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A comparison of schematic and taxonomic iPad® AAC systems for teaching multistep navigational AAC requests to children with ASD

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A comparison of schematic and taxonomic iPad® AAC systems for teaching multistep navigational AAC requests to children with ASD

by

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Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

May, 2015

Dedication

I dedicate this dissertation work to my family and friends for supporting me, and to all the children and families who have inspired me along the way.

Acknowledgements

First and foremost I owe thanks to my mother Sherry Gevarter. Without her insistence that I must find something to do with my time the summer I didn't want to go to camp, I never would have found my passion for working with individuals with disabilities. Before and since that point she's always encouraged me to do what I love to do, and to do it well. From teaching me to read, to creating my college "bible," to editing countless papers, to being an extra chaperone when I took my class to the zoo, she's always been there. I also thank my father Jeff Gevarter for showing me an example of a great work ethic. His commitment to his job and supporting his family in many ways enabled me to seek out a career I was passionate about.

I thank my siblings Franny, Adam, Allie and for being technical support advisors, and listening to me talk about my research and teaching experiences. A special thanks to Allie, the educational tech and social networking guru. This dissertation might be on a whole different topic if it weren't for her telling me years ago that I might want to start thinking about research with iPads®, and insisting that I have business cards to give to application developers at my first AAC conference.

A special thanks to three friends Janice Graboso, Laura Rojeski, and Cassandra Mendrano. Without Janice I may not have made it through my first year of teaching, and she was always a supportive phone call away during graduate school. Beyond being a great person to bounce research ideas off of, and edit my papers, Laura has been a true friend who was been there for me when I most needed it. Cassandra is a shining light of positivity and perseverance, and an inspiration to all mothers of kids with autism.

Shawn, thank you for being there through this, for listening, and for encouraging and reinforcing traits in me (e.g., integrity, humble confidence, breathing) that helped me along this path. I learned a lot from you (just maybe not your aptitude for brevity).

I also thank all the wonderful children at AMAC and Dr. Nyla Lamm for inspiring my interest in AAC and my love for ABA. Special thanks to Patti Alf for taking my call when I wanted to know if I should take a job at an ABA school.

I thank my advisor, Dr. Mark O'Reilly. I am extremely grateful for the fact that Mark supported my initiative to go out and start my own line of research. He always knew when to push and give guidance, and when to give me leeway to make decisions on my own. I am grateful for the opportunity to have had a research assistantship under Mark that allowed me to continue to work with children and families while pursuing my research interests. I also thank him for connecting me with his wide network of highly accomplished people like Dr. Jeff Sigafoos, who has given me wonderful feedback and support. I am also grateful to the additional members of this committee Dr. Marsha Barnes, Dr. Diane Bryant, and Dr. Terry Falcomata for their assistance and feedback on this dissertation, as well as for opportunities they have given me throughout my graduate career.

Finally, thank you to my peers, Raechal Ferguson, Heather Gonzales, Michelle Kuhn, Laura Rojeski, Nicolette Sammarco and Laci Watkins for their assistance in this study and for generally creating a supportive peer community.

A comparison of schematic and taxonomic iPad® AAC systems for teaching multistep navigational AAC requests to children with ASD

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The University of Texas at Austin, 2015

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The variety of augmentative and alternative communication (AAC) applications available on devices such as the Apple iPad®, necessitates research comparing different application components. AAC applications can include a variety of display formats such as: visual scene displays (VSDs; with vocabulary embedded into images of a scene or context), grid displays (with rows and columns of symbol buttons representing vocabulary), and hybrid formats (combining elements of VSDs and grids). To navigate through multiple pages of vocabulary, VSDs and hybrids are often organized schematically (i.e., by context or location) and grids are commonly organized taxonomically (i.e., by category).

This study compared how four young children (ages 4 to 8) with autism spectrum disorder (ASD) acquired two-step navigational requesting with an iPad® AAC application using a schematic VSD, or hybrid pop-up grid, and a taxonomic grid. Using a multielement design, acquisition was compared across two settings (e.g., living room, kitchen), and three categories of preferred items (e.g., drinks, food, toys). Intervention involved behaviorallybased strategies (e.g., time delay, least-to-most prompting). During intervention, three participants mastered the schematic systems (VSD or hybrid), but did not master the taxonomic grid. Two of these participants also generalized requesting with schematic systems to an untrained location with a new preferred item, and maintained responding across all three settings. A fourth participant mastered both a schematic VSD and a taxonomic grid during training. During generalization, she rapidly acquired requesting in the new environment with the schematic VSD, but did not meet mastery criterion with the taxonomic grid.

Across participants, the most common error with schematic systems was selecting the wrong scene (i.e., selecting an image of a location that did not match the location of the given session). In contrast, all participants showed a greater variety of error types with the taxonomic grid (including selecting the wrong category symbol, pressing the screen multiple times, trying to activate the screen with the wrong motion, and selecting the wrong item symbol). Differences in the types of errors observed suggest possible advantages and disadvantages with each system. Results have important implications for the development of AAC assessment and implementation protocols.

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Chapter 1: Introduction

Autism spectrum disorder (ASD) is a developmental disability that is estimated to affect 1 in 68 individuals (Baio, 2014). Currently, the diagnostic criteria for ASD includes an emphasis on deficits in the area of social communication and interaction (American Psychiatric Association, 2013). There is considerable variability with regards to the severity of language deficits (ranging from mutism to difficulty with advanced pragmatic skills) that may affect the social communications and interactions of individuals with ASD (Sigafoos, O'Reilly, Schlosser, & Lancioni, 2007). It has been estimated, however, that 20% of individuals with ASD may be functionally non-verbal (Armstrong & Jokel, 2012; Lord, Risi, & Pickles, 2004). Given this fact, children with ASD who have limited to no vocal speech are often considered candidates for augmentative and alternative communication systems (AAC; Binger & Light, 2006; Mirenda, 2003; Sigafoos, O'Reilly, & Green, 2007; Sigafoos, Schlosser, et al., 2013). AAC systems can be used to either augment existing vocal abilities, or to serve as a primary form of communication when vocal speech is absent (Mirenda, 2003; Sigafoos, Schlosser, & Sutherland, 2013).

TYPES OF AAC SYSTEMS

AAC systems involving elements external to the user are usually classified as aided systems, while manual signs and gestures are referred to as unaided AAC (Mirenda, 2003; Sigafoos, Schlosser et al., 2013). Aided forms of AAC typically involve either non-electronic picture, word, or symbol selection systems (e.g., picture books, boards, and exchange systems), or electronic selection systems often referred to as Speech Generating

Devices (SGDs) or Voice Output Communication Aids (VOCAs; Gevarter et al., 2013a; Lancioni et al., 2007; Sigafoos, Schlosser et al., 2013). While research suggests that individuals with ASD may acquire communication skills (e.g., requesting preferred items) with both electronic and non-electronic aided AAC systems, comparative research on preference has often favored SGDs (Gevarter et al., 2013a; van der Meer, Sigafoos, J., O'Reilly, & Lancioni, 2011). Until recently, the use of SGDs as primary AAC systems for young children with disabilities may have been limited due to various factors such as cost of devices, limited portability (e.g., large in size and heavy), lack of professional knowledge of assistive technology (AT), and perceived social stigmas (Binger & Light, 2006; Shane et al, 2012; McNaughton & Light; 2013). With the advent of tablet and touchscreen technology, easily accessible, less expensive, more portable, and potentially less socially stigmatizing SGD systems are now available via the use of AAC applications on portable multimedia devices such as the Apple iPad®, and iPhone® (Farrall, 2012; Gosnell, Costello, & Shane, 2011; McBride, 2011; McNaughton & Light; 2013; Shane et al., 2012).

Since the development of such technology, there has been a rapid growth in research involving the use of portable multimedia devices as SGDs for individuals with ASD (Kagohara et al., 2013). The use of such devices in AAC interventions is likely to continue to increase as the availability of communication-related applications for such devices continues to expand (Farrall, 2012; Gosnell et al., 2011; McNaughton & Light, 2013). Despite the use of tablet and other portable multimedia devices in successful AAC interventions (see Achmadi et al., 2012; Lorah et al., 2013; van der Meer, Kagohara, et al., 2012) the quality, design, and functional capabilities of applications may vary widely (Farrall, 2012; Gosnell et al., 2011; McBride, 2011; McNaughton & Light, 2013).

NEED FOR AAC ASSESSMENT

Given the fact that individuals with ASD and related developmental disabilities may often show idiosyncrasies regarding the acquisition of and/or preference for AAC systems, in order to choose between the many available systems, individualized assessment is recommended (Gevarter et al., 2013a; McNaughton & Light, 2013; Schlosser & Sigafoos, 2006; Shane et al., 2012; van der Meer, Sigafoos et al., 2011). Unfortunately, the availability and popularity of AAC applications on media devices may lead to families foregoing individualized AAC assessments and professional support (Gosnell et al., 2011; McBride, 2011; McNaughton & Light, 2013; Shane et al., 2012). Research demonstrating the utility of innovative AAC assessments that meet the needs of new technology options is, therefore, highly warranted (McNaughton & Light, 2013; Gevarter et al., 2014). Research is also needed to specifically demonstrate the potential effectiveness of a variety of AAC applications that may incorporate novel features not available in previously researched SGD systems. For instance, the camera and web search functions on such devices may enable the rapid creation of contextually relevant AAC vocabulary items that may increase the likelihood of capturing opportunities for communication (Shane et al., 2012).

SGD DISPLAY FORMATS

Grid displays

Despite the wide variety of AAC applications available, and the potential to evaluate novel AAC features and formats, most current research involving the use of tablet or other touchscreen media devices (namely iPods® and iPads®) as SGDs for individuals with ASD has evaluated only one application, Proloquo2Go® (Kagohara et al., 2013). Proloquo2Go® is an example of a grid-based SGD display. Grid-based systems typically involve pictures or symbols representing concepts displayed in rows, where touching or selecting a symbol activates a pre-stored vocal-output (Drager et al., 2004; Drager, Light, Speltz, Fallon, & Jeffries, 2003; Light et al., 2004). Traditionally, most SGDs have also utilized grid-based display formats (Drager et al., 2004; Drager,et al., 2003; Wilkinson & Jagaroo, 2004). One potential advantage of such systems is the fact that vocabulary items are given clear individual spaces which may enable effective perception and recall of such items (Wilkinson & Jagaroo, 2004). Generalization of vocabulary use across settings may also be supported because the symbols are the same across locations and contexts (Reichle & Drager, 2010).

Like most AAC applications on multimedia devices, Proloquo2Go® is also an example of a dynamic SGD which, unlike static systems, allows for screen changes and page navigation (Reichle & Drager, 2010). Ultimately, the efficient and effective use of a dynamic SGD requires strong navigational skills (Drager & Light, 2006; Reichle & Drager, 2010). Accurate and efficient vocabulary retrieval is critically important to prevent communication breakdowns and frustration that may lead to discontinued use (Wilkinson & McIlvane, 2013). In grid-based dynamic systems such as Proloquo2Go®, pages are typically organized taxonomically (i.e., by categories; Drager et al., 2004). For instance, pressing a category symbol (e.g., foods) on a main grid page may lead to an additional grid with related vocabulary such as a variety of food items or additional related categories (breakfast foods; lunch foods). Grids can also be organized alphabetically, semantic-syntactically (by parts of speech) or schematically with symbols representing a scene, context, or location (e.g., "playing game" symbol or kitchen symbol) that lead to additional grids with vocabulary symbols appropriate for that context (Drager et al., 2004; Drager et al., 2003). A novel approach to grid organization might also involve taking screen shots of individual grid pages and presenting these on a main front page (Drager et al., 2004). Although research has supported the use of the grid-based Proloquo2Go® for teaching simple AAC device operations (e.g., requesting preferred items from fields of one to four symbol icons; Kagohara et al., 2013), there is limited research (namely Achmadi et al., 2012; Strasberger & Ferreri, 2013) supporting the use of such systems when page navigation is required. The limited research has focused on navigation through taxonomically organized systems (Achmadi et al., 2012; Strasberger & Ferreri, 2013).

It has been suggested that the successful navigation through grid-systems may require individuals to possess certain developmental and cognitive skills (Drager et al., 2004; Drager et al., 2003; Light et al., 2004; Robillard, Mayer-Crittenden, Roy-Charland, Minor-Corriveau, & Bélanger, 2013; Thistle & Wilkinson, 2013). For instance, in a study involving typically developing children between the ages of 4 and 6, Robillard et al. (2013) found that age and cognitive ability were predictive factors of successful vocabulary retrieval when navigating through a taxonomically organized Proloquo2Go® SGD application. Older children, and those who scored higher on cognitive measures, were significantly more likely to correctly locate vocabulary items on the SGD. Given the potential for grid-based navigational systems to require certain developmental and/or cognitive skills, some researchers have proposed that alternative display formats may be more appropriate for young children with ASD and other developmental disabilities (Drager et al., 2004; Drager et al., 2003; Shane et al., 2012). More specifically, the use of schematically organized visual scene displays (VSDs) has been suggested as an alternative to grid displays (Drager et al., 2004; Drager et al., 2003; Reichle & Drager, 2010; Shane et al., 2012).

Visual scene displays

VSDs involve the use of contextually-embedded hotspots that may represent language concepts within a visual representation of a scene, context, or location (Drager et al., 2004; Drager et al., 2003; Light et al., 2004; Wood Jackson, Wahlquist, & Marquis, 2011). For instance, given a photographical image of a child's playroom, touching the portion of the scene that shows toy cars may lead to a vocal output of "play cars please." In VSD systems, links between pages can be organized schematically such that a user would select an image of a particular context or scene (e.g., photograph of individuals playing a game or photograph of kitchen) in order to navigate to language options appropriate for his or her current context or location (Drager et al., 2004). Hybrid models that may combine a grid of symbols available within a visual scene can also be organized in a schematic fashion (Light & Drager, 2007).

While grid-based AAC applications on media devices may be the most popular, several applications have options for either VSDs and/or hybrid systems (e.g., AutisMate by SpecialNeedsWare, GoTalk, by Attainment Company, and Scene & Heard by TBox Apps). The fact that some of these scene-based options are specifically marketed for use by individuals with ASD may relate to hypotheses regarding the advantages of schematic systems for learners who have difficulties processing complex language concepts, but may show strengths in the area of visual processing (Shane, 2006; Shane et al., 2012). For example, AAC researchers have proposed that scene-based systems can provide meaningful and interesting, contextually-based visual supports that may aid in the processing of more advanced language concepts (Light & Drager, 2007; Shane, 2006; Shane et al., 2012). It has also been suggested that schematic-based organizational systems may, in general, also be easy for young children to acquire (Drager et al., 2003; Drager et al., 2004; Fallon, Light, & Achenbach, 2003; Olin, Reichle, Johnson & Monn, 2010; Reichle & Drager, 2010). Related to this suggestion, researchers have proposed that schematically organized systems may place lower cognitive and/or developmental demands on the user than grid-based systems organized taxonomically (Drager et al., 2003; Drager et al., 2004; Light et al., 2004). Alternatively, potential disadvantages of scene-based systems may include difficulty generalizing vocabulary across contexts, and representing more abstract language concepts such as prepositions (Reichle & Drager, 2010).

Hypotheses regarding strengths associated with processing highly contextual visual scenes may be partially supported by research showing that in comparison to typically developing peers, individuals with ASD have been reported to perform better on the Children's Embedded Figures Test (EFT: Witkin, Ottman, Raskin, & Karp 1971) and related tasks which assess one's ability to discriminate items from surrounding contexts (Ropar & Mitchell 2001; Shah & Frith 1983; van Lang, Bouma, Sytema, Kraijer, & Minderaa, 2006). A review of such research suggests, however, that differences may only hold true with individuals with ASD who are considered to be lower-functioning (i.e., those who have more limited cognitive abilities; White & Saldaña, 2011). Furthermore, research specifically comparing abilities when processing visual information presented in scenes is mixed. In comparisons to typically developing peers, some studies suggest that individuals with ASD demonstrate enhanced visual awareness and abilities to discriminate changes to scenes (Smith, & Milne, 2009; Teunisse, Cools, van Spaendonck, Aerts, & Berger, 2001). Other researchers have reported deficits associated with attending to or remembering social elements within scenes (Rice, Moriuchi, Jones, & Klin, 2012; Williams, Goldstein, & Minshew, 2005) or rapidly recognizing contextually-mismatched changes to a scene (Loth, Gómez, & Happé, 2008). Still, other studies have found no differences (compared to typical development) in the way individuals with ASD process visual scenes (Sheth et al., 2011; van Eylen, de Graef, Steyaert, Wagemans, & Noens; 2013).

Although findings regarding visual scene processing abilities of individuals with ASD are mixed, the notion that VSDs may be developmentally and cognitively easy to acquire is at least partially supported by research conducted with typically developing young children. For instance, schematically organized systems may match how young children organize vocabulary items (Fallon et al., 2003). More specifically, Fallon et al. (2003) reported that when given a vocabulary organization task, 4 and 5-year-old typically developing children were most likely to organize concepts schematically. Additionally, Olin et al. (2010) reported that while typically developing children between the ages of 33 and 36 months initially located vocabulary items in a VSD faster and more accurately than 24-27 month-olds, with additional practice, children as young as 2 years rapidly increased accuracy and efficiency of responding.

Research comparing grids and VSDs

Direct comparisons involving VSDs and grids show mixed results, but VSDs may be more advantageous for younger children (Drager et al., 2003; Drager et al., 2004; Light et al., 2004). For instance, 2-and 3-year-old typically developing children were more accurate in locating vocabulary with schematically-based scene systems than with either schematically or taxonomically organized grid displays (Drager et al., 2003; Drager et al., 2004). Despite showing significantly better performance with VSDs as compared to grid-systems, 2 year-olds showed relatively low accuracy using all systems (Drager et al., 2003).

In contrast, differences between performance with the taxonomic grid, schematic grid, and schematic scenes were not replicated in a study with 4 and 5 year old typically developing children (Light et al., 2004). Another study, which did not assess navigational skills, but examined language communication skills with static VSDs and grid-displays, reported mixed results regarding communication outcomes for typically developing young children and those with communication disorders (including one participant with ASD; Wood Jackson et al., 2011).

Research on VSD systems alone, and in comparison to grid-based systems, among individuals with ASD is limited. Drager et al. (2005) reported on four case studies of young children with ASD who increased social interactions, vocabulary use, and understanding of semantic relations after the implementation of a multi-modal AAC intervention that included the use of VSDs. Unfortunately, the lack of experimental control in this study limits the conclusions that can be made. While not fully representative of complex visual scenes or grid systems involving multiple images or page navigation, a study by Gevarter et al. (2014) suggests that the visual format of language concepts in AAC systems may differentially affect mand (i.e., request) acquisition. Specifically, two out of three participants learned to mand single items presented in a field-of-one (i.e., only one vocabulary item represented on screen) with an iPad® SGD more rapidly and consistently when using an application that utilized photographic images of items in context (simpler form of VSD), as compared to one that used a symbol button (simpler form of grid). These same two participants did not demonstrate mastery of mands in a condition that involved a combination of a symbol and a photograph. Differences between application design elements such as the use of visual highlighting (e.g., borders) and haptic feedback (e.g., auditory or visual signal associated with touch), however, may also have impacted differences in acquisition (Gevarter et al., 2014). In a follow-up study, Gevarter et al. (2015) did, however, find that display formats within the same AAC application (AutisMate) also differentially impacted the acquisition of AAC requesting skills. Specifically, the study compared how individuals acquired discriminated requesting of preferred items (i.e., choosing between a variety of available preferred items represented on SGDs in fields greater than one) using four different display types. Displays included a symbol grid (rows of symbols representing preferred items), a simple VSD (photo image of preferred items in training context, with embedded voice output hotspots for each item), a hybrid (a photo image of items in training context, with embedded voice output hotspots for two items and symbol item hotspots for two items), and a hybrid pop-up grid (a photo image with a single whole scene hotspot that when pressed lead to a pop-up grid of symbols representing preferred items). Four of six participants mastered requesting items from a field-of-four with at least two displays, and one mastered requesting items in a reduced field-of-two. The sixth participant did not acquire discriminated requests. Individualized display effects were present, but the simple VSD appeared to have provided the most consistent advantages for four participants, and the hybrid pop-up grid was most beneficial for the fourth. Some errors were more or less common with specific displays and/or participants. Common errors included a lack of correspondence between hotspots pressed and items selected, as well as tapping hotspots multiple times.

Studies have also compared how visual design elements of AAC affect the acquisition of communication concepts among individuals with ASD and related developmental disabilities. For instance, some studies have reported that low-iconic versus high-iconic symbols or pictures versus photographic symbols does not differentially affect the aided mand acquisition of individuals with ASD (Angermeier, Schlosser, Luiselli, Harrington, & Carter, 2008; Jonaitis, 2011). Other studies, however, have found that visual design elements such as the distance of symbols, (Belfiore, Lim, & Browder 1993) or the use of different dynamic page navigation systems and/or fixed page displays may affect the latency and/or accuracy of AAC responses for individuals with developmental disabilities (Reichle, Dettling, Drager, & Leiter 2000).

RESEARCH SUMMARY AND DIRECTIONS FOR FUTURE RESEARCH

In sum, the literature suggests that there may be advantages and disadvantages of both scene and grid-based SGD systems that are mitigated by individual characteristics of AAC users (Reichle & Drager, 2010). Because individuals with ASD often show idiosyncratic preference and success with different AAC systems (Gevarter et al., 2013a; Schlosser & Sigafoos, 2006; van der Meer, Sigafoos et al., 2011), understanding how such perceived advantages or disadvantages affect individual AAC users with ASD is critical. With the myriad of easily accessible SGD-based AAC options that include grid, scene, and hybrid models, comparative research is essential for the further development of highly individualized and research-based AAC assessment and intervention practices (Gevarter et al., 2013a).

Research has supported the use of the grid-based application Proloquo2Go® for early acquisition AAC request skills (e.g., requesting preferred items by activating one hotspot on a single page; Kagohara et al., 2013). However; at least two studies have demonstrated that alternative display formats (e.g., simple VSDs) may provide learning advantages (e.g., in terms or rate of learning and consistency of performance) for some individuals with ASD (Gevarter et al., 2015; Gevarter et al., 2014). Although these studies build support for the use of simple VSD formats with one-step requesting skills, in order to make suggestions for AAC applications that may be used long term, the assessment of acquisition differences (e.g., how effectively, rapidly, and consistently an individual learns and applies AAC language responses) with more advanced, multi-step operations is necessary (Gevarter et al., 2013a; 2013b).

In particular, the assessment of navigational and vocabulary retrieval skills with different display formats is warranted, as these skills are important for the long term successful use of a dynamic SGD system (Drager & Light, 2006; Wilkinson & McIlvane, 2013; Robillard et al., 2013). Research with young typically developing children suggests that navigation and vocabulary retrieval can be affected by organizational structures (e.g., taxonomic or schematic; Drager et al., 2003; Drager et al., 2004). It is not known how such research would generalize to individuals with ASD.

STUDY PURPOSE

The purpose of this study was to compare how schematic and taxonomic organizations within an iPad® AAC application (AutisMate by SpecialNeedsWare) affects the acquisition of requesting when page navigation is required. More specifically, multistep requesting (e.g., choosing a category or scene, then choosing an item) with schematically organized VSD or hybrid models, and taxonomically organized grid-systems was assessed across at least two different settings, and three different categories of preferred items (e.g., drinks, food, toys) using a multielement design (Kennedy, 2005). Additionally, differences in acquisition of multistep requesting was considered in light of prior success with each display format for single-step discriminated requesting (e.g., when page navigation was not required, but items were selected from a field greater than one), assessed during a prerequisite study (Gevarter et al., 2015). A generalization phase (including an untrained setting and item) was also included. Examining how the acquisition of skills is consistent or differs across phases of learning may have important implications for assessment and practice (van der Meer et al., 2013). Finally, in order to better understand what contributes to inaccuracies in responding, descriptions of error types (such as step 1 errors involving selecting the wrong scene) were provided.

RESEARCH QUESTIONS

This study will address the following research questions:

1. Does the use of schematically organized (i.e., by location) VSD or hybrid displays, or taxonomically organized (i.e., by category) grid displays differentially affect

mastery, or rate of mastery, of multistep SGD requesting skills (i.e., choosing a category or scene from a field of three; choosing preferred item from a field of three) of young children with ASD?

2. What types of errors (e.g., selecting wrong category or scene, selecting wrong item, tapping hotspot too often) do individuals with ASD make when using VSD, hybrid, or grid-based AAC systems?

3. Does training of multistep navigational requesting generalize to one new setting with one new item/category, and maintain across three locations without continued intervention?

4. Do the acquisition results for multistep navigational requesting (i.e., choosing a category or scene from a field of three; choosing preferred item from a field of three) correspond with the acquisition results of an earlier stage requesting skill (i.e., choosing preferred items in field when page navigation was not required) from a previous study (Gevarter et al., 2015)?

Chapter 2: Review of Literature

To date, no studies have specifically compared how schematic or taxonomic vocabulary organization using VSDs, hybrids, or grid formats affect the acquisition of AAC skills among children with ASD (Gevarter et al., 2013a). There is considerable research demonstrating the efficacy of grid-based SGD systems that do not involve portable multimedia devices (e.g., iPads®, iPods®) with individuals with ASD (Lancioni et al., 2008; Ganz et al., 2012). Additionally, there is also growing research supporting grid-based tablet or touchscreen AAC applications; however, much of this research has focused primarily on early AAC acquisition skills (Kagohara et al., 2013). At this time, studies involving the use of VSDs or hybrid models with individuals with ASD appears to be limited to non-experimental case studies (i.e., Drager et al., 2005), or experimental studies assessing early acquisition skills (Gevarter et al., 2014; Gevarter et al., 2015).

Given the lack of research examining the use of different AAC application display formats and vocabulary organizational systems for individuals with ASD, a review of related research is necessary. It is important to review experimental research involving interventions with portable multimedia AAC applications for individuals with ASD, as well as comparative research assessing the effects of using different AAC organizational structures (e.g., taxonomic, schematic, alphabetic) and/or displays (VSD, grid, hybrid) with a variety of populations. This review will provide further information regarding the limitations of prior research (such as a lack of variety in the types of applications used, comparisons made, or AAC skills taught) that will guide the aims of this study. Such a review will also be used to determine intervention techniques that have been effective for teaching SGD responses on portable multimedia devices. Comparative research among non-ASD populations may also aid in the development of a comparative study involving individuals with ASD.

Current research involving the use of portable multimedia devices as AAC systems for individuals with ASD suggests promising results, but lacks variability in terms of participants, devices/applications, target skills, and intervention techniques. Additionally, although studies that have examined comparative effects of AAC display formats and organizational systems have demonstrated significant effects, variability of comparison types (i.e., different studies utilizing different types of organizational systems) and population types (typically-developing children, adults with disabilities) may limit generalization to individuals with ASD. In the following discussion, a review of both the strengths and weaknesses of research in these two areas will be provided in light of implications for the development of the current study.

Portable Multimedia Device SGD Research among Individuals with ASD

Recently, Kagohara et al. (2013) conducted a systematic review of intervention studies that utilized portable multimedia devices (including iPads®, iPods®, and iPhones®) in educational programs for individuals with developmental disabilities. Of 15 studies reviewed by Kagohara et al. (2013), 8 involved teaching participants with ASD to use AAC applications, and 7 of these 8 studies used experimental methodologies (i.e., single subject method, group randomized control). Since the publication of that review, several recent studies have also examined the use of Apple device AAC applications for individuals with ASD (Gevarter et al., 2014; Lorah et al., 2013; Sigafoos, Lancioni et al., 2013; Strasberger & Ferreri, 2013; van der Meer et al., 2013). Table 1 provides a summary of these studies, as well as the 7 included in the Kagohara et al. (2013) review.

Table 1. Portable media device AAC interventions for individuals with ASD

Citation	Participants	Devices/ Applications	Target SGD Skills	Intervention techniques	Results
Achmadi et al. (2012)	2 with ASD (ages 13, 17)	iPod® Touch with Proloquo2Go® with graphic symbols	Turn on, unlock screen, select SNACKS or TOYS category, select icon for one of three preferred toys or snacks	Time delay and least-to-most prompting	Both participants learned all targeted skills necessary to make requests.
Flores et al. (2012) .	3 with ASD (ages 8–9)	iPad® with Pick a Word software with photographs	Request one of four preferred items presented in a field of 4 photo buttons (with two additional phrase buttons for some)	Stimulus matching, modeling, time delay and least-to- most prompting	All participants requested using the iPad® and two showed higher rates of requesting using the iPad® than with non-electronic picture symbols.
Gevarter et al. (2014)	3 with ASD (ages 3)	iPad® with GoTalk with graphic symbols and Scene and Heard with photograph or combination of symbol and photograph	Request three preferred items each represented in a field of 1 using symbol button, photographical image, or symbol button displayed along with photograph	Time delay and least-to-most prompting	Two participants showed more rapid and consistent performance with the photographical hotspot than with the symbol button, but did not master the combined format. The third mastered all three conditions.

Table 1 (continued).

Citation	Participants	Devices/ Applications	Target SGD Skills	Intervention techniques	Results
Kagohara, van der Meer, et al. (2012)	2 with ASD (ages 13, 17).	iPod Touch and iPad® with Proloquo2Go® with graphic symbols	Name photographs by selecting symbols from field of 4 icons and field of 6 icons plus distractors	Time delay, least-to-most prompting, and differential reinforcement	Both participants were successful in using the iPad® SGD to name photographs.
Lorah et al. (2013)	5 with ASD (ages 3-5)	iPad® with Proloquo2Go® with graphic symbols	Request three preferred items each represented in a field of 1 with symbol button	Constant time delay with full physical prompts	All acquired the iPad® SGD, with three reaching mastery more rapidly than with picture exchange. Four had higher rates of manding with the iPad®.
Sigafoos, Lancioni, et al. (2013)	2 with ASD (ages 4, 5)	iPad® with Proloquo2Go® with graphic symbols	Request return of toy by pressing TOY PLAY symbol in field of 1	Time delay and graduated guidance	Both participants used the SGD to request continuation of toy play across intervention, generalization and maintenance.
Strasberger & Ferreri (2013)	4 with ASD (ages 5-12)	iPod® Touch with Proloquo2Go® with graphic symbols	Two-step request sequence ("I want" from field of 4, item from field of 4); and two- step response to "What is your name?" (select "Hi/Bye" in field of 4, select "my name is ___" in field of 4)	Time delay, graduated guidance, peer mediation	Two participants acquired two-step manding and two-step social question answering. One acquired two-step manding after given additional practice with one-step mands, and the fourth did not acquire two-step responses.

Table 1 (continued).

Citation	Participants	Devices/ Applications	Target SGD Skills	Intervention techniques	Results
van der Meer, Didden, et al. (2012)	3 with ASD* (ages 6–12)	iPod ®Touch with Proloquo2Go® with graphic symbols	Request preferred stimuli by selecting SNACK or PLAY graphic symbols from field of 2	Time delay, graduated guidance; reducing field, using 0s delay and differential reinforcement	One participant acquired the SGD in field of 2; another acquired field of one mands and the third required the use of a zero second time delay and differential reinforcement.
van der Meer, Kagohara et al. (2011)	1 with ASD (age 13)	iPod® Touch with Proloquo2Go® with graphic symbols	Request preferred stimuli by selecting graphic symbols from field of 3	Time delay, vocal prompting, physical guidance	The participant increased the rate of manding with the iPad® during post-acquisition training, and at follow-up.
van der Meer, Kagohara, et al. (2012)	2 with ASD, or Down syndrome and ASD (ages 7, 10)	iPod® Touch with Proloquo2Go® with graphic symbols	Request preferred stimuli by selecting graphic symbols, for SNACKS, PLAY, and SOCIAL INTERACTION (field of 3)	Time delay, graduated guidance, peer mediation	Both participants acquired and maintained mands with the iPad® SGD and did better with this modality as compared to manual sign.
van der Meer, et al. (2013)	2 with ASD (ages 10, 11)	iPod® Touch and iPad® with Proloquo2Go® with graphic symbols	Request preferred stimuli using “I want” symbol plus item symbol, plus “please” symbol. Respond to social interaction with symbols such as “hello”. All with 15 symbol grid that required scrolling	Time delay Least-to-most prompting and correspondence training	One acquired the iPod® SGD (slower than picture exchange and sign) but follow-up was inconsistent until iPad® introduced. The second participant did not acquire 3- step requests or social interactions.

Table 1 (continued).

Citation	Participants	Devices/ Applications	Target SGD Skills	Intervention techniques	Results
van der Meer & Sutherland, (2012)	4 participants with ASD (ages 4–11)	iPod® Touch with Proloquo2Go® with graphic symbols	Request preferred stimuli from field of 4 graphic symbols	Time delay, graduated guidance	Three out of four participants mastered iPad® SGD requests.

Intervention research involving portable multimedia devices as AAC for individuals with ASD has primarily involved the use of either the iPod® Touch, or the iPad® with the grid-based application Proloquo2Go® (Kagohara et al., 2013). In fact, 10 of the 12 studies presented in Table 1 exclusively used Proloquo2Go® with graphic symbols to represent communicative responses. A study by Flores (2012) utilized photographic icons in the Pick a Word application, but these were also presented in a grid format. Only the study by Gevarter et al. (2014) included the use of an application, Scene and Heard, with non-grid-based formats (i.e., involved simpler forms of VSD or hybrid models). The popularity of the Proloquo2Go® application provides researchers the opportunity to build support for its use (and possibly the use of similar grid-based systems), but a focus on this application alone may limit the social significance of AAC application research. Given the wide array of available AAC applications (many of which may be less expensive than Proloquo2Go®) that consumers may choose from (Farrall, 2012), research with a variety of applications is necessary in order to better inform AAC clinical practice and assessment. The fact that the majority of studies have only utilized graphic symbols may also limit the potential to explore unique advantages of new technology (Shane, 2012). Although previous research with non-electronic picture systems has not supported acquisition differences based upon the use of photographs or graphic symbols (Jonaitis, 2011) or different symbol sets (Angermeier et al., 2008), it is unclear whether or not these results will generalize to electronic systems. Additionally, it is possible that other grid-based applications, and/or applications with other display options may have design differences (e.g., haptic feedback, use of visual highlighting, or different sizing options for icons) that may impact acquisition.

Despite the lack of research across a variety of applications, it is important to note that current studies do support the use of behavioral principles such as time-delay and least-to-most prompting, to teach responses. Acquisition may, however, be impacted by target skill difficulty. More specifically, studies teaching simplistic one-step requests (e.g., Lorah et al., 2013; Sigafoos, Lancioni et al., 2013) may show more consistently positive results than studies teaching more complex multistep language responses (e.g., Strasberger & Ferreri, 2013; van der Meer et al., 2013).

With regards to one-step responses, time delay and physical prompting and/or graduated guidance have been used to teach children as young as 3 to request items presented in a field of one (i.e., only one vocabulary item represented on the screen) with Proloquo2Go® (Lorah et al., 2013; Sigafoos, Lancioni et al., 2013). Although individuals in these studies acquired the field-of-one requests using the grid-based Proloquo2Go®, the study by Gevarter et al. (2014) suggested that different display and design elements in the applications GoTalk Now and Scene and Heard impacted the acquisition of field-of-one requests, when similar behavioral strategies (time delay, least-to-most prompting) were used across formats. Two of three participants showed more rapid and consistent acquisition with a voice output hotspot embedded in a photographic image (i.e., simple VSD) in the application Scene and Heard, than with a symbol button format (i.e., simple grid) in the GoTalk application, but did not master a combined format (photo image with symbol hotspot) in the Scene and Heard application. The third participant mastered all three conditions at comparable rates (Gevarter et al., 2014).

Published research with one-step requesting skills involving larger fields (i.e., more than one item or vocabulary concept represented on SGD screen) has only utilized grid-based applications (Kagohara et al., 2013). Time delay and least-to-most-prompting (or graduated guidance) strategies have been used to successfully teach one-step discriminated requesting or labeling (i.e., choosing icons from field of two or more) with the Proloquo2Go® application (Kagohara, van der Meer, et al. 2012; van der Meer, Didden, et al., 2012; van der Meer, Kagohara et al., 2012, van der Meer, Kagohara et al., 2011; van der Meer, Sutherland, O'Reilly, Lancioni & Sigafoos, 2012). It appears, however, that at least some individuals with ASD may have difficulty acquiring discriminated requests using time delay and prompting strategies alone. For instance, two participants in the study by van der Meer, Didden, et al. (2012) required procedural modifications, and despite modifications, one participant failed to master mands in a field of two.

Although a majority of participants in studies involving one-step requests have demonstrated mastery of these skills, findings regarding complex multistep requesting skills are more mixed (Achmadi et al., 2012; Strasberger & Ferreri, 2013; van der Meer et al., 2013). In a study with positive findings, Achmadi et al., (2012) successfully used time delay and least-to-most prompting, to teach multistep requesting to two participants. Participants successfully learned to turn on their device, unlock the screen, select a SNACKS or TOYS symbol on a taxonomically organized category page, and then select an icon for one of three preferred toys or snacks. The study did not, however, utilize correspondence checks which may help to determine if the category and item icon requested selected actually correspond to a desired item. For instance, one form of a correspondence check utilized in the Picture Exchange Communication System (PECS; a non-electronic picture-based AAC system; Frost & Bondy, 2002) allows for confirmation that the item requested is the desired item by having communicators reach for the item they want following a request rather than having an instructor deliver the item requested. Without correspondence checks, it is possible that a participant may have pressed SNACKS, selected a preferred snack icon, and accepted that item when it was delivered, but really wanted to request a different snack item or a toy.

The Strasberger and Ferreri (2013) study taught multistep requesting and multistep social responses that required taxonomic page navigation using time delay, graduated guidance, and peer mediation. The study did not use correspondence checks, as only one preferred item was available at a time. Thus, although there were four item symbols to choose from on the SGD, only a request for the available item was considered correct. Similarly, although there were four categories, there was only one correct category for requests (i.e., I WANT symbol) following the verbal stimuli “What do you want?” and one correct social category to select after the verbal stimuli of “What’s your name?” Two participants mastered multistep requesting and social questions, and one participant was able to acquire two-step requests after given additional practice with one-step requesting. The fourth participant did not master any response prior to the end of the study.

Similarly, in the van der Meer et al. (2013) study, one participant acquired multistep requests (scrolling through a page of up to 15 icons and selecting several icons to build sentences or phrases) and social responses (notably at a slower rate than with other AAC systems), but the other participant did not master multistep responses (showed upward trend with requests when reduced to only two-steps). The study also utilized time delay and least-to-most prompting. Only snacks or toy items were available for a given set of trials. For the successful participant in the van der Meer et al., (2013) study, an alternative form of correspondence checks and error correction was utilized for item level discrimination. The correspondence checks involved allowing the child to reach from a variety of selected items after an SGD response, but if he reached for an item he did not request, the instructor prompted him to take only the item requested and said “You requested_____”, regardless if the item was desired (e.g., if participant pressed COOKIE and reached for cracker, he was prompted to take cookie). It was unclear, however, if these responses were considered correct or incorrect. The other participant only had one item available at a time, and requests for unavailable items were corrected (e.g., if participant requested cracker, but only cookie was available, participant corrected to press COOKIE).

More studies examining the acquisition of advanced AAC skills including discriminated requesting in larger fields, and responses that require scrolling or page navigation are necessary to make recommendations for AAC assessment and implementation. As some individuals with ASD have failed to acquire these skills with grid-based systems (Strasberger & Ferreri, 2013; van der Meer & Didden et al., 2013) and correspondence checks for navigational requesting involving multiple available items have not been utilized (Achmadi et al 2012; Strasberger & Ferreri, 2013), it is important to examine whether or not other display formats and organizational structures may aid in the acquisition of more complex AAC skills. Furthermore, the fact that some individuals may struggle to acquire more advanced skills despite having acquired simpler skills with the same application, may suggest that assessment of early AAC skills alone may not be enough to predict long term success for more advanced skills. For instance, while two participants had success with acquiring one-step discriminated requests in the study by van der Meer, Sutherland et al. (2012), only one of the same participants acquired multistep navigational requesting in a follow-up study (van der Meer et al., 2013).

In sum, the current research involving the use of portable multimedia devices as SGDs for individuals with ASD supports the use of behavioral instructional strategies, but is limited by the primary focus on one grid-based application, and the dearth of research with advanced SGD operation skills. Studies comparing the acquisition of advanced skills with different display types (VSDs, grids, hybrids) and organizational structures (e.g., schematic, taxonomic) may help to elucidate potential advantages or disadvantages. They may also exemplify assessment options for individuals who fail to acquire complex skills with one system. In order to develop such studies, it is important to review how researchers have made these comparisons with other populations.

REVIEW OF SGD DISPLAY AND ORGANIZATIONAL COMPARATIVE RESEARCH

There is currently limited research comparing different SGD display formats (grid, VSD, hybrid) and/or organizational structures (e.g., taxonomic, schematic, alphabetic). Available research has primarily been conducted with young typically developing children (Drager et al., 2004; Drager et al., 2003; Light et al., 2004; Wood Jackson et al., 2011) or adults with traumatic brain injuries (Burke, Beukelman, & Hux, 2004; Burke, Wassink, Martin, & Seikel, 2008) using group designs. Comparisons have involved different static AAC display formats (VSD, grid; Wood Jackson et al., 2011), or different vocabulary organizations for navigation (taxonomic, schematic, alphabetic; Burke et al., 2004; Burke et al., 2008; Drager et al., 2004; Drager et al., 2003; Light et al., 2004). Findings from these studies provide support for the notion that SGD display types and organizational structures can affect performance (Burke et al., 2004; Burke et al. 2008; Drager et al., 2004; Drager et al., 2003; Light et al., 2004). In addition, age (and/or developmental and cognitive abilities), disability, and SGD tasks may be associated with differential results. Detailed information on these studies can be found in Table 2 and are further described below.

Table 2. Comparisons of SGD displays and organizational formats

Citation	Participants	Comparisons	Skills Assessed	Findings
Burke et al. (2004)	12 adults with traumatic brain injuries (ages 18-50)	Written words organized by semantic topic, geographic place, or alphabetically	Find 16 words with each organization; choose between organizational system to answer additional 32 questions	Alphabet was significantly more accurate and faster for locating category than place and topic. There were no differences for rate of word retrieval. Participants chose to use topic 46.35% of the time, place, 30.47% of the time and alphabet 23.18% of the time.
Burke et al. (2008)	6 adults with traumatic brain injuries (ages 32-61)	Written words organized by semantic topic, geographic place, or alphabetically	Answer 16 questions that require vocabulary retrieval with each organization; choose between organizational system to answer additional 32 questions	Alphabet was significantly more accurate and faster than place for locating category and word and significantly faster than topic for category and word. Participants chose topic 27% of the time, place 31% of the time, and alphabet 43% of the time.
Drager et al. (2004)	30 3-year-old typically developing children	Schematic symbol-grid; Grid with screen shots of grid pages; schematic scene	Find 18 target words using one of the 3 systems taught over 4 sessions (participants randomly assigned); find 18 novel words with assigned system on one session without any teaching	After the first session participants using the schematic-VSD performed significantly better than participants using either of the grid systems. Generalization was limited across conditions with no statically significant effect of organization.
Drager et al. (2003)	30 2-year-old typically developing children	Taxonomic grid, schematic-symbol grid, schematic scene	Find 12 target words using one of the 3 systems taught over 4 sessions (participants randomly assigned); find 12 novel vocabulary words with assigned system on one session without teaching	Participants using the VSD performed significantly better than participants in either grid condition Generalization was limited across conditions with no statically significant effect of organization,

Table 2 (continued).

Citation	Participants	Comparisons	Skills Assessed	Findings
Light et al. (2004)	80 4 and 5-year old typically developing children	Taxonomic grid, schematic-symbol grid, schematic scene, and iconic encoding	Find 24 or 30 target words using one of the 4 systems taught over 4 sessions (participants randomly assigned); find 24 or 30 novel words with assigned system on one session without any teaching	All participants were significantly more accurate with the scene and grid systems than with iconic encoding during instruction and generalization, but there were no differences between the scene and grid conditions.
Wood Jackson et al. (2011)	26 typically developing children; 13 with complex communicatio n needs (one with ASD) ages 2-5	Static VSD and static grid	Spontaneous SGD activations during exploration with storybook and listening to storybook; number of accurate responses to closed and open-ended questions related to storybook	Significantly more activations during book exploration with grids, but also more silent hits (not activating speech output) with VSDs. Children with communication needs significantly more likely to use grid to answer open-ended questions, and showed slight accuracy advantage (not significant) with VSD for close-ended questions.

In a study involving 2 to 5-year-old typically developing children and those with complex communication needs (including one child with ASD), Wood Jackson et al., (2011) compared differences between static grid and VSD formats on an SGD. The results of this study were mixed, but some findings suggested that individuals with disabilities may show differential success with systems and outcomes in ways that diverge from those for typically developing peers. For instance, children with complex communication needs were significantly more likely to use the grid display to answer open-ended storybook questions and showed a slight accuracy advantage (not significant) with a VSD format for close-ended questions. In contrast, no differences between grid and VSD displays for question answering were observed for typically developing children. Across participant groups, however, children with and without disabilities were significantly more likely to spontaneously activate grid-displays while exploring a storybook (but rate of spontaneous activation was low across participants). Although these findings are limited, they suggest that individuals with disabilities perform similarly to peers for some AAC related tasks, but on other tasks, SGD display formats may lead to differential performance not seen in typically developing peers (Wood Jackson et al, 2011).

In contrast to the Wood Jackson et al. (2011) findings, studies comparing dynamic SGD vocabulary organizational systems appear to show more consistent advantages of different systems for different populations. Studies have included comparisons of schematic organizations (with symbols, scene images, or words) and taxonomic organizations (with words or symbols) and additional organizational systems including iconic coding and alphabetical organizations (Burke et al., 2004; Burke, et al., 2008; Drager et al., 2004;Drager et al., 2003; Light et al., 2004).

The two studies by Burke and colleagues (2004; 2008) compared how adults with traumatic brain injuries (TBI), but not demonstrating signs of aphasia, use semantic topic organization (i.e., taxonomic), geographic place (schematic) organization, and alphabetical organization of written words on an SGD. Assessment measures included the accuracy and speed with which participants retrieved words and the correct first category (e.g., selected correct geographic place category in which target word could be found then correct word) in response to instructions to find a specific word (Burke et al., 2004 study) or to questions that required answering with a certain word (Burke et al., 2008). In both studies, alphabetic organizational systems led to more accurate and rapid word and/or category retrieval than either schematic or taxonomic organizations (Burke et al., 2004; Burke et al., 2008). This may not be surprising, given the fact that the participants in the studies all demonstrated reading level abilities above a third-grade level. Interestingly, however, while participants also chose to use the alphabetic organization more often in one study that involved direct instructions to find a word (Burke et al., 2004), participants chose to use taxonomic organization more often to find words needed to answer specific questions (Burke et al., 2008). Preference for a given organizational system may, therefore, be affected both by ease of use as well as different task requirements, as well as prior knowledge and learning.

Studies by Drager et al. (2003; 2004) and Light et al., (2004) involved typically developing children ages 2 to 5-years-old. All three studies assessed target vocabulary retrieval during four instructional sessions, and novel vocabulary retrieval during one generalization session. The Drager et al (2003) and Light et al. (2004) studies compared retrieval using a taxonomically organized grid (e.g. symbols on main grid page represented topic categories such as “drinks”), a schematic-symbol grid (e.g., symbols on main grid page represented schematic contexts such as “playing games”), and a schematic scene (e.g., VSD images with contextually embedded vocabulary items represented locations such as a living room). The Light et al., (2004) study also included an iconic encoding organization which required SGD users to select a sequence of symbols from a grid to produce a target output. For example, pressing PEOPLE + LOVE would lead to an output of BABY. While Drager et al. (2004) also included schematic-symbol grid and schematic scene conditions, instead of using a taxonomically organized grid, the authors included a grid condition in which a screenshot of each individual grid vocabulary page was used to represent options on a main page.

Findings from Drager et al., (2004) and Drager et al. (2003) support hypotheses that schematically organized VSD systems are easiest for very young children to acquire (Fallon et al., 2003; Olin et al., 2010; Reichle & Drager, 2010). The findings from Light et al. (2004) suggest, however, that advantages may dissipate as developmental skills strengthen. For young typically developing children ages 2 and 3, studies reported significant differences supporting advantages of schematically organized VSDs in comparison to all grid systems (whether they were organized taxonomically, schematically, or using screenshots) during instruction (Drager et al., 2004; Drager et al., 2003). There were no significant differences between grid systems. It is important to note, however, that results from instructional sessions did not generalize to new vocabulary items (participants performed poorly across conditions during generalization). Additionally, the differential effects were not immediately apparent without continued instruction for 3-year-olds (Drager et al., 2004), and 2-year-olds had low response rates across conditions. In contrast, Light et al.'s 2004 findings indicated that 4 and 5-year-old typically developing children did not show differences between performance with VSD and grid systems (showing high levels of success with both). The only significant differences reported for the older children suggested that participants performed better with VSD (schematic) and grid (schematic or taxonomic) systems than they did with iconic encoding. Together, these findings (Drager et al., 2003; Drager et al., 2004; Light et al., 2004) may support other research that has demonstrated that success with grid-based systems increases along with increases in age and cognitive abilities (Robillard et al., 2013). Such findings warrant the need to assess how developmental delays, common among young children with ASD, may affect the ability to acquire different SGD formats and organizational structures.

Research is needed in order to determine whether results from these studies may generalize to young children with ASD across a variety of functional SGD responses. Modifications to the types of skills assessed and the research methods used may be helpful when designing related studies for individuals with ASD. Research with other populations has focused on word retrieval tasks and statistical analyses to measure differences across groups. Research with individuals with or without ASD should: include tasks that involve more functional SGD responses such as requesting, assess multiple stages of learning, and use research methodologies that may show individual and idiosyncratic differences. In other comparative AAC research conducted with individuals with developmental disabilities, requesting is often the most common dependent variable (Schlosser & Sigafoos et al., 2006; Gevarter et al., 2013a; 2013b). Word retrieval tasks may show differential effects, but using requesting as a dependent measure may better approximate common uses of AAC systems for young children with disabilities as well as increase task motivation. In addition to assessing requesting skills, future research should incorporate common instructional sequences used for teaching SGD acquisition. For individuals with ASD, this may involve assessing acquisition differences at various stages of instruction including simple one-step requesting, discriminated requesting in fields, and multistep requests that may involve sentence building and page navigation (Achmadi et al., 2012; van der Meer et al., 2013). Finally, while statistical measures have been used to demonstrate advantages of different SGD formats and organizational structures across groups, single subject research methodologies may be more appropriate for assessing individual differences suggested by Wood Jackson et al. (2011). Single-subject research methods such as multielement designs are typically the most commonly used approaches for comparative AAC research for individuals with developmental disabilities (Schlosser & Sigafoos, 2006; Gevarter et al., 2013a; 2013b).

CONCLUSIONS

Research supports the use of behavioral techniques to teach early AAC skills to individuals with ASD using the grid-based Proloquo2Go® AAC application. Further research is, however, needed to determine whether a majority of individuals with ASD can also acquire navigational skills using grid-based applications. Behavioral techniques such as time delay and least-to-most prompting should continue to be applied in research involving advanced AAC skills, but comparisons of grid-based systems to alternative display formats (VSD, hybrids) should also be considered. Given the fact that research with non-ASD populations has demonstrated differential navigational performance with different display formats and organizational systems, such research warrants the testing of these variables in individuals with ASD. In particular, research supporting developmental advantages of schematically organized VSD systems over grid-based systems, may suggest that AAC applications with VSD options could be more appropriate for teaching navigational skills to young children with ASD. Although no comparative research has been conducted with hybrid models, it is possible that advantages of VSD models may generalize to schematically organized hybrids. Alternatively, individuals with ASD may have more success with grid-systems, show idiosyncratic acquisition differences, and/or show acquisition that is impacted by prior performance during earlier stages of training. Examining if and how these differences occur is an important step for developing individualized AAC assessment and intervention plans that take advantages of new SGD technologies.

Chapter 3: Method

PARTICIPANTS

Four children with ASD (three males and one female) between the ages of 4 and 8 participated in the study. Participants were initially recruited from two agencies providing services for individuals with developmental disabilities, as well as from a local school district, to participate in a prerequisite study (Gevarter et al., 2015). Initially, an age range of 3 to 10 was used during recruitment. The minimum age of 3 was used due to prior research suggesting that typically developing 2 year-olds might have limited accuracy with SGD navigational skills (Drager et al., 2003). The range of preschool-age through elementary-age participants was selected in order to focus on childhood, but also provide variability that might lead to potential hypotheses regarding the impact of participant age on SGD display acquisition.

The prerequisite study compared how individuals acquired non-navigational (i.e., did not involve multiple linked pages) discriminated requesting (i.e., requesting preferred items from a field of four) using four different AutisMate displays (Gevarter et al., 2015). To move on to the current study, participants were required to have demonstrated prior mastery (80% correct across three sessions) of discriminated requesting skills using a grid-layout AND either a simple VSD or one of two hybrid formats. The grid display was a two-by-two grid of drawing-based symbols with voice output hotspots that represented preferred items. The simple VSD was a photograph of the preferred items in the training context (with no other items or people visible), with borders around the images of each item to indicate voice output areas. The hybrid was a photograph of the preferred items in the training context (with no other items or people visible), with borders around images of two items indicating voice output hotspot areas, and drawing-based symbols placed on the bottom of the screen to indicate voice output hotspot areas for two other items. The hybrid pop-up grid included a page with a photograph of the four preferred items in the training context (either out on a table or floor, or inside a therapy bag depending on the participant), and a large border around the entire image that indicated a hotspot area which, when pressed, would lead to a pop-up grid. The pop-up was a two-by-two grid of symbols (voice output hotspot areas) representing the items. Four of the six participants from the prerequisite study met the criteria to move on to the current study.

Prior to the start of the prerequisite study (which lasted 1-2 months, and occurred immediately prior to the start of the current study), the second edition of the Childhood Autism Rating Scale (CARS2; Schopler, Reicheler & Renner, 2010) as well as the communication domains of the Vineland Adaptive Behavior Scales (Sparrow et al., 2005) were administered. Participants were required to have had independent diagnoses of ASD (further confirmed via the CARS2) and to be delayed in expressive language, with no more than 10 spontaneous vocal words (as assessed via the Vineland). Communication age estimates and ASD severity ratings are provided for each participant in Table 3. In addition to these formal assessments, parents and therapists provided information on participants' prior use of AAC systems (including PECS, sign and SGDs), as well as prior use of portable multimedia devices for play. Participants could have had prior SGD experience, but could not be reported to use current systems to be able to make discriminated requests (i.e., request preferred items from a field) prior to the prerequisite study. If an alternative SGD system (i.e., not application used in study) was available to the participant, a semi-structured AAC observation was conducted. Specifically, the researcher presented preferred items already programmed in the alternative SGD system and asked the participant “What do you want? The researcher took anecdotal notes on the participant’s correct use of the system to make discriminated requests.

Table 3. Participant assessment information

Participant	Age	CARS2 Score	Vineland communication standard score	Vineland communication age equivalents	Prior AAC experience
Addie	4.0	37.5 (severe symptoms)	55 (low level)	Receptive:1.5 Expressive:1.0	PECS; AutisMate, LAMP, GoTalk Now, Scene and Heard
Donna	4.5	36.5 (mild to moderate symptoms)	59 (low level)	Receptive: 2.2 Expressive: 1.2	PECS; sign; AutisMate
Quinn	8.9	43 (severe symptoms)	54 (low level)	Receptive 1.3 Expressive: 1.10	PECS; sign; AutisMate; MyTalkTools
Ricardo	6.5	38.5 (severe symptoms)	49(low level)	Receptive:1.11 Expressive:1.0	PECS; sign; AutisMate; GoTalk Now

Addie was a 4.0 year-old African-American male who did not use any vocal words. Addie used PECS (up to Phase III) when he was in an early intervention program, but PECS was not maintained after services ended at age 3. He had some experience playing with touchscreen devices, and could operate simple games with minimal assistance. He used the iPad® applications GoTalk Now, and Scene and Heard to request items in a field-of-one during a previous research study (Gevarter et al., 2014). He had limited experience using the LAMP Words For Life™ by Prentke Romich Company AAC application in school, but at home was observed to repetitively press symbols, rather than functionally use the application to request available preferred items. During the prerequisite study, without any modifications, Addie had mastered discriminated requesting in a field of four preferred items using a grid-display and a hybrid pop-up grid format within the AutisMate application (Gevarter et al., 2015). His performance was most consistent with the hybrid pop-up grid. An analysis of error types was not conducted for Addie.

Donna was a 4.5 year-old white female who did not emit any vocal words. Donna used PECS (to phase III) as well as a variety of signs to communicate. She had experience watching videos and playing games on touchscreen devices, but did not typically operate devices without assistance. During the prerequisite study, Donna mastered discriminated requesting in a field of four using a simple VSD, a grid, and a hybrid pop-up grid with the AutisMate application. She acquired the simple VSD most rapidly, and remained most consistent in responding with this format. Her most frequent errors across displays were pressing the hotspot areas multiple times, and pressing a hotspot that did not match the item she then selected.

Ricardo was a 6.5 year-old Mexican American male who did not have any vocal words. His mother primarily spoke Spanish, but Ricardo received therapy in English.

Ricardo used PECS (to phase IV) as well as a variety of signs to communicate. He had some experience operating touchscreen devices for play activities, requiring physical assistance for some games. He had prior experience using GoTalk Now in another study focused on increasing vocalization rates. During the prerequisite study, Ricardo mastered discriminated requesting in a field of four using a simple VSD, a grid, and hybrid pop-up grid with the AutisMate application. He mastered the three displays at a similar rate, but was most consistent in responding using the simple VSD. With all displays except the VSD, he displayed a variety of error types (e.g., pressing hotspots multiple times, pressing navigational buttons that led away from the page, no response, no correspondence between the hotspot he pressed and the item he chose) in more than 10% of trials.

Quinn was an 8.9 year-old white male who rarely initiated with vocal words, but could, with prompting and strong reinforcement, vocally imitate words. Prior to this study, Quinn had been taught to use a picture card, and an iPhone® with the MyTalkTools Mobile Lite application by 2nd Half Enterprises LLC to request single items presented in a field-of-one during a functional communication training (FCT) study. He had not continued to use these systems. His mother reported that at various times he had been introduced to PECS and had been successful up to phase III, but the system had not been maintained. He had extensive experience independently operating touchscreen devices for play activities and video watching. During the prerequisite study, he mastered discriminated requesting in a field of four using a VSD, a grid, a hybrid, and a hybrid pop-up grid with the AutisMate application. He acquired the simple VSD rapidly, and also showed the most consistent performance with it. The only display in which he showed the same error for more than 10% of responses was with the grid (i.e., hotspot pressed did not match item selected).

SETTING AND INTERVENTIONISTS

The sessions occurred in two different rooms (intervention) and an outdoor location (generalization) of participants' homes. Locations were initially selected based upon the differential availability of preferred toy items in each setting (e.g., kitchen table-top toys versus bedroom floor toys). These locations included kitchens, living rooms, and bedrooms (intervention), as well as backyards and outdoor balconies (generalization). The lead author was the sole interventionist for Quinn and Addie. For Ricardo and Donna, about half of the sessions were conducted by the author, and the other half were conducted by trained masters or doctoral level students in special education.

MATERIALS AND SELECTION PROCEDURES

Materials included preferred items (determined via preference assessment) and Apple iPads® or Apple iPad® Minis with the AutisMate AAC application. AutisMate was used to create a taxonomically organized grid for each participant as well as a schematically organized VSD or hybrid pop-up grid (selected based upon prior success with VSD or hybrid models during Gevarter et al., 2015). AutisMate was selected as it provides options for developing multiple display options within the same application (thus increasing control, by eliminating design differences across applications).

Initial Preference Assessment

Preferred items across the categories food, drink, toys/play items) were selected based upon a two-stage preference assessment (Green et al., 2008). Parents and/or in- home behavioral therapists were asked to make a list of a child's preferred items across food, toys (or non-traditional things used as play items, such as kitchen condiments), and drink categories. For toys/things, parents and/or therapists were asked to select items that were typically differentially used across the two locations in the home. For example, they might be asked to list three preferred toys most often used in the living room, and three preferred toys most often used in a the child's bedroom. Electronic-based activity items (iPads®, phones) were not assessed in the toy category since most parents suggested that only one type of electronic system was preferred and used across locations (as opposed to different systems used in different locations).

Direct assessment using a multiple stimulus format without replacement (MSWR; DeLeon & Iwata, 1996) was then used to determine one highly preferred food item and one highly preferred drink item to be used across locations, and one highly preferred toy or thing for each of the given contexts. Therefore, there were 4 preference assessments (one for food, one for drinks, two for toys/things). For each assessment, three items were presented by placing them directly in front of the child. The child was asked "What do you want?" and whatever the child touched or pointed to, and then consumed or played with, was recorded. Each child was allowed to consume a snack or drink, or play for 10 s and then that item was removed. The child was then asked "What do you want?" but only given a choice of the remaining items. This process was repeated three times and the order in which each item was selected was recorded. The assessment was repeated three times over the course of two to three days and an average rank order for each item was computed. For each assessment, the highest ranked item was selected for use during intervention (i.e., one food item, one drink item to be used across both locations; two different toys/things used differentially across locations). Parents were also asked to report a preferred item in each category that was not readily available in the home (soda for example), as well as a non-preferred item in that category.

Additional Preference Assessments

To determine additional items for the generalization phase occurring in an outdoor location (i.e., backyard or balcony) a preference assessment (following same procedures above) across an additional category associated with the child's outdoor preferences (e.g., activities, art items) was implemented. The highest ranking outdoor item was selected for the generalization phase.

Additionally, if based on the initial assessment, participants did not have stable preferences across food, drink, or toy items, a different preference category suggested by parents and/or therapists was assessed. Specifically, although Quinn showed a high preference for one drink, as well as a table-top toy he used in the kitchen, and a floor toy he used in his bedroom, his interest in food appeared to be highly variable depending on the time of day, and he did not show a consistent preference. His mother suggested an assessment of preferred electronics (e.g., computer, Nabi® tablet, iPad® tablet). As the iPad® tablet (different than one used as the SGD) was consistently preferred, Quinn had an electronics category instead of a food category. On the initial assessment Addie, Donna, and Ricardo showed stable preferences across food, drink and play items so additional categories were not assessed prior to the start of the study

However, when Donna and Ricardo appeared to show decreased interest in the items selected (see procedural modifications and results), additional assessments were conducted. First parents/therapists were asked if there were additional highly preferred toy/thing items used in each context that were not initially assessed. As parents did not have suggestions for additional items that they thought would be more preferred than those initially assessed, they were then asked if there were additional preferred items not in the food, drink, or toy categories, which may be more stable preferences. iPad® play tablets were suggested for both participants. A play-based iPad® (i.e., not one to be used as SGD) was then assessed along with the previously suggested three toy items for each environment using a MSWR format (repeated three times). For both participants, the iPad® was the most preferred item across both locations. Next, parents were asked if the participant had at least two additionally highly preferred food items, of similar preference, that were not typically readily available in the home (i.e., could be restricted to increase motivation and prevent satiation, and could be programed to be available in one specific home location). The new food items were then assessed along with the previously suggested items using a MSWR format. The top two ranked food items were then randomly assigned to be available in one of the two locations. The initially selected drink item was not reassessed, as both participants appeared to request the drink after several food item requests (i.e., satiation of drink item may not have occurred, but was just less likely due low interest in food).

Intervention displays

During intervention, both display conditions were initially designed to include hotspots corresponding to a preferred food item and a preferred drink item that remained the same across locations, and a hotspot for a toy/play item that was differentially available based upon the location for a given session. For instance, Ricardo initially could request milk, raisins, or a gear toy in both conditions in the living room (where gear toy was usually played with), and he could request milk, raisins and puzzle in the bedroom (where puzzle was usually played with). As Quinn did not show a stable preference for any one food item (see preference assessment), his hotspots corresponded to a preferred electronic item and drink item available in both locations, and differential toys by location.

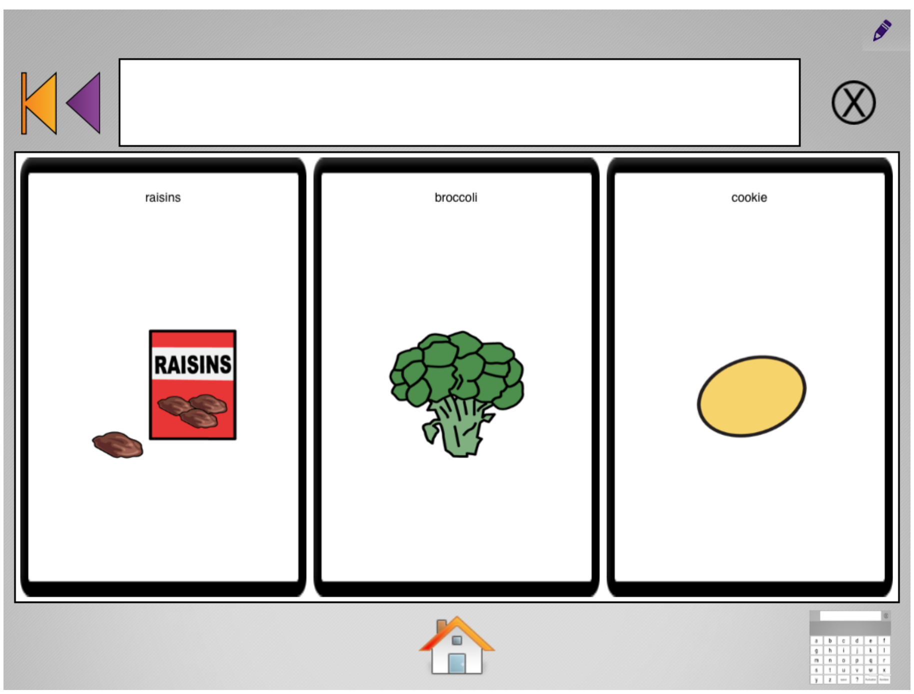
The use of two identical items and one differential item in each location (with items from three categories) was done in order to: (a) approximate the differential availability of items across settings that may occur naturally (e.g., some items might be available in multiple settings, but others may only be available in specific settings), (b) create discriminable differences between scenes without creating substantial differences in the reinforcing value of items across locations (c) assess and compare requesting for items across different categories using each of the display formats. Initially, the toy/things were selected to differ across locations, as this what was most typical in the natural environment. For instance, two preferred foods or two preferred drinks might not typically be differentially associated with two different locations (e.g., eating chips in the kitchen, but cookies in the living room). In contrast, children might be more likely to use different toys based upon location (e.g., different sets of bedroom toys and kitchen table top toys).

Initially, the taxonomic grid was intended to have a main page displaying symbol buttons for the categories foods, drinks, and toys, corresponding to the three preferred available items (see Figure 1). Addie and Ricardo's initial preferences enabled the use of these categories. Donna's categories were foods, drinks, and "things." The "things" category was used because Donna's preferred play items (e.g., kitchen condiments) were not traditional toys, and might not have been appropriately represented via a "toys" symbol. Since Quinn did not have a stable food preference, he had an "electronics" category instead of food. For each participant, the first symbol available in the AutisMate symbol library for the category label was selected. Ordering of the three symbols was randomized.

Pressing a category symbol would lead to a second page (see Figure 2) displaying three symbols representing items related to the category (e.g., three food items presented on page two after selecting the food category). For all participants, one item symbol represented the preferred and available item for that given category (determined via preference assessment), one represented an unavailable and non-preferred item (suggested via parent report) from that category, and one represented a preferred, but unavailable item (suggested via parent report) from that category. This was done to approximate traditional grid displays in which multiple items may be represented under a category, but not all items may be consistently available across contexts and settings.

Figure 1. Example of taxonomic grid category page.

Figure 2. Example of taxonomic grid item page



For the schematic condition, a main page showed three photographical images representing locations (See Figure 3). Two of the images were photographs of the child interacting with preferred items in each of the intervention locations, and the third photograph was a distractor representing an image of a location without preferred items (e.g., photograph of a door). Selecting either of the non-distractor location photographs would lead to the opening of a second page in which the initial scene photograph was enlarged. Vocabulary hotspots were incorporated using either a VSD (Figure 4) or a hybrid pop-up grid format (Figure 5). The selection of the VSD or hybrid pop-up grid models for the schematic condition was based on participants' prior performance with each system during the prerequisite study (Gevarter et al., 2015). Specifically, participants used the VSD or hybrid model with which he or she had demonstrated the most prior success (in terms of mastery, rate of mastery, and consistency or performance) when navigation was not required. For Donna, Quinn, and Ricardo, the second page displays were VSDs (see Figure 4). In the VSDs, the enlarged scene was a photograph of the child interacting with the three preferred available items (e.g., one food or electronic item, one toy/thing, and one drink) for the given location, with borders placed around the images of the preferred items to indicate voice output hotspot areas. Addie's second page displays were hybrid pop-up grids (see Figure 5). In his displays, a border was placed around the entire scene (photograph of him interacting with preferred items in location), which when pressed, activated a choice board with preferred item symbols that indicated voice output hotspot areas (see Figure 5).

Figure 3. Example of schematic scene page (participant's image blacked out).

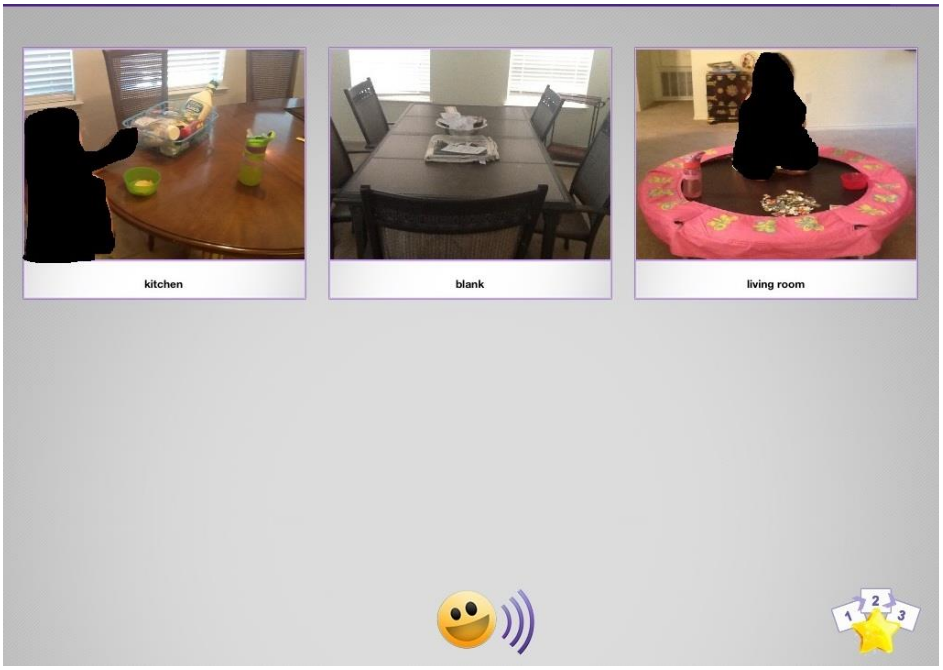


Figure 4. Example of VSD item page (participant's image blacked out).

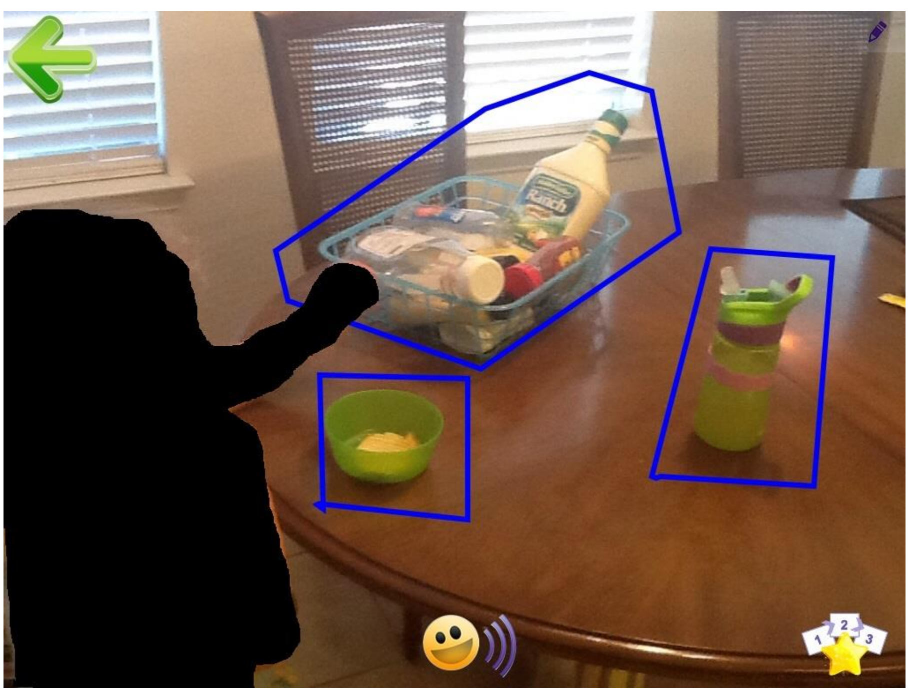
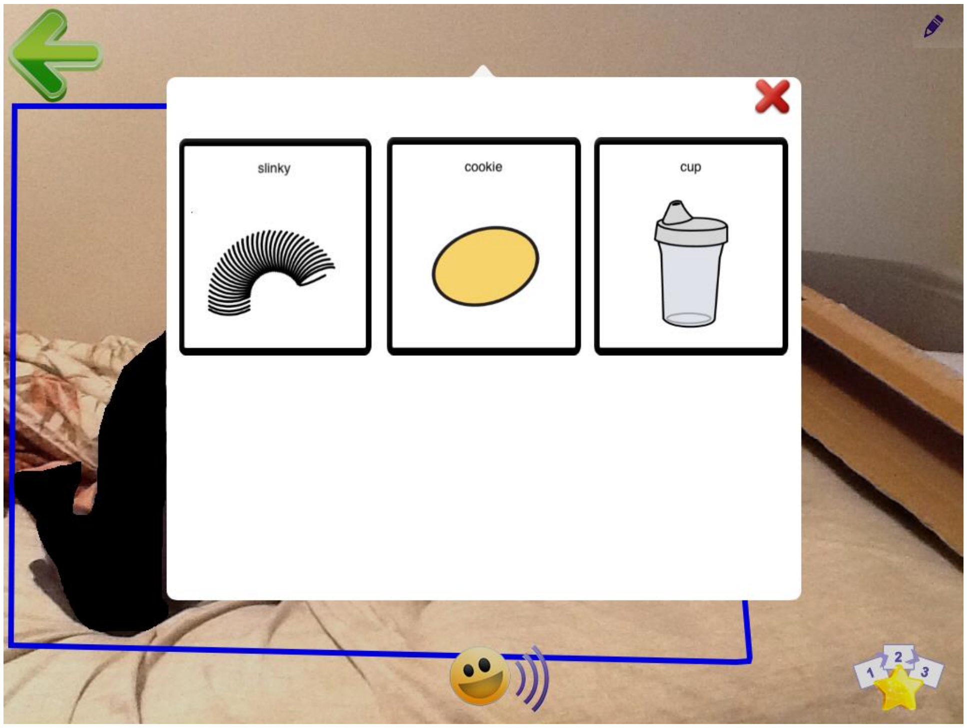


Figure 5. Example of hybrid pop-up grid (participant's image blacked out)



Display modifications

When Donna and Ricardo's preferences appeared to change (see results) and additional highly preferred items already associated with the training locations were not identified (see additional preference assessments), the toy/thing category was replaced with an electronics category. Since both participants only had one highly preferred electronic item used across contexts, two new food items (not typically readily available in the home) were identified and randomly assigned to be contingently available in one of the training locations (e.g., popcorn in living room, candy in kitchen; see additional preference assessment).

Generalization displays

During a generalization phase, a novel third location (outdoor area) and new item from a novel category was introduced. The previously used food item (or electronic item for Quinn) and drink item were available and still represented in displays in both conditions. In the taxonomic grid condition, while two previous categories (e.g., food, drinks) stayed the same, a third category was replaced with an additional category determined based upon the child's preferred interests or activities in the new location (e.g., "activities"). Pressing the new category led to a second page that included a symbol icon for the novel preferred item or activity from this category (determined via preference assessment) along with two distractor items from the same category. In the VSD or hybrid pop-up grid, one of the previous locations was replaced with an image of the new location. When the outdoor scene image was selected, a voice output for the novel item (either as an embedded hotspot or symbol in pop-up grid) was available along with two of the previous items. For Ricardo, after several generalization sessions in which he showed decreased interest in preferred items, the previously available food item was replaced with his play iPad® (similar to the modification made during intervention).

EXPERIMENTAL DESIGN AND SESSIONS

A multielement design (Kennedy, 2005) was implemented in an attempt to demonstrate experimental control within each participant's data set. A session for each condition (i.e., taxonomic grid or schematic VSD/hybrid pop-grid) consisted of 10 opportunities to request preferred items by navigating to the correct scene image or category symbol and requesting an available item. Two to four sessions (with an equal number of sessions across conditions) were conducted during one home visit (occurring 2-4 times a week for up to 10 weeks) for a total of 20 sessions per condition. The order of conditions was randomized for each set of two sessions, while the order of locations remained fixed (e.g., a condition selected to occur 1st always occurred in room 1, and a condition selected to occur 2nd always occurred in location 2). A change to ordering was made, however, if a condition was selected for the same order/location for more than 2 consecutive sessions. A 2 to 5 minute break (depending on participants' continued interest in requested preferred items) occurred between sessions. Four sessions were only conducted on days when participants initiated continued interest for requesting the preferred items (e.g., leading researcher back to items, reaching for items or iPad® to make additional requests) after the first two sessions were completed. Intervention in each condition continued until (a) the child reached a mastery criterion of 80% correct responding for four of five consecutive sessions (consisting of two sessions at or above 80% for each location; with no scores below 70%) or (b) the child did not reach mastery in the condition within 20 sessions after the initial generalization probe (end of study).

Once the participant mastered one condition across two settings, a generalization phase (across a third setting with a new item from a novel category) was introduced for that condition. Mastery criterion for the third location was three consecutive sessions at or above 80%. If a participant mastered the generalization phase before 20 total sessions (excluding generalization probe session), a post-treatment maintenance phase was introduced. The maintenance phase consisted of randomly rotating locations for the condition, and continued until the end of the study.

DATA COLLECTION AND RESPONSE DEFINITIONS

The percentage of correct request responses per session was recorded and used to determine mastery and rate of mastery (dependent variables). Additionally, all incorrect responses were coded according to error type.

Correct and incorrect iPad® responses

Correct responses for the grid condition occurred when the child independently (that is without any physical, gestural, modeled, or vocal prompts) completed the following steps: pressed a category within 6s of the iPad® being placed in front of him, pressed icon representing available item within 6s of secondary page appearing, selected actual item matching icon chosen. Correct responses in the VSD involved the following steps: selected the image representing the current location within 6s of the iPad® being placed in front of him, pressed embedded hotspot representing available item within 6s of secondary page appearing, selected actual item matching hotspot chosen. The hybrid pop-up grid consisted of the same requirements, however, participants needed to first press the whole scene hotspot image (within 6s of page appearing), before they selected the appropriate symbol button from pop-up grid (within 6s). Although previous iPad® SGD studies with individuals have used time delays ranging between 2 and 10s, 6s was selected as the delay in this case in order to provide participants time to scan the screen, but also promote response efficiency.

The following criteria were also necessary for correct responses across all conditions: (a) symbol buttons, images, or hotspots (on first and second page) were pressed no more than twice with enough pressure to produce speech output, but no more than one output produced (additional responses were considered errors); (b) the child used only one or two fingers; (c) the child did not touch another part of iPad® prior to or less than 3s after making the response; and (d) the child did not attempt to grab the item prior to completing the entire response chain. Pressing no more than twice was considered an important criterion as pressing multiple times could lead to inappropriate repetitive vocal outputs or a delay in the speech output. Participants were allowed a second press (that did not produce an additional output) as data from previous studies (Gevarter et al., 2015; Gevarter et al., 2014) suggested that on occasion tablet screens might not always register a first response. Accidental or non-discriminatory hits of the iPad® that may have produced speech output were ruled out as correct responses via the two finger maximum. Grabbing items, or touching different parts of the iPad® screen were considered incorrect as they could have led to the reinforcement of incorrect behavioral chains. Responses in which the individual's fingers hovered over, but did not physically touch an incorrect screen spot prior to a correct response within the 6s interval were, however, still considered correct. If additional responses (e.g. multiple taps or touching another part of screen) occurred 3s after a correct first response, it was considered researcher error (e.g. reinforcement not delivered fast enough) and this was not counted against correct responses. Behavioral indications (such as pointing to items) not involving touching the iPad®, or attempting to grab the reinforcing item were not considered to be correct or incorrect.

Error types

Errors during step 1 (choosing category or scene button) and step 2 (choosing representation of preferred item) were coded according to the type of errors made (see data collection sheet in Appendix A). For step 1, the following error types were coded: tapping multiple times, touching another part of iPad®, waiting longer than 6s to make a response, pressing a navigational button (e.g., arrow back), grabbing an item, making incorrect motion or using incorrect topography (e.g., swiping, hitting), touching more than one area, or touching an unavailable location (i.e., distractor or location not matching the current setting) in the VSD or hybrid pop-up grid only. During step 2 (choosing preferred item), error codes were the same for the first step except that instead of touching a distractor or mismatched location with VSD or hybrid pop-up grid, errors with selecting an unavailable item in the grid condition could be recorded. Finally, minuses were recorded if participants did not select the physical item that matched the icon or hotspot they pressed. On the data sheet this is listed as the third response in the chain, but for purposes of discussing errors, selecting an item that did not correspond to the item requested was considered a step 1 error for the grid condition (i.e., participant had not correctly discriminated the right category if they took a different item), and a step 2 error for VSD or the hybrid pop-up grid condition (i.e., did not correctly discriminate between icons or hotspots representing available items). Percentages for each error type were computed across all sessions for each condition.

Inter-observer Agreement (IOA)

During each session, the trainer recorded responses for each step as correct or as incorrect. Errors were also coded. For each individual, a minimum of 25% of sessions for each condition was randomly selected for IOA checks. IOA checks were conducted in vivo for participants (Donna, Ricardo) whose responses were sometimes difficult to code from videos during the prerequisite study. Observers were doctoral or masters 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. The observers (either in vivo or while watching videos) used the same data collection sheet as the trainer to record correct or incorrect responses for all steps and coded all errors. IOA was calculated using the formula: agreements/ (agreements + disagreements) x 100% for overall correct and incorrect responses as well as for error codes. Mean IOA scores for overall correct/incorrect responses 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 scores for error codes 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 during the study in order to observe trends in data (e.g., decreased responding in both conditions) that might indicate the need for modifications. Determinations of mastery were based on the previously stated criteria rather than visual analysis alone. Conditions were compared in terms of overall differences in mastery and rate of mastery of phases, as well as differences in data paths, (in terms of level, trend, and variability).

Error types were also continuously analyzed to determine whether high rates of specific error types might indicate the need for a modification. Error types occurring in more than 10% of responses for individuals, and on average across participants, were reported for each condition.

PROCEDURES

Generalization probe

For all participants except Addie (pilot participant), a generalization probe in each condition was conducted prior to the start of intervention. During the generalization probe, each condition was presented in the generalization training environment (i.e., outdoor location) with the generalization display and preferred items for that environment. The preferred items were placed out of reach and the SGD with the appropriate application main page (with three categories or three scenes) was then presented between the child and the items (start of trial). The participant was given 6s to make a correct response. Correct responses were reinforced with access to the preferred item, but if incorrect responses were made, the iPad® was removed for 5s and the trainer then presented it again and say "try again."

Intervention

The items selected for each location were placed in front of the child (in random orders), at a distance just beyond a reach. For step 1 (child selects category or scene) the iPad® with the appropriate application main page (with three categories or three scenes) was then presented between the child and the items (start of trial). The trainer then waited 6s for the child to independently press a category symbol button or image of a scene. If the child made no response or an incorrect response during step 1 (see response definitions) during the 6s delay, the trainer implemented a least-to-most prompt hierarchy consisting of a partial physical prompt (guiding the child's hand to a position just above symbol or photo image), and a full physical prompt (physically assisting the child to make the correct response). When there was no response in the grid condition, the trainer prompted selection of the last previously requested category. If it was the first trial of a session, the trainer asked "what do you want?" and then prompted whatever category corresponded to an item that the child reached for, pointed to, or signed (if the child did not show interest in the items at all, the session was discontinued until interest was established). In the VSD or hybrid pop-up grid conditions, if there was no response, the trainer prompted the participant to select the scene matching the current location. Incorrect responses that involved grabbing the item, pressing the iPad® off button, or touching a part of the iPad® that changed the display were, as necessary, physically stopped before delivering the prompt sequence.

For step 2, if the child did not respond or made an incorrect response during a second 6s delay, the trainer also implemented a least-to-most prompt hierarchy consisting of a partial physical prompt (guiding the child's hand to a position just above symbol representing available item), and full physical prompt (physically assisting the child to make the correct response). In the grid condition if there was no response the trainer prompted the child to select the symbol representing the available item from the category. In the VSD or hybrid pop-up conditions, if there was no response the trainer prompted the child to select the hotspot or symbol representing the last chosen item. If it was the first trial of a session, the trainer asked "what do you want?" and as needed and prompted whatever item hotspot/symbol that corresponded to the item that the child reached for, pointed to, or signed (if the child did not show interest in the items at all, the session was discontinued until interest was established).

After steps 1 and 2 were completed (prompted or independently), the trainer removed the iPad®, said "take it" and waited for the child to take the preferred item from the field of three. If the child reached for an item that differed from the one requested, the participant was blocked from taking that item and a form of correspondence training adapted from the PECS Protocol (Frost & Bondy, 2002) was initiated. For the grid condition if the wrong category was chosen, correspondence training consisted of saying "you want the ___", physically prompting the child to select the appropriate category from step 1, and then the appropriate item from step 2. For hybrid conditions, correspondence training consisted of saying "you want the ___" and physically prompting the child to select the correct symbol or hotspot on the step 2 page.

Generalization

During generalization, procedures were similar to training, however, no prompting was provided. Correct responses were reinforced with access to the preferred item, but if incorrect responses were made, the iPad® was removed for 5s and the trainer then presented it again and say "try again." The generalization phase continued until the participant reached mastery criterion (3 consecutive sessions at 80%), or until the end of the study (i.e. on 20th session in condition, excluding initial generalization probe).

Post-treatment maintenance

If a participant mastered generalization in a given condition, a post-treatment phase was introduced. During this phase, each location was used once for every set of three sessions, with the order of locations randomly selected for each set of three sessions. Procedures mirrored the generalization phase. Specifically, participants were reinforced for correct responses, but if incorrect responses were made, the iPad® was removed for 5s and the trainer then presented it again and said "try again." The phase continued until the end of the study (i.e., 20th session in condition, excluding initial generalization probe).

Procedural modifications

Training modifications were introduced for Quinn, Ricardo, and Donna based on the analysis of data trends, observations, and error analysis codes. The first modification introduced for Donna was based on the observation that her SGD responses and correspondence checks were inconsistent with alternative responses she spontaneously emitted prior to her SGD response (e.g., manual signs, pointing to different item than what she ultimately requested and took; see results for more in-depth description). Due to a concern that there may be false positives (e.g., she was requesting and taking items that she did not actually want most), an attempt was made to determine whether it was possible to assess which item she desired prior to her SGD response. Thus, during this modification phase, prior to the SGD being placed in front of Donna, the instructor 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, but the SGD could still be placed between her and the preselected item. Once the SGD was placed between her and the item, she was given 6s to respond. Correct responses involving selecting the hotspot that corresponded to the preselected item were reinforced with that item. For incorrect or no responses, the same prompt hierarchy for the regular intervention procedures were used (e.g., corrected multiple taps with partial and/or physical prompt), except if she made a response that did not correspond with the preselected item (e.g,, selected food category or embedded hotspot of food item when drink was preselected) she was immediately prompted to make a response corresponding with the preselected item. Prompted responses were also reinforced with the preselected item. Thus, if she signed for her drink item prior to the SGD trial and then made an attempt to request the food category this was considered an error (non-correspondence) and she was prompted to select the drink category instead. This procedure did not ultimately seem to be an appropriate way to assess which item she desired as she sometimes reacted negatively (e.g., whining, pushing away item) when given the preselected item after being prompted to request it. After three days of the modification, a reversal back to the initial procedures was intended, however, Donna showed no interest in her preferred items (pushed items away and walked away from training area). Thus at this point, a modification of preferred items was made (see display modifications and additional preference assessments) prior to returning to the initial procedures.

Ricardo's preferred items were also re-evaluated (see display modifications and additional assessment preference assessments), following a decrease in performance in both conditions, and an attempted session in which Ricardo showed no interest in requesting the selected items (shaking head, walking away). Similarly, during generalization when Ricardo showed decreased interest and delayed responding in making requests for the last several trials (e.g., made several correct responses for one item, then appeared to lose interest and made incorrect responses rather than request alternative item), a decision was made to replace the food item (not commonly requested) with his play iPad®.

For Quinn, a decision was made to change one of the "distractor" symbols in the electronics category of the grid condition after he demonstrated that he could differentiate between distractors in another category (i.e., began correctly requesting his available drink and not pressing distractor). Specifically, there was a concern that his most common error of pressing a “computer” distractor prior to selecting the iPad® icon was due to the fact that the “electronics” category symbol was also a computer (different, but similar symbol). During this modification, a different distractor (video game) replaced the computer icon.

Procedural Integrity

Procedural integrity across intervention sessions and generalization/post-treatment maintenance sessions (Appendix C) was assessed for a total of 25% of all sessions, with an equal number of sessions for each conditions. Sessions were randomly selected. Similar to IOA, integrity checks were conducted in vivo for Donna and Ricardo, whose responses were sometimes difficult to code from videos during the prerequisite study. Addie and Quinn’s integrity checks were conducted via video. Integrity checks for each child were conducted by independent observers using a checklist that outlined each step of the procedures for intervention (see Appendix B) and generalization/post-treatment maintenance (see Appendix C). Observers were trained by reading study procedures, observing sessions not selected for integrity checks, and reviewing each step of the checklist with the primary researcher. Procedural integrity was calculated using the formula: Number of steps correctly implemented/ (number of steps correctly implemented + number of steps incorrectly implemented) x 100%. Mean integrity scores 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%).

Chapter 4: Results

The acquisition of multistep SGD requesting skills differed across schematically organized VSDs or hybrid pop-up grids, and taxonomically organized grids. Below, results across participants are summarized for each research question. Subsequently, individual results are presented in the text, and summarized graphically in Figures 1 through 4.

Differential Effects on Mastery and Rate of Mastery (Question 1)

Table 4 summarizes which conditions were mastered by participants, and how many sessions were required to meet mastery criterion. Three out of the four participants (Addie, Quinn, Ricardo) mastered multistep requesting with a schematically organized VSD or a schematically organized hybrid pop-up grid in 9 to 11 sessions, but did not meet mastery criterion with a taxonomically organized grid display before the study's end. Performance with the taxonomically organized grid was, however, on an upward trend for these three participants. The fourth participant (Donna) mastered both a schematically organized VSD and a taxonomically organized grid at the same rate (14 sessions).

Table 4. Mastery and sessions to mastery across conditions

Participant	Phase	Schematic	Taxonomic
Addie	Intervention	Y (11)	N
	Generalization	Y (4)	N/A
Donna	Intervention	Y (14)	Y (14)
	Generalization	Y (3)	N
Quinn	Intervention	Y (9)	N
	Generalization	Y (4)	N/A
Ricardo	Intervention	Y (9)	N
	Generalization	N	N/A

ERROR TYPES ASSOCIATED WITH CONDITIONS (QUESTION 2)

Table 5 presents error types occurring in more than 10% of responses for individual participants, and average percentages across all participants that were above 10%. For the schematic conditions (VSD, hybrid pop-up grid) the only error occurring for more than 10% of responses for any participants was a step 1 error involving selecting the wrong scene (i.e., selecting location not matching location for that session). Across participants, this error occurred on average in 14.8% of responses (range 9% to 19.5%). Quinn was the only participant who did not demonstrate this error in more than 10% of responses.

In contrast, participants showed a variety of errors occurring in more than 10% of responses for the taxonomic grid. Error types with averages (across participants) that were above 10% included: making multiple hits on the category page during step 1 (M=13.3%, range 11% to 18%), selecting the wrong category symbol during step 1 (i.e., selecting a category symbol that did not match the item selected; M=12.3%, range 1% to 31.5%), and selecting the wrong item symbol during step 2 (i.e., selecting symbol for unavailable item;

M= 24. 9%, range 8% to 45%). Other errors occurring in more than 10% of responses for individual participants included using the wrong motion (e.g., swiping) during step 1 (two participants), and attempting to grab the item before completing step 2 (one participant).

Table 5. Errors occurring in more than 10% of total responses per condition

	Schematic	Taxonomic
Addie	1st step: Wrong scene 13.5%	1st step: Multiple hits 18%; Wrong motion 10.5% 2nd step: Grabbed item 17.5%; Multiple hits 15%; Wrong item symbol 11%
Donna	1st step: Wrong scene 19.5%	1st step: Wrong category symbol 14%; Multiple hits 11%; Wrong motion 10%
Quinn	None above 10%	1st step: Multiple hits category 11% ; 2nd step: Wrong item symbol 45%
Ricardo	1st step: Wrong scene 17%	1st step: Wrong category symbol 31.5%; Multiple hits 13% 2nd step: Wrong symbol item 35.5%
Average All participants	1st step: Wrong scene *M*=14.8% (range 9% to 19.5%)	1st step: Multiple hits *M*=13.3% (range 11% to 18%) Wrong category symbol *M*=12.3% (range 1% to 31.5%) 2nd step: Wrong item symbol *M*= 24. 9% (range 8% to 45%)

GENERALIZATION AND MAINTENANCE (QUESTION 3)

Three participants (Addie, Donna, Quinn) met generalization mastery criterion with his or her schematic system when a new location with a new item was introduced (see Table 4 for a list of mastered generalization phases and sessions to mastery). Ricardo had several sessions at mastery level during generalization with the schematic VSD, but was not consistent enough to meet mastery criterion. Donna was the only participant who reached a generalization phase using the taxonomic grid. She did not meet mastery criterion using the taxonomic grid, but her performance was on an upward trend. When post-treatment maintenance was introduced (i.e., randomly rotating all three locations with no intervention procedures) in the schematic condition for Addie, Donna, and Quinn, all three showed a brief drop in performance on the first session, but then increased back to mastery level performance during final sessions.

CORRESPONDENCE WITH PREREQUISITE STUDY RESULTS (QUESTION 4)

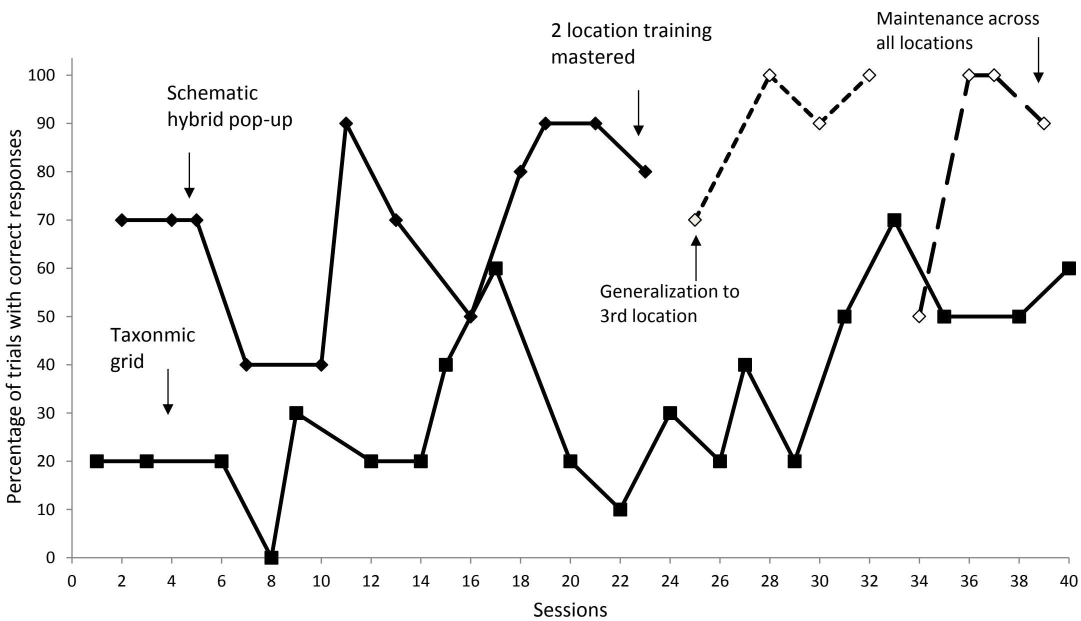
In general, the results from the prerequisite study (Gevarter et al., 2015) were predictive of results in the current study for Addie, Quinn and Ricardo. In particular, prior consistency in correct responding with a display format appeared to predict success with that system when navigation was introduced. Donna's prior performance was less predictive of success during the intervention phase of this study, but may have predicted differential performance during generalization. Across participants, some errors common in the prior study also appeared to correspond with errors seen in this study. Analyses of individual participants' performance are further discussed below.

ADDIE

Acquisition, generalization and maintenance

Addie's data is presented in Figure 6. He mastered requesting items across two locations using a schematic hybrid pop-up grid in 11 sessions, and met generalization (a new location with a new item) criterion in 4 sessions. During post-treatment maintenance, after a brief drop in performance, Addie maintained responding at mastery level. In contrast, Addie did not master requesting across two locations with a taxonomic grid. His performance was on a gradual upward trend, but never reached mastery level.

Figure 6. Addie's correct responding with multistep requesting in both conditions.



Error types

With the schematic hybrid pop-up grid, Addie's most frequent error was selecting the wrong scene (13.5% of responses). In contrast, he had multiple common error types using the taxonomic grid. First-step errors (i.e., those occurring on the category symbol page) included: making multiple hits of the category symbol (18%), and using the wrong motion (swiping; 10.5%). During the second step (i.e., choosing an available item symbol), common errors included: attempting to grab the item instead of selecting the icon (17.5%), making multiple hits of the item symbol (15%), and selecting the wrong (i.e., unavailable) item symbol (11%).

Comparison to prerequisite study

In the previous study, Addie acquired a grid display and a hybrid pop-up grid at similar rates, but generally showed more consistent correct responding with the hybrid pop-up grid. In this study, he continued to demonstrate advantages with the hybrid pop-up grid. No prior error analysis was conducted for Addie so comparisons of errors was not possible.

Observations

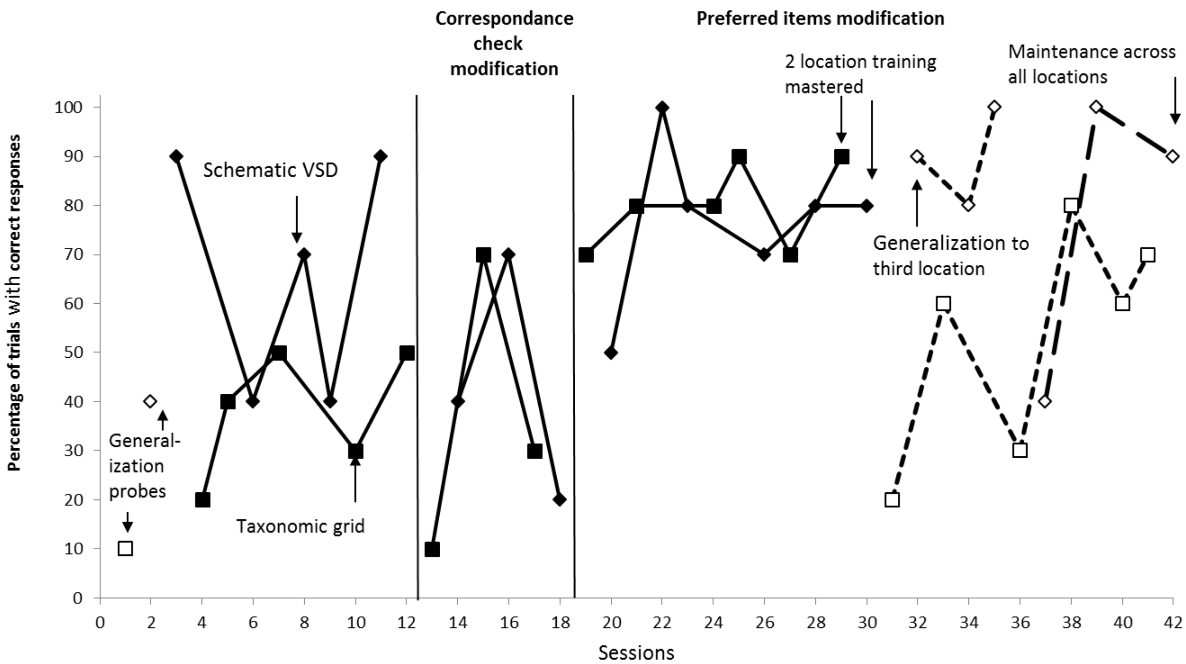
Addie requested all items across categories and locations.

DONNA

Acquisition, generalization and maintenance

Donna's data is displayed in Figure 7. After two modifications (described further below and under procedural modifications), Donna mastered both the schematic VSD and the taxonomic grid (in 14 total sessions each). During initial generalization probes, she responded correctly in 40% of VSD trials, and 10% of grid trials. After intervention, she mastered generalized requesting to a new location with a new item in the schematic VSD condition, but did not meet mastery criterion in the generalization phase with the taxonomic grid (on an upward trend). Donna showed a brief drop in performance when all three locations were rotated across final sessions in the schematic condition (due to an error selecting the wrong scene), but then increased to mastery level responding for the following two sessions.

Figure 7. Donna’s correct responding with multistep requesting in both conditions.



Error types

Overall, Donna’s most common error in the schematic VSD condition was selecting the wrong scene during step 1 (19.5% of responses). In the taxonomic grid condition, errors with rates above 10% included: selecting the wrong category symbol (14%), making multiple hits of the category symbol (11%), and using the wrong motion (swiping) on the category page (10%).

Comparison to prerequisite study

For Donna, results from the prior study indicating more rapid acquisition and consistent performance with a simple VSD than a grid, did not predict differences during intervention (schematic VSD and taxonomic grid mastered at similar rates). Her more consistent responding with the simple VSD during the previous study may, however, have predicted her stronger generalization skills with the VSD. Although multiple taps were a common error for her in both conditions (higher in grid) in the previous study, this error did not persist in the VSD condition in this study. Her error with using the wrong motion was also novel to this study and the grid category page. Although she had had errors selecting the wrong symbol or photograph of item in the prior study, in this study these errors were not common at the item level (only scene or category level) except during the first modification phase.

Modifications and observations

Initially, during early sessions Donna showed high proficiency with the second step in the schematic condition (i.e., selected embedded hotspot and then reached for corresponding item), but had variable performance in this condition due to errors with step 1 (selecting the scene that matched her location). In contrast, she displayed a wider array of error types (including swiping on the category page, multiple taps, grabbing items, and selecting the wrong category or symbol item). It was observed, however, that the majority of attempted responses in the grid condition involved selecting only the "food" category, despite the fact that just prior to the SGD being place in front of her Donna would sometimes sign "drink" or point to her preferred "things" (i.e., basket of food condiments, box of paper cutouts and stickers). After her SGD responses requesting food, however, she still reached for the food item. In contrast, in early sessions in the VSD condition she requested and took the food, drink, and thing items. Due to a concern that there may be false positives in the grid condition (e.g., requested and took food, but actually desired drink or thing), a modification in which Donna was asked what she wanted prior to her SGD response (see procedural modifications) was introduced.

Although this procedure lead to requests across a wider array of categories in the grid condition, she had variable performance in both conditions and began to show negative reactions (e.g., pushing away items) after error corrections in which she was prompted towards SGD responses corresponding with her initial selection. For example, if she reached for her basket of kitchen condiments (preferred thing) just prior to SGD placement, but then made an attempt to request the preferred food item (chips) with the SGD, she reacted negatively when then prompted to request the basket. After three days with this procedure, she no longer showed interest in her selected preferred items (would not come to training areas).

Following a return to the initial correspondence check procedures (i.e., occurring after SGD response instead of prior), as well as a change to preferred items (see display modifications, additional preference assessments, and procedural modifications) Donna showed an immediate increase in both conditions. Donna's requests with the taxonomic grid condition still primarily included requests for food items, with infrequent requests for the drink and only one request for the electronic item. In contrast, although food was still most requested in the schematic VSD, she more frequently requested the drink and electronic item in this condition.

During generalization, multiple tap and wrong motion errors that had become less frequent during the last intervention sessions with the taxonomic grid, increased dramatically in this condition. Additionally, she made no attempts during generalization to select the new category "art supplies" that contained the symbol for the new preferred item (sidewalk chalk). In contrast, in the VSD condition she frequently requested the sidewalk chalk and her food item.

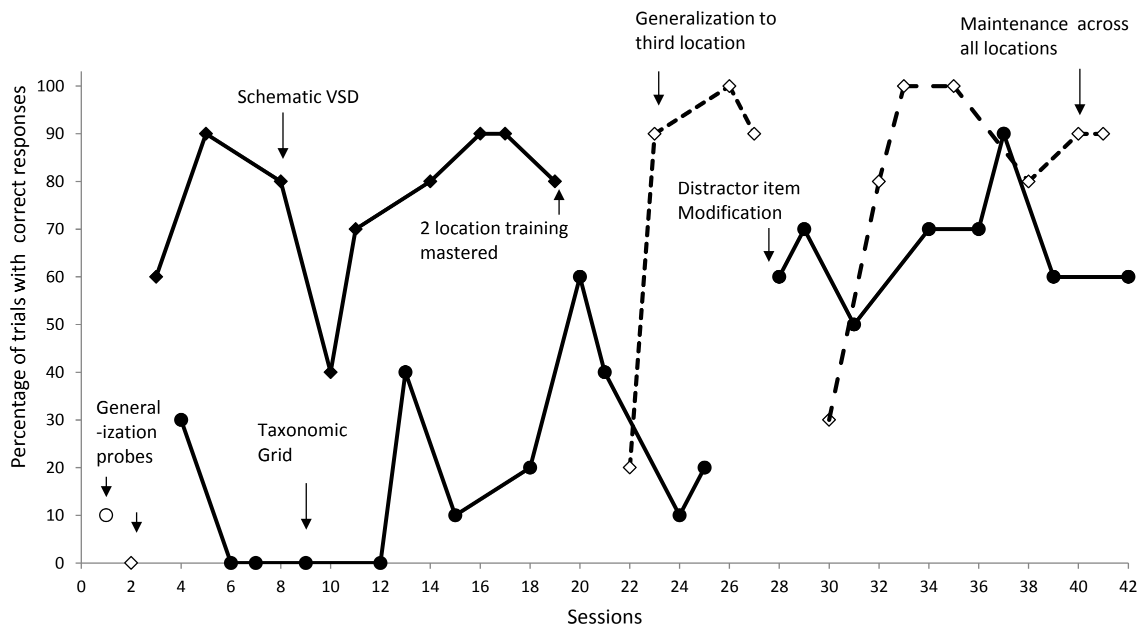
After the study concluded, to test the hypothesis that Donna did not attempt to select unfamiliar categories, a 10 trial probe with the generalization grid display (i.e., food, drink, art supplies categories) was conducted when only the sidewalk chalk was present and available. Donna selected the correct category on 0% of responses during the probe. Following the probe, teaching trials (involving a time delay, followed by a hand-over-hand prompt to select the art supplies category) were introduced. A criterion of 10 consecutive trials selecting the correct category was set. It took Donna only 13 trials to meet criterion.

QUINN

Acquisition, generalization and maintenance

Quinn's data is displayed in Figure 8. Quinn mastered the schematic VSD in nine total sessions, but did not reach mastery criterion with the taxonomic grid. Performance in the taxonomic grid was on an increasing trend and had increased in level following a modification (discussed in more detail below and under procedural modifications). During initial generalization probes, Quinn responded correctly for 0% of VSD responses and 10% of grid responses. After an initial drop in performance during the post-intervention generalization phase (due to not selecting the new location scene) with the schematic VSD, Quinn mastered the generalization phase with no additional intervention. He showed a similar brief drop in performance when all three locations were rotated, but then increased to mastery level during final sessions.

Figure 8. Quinn's correct responding with multistep requesting in both conditions.



Error types

Quinn did not show a specific error type in more than 10% of responses for the schematic condition. With the taxonomic grid he pressed category symbols multiple times (11% of responses), and selected the wrong symbol item in 45% of responses.

Comparison to prerequisite study

Similar to results in this study, during the prerequisite study, Quinn performed better with a simple VSD in terms of both rate of mastery and consistency of correct responding. In addition, in both studies he had frequent errors in which he selected the wrong item symbol using the taxonomic grid, but did not have high rates of any one error type using VSD formats. Issues with multiple taps on the category page of the taxonomic grid were not predicted by errors in the prior study.

Modifications and observations

A modification for Quinn was introduced in the grid condition due to high rates of one specific error type in which he frequently pressed a distractor symbol for "computer" (unavailable) rather than selecting the symbol for an available "iPad®." After several sessions in which he was corrected by being prompted to select the iPad® icon, he continued to select the computer icon, but then appeared to move his hand towards the "iPad®" symbol just prior to the instructor prompting this response (i.e., appeared either to attempt self-corrections, or to have learned a chained response of computer symbol plus iPad®" symbol). Initially, Quinn showed some errors selecting a distractor symbol under the "drinks" category as well, but this error rapidly dissipated, while the distractor error in the electronics category remained. Given the fact that the category symbol for electronics was also a computer, a decision was made to change the distractor symbol on the item page from a computer to a video game. Once this was introduced, Quinn initially showed errors in which he first selected the video game icon, but this error dissipated. He did however, still have multiple tap errors in the grid condition that prevented mastery.

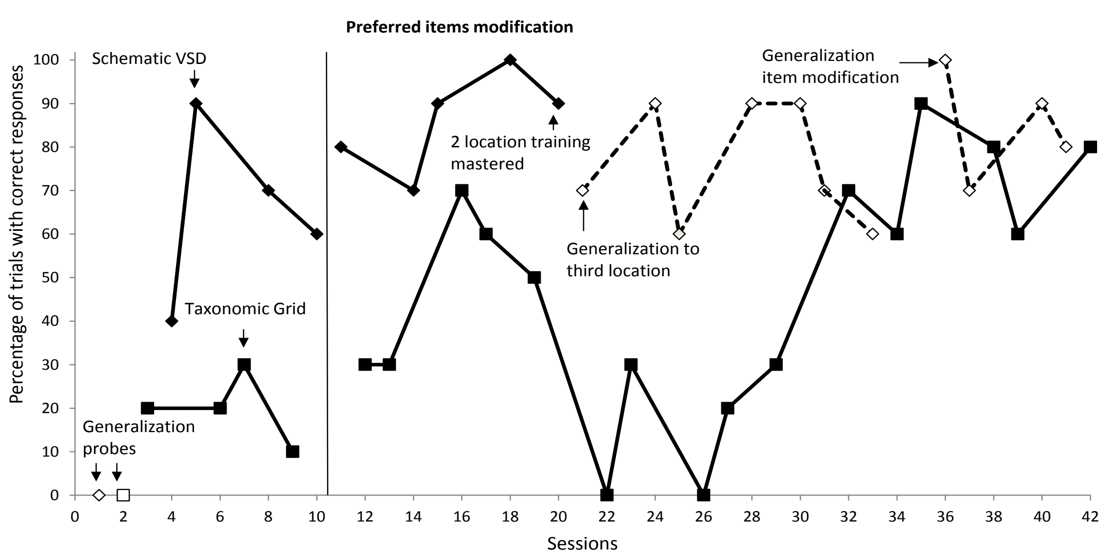
Similar to Donna, Quinn showed differences in which items he selected in the grid versus VSD conditions. Specifically, although he requested the iPad® and drink items with both conditions, he only ever made requests for his toy items using the VSD condition (i.e., never pressed "toys" category in grid condition).

RICARDO

Acquisition, generalization and maintenance

Ricardo's data is displayed in Figure 9**.** After a modification involving a change of preferred items (see display modifications, additional preference assessment, and procedural modifications), Ricardo mastered the schematic VSD (nine total sessions), but did not master the taxonomic grid. After a drop in performance with the grid, his performance was on an upward trend for final sessions. Initially, Ricardo showed 0% correct responding during generalization probes in both conditions. When generalization was introduced with the VSD after intervention, Ricardo had variable performance (with some sessions at mastery level). Following a similar item modification used during training, there was a slight increase in level of responding, but he still did not reach mastery.

Figure 9. Ricardo's correct responding with multistep requesting in both conditions.



Error types

In the schematic VSD Ricardo selected the wrong scene in 17% of responses. In contrast, he showed a wider variety of errors with the taxonomic grid. During the first step in the grid condition, he selected the wrong category symbol in 31.5% of responses and used multiple hits of the category symbol in 13% of response. During the second step, he selected the wrong symbol item in 35.5% of responses.

Comparison to prerequisite study

In the prior study, Ricardo mastered the grid and simple VSD at similar rates, but showed more consistent correct responding with the VSD. In this study, he mastered the schematic VSD and was showing more gradual progress with the taxonomic grid. He also similarly had errors involving multiple taps, selecting the wrong item symbol, and using the wrong topography in the grid condition of the previous study. Although he continued to have low rates of selecting the wrong item within a VSD, he did have difficulty selecting the correct scene in this study.

Modifications and observations

Ricardo's item modification was introduced after a drop in performance in both conditions, followed by an attempted session in which he showed no interest in requesting available items (walking away and shaking head). He initially showed an increase in performance in both conditions following the change of items, followed by a decrease in the grid condition. The decrease in the grid condition did not appear to be related to loss of interest in items (still actively coming to training areas, reaching for items, and engaging with items for full reinforcement time). In the generalization phase, which initially utilized the previously replaced food item, he primarily was requesting only the novel item (water toy) with correct responding during beginning trials (e.g. trials 1-7), and errors during final trials (8-10). In order to increase interest in selecting more than one item outside, the initial food item was replaced with his play iPad®. This lead to more requesting across items (water toy and iPad®), but he was still one session short of reaching mastery criterion.

Chapter 5: Discussion

The results of this study suggest that SGDs with schematic VSDs or schematic hybrid pop-up grids can provide advantages for individuals with ASD in comparison to taxonomic grid displays. Findings are in line with research supporting advantages of VSDs for very young typically developing children (Drager et al., 2004; Drager et al., 2003), and theorized advantages of scene-based systems for individuals with ASD (Light & Drager, 2007; Shane, 2006; Shane et al., 2012). The rapid acquisition of displays with scene-based components also supports prior research with young, typically developing children (Olin et al., 2010). Results differ from findings with 4 and 5 year-old typically developing children, who did not demonstrate differences between different schematic and taxonomic SGD display formats and organizations (Light et al., 2004).

In terms of research question 1 (i.e., are there differences in mastery and rate of mastery of multistep requesting across conditions?) three out of four participants mastered multistep requesting with schematic VSDs or hybrid models, but did not master a taxonomic grid condition. These participants all, however, had increasing trends in the taxonomic condition, possibly suggesting that mastery in this condition may have occurred with additional time. The fourth participant (Donna) mastered both conditions at similar rates following two procedural modifications. Initially, all participants started at higher levels of performance with his or her schematic condition, in comparison to the taxonomic condition. With the exception of Donna, there were no overlapping scores between conditions for at least the first five sessions in each condition. All participants also had at least one session at mastery level in the schematic condition within the first five sessions, as compared to no mastery level performance within the first nine taxonomic sessions for any participants (Addie never had a mastery level score with the taxonomic grid while Donna, Quinn and Ricardo demonstrated first instances of mastery level at intervention sessions 10, 18 and 17 respectively).

Error analysis did indicate differences across conditions (research question 2). Only one error type (selecting a scene that did not match the given location) was common in schematic systems, compared to a variety of common error types in the taxonomic grid condition (e.g., multiple hits of the category symbol, selecting the wrong category symbol, and selecting the wrong item symbol). Additionally, some participants had high rates of more unique error types (e.g., attempting to grab item before completing second step) in the taxonomic grid condition.

With regards to research question 3 (would participants generalize and maintain responding without intervention techniques), three participants rapidly generalized the schematic condition when a new location and new item were introduced, and maintained mastery level performance across locations after a brief dip in performance. Ricardo did not meet generalization criterion with the VSD, but generally performed at a high level with several mastery level sessions. Donna, who was the only participant to reach the generalization phase in both conditions, generalized the schematic condition, but did not meet generalization mastery criterion with the taxonomic grid. Such findings may counter the suggestion that the use of VSDs can inhibit generalization of vocabulary items across settings (Reichle & Drager et al., 2010). Since only one participant reached a generalization phase with the taxonomic grid, less can be said about the utility of taxonomic grids for generalization across settings.

Overall differential success with systems (taking in account both intervention and generalization for Donna) was in line with prior differential success in the prerequisite study (Gevarter et al., 2015) assessing non-navigational requesting (research question 4). Specifically, participants continued to perform better with the system they correctly responded with most consistently and/or acquired more rapidly in the previous study (Gevarter et al., 2015).

In the discussion that follows, findings regarding research questions 1 and 3 (i.e., differential success during intervention, generalization, and maintenance) are examined in terms of the error types observed with each condition (research question 2), and how such errors corresponded with errors seen during the Gevarter et al., (2015) study (research question 4). Differences in error types between conditions may provide possible hypotheses regarding the overall better performance with schematic systems (including potential study limitations that may have affected results). Although it is possible that schematic systems may be advantageous in part due to previously suggested hypotheses (e.g. that they provide meaningful context driven supports, and are cognitively and linguistically easy to acquire; Fallon et al., 2003; Light & Drager, 2007; Olin et al., 2010 Shane, 2006; Shane et al., 2012), error analyses in this study suggest additional contributing factors (e.g., differences in physical ease of use). Following the analysis of the results in terms of error types, other considerations such as the effects of prior experience and individual characteristics as well as additional study limitations are presented. Finally, implications for practice, and directions for future research are highlighted.

DIFFERENTIAL RESULTS IN TERMS OF OBSERVED ERRORS

Although participants initially showed lower average error rates with their schematic condition compared to the taxonomic condition, they also showed variability in responding with the schematic condition. This variability was primarily associated with errors selecting the wrong scene. In contrast, performance started at lower levels in the grid condition and error types were varied. Generally it appeared that although some participants experienced errors selecting the appropriate category during step 1 (similar to step 1 errors selecting the appropriate scene in the schematic condition), there was a greater presence of physical issues (i.e., form used to make response), and item level discrimination (i.e., selecting the correct item icon for an available item) in the taxonomic condition.

Discrimination of Scenes of Categories

Step 1 errors involving the appropriate selection of a scene (VSD or hybrid pop-up grid) or category (grid) had averages above 10% in both conditions. Averages for these types of errors across participants were 14.8% (range 9% to 19.5%) for schematic, and 12.3% (range 1% to 31.5%) for taxonomic. Three of the four participants selected the wrong scene in more than 10% of responses (Addie, Donna, Ricardo) and two of four (Ricardo, Donna) selected the wrong category in more than 10% of responses.

Additionally, it was observed that two participants (Donna and Quinn), did not make frequent requests across all three categories with the taxonomic grid, despite making requests for the same items across categories with the schematic VSD.

As all participants eventually mastered schematic conditions, results do suggest that discrimination between visual scenes can be acquired rapidly via the use of error correction (time-delay and least-to-most prompting). It should be noted, however, that with the mastery criterion set at 4 of 5 sessions at 80% (with no scores lower than 70%), participants could still on occasion make such errors (and receive error corrections), and be considered to have mastered the condition. Results from generalization and post-treatment maintenance conditions, suggest, however, that even if there is a short drop in performance when error correction procedures are discontinued (and a new location is added), mastery level performance without continued intervention can be obtained.

Although the intervention procedures were overall successful in reducing variability in responding associated with errors selecting the wrong scene, aspects of the study design may, in part, have contributed to the occurrence of this error. First, the decision to include two identical items across locations (with only one item differing across locations) may have hindered discrimination abilities. For instance, if a participant was motivated to request a preferred food item that was visible in two scenes, it is possible that he/she only scanned for and/or attended to the image of the food item within a scene, rather than the entire context of the scene. Thus, if a cookie was visible in both a kitchen and living room scene, participants may have had difficulty discriminating that a correct response involved selecting the scene corresponding to where the cookie was currently present. This theory may be supported by research suggesting that individuals with ASD have enhanced abilities to discriminate an item from a scene (Ropar & Mitchell 2001; Shah & Frith 1983; van Lang, et al., 2006).

Additionally, the decision to include three categories of items across locations may have decontextualized the visual scenes. Previous researchers have suggested that one of the advantages of VSDs is the ability to create highly contextual representations of the naturalistic environment (Light & Drager, 2007; Shane, 2006; Shane et al., 2012). In this study, although all participants had experience requesting food, drink, toy, and electronic items across a variety of home locations during previous research and or behavioral therapy sessions (e.g., when a choice of items were available as reinforcers for learning tasks), in more natural activities, these items might not always be used together and/or food and drink items might not be readily available across locations. Additionally, areas within room locations where participants interacted with items were not always highly different (e.g., Ricardo interacted with items on carpeted floor in living room and bedroom). Efforts were made, however, to make sure visual scenes included other contextual elements that indicated the location (e.g., making sure Ricardo's bed was visible in the bedroom scene, and living room furniture was visible in the living room scene). It is possible, however, that participants may have more easily discriminated between more heavily contextual naturalistic scenes (e.g., photograph of child playing with a variety of toys that are often used together in playroom, compared to photograph of child reaching for food items in kitchen pantry).

Although these design decisions could be seen as limitations, they were made for several reasons. First, it is possible that in some cases, items across categories might be available in multiple contexts and used together in the natural environment. For instance, Donna commonly did use her play iPad® in multiple locations (e.g., sitting at table in kitchen, or in sofa chair in living room) and often was allowed to eat a snack while playing with it. Thus, in some situations, it may be important for individuals to learn to request the same item across multiple different locations when using schematic systems. VSDs designed in this manner may also help learners understand what items may or may not be available across locations, and what items may be restricted to certain locations. They may also help to promote generalization of vocabulary items across settings (cited as a potential limitation of VSDs by Reichle & Drager, 2010).

Additionally, since mastery criterion included the acquisition of requesting across two locations, it was intended that the availability of two identical items across locations would reduce variability in responding that might be due to differences in the reinforcing value of available items. For instance, if the items available in one location were more highly preferred (e.g., food items in kitchen being more preferred than toys in the living room), higher percentages of selecting the wrong scene may have occurred in the location with less preferred items. Furthermore, the use of items from three different categories was important in order to compare performance of choices made across categories using a grid display.

Another potential limitation that may have led to scene selection errors is that alternating two locations within the same condition may have caused carryover effects. For instance, participants often had high rates of errors selecting the wrong scene after two previous sessions for the schematic condition had been in the other location. Similarly, when post-treatment maintenance was introduced for Addie, Donna, and Quinn, all three had a dip in performance primarily accounted for by the fact that they continued to select the generalization location that had just been acquired. Ultimately, however, individuals may be required to make rapid scene discriminations in the natural environment (e.g., when changing between learning centers in a classroom). Thus, carryover effects may be important to consider when designing practical interventions (Hains & Baer, 1989).

Finally, it is possible that "errors" in selecting a scene that did not match the current location were in fact requests for the alternative location. For instance, when in the living room, a participant may have desired an item only present in the kitchen, and thus a perceived error could have been an attempt to make a request to go to the kitchen. Although such "location" requests should be taught in order to give individuals the ability to control their environments and fully express wants and needs, it may also be important for individuals to learn that sometimes other locations are not available, and thus their choices are limited to what is available in the current context.

In contrast to the schematic condition, difficulties beyond appropriate step 1 selection may have contributed to the fact the most participants did not master the taxonomic grid condition. Still, however, difficulty selecting the appropriate category for a desired item did contribute to grid-based errors for Donna and Ricardo (who made "wrong category" errors in in 14% and 31.5% of responses respectively). Additionally, although Quinn had a low rate of selecting a category that did not match the item he ultimately selected, his limited variability in responding across categories (similar to Donna) may also suggest hypotheses regarding difficulty with acquiring all categories without explicit teaching.

The reliance on a post-correspondence check error correction procedure may have limited the explicit teaching of categories that participants did not select on their own. Participants were only prompted to go back to step 1 and select an "un-pressed" category if they first selected a different category and item, but then reached for an item from the "un-pressed" category. Ricardo frequently made this type of error (e.g., pressed food category, pressed hotspot for food item and then reached for play iPad®), and thus the error correction procedure (e.g., prompting selection of the iPad® category) was used often with him. Although this error type was on a decreasing trend for Ricardo in final sessions (corresponding with an overall increase in performance in the grid condition) progress was gradual. This may be due to the fact that this correction could not be immediate. Specifically, because category selection occurred at step 1, and the correspondence check to determine what item was desired (and therefore which category was correct) did not occur until the end of the entire response sequence, correction could only occur after the entire chain. This was in contrast to error correction for step 1 selection in the schematic condition, where it was immediately apparent if a participant selected the wrong scene.

In contrast to Ricardo, initially, Donna did not have frequent errors selecting the wrong category, but was almost exclusively selecting the "food" category and then choosing the food item, despite signing for drink or pointing to "thing" items. Thus, she was never prompted to use the alternative categories in the grid condition despite the fact she was indicating a desire for these items prior to SGD responses in the taxonomic grid, and requesting and choosing all items (including drink and thing items) across locations using the schematic VSD. It was, therefore, unclear if Donna's responses were a true reflection of what she wanted, or if she was just requesting and then choosing the food item because she was unaware of how to request the actually desired item.

When an attempt was made to determine what item Donna wanted prior to the SGD response (modification phase), so that prompting of the drinks or things categories could occur, she had high rates of selecting the wrong category prior to the prompt. It was still unclear, however, if this procedure accurately represented which item she wanted, as she sometimes reacted negatively when prompted to request the item that matched her initial request. Thus, it is possible that this modification skewed her rate of "wrong category" errors. After this procedure was discontinued, there was, however, an increase in correct responses involving selection of the "drinks" category (suggesting that prompting to use this category during the modification may have contributed to the acquisition of the response chain to request her available drink). Thus, it is also possible that the modification led to learning that ultimately affected Donna's ability to master the grid condition (e.g., she made more correct responses once two categories were known). In contrast to her use of the drink category after the modification, and continued use of the food category, when a new category of "electronics" (corresponding to a preferred play iPad®) was introduced after the first modification, she was only observed to select this category once. She still, on occasion, reached for the iPad® prior to an SGD response for a different item in the taxonomic condition, and correctly requested the play iPad® (electronic item) with the schematic VSD. Similarly, during the generalization phase, Donna never tried to activate an "art supplies" category in the grid condition despite reaching for the available item from the category (sidewalk chalk) prior to an SGD response, and frequently requesting the sidewalk chalk with the VSD. To test the theory that Donna had "unknown categories" for some desired items, a probe of her responses when only the sidewalk chalk was available (but all three categories on the SGD were visible) was conducted after the end of the study. During the probe, she selected the correct category in 0% of responses. When training trials were introduced in which she was physically prompted to select the "art supplies" category after a time delay, it took Donna only 13 trials to reach a criterion of 10 consecutive correct category selections.

In accordance with this theory of "unknown categories," Quinn was never observed to select the "toys" category despite requesting toys using the VSD. Similar to Donna, he did not reach for a toy item after making an SGD response for another item, but unlike

Donna, he did not exhibit pre-SGD response behaviors indicating that he wanted the toy. In contrast to the taxonomic grid, the embedded visual images of the toy items for Quinn and things/electronic item for Donna in the VSDs may have provided a more recognizable visual stimuli (in comparison to unfamiliar category symbol icons) indicating these items were available for request.

It is possible that a different teaching approach may have led to more responding across categories for Donna and Quinn, and faster learning of correct categories for Ricardo. For instance, results might be different if all options in both conditions were modeled as part of the intervention, or if only one preselected item was present/available at a time so that a correct category response for that item could be immediately prompted (similar to procedures used by Strasberger & Ferreri, 2013). Such modifications are not without limitations, however, as noted by the fact that Donna lost interest in requesting items when a preselected item (of her choosing) was the only one available for a given trial during her first modification phase. Additionally, not all participants in the prior study mastered navigational requesting when the selection of a specific category corresponding to a preselected item was considered to be correct for a given trial (Strasberger & Ferreri, 2013).

Physical Issues

Within the application AutisMate, it appeared that VSDs and hybrid pop-up grids were generally easy for participants to physically activate. Participants did not frequently have errors involving tapping hotspots multiple times with VSDs or the pop-up hybrid, but this error was common with taxonomic grid, particularly when selecting a category symbol (M=13.3% ; range 11% to 18%). Although it is unclear what elements of these displays may contribute to this finding, results are similar to the prior study with AutisMate (Gevarter et al., 2015) as well as a previous study using the applications GoTalk Now and Scene and Heard (Gevarter et al., 2014), both of which suggested multiple tap errors occurred more with symbol buttons, than with embedded hotspots. It may be important to note that, generally, across all three studies, participants did not often experience "silent hit" activation issues (i.e., pressing a hotspot, but no output) when using embedded hotspots, but did so more frequently with symbol buttons. Other design differences such as differential haptic feedback elements (e.g., symbol buttons briefly become faded after pressed, while embedded hotspots do not change visually when pressed in the AutisMate application) may also be important to consider.

Another interesting finding is the fact that two participants (Addie and Donna) also had high rates of an error involving attempting to "swipe" across the category page. This error was not observed on the first page with the schematic systems in this study, or often at item level pages in any condition in this study or in the prerequisite study (Gevarter et al., 2015). It is unclear what elements of the category display page contributed to this response. Additionally, Addie's high percentage of attempting to grab items after the first response (17.5% of responses) in the grid condition, but not with his hybrid pop-up grid condition, appeared to suggest a difference in how he perceived the correct response chain across conditions. For instance, the fact that "drinks" category icon (two cups) was similar to his drink item icon (sippy cup) may have prevented him from realizing an additional response was required after the initial category selection.

Discrimination of Items

In this study, participants did not typically have difficulty discriminating between available item hotspots after navigating to the correct VSD and/or hybrid page (i.e., selected available item hotspot that then matched the item they then chose). In contrast, participants often had errors (*M*= 24. 9%; range 8% to 45%) selecting an available item once having navigated to a category page (i.e., selected icons for unavailable items).

These results are generally in concordance with results from the prior study, in which participants had higher rates of selecting the wrong symbol hotspot in the grid condition (i.e., chose icon that did not match the item then selected) in comparison to selecting the wrong embedded hotspot in simple VSD configurations (Gevarter et al., 2015). Although these results may suggest differences between the ability to discriminate between symbol drawings and embedded photo images, other factors may also have contributed to these results (especially for Addie who chose between symbols in both conditions).

Specifically, the presence of icons representing unavailable items in the grid condition may have contributed to these results. The grid condition was designed this way in order to approximate how grids are typically organized (e.g., a variety of both available and unavailable items may be represented under one category), in comparison to VSDs which may only include vocabulary relevant to the specific context or location. Although there were no distractors at the "item" level (i.e., on page two) in the schematic conditions, the use of one preferred and unavailable location, and one non-preferred and unavailable location in the schematic conditions was equated to the use of icons representing a preferred unavailable item and a non-preferred and unavailable item in the grid condition. Thus "errors" in which participants selected a preferred, but unavailable item in the grid condition may have been similar to errors in which participants chose a preferred, but unavailable scene in the schematic conditions (i.e., actually desiring unavailable location or item). Again, while it may be important to teach individuals to request items not immediately available (e.g., may be out of sight, but could be obtained), it also important to be able to make requests with available items when more preferred items cannot be made available. For instance, anecdotally, this was the type of error Addie's mother reported seeing in home (and was observed by the researcher) when Addie used his LAMP grid-display application. Specifically, he would repetitively press 1-2 icons representing highly preferred items that were not readily available at home, and would not make requests for available preferred items.

In addition to the possibility that responses involving an unavailable item were actual attempts to request that item, it is also possible that participants had difficulty determining which icon represented the available item. In particular, Quinn's error, in which he consistently selected a computer icon distractor (and then learned to reach for the correct iPad® icon after selecting the computer icon) appeared to suggest confusion over which icon corresponded with the iPad®. There may have been further confusion given that the category symbol for "electronics" was also a computer icon (visually different than the item level computer icon). The fact that Quinn's selection of the wrong icon rapidly reduced when the item level computer icon was replaced with a video games symbol, may suggest that icons more similar to the category icon and/or icon for available item may provide greater levels of distraction than more visually dissimilar items.

LEARNER CHARACTERISTICS AND PRIOR EXPERIENCE

It is important to consider how learner characteristics (e.g., age, ASD severity, language skills, cognitive functioning) and prior experience (e.g., with AAC systems and touch screen devices) may have impacted the results of this study.

Unlike Light et al.'s (2004) findings with typically developing children, individuals aged 4 years and above showed performance differences across schematic and taxonomic conditions (generally favoring schematic systems). Although this study is limited by the number of participants of different ages, it may suggest that age may be less of a predictive factor of increased success with a greater variety of SGD display formats for individuals with ASD in the preschool to elementary age range. An overall larger chronological age range of participants might, however, have produced different results. Alternatively, it is possible that factors other than chronological age (e.g., ASD characteristics and severity, language skills, and cognitive skills) may be more relevant. Although the study provides support for the use of VSDs and schematic systems for individuals with ASD, it cannot confirm causal relationships between specific ASD characteristics and advantages of schematic systems. For instance, it remains unclear if participants showed greater success with schematic systems due to difficulties processing complex language concepts, but strengths in the area of visual processing (Shane, 2006; Shane et al., 2012).

In terms of ASD severity, it is possible, that individuals with less severe ASD may perform differently than participants in this study. Three participants were classified as having severe ASD and although Donna was classified as having only moderate to mild symptoms of ASD (compared to severe symptoms for other participants), her score was the top cutoff score for this categorization (i.e., only 0.5 points away from a severe classification). Additionally, the fact the all participants had expressive and receptive language skills estimated to be below those of a typically developing 3 year-old, may, in part, explain why chronological age was not a predictive factor of differential success with systems as it was with typically developing children (Drager et al., 2004; Drager et al., 2003; Light et al. 2004). Although AAC candidates are likely to have low expressive language abilities, individuals with ASD and stronger receptive skills might perform differently than the individuals in this study. Additionally, since no cognitive tests and/or skill assessments were conducted, it is unclear how individuals with different IQs and/or specific cognitive skills might respond differently. Previous research has suggested that differences in cognitive functioning may affect the ability to navigate through taxonomic grids (Robillard et al., 2013), and that individuals with ASD considered to be lower functioning may show differences in how they process visual scenes (White & Saldaña, 2011).

Other individual characteristics, such as the willingness to request and accept an item less preferred in the moment, when unsure of how to request a more preferred item, may play a role in the ability to acquire requesting across multiple categories without explicit teaching. Specifically, Ricardo was taught categories that were originally "un-pressed" because he did not accept lesser preferred items when he did not exhibit the correct response for an item he actually desired. Instead he continued to reach for the item he wanted after choosing a non-corresponding category. Thus post-response correspondence checks appeared to be an effective way to assess which items he desired. In contrast, Donna would point to or sign for an item prior to an SGD response, but then request and take an alternative item. Similarly, it is possible that correspondence checks did not adequately assess Quinn's preferences in the grid condition given that he never selected his toy category, or reached for his toy after requests for other items, despite requesting toys with the VSD. Although an alternative correspondence-check method (i.e., pre-SGD response) may not have been an effective way to determine Donna's in-the-moment preference, alternative methods could be considered for individuals like Donna and Quinn. For example, responses for preferred items organized under an infrequently selected category folder could be trained when only items from that category are available (similar to procedures used by Strasberger & Ferreri, 2013).

In terms of prior experience, participants in this study were all similar in that they showed overall better performance with non-navigational simple VSDs (Donna, Quinn, Ricardo) or hybrid pop-grids (Addie) in comparison to a non-navigational symbol grid at a previous stage of learning (Gevarter et al., 2015). Finding and including individuals who showed more success with grid displays than VSDs or hybrids at a prior learning stage may have demonstrated greater individualized differences (e.g., such individuals might have also done better with grids at the navigational stage).

Prior experience with AAC systems that have similarities to the AutisMate taxonomic grid system did not predict greater success with this system. For instance, all participants had previous experience using symbol-based PECS at phase III (i.e., involving discrimination between multiple symbols). All participants were reported to be able to select a PECS icon for an available item from a page that included symbols for several unavailable items, but participants frequently had difficulty with this type of response in the SGD grid condition (i.e., selecting unavailable items). Additionally, Addie's prior experience with the grid-based LAMP system, did not seem to benefit his acquisition of the grid-based system in AutisMate. Although it is possible that his prior experience aided in his understanding of categories (he was the only participant to make requests across all categories without frequent errors in selecting the wrong category), other errors he was observed to experience with the LAMP application (multiple taps, selecting unavailable icons) were also common with the AutisMate grid.

Prior experience with play-based touchscreen devices might also have influenced the occurrence of certain error types. Specifically, the "swiping" motion used by Donna and Addie may have been due to prior experience playing with applications on touchscreen devices that may have required a swipe. It is unclear, however, what elements of the category page in the taxonomic grid may have signaled the swiping behavior.

ADDITIONAL STUDY LIMITATIONS

In addition to design limitations that may have affected the occurrence of certain error types, and limitations regarding participant characteristics, other aspects of this study may limit the generalization of findings and/or limit further understanding of causal relationships.

First, it may be unclear how results would generalize to other SGD applications. It is possible that some results were directly affected by the specific characteristics of the AutisMate application. Although using the same application for both conditions decreased confounds of application differences across conditions, schematic and taxonomic systems in other applications may have different features (e.g., differences in haptic feedback or button sensitivity) that could affect performance.

This study is also limited by the use of discrete trial training to teach SGD responses in very restricted contexts. It is unclear how participants would perform using SGD systems in more naturalistic ways, or with a greater variety of preferred items programmed into the displays. The fact that at least two participants lost interest in the preferred items selected for training, may suggest that to teach SGD requesting skills more naturalistically, a greater variety of items and/or the ability to change and/or add new items easily may be important. The study did not take into account how easy it is for instructors to add new vocabulary in each system. This type of “just in time” programming is highly relevant to the functional use of SGD systems (Light & Drager, 2007).

The restrictions of this study that required the use of at least two preferred toys used differentially by location may also limit generalization to the use of SGDs in more naturalistic environments. This requirement may have initially limited the use of the most highly preferred items (e.g., not using highly-preferred play iPads® for Donna and Ricardo from the start). It was also difficult to find a variety of preferred toy items in each home location, which may be common due to the restricted interests of individuals with ASD (American Psychiatric Association, 2013). It is possible that some individuals with ASD might have only a few highly preferred items that generally should be included across VSDs for different home locations. Therefore, in terms of social significance, it may have been more appropriate to assess items used differentially across settings (e.g., school versus home) in comparison to different locations (e.g., rooms) within the home setting.

Additionally, another aspect of this study that may limit social significance is the fact that generalization was only assessed across one new location with one new item. Similarly, the maintenance phase was not long-term, but rather immediately after the intervention and generalization.

In terms of understanding variables that may impact study results, one potential variable that was not assessed was latency in responding with each condition. Participants had only 6s to make a correct response in either condition, and although “non-responding” was not common in either condition, it is unclear whether there may be differences in the time needed to discriminate between scenes or categories, embedded items in a scene, or symbol icons in a grid. Although it is possible that a longer time delay could have led to different results if more scan time is needed for some displays, ultimately the fast and efficient use of an SGD display is an important factor to consider (Light, 2007; Olin et al., 2010; Reichle & Drager 2010).

Implications for Practice

This study provides several implications for SGD assessment and intervention for individuals with ASD. In terms of assessment, a variety of suggestions emerged. First, the study suggests that alternative display formats and applications beyond grid-based systems or Proloquo2Go® should be considered for individuals with ASD. The design of the study (alternating two conditions) demonstrates a potential way in which practitioners can assess differences in the acquisition and rate of acquisition of different SGD display formats and/or applications. Although more research is needed, it is possible, however, that acquisition assessments at prior stages of learning (e.g., not navigational requesting in a field) may predict differences at more advanced stages (thus eliminating the need for more time consuming lengthy assessments). In addition, for some individuals, the use of correspondence checks (as opposed to delivering whatever item requested) during assessment may be a useful way determine if participants are making responses that correspond to the item actually desired. Furthermore, the error codes and error analysis procedures used in this study could be adapted in order to help practitioners identify specific problems individuals are experiencing with different systems. Such analyses could then be used to modify and/or tailor interventions. For instance, an individual consistently showing multiple tap errors might benefit from additional prerequisite skills training focused on the appropriate physical response (Gevarter et al., 2015). Individuals having difficulty discriminating between different icons might benefit from a change of icons to enhance the difference between item icons and category icons.

Additionally, findings provide other suggestions for intervention. Although a time-delay and error correction procedure appeared appropriate for teaching schematic systems, alternative methods might be needed to ensure the use of multiple categories in taxonomic grid displays. Specifically, it may be important to explicitly teach new or infrequently pressed categories either by modeling their use, or by making only items from infrequently pressed or new categories available for a given training session (similar to Strasberger & Ferreri, 2013).

In addition, though limited, results of this study may also suggest that although schematic systems may be more rapidly acquired, gradual progress might occur with taxonomic grids. Ultimately taxonomic grids may be easier to program (e.g., no need to add a new visual scene when a new toy becomes available in the home, or reprogram all school vocabulary when a child changes classrooms from year to year). Thus, practitioners may consider starting with VSDs or hybrid models to build functional communication skills and ensure needs and wants are being met, and gradually transition to grid-based displays over time. The use of a functional schematic system while grids are more gradually acquired might be particularly important for individuals who use challenging behaviors in replace of functional communication systems (Gevarter et al., 2015).

FUTURE RESEARCH

The findings and limitations of this study suggest several avenues for future research. First, replication is necessary. If multiple display formats become available in other applications, the study should be replicated across other applications to ensure that results are not specific to the design elements of each display within AutisMate. The study could also be replicated across participants with different characteristics (e.g, age, ASD severity, prior differential success with grids and VSDs and lower stages of learning). More pre-intervention assessments (e.g., assessment of IQ and cognitive tasks such as picture matching and categorization abilities) could be conducted in order to elucidate potential characteristics that might predict differential success with different systems. For instance, a recent study suggested that certain skills such as cognitive flexibility (easily changing back and forth between different ideas and strategies; Hux & Manasse, 2003) may best predict success navigating through taxonomic SGDs for individuals with ASD (Rondeau, Robillard, Roy-Charland, Mayer-Crittenden, 2014). Such research needs replication and extension to determine what cognitive factors may predict success with schematic systems.

Alternative design and intervention methods could also be assessed. For example, a study could include a comparison of two locations with items from only one category present (e.g., living room with only toy items, kitchen with only food items), and a choice of either two scenes or categories (e.g. living room versus kitchen and foods versus toys).

Although this would limit the ability to assess individuals' abilities to make continuous requests across categories within one environment, it might allow for more contextualized scenes, as well as more explicit modeling of categories.

Because differences in scene discrimination (selecting correct scene) and category discrimination (selecting correct category) were not the primary and/or sole factor contributing to differential success between systems (e.g., item level discrimination played a role as well) other elements associated with the organizational design of grids and VSDs could be examined. For instance, grids could include sub-folders that might allow for schematic elements within taxonomic systems. Specifically, for example, to avoid the problem of individuals being distracted by unavailable items within a "food" category, sub-folders such as "home foods," "school foods" and "special treats" could be created. Alternatively, researchers could examine the use of grids organized schematically (i.e., a symbol in a grid folder could represent a context or location rather than a category; Light et al., 2004). Hybrid models such as the pop-up system used in this study could also be used to organize symbol-based vocabulary in a schematic format initially, with additional taxonomic categories in the pop-up grid. In such a system, an individual might select a picture of a kitchen, and then activate a pop-up grid with folders for both drinks and foods that would contain icons for items available in the kitchen. Future studies should consider assessing such alternative options.

Research is also needed to examine the most effective ways to transition from VSDs to grid-based systems. For instance, would the introduction of hybrid elements (e.g., pairing a symbol with an embedded image hotspot) aid transition to grid systems? Alternatively, longer studies may be able to demonstrate that grids can be learned gradually without such additional transitional methods.

Research also needs to account for social validity concerns such as generalization to more naturalistic situations outside of discrete trial training, and parent and/or practitioners' ability to program each type of system and/or make "just in time" adaptations (Light & Drager, 2007) when preferences change. Related to social validity, individuals' abilities' to request new locations, or items out of sight with various display formats should also be considered. The preference changes seen in this study, might also suggest the need to either: (a) add intervention components that might reduce the likelihood of satiation of preferred items, or (b) create intervention protocols that are more sensitive to continuous preference changes.

In addition, although this study expands the complexity of SGD requesting skills beyond simple one-step requesting common in previous research (Kagohara et al., 2013), a multitude of more advance requesting skills (e.g., sentence building), and/or alternative language skills (e.g., commenting during play, answering social or academic questions) still need to be explored with multiple display formats. It is possible that different display formats might provide advantages for different skills (e.g., a hybrid model with phrase buttons such as "I want" or "Give me" and embedded hotspots for preferred items might be appropriate for teaching sentence building). Studies involving different hybrid options, or VSDs with different design elements (e.g., not using borders around items) across other applications should also be considered.

Furthermore, given the commonly observed physical issues with symbol buttons in this study as well as in previous studies (Gevarter et al., 2014; Gevarter et al., 2015), future research should determine if this is a concern in other applications with grid displays beyond AutisMate and GoTalk Now. If possible, studies could also compare physical difficulties with systems with different haptic feedback or other technological design elements. Finally, the procedures used in this study 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.

Appendices

Appendix A

Participant Initials		Researcher Initials		Date:
Session #s
Mark +or – for each step and code all errors for steps 1 and 2: D= more than double tap; R=touched random spot L=longer than 6 sec; N= touched navigational button; G=grabbed item M=wrong motion 2=touched two areas W: wrong item or scene

Display:				Location:

	1	2	3	4	5	6	7	8	9	10	%
Pressed category or scene											
Pressed symbol/hotspot for available item											
Chose same item as selected											
All steps correct (+) any incorrect (-)											Total %

Display:				Location:

	1	2	3	4	5	6	7	8	9	10	%
Pressed category or scene											
Pressed symbol/hotspot for available item											
Chose same item as selected											
All steps correct (+) any incorrect (-)											Total %

Appendix B

Procedural Integrity Intervention

Initials of Observer: Participant initials: Session #:

Condition:

Trial	1	2	3	4	5	6	7	8	9	10
Places iPad® with correct condition between child and preferred items (placed just out of reach)										
Gives child opportunity to independently respond correctly (up to 6 seconds or until incorrect response)										
Uses least-to-most prompting (partial, full and blocking as needed) if incorrect or no response prior to correspondence check										
Removes iPad® and allows child to take item within 3s of correct or prompted response, or blocks access to item not matching selection and delivers correspondence training										
Total correct out of 40										

Appendix C

Procedural Integrity Generalization/Maintenance
Initials of Observer: Participant initials: Session #:
Condition:

Trial	1	2	3	4	5	6	7	8	9	10
Places iPad® with correct condition between child and preferred items (placed just out of reach)										
Gives child opportunity to independently respond correctly (up to 6 seconds or until incorrect response)										
Does NOT provide any prompting if child makes an error										
Removes iPad® and allows child to take item within 3 seconds of correct response (including correct correspondence) or if incorrect or no response removes iPad®/blocks access to reinforcers for 5s prior to next trial										
Total correct out of 40										

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Vita

Cindy Gevarter was born in New York City and is the daughter of Sherry and Jeffrey Gevarter. As a teenager, Cindy began volunteering and then working for extended school year and summer camp programs for children with disabilities. After graduating from Middletown High School South in Middletown, NJ in 2001, Cindy entered the University of Virginia. She earned her bachelors in psychology and masters in teaching in special education in 2005. Cindy then moved to New York City where she was a special education teacher for 5 years, serving preschool and elementary aged children with disabilities. During her time teaching she was able to pursue certification in applied behavior analysis via coursework from Florida Institute of Technology and supervision at the Association of Metroarea Autistic Children. In 2011, Cindy enrolled in a doctoral program in special education at the University of Texas at Austin. She has been the lead author on several peer-reviewed journal articles, and a co-author on additional articles and book chapters.

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