline was excluded to avoid confounds that would not allow for display comparisons with an intervention in place.

A session consisted of 10 trials to make requests for three preferred items in one of two
<table>
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<tr>
<th>Participant</th>
<th>Age</th>
<th>CARS2 Score</th>
<th>Vineland Communication Standard Score</th>
<th>Vineland Communication Age Equivalents</th>
<th>Prior AAC Experience</th>
<th>Prior Experience with Touchscreen Devices for Play</th>
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| Addie       | 4;0 | 37.5 (severe symptoms) | 55 (low level) | Receptive: 1.5  
Expressive: 1.0  | PECS (fields of 3); Grid, hybrid, and VSD precursor (non-navigational) iPad systems; non-functional use of taxonomic grid iPad application | Played a variety of games independently on smart phones, Android tablet, and iPad® daily |
| Donna       | 4;5 | 36.5 (mild to moderate symptoms) | 59 (low level) | Receptive: 2.2  
Expressive: 1.2  | PECS (in large fields); signs; Grid, hybrid, and VSD precursor iPad systems (non-navigational) | Watched videos on iPad® daily, but did not independently operate |
| Quinn       | 8;9 | 43 (severe symptoms) | 54 (low level) | Receptive: 1.3  
Expressive: 1.10 | PECS (in large fields); Grid hybrid and VSD precursor iPad systems (non-navigational) | Played a variety of games independently on Nabi tablet daily |
| Ricardo     | 6;5 | 38.5 (severe symptoms) | 49 (low level) | Receptive: 1.11  
Expressive: 1.0  | PECS (in large fields), sign; Grid, hybrid, and VSD precursor iPad systems (non-navigational) | Occasional access to games on therapist’s iPad®, but needed physical assistance to operate |

conditions (schematic, taxonomic). A grid display was used for all participants in the taxonomic condition (all had mastered a non-navigational grid in the prerequisite study). For the schematic condition, three participants used a VSD, and one (Addie) used a schematic hybrid (pop-up grid). Addie used the hybrid because he had more success with a non-navigational hybrid format than a photo image with hotspots (i.e., VSD precursor) in the prerequisite study (Gevarter, 2014b). Both the VSD and hybrid could be easily organized schematically (using the photo image of the scene) and thus were both included in this condition. Sessions of the two conditions (schematic and taxonomic) were rotated across two rooms. Two to four sessions (i.e., one to two sessions per condition) were conducted during home visits occurring two to four times a week. Room order remained fixed, and condition order was randomized for each set of sessions (e.g., the schematic condition may be in the kitchen first for one visit and in the living room second for another). Changes were made if a condition was selected for the same order/location for more than two consecutive sessions. A 2 to 5 min break (depending on continued interest in requesting) occurred between sessions. The intervention phase continued until: (a) the child reached mastery criterion of 80% correct for four of five consecutive sessions (with two sessions at or above 80% for each location and no scores below 70%) or, (b) there were 20 total sessions. The criterion of four of five consecutive sessions allowed for some latitude for responding to occur across two settings. After mastery, generalization in a third setting was introduced. If a participant mastered generalization, (three consecutive sessions at 80%), post-treatment maintenance (randomly rotating locations) continued the study’s end.

**Materials and Selection Procedures**

Preferred items and Apple iPads® or Apple iPad Minis™ with the AutisMate application (SpecialNeedsware LLC, © 2012) were used. AutisMate was an application that allowed for the creation of VSDs, grids, and a variety of unique hybrid formats. AutisMate was initially selected as it was one of the earliest applications to include multiple display formats. AutisMate, now called Oneder (SpecialNeedsware LLC, © 2016), has transitioned to focus on school-based differentiation, but still includes options for AAC displays.

**Preferred items.** Parents and therapists made a list of a child’s preferred items across foods, toys/play items, and drinks. For food and drinks they recommended three items per category, and for toys/play items they suggested three items typically played with in one location (e.g., living room toys) and three items from another (e.g., bedroom toys). A multiple stimulus without replacement procedure (MSWR; Leon & Iwata, 1996) was used to determine highly preferred items across categories. For each category, parents also recommended a preferred item not available in the home and a non-preferred item. To determine a generalization item, a MSWR was conducted for three preferred outdoor items (e.g., ball, bubbles, chalk).

**Modifications.** Because Quinn’s interest in food appeared to be highly variable, his mother suggested assessing his preference for different electronics. An iPad® tablet with various game applications (different than one used as the SGD) was consistently preferred, so Quinn had an electronics category instead of a foods category on his SGD. During intervention, Donna and Ricardo showed decreased interest in selected food and play items. Parents could not think of additional preferred toys for each location, but suggested that an iPad® with games and videos were stable preferences across locations for both participants. An iPad® was assessed along with the previously suggested toy/play items. For both participants, the iPad® was most preferred. Next, parents were asked if participants had at least two highly preferred food items, not readily available in the home, that could be restricted to increase motivation, and programmed to be available in specific home locations. The new food items were assessed along with previous items. The top two ranked foods were randomly assigned to one of the two locations.

**Intervention displays.** Figure 1 shows examples of SGD intervention displays (with participant images blacked out). The taxonomic condition (grid) had a main page displaying symbol buttons for FOODS, DRINKS, and TOYS. For Donna, a THINGS category symbol
was used because her preferred play items (e.g., empty kitchen condiment bottles) might not have been appropriately represented via TOYS. Quinn had an ELECTRONICS symbol instead of FOOD. Pressing a category symbol led to a second page that displayed three symbols of items in that category. One symbol represented the preferred available item from that category (i.e., highest ranked item from preference assessment), and two symbols were distractors (i.e., one non-preferred and one preferred item not physically present). This was done to represent typical taxonomic displays which have category folders containing symbols for items that may not consistently be available across settings. The same symbols for drink and food items (or electronics for Quinn) were displayed regardless of session location. Toy/things distractors were the same in both locations, and the symbol for the available item varied based upon session location (e.g., PUZZLE in bedroom, GEAR TOY in

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living room). Initially, the toy/things were selected to differ across locations, as this was considered to be fairly typical in the natural environment (e.g., children had different sets of bedroom toys and kitchen tabletop toys). When Donna and Ricardo’s preferences changed, and additional items already associated with the training locations were not identified, the TOY/THING category was replaced with ELECTRONICS. Two new food items were identified and randomly assigned to be contingently available in one location (e.g., popcorn in living room, candy in kitchen).

For the schematic condition, a main page showed three photo images of locations. Two images were photographs of the child interacting with preferred items in each of the intervention rooms, and the third was a location without preferred items. Thus, there were two distractors (one preferred currently unavailable location, one non-preferred location). Selecting a location image opened a second page enlarging that image. The format for the second page was based on participants’ prior performance with non-navigational displays (Gevarter et al., 2017, 2014b). For Donna, Quinn, and Ricardo, the second pages were VSDs. Addie’s second page displays were hybrid pop-up grids, with a bordered hotspot around the entire scene, which activated a pop-up page with symbols of the three preferred items also depicted in the image. Food and drink items were the same across locations, and toy/play items were based on location.

During generalization, a third location (outdoor area) and a new item were introduced. The previously used food (or electronic item for Quinn) and drink were available and represented in displays in both conditions. In the taxonomic condition, the third category was replaced with a new category based on the child’s highest ranked item or activity in the new location. Pressing the new category led to a page with a symbol for the novel preferred item along with two distractor items. In the VSD or pop-up grid, one of the previous locations was replaced with an image of the new location and an embedded hotspot or symbol for the novel item was available.

Data Collection and Response Definitions

For each session, the trainer recorded responses for each step as correct or incorrect and coded errors. The percentage of correct SGD requests per session was then recorded. Correct responses in the taxonomic condition occurred when the child independently completed the following steps: (a) pressed a category within 6 s of the iPad® being placed in front of him, (b) activated the voice output for the available item within 6 s of the secondary page appearing, and (c) reached for the item that matched the request/output activated. Correct schematic condition responses were identical except Step 1 involved selecting the image matching the current session location, and in the pop-up grid, the participant needed to press the large scene hotspot prior to selecting a symbol. Across conditions, it was also necessary that participants: (a) pressed symbol or image hotspots no more than twice, (b) used no more than two fingers to press the hotspot, (c) did not touch another part of the screen prior to or less than 3 s after the response, and (d) did not attempt to grab items prior to completing the response chain. These requirements were imposed to prevent the reinforcement of inefficient or ineffective response topographies/patterns and were determined prior to the start of the study (participants had successfully learned to physically operate single page systems in the prior studies).

Errors during Step 1 (choosing category or scene) and Step 2 (choosing representation of preferred item) were coded. Errors that involved reaching for an item that did not correspond to the item requested was a Step 1 error for the taxonomic condition (i.e., did not choose category folder containing desired item), and a Step 2 error for schematic condition (i.e., did not choose symbol or image hotspot for desired item). Step 1 errors included: tapping multiple times, touching another part of iPad®, not responding, pressing a navigational button (e.g., home button), grabbing an item, making an incorrect motion (e.g., swiping, hitting), or selecting the wrong location image (i.e., location not matching current setting) or wrong category symbol (i.e., ultimately reached for item from different category after SGD response chain).
Step 2 errors were identical except instead of errors involving the selection of wrong locations or categories, participants could make errors involving selecting the wrong symbol (i.e., distractor symbols) in the taxonomic condition, or activating an output for an available item that did not ultimately match the reached for item in the schematic condition. Percentages for error types were computed and errors occurring in more than 10% of responses were reported for each condition.

**Inter-observer agreement (IOA).** IOA was conducted for 25% of sessions per condition/per participant. Random checks were conducted in vivo or from videotapes. Independent observers recorded correct or incorrect responses for all steps and coded errors.

Observers were graduate students who were trained by reviewing the operational definitions for correct and incorrect response and error codes, as well as by observing sessions not selected for IOA. IOA was calculated using the formula: agreements/(agreements + disagreements) × 100%. Mean IOA scores were: 98% (range = 90 to 100%) for Addie, 99% (range = 90 to 100%) for Donna, 98% (range = 90 to 100%) for Quinn, and 96% for Ricardo (range = 80 to 100%). Mean IOA for errors were: 94.3% (range = 86.7 to 100%) for Addie, 98.7% (range = 93.3 to 100%) for Donna, 99.3% (range = 96.7 to 100%) for Quinn, and 98.7% for Ricardo (range = 96.7 to 100%).

**Data analysis.** The percentage of correct responses in each condition was continuously graphed to observe trends (e.g., decreased responding in both conditions) that might indicate the need for modifications. Conditions were compared in terms of differences in mastery and rate of mastery, as well as differences in data paths (e.g., level, trend, and variability). Error types were analyzed to determine the need for modification, and types occurring in more than 10% of responses for individuals, and on average across participants, were reported for each condition.

**Instructional Procedures**

The three items for a location (e.g., most preferred food, drink and toy) were placed in front of the child, at a distance just beyond reach. The SGD with the condition’s main page (i.e., three categories or three scenes) was put between the child and the items. For Step 1, if the child made no response or an incorrect response during a 6 s delay, the trainer implemented a least-to-most prompt hierarchy (partial physical, full physical). Prompts for errors involving activation issues (e.g., hitting a category or scene multiple times) were provided. In the taxonomic condition when there was no response the trainer prompted selection of the last previously requested category. In the schematic condition, no response or the selection on an unavailable location (distractor) led to prompting selection of the current location. For Step 2, if the child did not respond or made an incorrect response during a second 6 s delay, the trainer also implemented a least-to-most prompt hierarchy. In the taxonomic condition, if there was no response, or the participant selected an icon for an unavailable item (distractor), the trainer prompted activating the symbol for the available item. In the schematic condition, if there was no response the trainer prompted selection of the last chosen item. After Steps 1 and 2 were completed (prompted or independent) a correspondence check (Frost & Bondy, 2002) was implemented to determine whether the SGD response emitted was aligned to a participant’s desire for a particular item. The trainer removed the iPad®, said “Take it” and waited for the child to take an item from the field of three. If the child reached for an item that differed from the one requested, the response was blocked, and correspondence training adapted from PECS (Frost & Bondy, 2002) was initiated. For the taxonomic condition, the trainer prompted the child to select the appropriate category symbol and then the appropriate item symbol. For schematic conditions, the trainer prompted the selection of appropriate item symbol or hotspots on the Step 2 page (any mistakes selecting the location hotspot would have been corrected in Step 1).

For all participants except Addie (the pilot participant), a generalization probe in each condition was conducted prior to intervention. Each condition was presented in the outdoor location with the generalization display and items for that environment. Procedures were similar to training, but no prompting
occurred. After an incorrect response, the SGD was removed for 5s and the trainer then represented it and said “Try again”. After mastering intervention in a condition, generalization probes were reintroduced. If a participant mastered generalization, post-treatment maintenance was introduced. Sessions were conducted across all three settings (e.g., bedroom, kitchen, outdoors) with each setting used once for every set of three sessions (order randomized). Procedures mirrored generalization.

Modifications. A modification for Donna was implemented based on the observation that her SGD responses and correspondence checks were inconsistent with alternative responses spontaneously emitted prior to her SGD response (e.g., manual signs, pointing to items). Due to a concern that she was requesting and taking items that she did not actually want, an attempt was made to determine whether it was possible to assess which item she desired prior to her SGD response. Prior to the SGD being placed in front of Donna, the trainer said “Show me which one you want”. The item Donna then reached, signed for, or pointed to was considered the corresponding item for the subsequent request. The other items were pushed away so that the preselected item was closest to Donna. If she made a response that did not correspond with the preselected item, she was immediately prompted to make a corresponding response. This procedure did not ultimately seem appropriate to assess which item she desired as she sometimes reacted negatively (e.g., whining, pushing away item) after a prompted request. After three sessions of the modification Donna showed no interest in her preferred items (walked away from training area). A modification of preferred items was made prior to returning to initial procedures. Similarly, Ricardo’s preferred items were re-evaluated following a decrease in performance across conditions and an attempted session in which he showed no interest in requesting. For Quinn, a decision was made to change one of the distractor symbols in the grid electronics category because his most common error of pressing a COMPUTER distractor instead of an IPAD icon may have been due to the fact that the ELECTRONICS category symbol was a different computer symbol. A different distractor (VIDEO GAME) was introduced.

Procedural integrity. Procedural integrity was assessed in vivo or from videotape for 25% of sessions per condition for each participant using a checklist outlining procedural steps for each phase. Integrity was calculated as: Number of steps correctly implemented/ (Number of steps correctly implemented + Number of steps incorrectly implemented) × 100%. Means were: 99% (range = 95 to 100%) for Addie, 98.3% (range = 92.5 to 100%) for Donna, 99.8% for Quinn (range = 97.5 to 100%), and 95.8% for Ricardo (range = 90% to 100%).

Results

Table 2 summarizes which conditions were mastered, how many sessions were required to meet criterion, and the types of errors seen in more than 10% of responses for each condition. Three participants (Addie, Quinn, Ricardo) mastered navigational requesting with a schematically organized VSD or pop-up grid in nine to 11 sessions but did not meet mastery criterion with a taxonomically organized grid within 20 sessions. Donna mastered both a schematic VSD and a taxonomic grid in 14 sessions. In the schematic condition, the only commonly occurring error for all participants was selecting a scene that did not match the current setting (M = 14.8%; range = 9% to 19.5%). Participants showed a variety of common errors in the taxonomic grid, including making multiple hits on the category page (M = 13.3%, range = 11% to 18%), selecting the wrong category (M = 12.3%, range = 1% to 31.5%), and selecting the wrong item symbol (M = 24.9%, range = 8% to 45%). Three participants (Addie, Donna, Quinn) mastered generalization with schematic systems. Donna was the only participant who reached a generalization phase using the taxonomic grid, which she did not master, but her performance was on an upward trend. During post-treatment in the schematic condition, Addie, Donna, and Quinn all showed a brief drop in performance followed by an increase back to mastery level.

Addie’s data are presented in Figure 2 panel 1. There appeared to be an immediate split in performance levels across conditions.
(beginning with 70% correct with the schematic condition and 40% with the taxonomic). Data for the schematic condition was variable during the first 8 sessions but was then relatively stable (except for brief drops during the first session of generalization and maintenance). He mastered the schematic pop-up grid in 11 sessions and met generalization criterion in four. In contrast, his performance with the taxonomic grid was on a gradual upward trend but never reached mastery level. With the schematic pop-up grid, his most frequent error was selecting the wrong scene (13.5%). Common errors with the taxonomic grid included multiple hits of category symbol (18%), wrong motion (swiping; 10.5%), attempting to grab the item after step 1 (17.5%), multiple hits of the item symbol (15%), and selecting the wrong (i.e., unavailable) item symbol (11%). He requested across all categories.

Donna’s data are displayed in Figure 2 panel 2. Initially, performance with the schematic condition was highly variable (scores ranging from 40 to 90%), and performance with the taxonomic condition was less variable but at a lower level (with a very slight upward trend). After modifications related to the preferred items (see methods) she mastered both conditions in the same number of sessions but only successfully mastered generalization with the schematic condition. Generalization data for the taxonomic condition was on an upward trend. Donna’s most common error with
Figure 2. Percentage of correct responses across conditions and phases for each participant.
the schematic VSD was selecting the wrong scene (19.5% of responses). With the taxonomic grid common errors included selecting the wrong category symbol (14%), multiple hits of the category symbol (11%), and using the wrong motion (swiping) on the category page (10%). During early sessions with the grid, the majority of Donna’s responses involved selecting the FOOD category, despite the fact that just prior to the SGD response she would sometimes sign DRINK or point to her preferred play items (Donna used only a few signs functionally, including DRINK). In contrast, in the schematic condition she requested and took the food, drink, and play items. Due to a concern that there may be false positives in the taxonomic condition, a modification in which she was asked what she wanted prior to her SGD response was introduced. Although this procedure led to requests across a wider array of categories with the grid, she had variable performance in both conditions and began to show negative reactions (e.g., pushing away items). Following a return to the initial procedures and a change in items, she showed an increase in both conditions. A majority of requests with the grid were still food requests, but there were more correct requests for drink and only one request for the electronic item. She more frequently requested the electronic item with the VSD. During generalization, Donna’s multiple tap and wrong motion errors with the grid increased, and she never selected the new category ART SUPPLIES that contained a symbol for the new item (sidewalk chalk). In contrast, she generalized the VSD, frequently requesting chalk and food. After the study ended, a 10 trial probe with the generalization grid was conducted when only the chalk was present. She selected the art category on 0% of trials. Teaching trials (time delay, and physical prompt to select ART SUPPLIES) were introduced with a criterion of 10 consecutive trials selecting the correct category. It took Donna only 13 trials to meet criterion.

Quinn’s data are displayed in Figure 2 panel 3. There appeared to be an immediate split in performance levels across conditions (higher level for schematic). He mastered the schematic VSD in nine sessions and generalized it in four but did not master the taxonomic grid. Performance with the schematic VSD was relatively stable except for first sessions of generalization and maintenance. Performance with the grid was on an increasing trend and had increased in level following a modification. He did not show a specific error type in more than 10% of responses for the schematic condition. With the grid, he frequently pressed category symbols multiple times (11%) and selected the wrong item symbol in 45% of responses. A modification was introduced with the grid due to high rates of pressing a distractor COMPUTER symbol that was similar to the category level symbol. When the COMPUTER symbol was changed to VIDEO GAME, this error dissipated. Quinn also showed differences in which items he requested by condition. He requested the iPad® and drink in both conditions but only requested toys with the VSD (i.e., never pressed TOYS in grid).

Ricardo’s data are displayed in Figure 2 panel 4. The initial level of performance with the schematic VSD was higher than the taxonomic grid, but there was a decreasing trend in both conditions that appeared to correspond with decreased interest in items. After a change of items he mastered the schematic VSD in nine sessions but did not master the taxonomic grid (performance was on an upward trend for final sessions). In the VSD, Ricardo selected the wrong scene in 17% of responses. He showed a wider variety of errors with the taxonomic grid, selecting the wrong category symbol in 31.5% of responses, using multiple hits of the category symbol in 13%, and selecting the wrong symbol item in 35.5%. During generalization with the schematic VSD, Ricardo’s percentage correct varied between 60–100%. He primarily was requesting only the novel item (i.e., water toy) with errors during final trials. To increase interest in selecting more than one item, the initial food item was replaced with his play iPad. This led to more requesting across items, but he was still one session short of mastering generalization.

Discussion

In line with research supporting potential advantages of schematic SGDs for young, typically developing children (Drager et al., 2004,
three of four participants mastered requesting with the schematic display but not with the taxonomic. Although schematic displays may be advantageous due to previously suggested hypotheses (e.g., cognitively or developmentally easier to acquire), error analysis suggested additional contributing factors.

One possible reason for results favoring schematic systems is that variability in responding with the schematic condition was primarily associated with one specific error type, rather than a variety of errors. This error involved selecting a scene that did not match the session’s location. Intervention was successful in reducing this error, and during generalization and maintenance it also reduced rapidly without continued intervention. Despite the successful results, participants may have more easily discriminated between more contextual/differentiated scenes (e.g., with no common items repeated across scenes). Carryover effects may also have occurred, given that participants often had high rates of selecting the wrong scene after previous sessions in another location. Carryover effects should be considered when designing interventions (Hains & Baer, 1989), given that individuals often need to rotate between VSDs in natural environments (e.g., when changing classroom learning centers). It is also possible that selecting a scene represented a request for the alternative location rather than an error.

Although different procedures may have reduced such errors, the VSD design choices were made for socially significant reasons. First, repeating common objects across scenes was done because in natural environments items across categories might be used together and available in multiple contexts. For instance, Donna commonly used her play iPad® in multiple rooms and often ate a snack while playing with it. VSDs designed in this manner may promote generalization of vocabulary across settings and help learners understand what items may be available or restricted across locations. Additionally, the use of two identical items across locations was intended to reduce variability in responding due to differences in preference. Although “location” requests (i.e., requesting to go to the kitchen) should be taught, it may also be important for individuals to learn that sometimes the availability of choices is limited by the current context. For instance, if a vocal child requested a cookie in the playroom, a parent may respond by saying “We can’t go the kitchen for a cookie now, but you can choose a toy here.”

Although errors with selecting the correct scene were common across participants, category selection errors in the taxonomic condition were only above 10% for Donna and Ricardo. This error type was on a decreasing trend for Ricardo (who selected across categories), but progress was gradual. Both Donna and Quinn did not readily select all three categories. Initially, Donna was almost exclusively selecting the FOOD category and eventually taking the food item (while often displaying other error types), despite signing DRINK or pointing to play items prior to SGD responses and requesting these items with the VSD. Similarly, during generalization, Donna never activated an ART SUPPLIES category despite reaching for the available item from the category (i.e., sidewalk chalk) prior to a grid SGD response and requesting the chalk with the VSD. Post-study probes when only the chalk was present demonstrated that although Donna did not select the correct category without intervention, she rapidly learned the response. Similar to Donna, Quinn was never observed to select the TOYS category in the taxonomic condition despite requesting toys with the VSD. Embedded images may provide more recognizable visual stimuli (in comparison to unfamiliar category symbols) indicating item availability. Results might have been different if responses were modeled, or if one preselected item was present at a time so that categories could be errorlessly prompted (see Strasberger & Ferreri, 2014). Such modifications are not without limitations, as noted by the fact that Donna lost interest when a preselected item of her choosing was the only one available.

In addition to category selection errors, selecting a symbol for an unavailable (distractor) item was also common in the taxonomic condition. This error may have occurred for several reasons. Some participants may have had difficulty discriminating between symbols (Gevarter et al., 2017). For instance, Quinn’s selection of a COMPUTER distractor (drawing of desktop computer) appeared to suggest confusion over which icon corre-
responded with his preferred available iPad, which may have been impacted by the fact that the ELECTRONICS category symbol was also a computer icon (drawing of a laptop computer). The fact that Quinn’s selection of the wrong icon reduced when the item level computer icon was replaced with a video game icon may suggest that presenting similar icons together, or using a category icon too similar to an item icon, may cause confusion. In contrast, Ricardo’s item level non-correspondence errors often coincided with initial selection of an incorrect category (e.g., if he ultimately reached for drink but had initially mistakenly selected the food category, he seemed to just randomly pick any food icon). Across participants, the presence of icons representing unavailable items in the grid may have also contributed to errors at this level. For instance, although Addie used symbol-based icons in both conditions, he had more frequent errors selecting the wrong symbol with the taxonomic grid. The taxonomic condition was designed to represent how grids are typically organized (e.g., a variety of available and unavailable symbols in a category), in comparison to VSDs, which include only vocabulary relevant to the specific context or location. Although there were no unavailable distractors at the “item” level (i.e., on page two) in the schematic condition, the use of one preferred unavailable location, and one non-preferred, unavailable location in the schematic condition was equated to the use of distractor items in the grid. Thus “errors” in which participants selected an unavailable item with the grid may have been similar to errors selecting unavailable scenes. Again, although it is important to be able to request items not immediately available, it is equally necessary to be able to choose from available items.

It also appeared that physical activation errors were more prominent with the grid. Tapping symbols multiple times was common with the taxonomic grid. It is unclear what display elements contributed, but results are similar to prior studies with a variety of applications (Gevarter et al., 2017, 2014a, 2014b). This error has social significance as such responses lead to inefficient or atypical voice outputs (e.g., delaying or repeating output). Another interesting finding is that Addie and Donna had high rates of an error involving “swiping” across the grid category page (which led to navigation to a blank page). Additionally, Addie’s high percentage of attempting to grab items after the first response with the taxonomic grid, but not with the schematic pop-up grid, appeared to suggest a difference in how he perceived the response chain across conditions. The fact that the DRINKS category symbol (two cups) was similar to his item icon (SIPPY CUP) may have prevented him from realizing an additional response was required.

In addition to examining errors, it is important to consider how prior experience (e.g., with AAC systems and touch screens) and other learner characteristics may have impacted results. Interestingly, prior experience with AAC systems with similarities to a taxonomic grid (e.g., PECS) did not predict greater success with this system. Unlike Light et al.’s (2004) findings with typically developing children, individuals ages 4 years and above showed performance differences across schematic and taxonomic conditions. It is possible that other factors (e.g., ASD severity, cognitive skills) may be relevant. Additionally, although participants in this study had mastered the use of prerequisite displays for both conditions, they all also had demonstrated faster rates of acquisition and/or more consistency in correct responding with the VSD and hybrid prerequisite displays (Gevarter et al., 2016, 2014b). Individuals who showed more rapid acquisition with grid displays than photo images or hybrids at a prior learning stage, or individuals without any prior skills, may have demonstrated different results. Initial generalization probes and first data points for some participants may also indicate that slight differences in level of responding may have been apparent in baseline, but it is unclear if upward trends would have occurred without instruction. Had a baseline showed differences across conditions, it may have been evidence of greater generalization from prior learning phases in one display over another, or implicit advantages of one system without explicit instruction. That information would be valuable but would not allow for the demonstration of differences between display formats with intervention in place (the research question at hand). Future research could therefore seek to determine whether there are differences in
responding across displays without intervention in place for individuals with and without prior experience.

Other aspects of this study may limit findings. First, it may be unclear how results would generalize to other applications or how participants would perform in more naturalistic contexts. The fact that at least two participants lost interest in the preferred items selected for training may suggest that a greater variety of items and/or the ability to change items easily may be important. The selection of two preferred toys used differentially by location may have initially limited the use of the most highly preferred items. As some individuals might have only a few preferred items that generally should be included across home VSDs, it may have been more appropriate to assess items used differentially across larger settings (e.g., school versus home).

This study provides several implications for assessment and intervention. The design demonstrates a potential way in which practitioners could compare different SGD displays during intervention. The fact that differential responding was seen during intervention (without the need for a pre-assessment), suggests that AAC assessment could be embedded into instruction, thus limiting delays to adopt AAC. Decisions regarding the most appropriate formats and strategies to continue with could be determined via data collection and error analysis.

The use of correspondence checks during assessment may be useful, as some participants frequently made SGD responses that did not correspond with the item they reached for and therefore might have received less desirable responses to communication attempts if correspondence checks were not conducted. The error analysis procedures could be adapted to identify specific problems individuals are experiencing with systems, and results could be used to modify and/or tailor interventions. Although a time-delay with error correction appeared appropriate for teaching schematic systems, alternative methods might be needed to ensure correct use of multiple categories in taxonomic grids. For instance, although Donna had demonstrated strong discrimination skills in her use of a Pecs system up to phase V prior to this study, she struggled to discriminate between category based symbols. Modeling could be used for new or infrequently pressed categories, or only items from such categories could be made available for a given training session (see Strasberger & Ferreri, 2014). Alternatively, individuals could practice matching stimuli to a category. In addition, as taxonomic grids may be easier to program (e.g., no need to reprogram vocabulary with classroom changes), practitioners may consider starting with schematic models and gradually transitioning to taxonomic. The use of a functional schematic system while a taxonomic grid is being gradually acquired might be particularly important for individuals who use challenging behaviors in replace of functional communication (Gervat et al., 2017). Additionally, teaching more than one format would allow AAC users to have a choice to use the system most appropriate for a given context. For example, an AAC user might use a taxonomic grid for responses that generalize across settings but use a schematic VSD to have a social conversation about a recent activity or event.

The findings and limitations of this study suggest several avenues for future research. First, the study should be replicated across applications and across participants with different characteristics. More pre-intervention assessments (e.g., matching and categorization abilities) could elucidate characteristics that might predict differential success. Alternative display and intervention methods could also be explored (e.g., use more contextualized scenes with items related to the same activity; explicitly model category and scene selection). Because differences in selecting the correct scene or category were not the sole factor contributing to differential success, other elements associated with the organizational design of displays could be examined. For instance, to avoid the problem of individuals being distracted by unavailable items within a FOODS category, sub-folders such as HOME FOODS and SPECIAL TREATS could be created. Alternatively, researchers could examine schematic grids. Research also needs to explore more naturalistic situations and parent and/or practitioners’ ability to program systems and make rapid adaptations when preferences change. Abilities to request locations or items out of sight should also be considered. Preference changes seen in this
study might also suggest the need to either (a) add components to reduce the likelihood of item satiation or (b) create protocols sensitive to preference changes (e.g., incorporate repeated preference assessments).

Although this study extends SGD research beyond simple one-step requesting, a multitude of more advanced requesting skills (e.g., sentence building, requesting social engagement) and/or alternative language skills (e.g., commenting, answering questions) need to be explored with multiple display formats across environments. It is possible that different displays might provide advantages for different skills or that fluidity with taxonomic systems will increase along with the introduction of more advanced language. Furthermore, given the commonly observed physical issues with symbolic buttons across studies (Gevarter et al., 2017, 2014a, 2014b), future research should examine this across applications. Finally, study procedures could be modified to create a practitioner-friendly assessment and intervention protocol. Research would be needed to assess the efficacy, validity, and reliability of such a protocol.

References


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