Learning of Embedded and Non-embedded Visual Scene Display AAC Technologies by Typically Developing 2-Year-Olds

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Abstract

Purpose: Evidence suggests that young children learn to locate symbols on visual scene displays (VSDs) more efficiently than on traditional grid displays (Drager, Light, Speltz & Jefferies, 2003). This study examined the effects of two different types of VSDs on three typically-developing two-year-olds' abilities to locate 36 symbols that represented vocabulary items. The VSD types were embedded VSDs that clearly displayed all associated symbols on the main page and non-embedded VSDs that set the context but did not directly display the associated symbols on the main page.

Method: Three children participated in 10 experimental sessions during which they located 36 symbols that represented vocabulary items using a DynaVox Vmax™. The DynaVox Vmax™ had six VSDs on the main page; three VSDs were embedded and three VSDs were non-embedded. Dependent measures included the accuracy of selection and the latency of correct selections. One maintenance session was conducted 6 ½ weeks after the final experimental session.

Results: Results support those of previous studies which demonstrated that learning to navigate speech generating devices (SGDs) is difficult for young learners. All participants performed faster and more accurately with embedded VSDs than with non-embedded VSDs. Two of the three participants were more accurate locating the correct scene for the symbols in the first 12 opportunities compared to their performance during the last 12 opportunities of the session.

Conclusion: Overall accuracy was low for both embedded and non-embedded conditions. Children in the current investigation failed to approximate a criterion of performance in either condition that would allow reliable communication. However, there was a significant difference favoring embedded scene displays when compared to non-embedded scene displays. Implications for future research as well as for clinical/educational applications are discussed.

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Introduction

Speech generating devices (SGDs) are a form of aided augmentative and alternative communication (AAC) that offer individuals with significant speech disabilities an opportunity to express themselves using the common conventions of spoken language. Speech-generating AAC technologies provide several advantages for children who are developing language including consistent, predictable models of spoken language; the ability to store and represent language in a variety of pre-literate means, such as picture symbols or personalized photographs; and speech output in the form of stored phrases that can surpass the child's own physical or cognitive-linguistic production capabilities. Additionally, speech generating devices have also demonstrated the benefit of increasing collateral speech production and comprehension in children with communication disorders (Blischak, 1999, Bondy & Frost, 1994, Harris & Reichle, 2004, Qian, Dimian, & Reichle, 2011, & Yoder & Layton, 1988).

Current intervention models designed to teach children to use speech generating devices are based on conceptual models of adults without disabilities. Although outcomes from these studies may be helpful in informing intervention for children, these models are not necessarily the most efficient because children often need more context than adults (Drager, Light, Speltz, Fallon, & Jeffries, 2003; Light, 1997; Light & Drager, 2002; Light & Lindsey, 1991). When implementing devices with children, the two basic types of displays that have been the focus of empirical investigation include fixed/static and dynamic displays.

Fixed/Static and Dynamic Displays

A fixed display contains symbols that are "fixed" in a particular location, so the learner's entire communicative repertoire of symbols are simultaneously visible. A disadvantage of this display type is the limited number of symbols that can be placed on the display. Locations for message construction can be increased by: 1) reducing the size of symbols, 2) creating additional pages of symbols for a display, and/or 3) combining individual symbols to create new messages.

A dynamic display addresses this issue of limited space by allowing superordinate symbols to be linked to pages containing subordinate symbols (Beukelman & Mirenda, 2005). The additional pages that can be accessed from the superordinate symbols increase the display capability of the device. The use of subordinate symbols requires the user of a dynamic display to possess sequential or temporal discrimination because the learner cannot simultaneously monitor all symbol choices. This requires that dynamic display users learn search paths to navigate their communication displays.

One dynamic display symbol organizational strategy is the visual scene display (VSD). In VSDs, elements (e.g. events, people, objects, and related actions) that are considered essential components of a specific scene are displayed in a picture, photograph, or virtual environment (Beukelman & Mirenda, 2005). VSDs utilize "hot spots" to allow access to vocabulary symbols that are a part of the scene. There are both advantages and disadvantages of using VSDs (Drager et al., 2003). A VSD may decrease the metalinguistic demands of the task because the vocabulary items are built into a picture that provides contextual cues for a child. When compared to a traditional grid display, a VSD may decrease the demand on a child's working memory because similar vocabulary items are grouped and represented together in a picture.

When compared to traditional grid displays, there are some disadvantages with VSDs. The visual density of the VSDs may be too complex for children with visual-spatial disabilities. Also, the use of direct selection may be more difficult with a VSD because of the location of the symbols in the picture. Direct selection may be easier to use with a traditional grid display because each symbol is displayed in its own square and is equally spaced and sized.

For an individual to successfully use a dynamic display, he or she must be able to: 1) understand that other graphic symbols are available in the system, even when they are not visible, 2) determine or remember the page where the item is located, and 3) determine or remember the correct path needed to access the desired message (Drager, Light, Carlson, D'Silva, Larsson, Pitkin, & Stopper, 2004; Drager et al., 2003; Reichle, Dettling, Drager, & Leiter, 2000). Understanding that symbols that are not displayed on the immediate page are still accessible by navigating to another page may be difficult for children who are younger than 24 months old. The ability to talk about objects that are absent from the immediate setting emerges by 24 months; however, most communication at this age is still centered on objects in the child's present environment (Paul, 2007). Age and developmental skills, among other learner characteristics, must be carefully considered when choosing between fixed and dynamic displays. Once a display type is chosen, the interventionist must consider how to display the necessary symbols.

Display Features When Combining Dynamic Display with Visual Scene Displays: Embedded and Non-embedded Target Symbols

Finding the most efficient symbol organizational strategy for children is an area with limited empirical research. Within the past several years, two distinct strategies have emerged for arranging symbols within a VSD. Throughout this paper, these strategies will be referred to as embedded and non-embedded.

Symbols in an embedded VSD are pictured and visible on the main page. When the child selects an embedded VSD from the main page, a second page will appear that displays a "blown up" image identical to the one found on the main page. For example, on a main page, the child might see a picture of the different rooms of a house. When the child selects a particular room, it will enlarge to fit the screen so the child can see the individual objects in the room. This type of display will be referred to as "embedded" throughout this paper because the target symbol, although small, is embedded within the VSD, making it visible on the main page.

Symbols that represent vocabulary items in a non-embedded VSD are not visible on the main page. When a child selects a non-embedded VSD from the main page, a second page will appear that contains symbols that are related to, but not identical to, any of the symbols depicted on the main page of the dynamic display. For example, on the main page, a child might view a picture of the outside of a toy store, a clothing store, and a restaurant. If the child selects the clothing store VSD, the main page will link to a second page that displays the inside of the store. From this page, the child could select specific symbols, such as pants, a shirt, or a belt. In this option, the context for the target symbol was shown, but the actual symbol depicted on the subordinate (second) page was not visible on the main page. This type of display will be referred to as "non-embedded" throughout this paper because the symbols are not embedded and are not visible on the main page.

When using non-embedded VSDs, the learner must be able to match a superordinate category (e.g. clothing store) to a subordinate item (e.g. pants). This skill requires a level of non-identity matching. It also may require matching symmetry (being able to juxtapose samples and choices without a degrading of learner performance).

Performance on Display Features as a Function of Chronological Age

The performance of young children in locating a target symbol in different display layouts has been examined (Drager et al., 2003, Drager et al., 2004, & Light et al., 2004). These studies all used SGDs with four scenes on the main page, each of which was linked to a second page where specific symbols could be selected. The one exception to this was the iconic encoding layout that was used in Light et al. (2004). In this investigation only a one page display was utilized. To make a symbol selection, the participant had to remember a two-item code that was associated with the specific vocabulary item they wanted.

Participants in each of these studies completed five sessions with an interventionist. Three learning sessions occurred two-four days apart and were followed by a generalization session during which the interventionist assessed the participants' generalization to new symbols not probed during the first three sessions. The vocabulary items used during the first three sessions were examined during play situations to see if generalization across settings occurred. A maintenance session was scheduled two weeks after the final learning session.

Drager et al. (2003) examined the performance of ten typically developing 2 ½-year-olds with three different layouts: taxonomic grid, schematic grid, and schematic scene. The taxonomic grid organized symbols in a grid layout. The symbols were grouped according to hierarchical categories, such as people and actions. The schematic grid also organized symbols in a grid layout, but in this display the vocabulary was grouped by event, such as going to a party and eating cake. The schematic scene was a VSD that showed symbols in pictures of different rooms of the house, such as the living room and kitchen.

There were 61 vocabulary items represented in each type of display. One item was used as an example. Half of the remaining 60 vocabulary items were concrete while the other half were abstract. Twenty-four (12 concrete and 12 abstract) of the symbols were addressed during learning sessions, and 12 (6 concrete and 6 abstract) were used during the generalization session.

Drager et al. (2004) compared how well 10 three-year-olds could find target symbols while using either a traditional grid display or a VSD. The layouts included two types of grid layouts and a contextual scene. One of the grid layouts represented the options on the main page with a single symbol. The second grid layout type represented the options on the main page with a screen shot of the actual vocabulary page. The contextual scene layout represented the options on the main page by displaying the actual pages of vocabulary that were smaller than the real page.

Light et al. (2004) examined the performance of 4- and 5-year old children who were typically developing. Four different layouts were used on speech generating devices, including taxonomic grid, schematic grid, schematic scene, and iconic encoding. In the taxonomic grid layout, the vocabulary was organized into a grid layout according to hierarchical categories (e.g., people, actions, things, social expressions). In the schematic grid, the vocabulary was organized into a grid layout according to certain events, such as arriving at the party, eating cake, and playing games. The schematic scene organized vocabulary into pictures of certain rooms in the house. The pictures shown on the main page were the exact pictures shown on the second page except for the fact that they were smaller in size. The iconic encoding layout had 49 symbols displayed on the main page.

This study was broken up into two experiments: the performance of 40 typically developing 4-year-olds (Study 1) and the performance of 40 typically developing 5-year-olds (Study 2). One question addressed during this experiment involved the accuracy of typically developing 4- and 5-year-old children locating symbols using the four different layouts previously mentioned. The effect of learning sessions on performance, the accuracy of concrete vocabulary versus abstract vocabulary, and generalization of learning were also researched.

Drager et al. (2003) and Drager et al. (2004) found that neither the schematic scene system nor the grid display layouts were transparent to the 2 ½- and 3-year-olds. The 2 ½-year-olds performed significantly better with schematic scene system when compared to the grid display layouts. The 2 ½-year-old participants also performed significantly better across each session. Drager et al. (2003) reported no evidence of generalization to new symbols. The 3-year-old children using the contextual scene layout performed better than the children using either of the grid layouts. Although there was some evidence of generalization for the 3-year-olds, the learning was minimal and 40% of the children did not demonstrate generalization (Drager et al., 2004).

Light et al. (2004) found that both the 4- and 5-year old children were significantly more accurate with the dynamic displays than with the iconic encoding. The dynamic displays were moderately transparent to both the 4- and 5-year olds, but the iconic encoding was not transparent to either group. The rate of learning for the iconic encoding (chaining two symbols together that appeared on a fixed symbol display) was significantly slower than the dynamic display for both the 4- and 5-year olds. From the first session to the generalization session, the main effect of organizational technique was statistically significant for both age groups. There was evidence to support generalization to novel vocabulary items in all display types, but generalization to free play situations was not noted.

In Olin, Reichle, Johnson, and Monn (2010), 11 children between 22 and 27 months and 12 children between 33 and 36 months were exposed to an embedded VSD. The VSD was a toy house scene with nine symbols, which were all familiar objects. Each child completed up to 12 experimental sessions that were held 2-4 days apart until they could correctly identify over 75% (seven out of nine vocabulary items) over three consecutive sessions. A maintenance session took place approximately two weeks after the final experimental session. In addition to accuracy data, latency data were collected.

The results of this study showed that at initial exposure, the 33-36 month-olds were significantly more accurate and significantly faster navigating through the VSD. Children who were 24-27 months old required significantly more experimental sessions to achieve the pre-set criterion of 75% accuracy over three consecutive sessions, the maintenance data was similar for both groups. All children were able to learn to use the VSD in 12 or fewer sessions, which suggests that children as young as two years of age could understand and utilize VSDs.

Some recent studies have used latency data for correct responses as a dependent measure in addition to accuracy (e.g., Olin et al., 2010). Latency measures have been used as an indicator of cognitive challenges in studies investigating specific language impairment and in examining language difference and impairment in English and bilingual speakers (e.g. Windsor & Kohnert 2004).

Several investigators have examined the relationship between navigation in real versus representational environments. Several studies (DeLoache, 2004; DeLoache, 1995; DeLoache & Burns, 1993; DeLoache & Burns, 1994) examined young children's ability to find objects in a room after seeing the location in a picture of the room or scale model of the room. In these studies 2 ½- and 3-year-old children located a Snoopy doll in a large room after seeing the location in a picture or a scale model. Three-year-olds were able to find Snoopy without error during both conditions. Two and a half-year-olds found Snoopy without error when shown the photograph but not the scale model. DeLoache suggested that the dual role being played by the model (the scene being both a real object and a representation at the same time) caused the two and a half-year-olds to have difficulty with the task. While young children's representational skills are not yet fully developed, by two and a half-years-old they may be able to use photographs as representations in the context of a VSD (Reichle & Drager, 2010). However, in the context of a VSD utilizing a dynamic communicative display, little is known about the relative ease of several distinctly different symbol display variations.

The current research suggests that children have difficulty learning to use SGDs, but with teaching sessions, they can learn to navigate them successfully. Children have been shown to be more successful navigating VSDs than traditional grid displays, but there continues to be a need to research the best way to display symbols in VSDs. The purpose of the current study was to compare the performance of three typically developing 2-year-olds when using embedded and non-embedded VSDs.

Method

This study was conducted in accordance with ethical research protocols approved by the Institutional Review Board.

Participants

Three typically developing 26-month-old triplets (two females, one male) participated. The triplets were born at 27 weeks; when adjusted for prematurity they were 23 months old at the onset of participation. Each child met the following selection criteria: (a) no motor, cognitive or language delays; (b) normal vision and hearing; (c) consent of parent to participate. Screening procedures are described later. Typically developing children were used in this study for several reasons. Research with typically developing children can highlight the cognitive demands of SGD technologies without raising ethical concerns about allocating the resources of these children to learning an experimental AAC technology that may not provide direct benefit (Light et al., 2004). Existing literature on the present topic involves typically developing children and was free of the additional effects other impairments, such as motor, sensory, or perceptual impairments. Typically developing children may improve our understanding of the cognitive processes involved in learning to use SGDs, as well as highlight effective teaching strategies associated with different symbol systems (Higginbotham, Scally, & Lunde, 1995).

Materials

During each experimental session, participants were exposed to a main page that showed six VSDs (three embedded scenes and three non-embedded scenes). The embedded scenes pictured on the main page included a bedroom, foyer, and living room. The non-embedded scenes on the main page included a bathroom, playroom, and kitchen. Figures 1 and 2 show examples of embedded and non-embedded VSDs.

[Insert Figures 1 and 2]

Each VSD contained six symbols that represented vocabulary items. The 36 target vocabulary words that were used in this experiment were selected from the MacArthur Communication Development Inventories [MCDI] (Dale & Fenson, 1996) and were produced by 60% of two-year-olds. As shown in Table 1 and Figure 1, the bedroom scene depicted a bed with a side table that held an illuminated lamp, some clothing items, and a mosquito-like bug on the wall. This scene contained the symbols: *pants, shoes, socks, bug, light,* and *bed.* As displayed in Table 1, the foyer depicted a man in a foyer receiving a pizza delivery with his television and telephone shown in the background and contained the symbols: *TV, telephone, hat, keys, door,* and *pizza*. As shown in Table 1, the living room VSD displayed a family sitting with their baby and cat and contained the symbols: *kitty, diapers, baby, bottle, foot,* and *mommy*. As depicted in Table 1 and Figure 2, a typical residential bathroom was depicted in the bathroom VSD and contained the symbols: *toothbrush, duck, water, potty, bathtub*, and *soap*. As shown in Table 1, the playroom VSD depicted a variety of toys and children's art tools and contained the symbols: *crayons, paper, blocks, frog, monkey,* and *elephant*. As depicted in Table 1, the kitchen VSD showed a typical residential the kitchen with cupboards, countertops and appliances and contained the symbols: *apple, banana, cheese, crackers, milk,* and *spoon*.

Before beginning this experiment, the relatedness of vocabulary words and the VSD that contained them was confirmed by a group of speech-language pathologist graduate students. Twelve students completed a survey in which they answered the question, "How likely would the first ITEM be found in the following GROUP of items?" The survey did not show pictures of the scenes but provided each of the 36 target vocabulary words and their corresponding group of six vocabulary words with which they were contained in one VSD. Responses were provided on a 5-point rating scale with 1, "very unlikely" to 5, "very likely. Ninety-two percent of the vocabulary items (33 of the 36 items) were rated as "neutral," "likely," or "very likely" to be found in the corresponding group. Table 1 displays the vocabulary found in each scene, the MCDI percentage for each vocabulary item, the MCDI average percentage for each VSD, adult survey rating average for each vocabulary item, and adult survey rating average for each VSD.

[Insert Table 1]

When the participant touched one of the six VSDs displayed on the main page of the DynaVox Vmax™, a second (subordinate) page appeared and the main page display disappeared. In the embedded VSDs, each of the six symbols that represented vocabulary items was clearly visible from the main page. The subordinate page for the embedded VSDs was a larger version of the same VSD displayed on the main page.

The non-embedded VSDs on the main page did not display the symbols that represented vocabulary items; the target symbol depiction was not available as part of the main page scene display in this condition. Non-embedded VSDs depicted the appropriate VSD context, but not the actual symbols. When touched, a second (subordinate) page appeared and the main page display disappeared. The subordinate page for the embedded VSDs was a similar context and it displayed the symbols that represented vocabulary items. For example, in the non-embedded condition the superordinate VSD on the main page depicted a typical residential kitchen. The corresponding subordinate VSD also displayed a typical residential kitchen, but it also displayed each of the symbols that represented vocabulary items. Thus, non-embedded VSDs required the participant to engage in a nonidentity match-to-sample task while the embedded scenes resembled more of an identity matching to sample task.

Each subordinate page was linked to a white screen. This screen was used as a reference point when calculating latency data using the data logging feature of the

DynaVox Vmax™. The white screen was linked to the main page which contained the six VSDs.

The scenes and individual symbols in both formats were captured by two different cameras: a Sony Cyber-shot 7.2™ mega pixel digital camera and a Casio Exilim 7.2™ mega pixel digital camera. Some target symbols were modified or digitally inserted into the scene using Adobe Photoshop CS4® (Adobe Systems Incorporated). The scenes were then imported into the DynaVox Vmax™ device.

Setting

Sessions took place in the child's home and were conducted in the child's living room while the child's siblings and mother were in an adjacent room. According to child preference, he or she either sat with the interventionist on the floor with DynaVox Vmax™ device placed directly in front of the child on the floor, or they sat at a child-sized chair and table set with the DynaVox Vmax™ device placed directly in front of the child on the table.

Screening Tasks

Vision, fine motor, and vocabulary comprehension were directly tested prior to experimental sessions. The investigator also obtained information regarding hearing and cognitive development via parent report.

Vision screening.

A variation of the *Child's Recognition and Near Point Test* (Allen, 1957) was used to assess each participant's vision skills. Nine black and white line drawn symbol cards were scanned and imported into the DynaVox Vmax™ device. The symbols included a cake, telephone, car, house, the letter E, a bear, a flower, a tree, and a horse. They were displayed in a nine-space (3x3) grid with approximately 2 inches in between each picture. Each drawing was approximately 1.5 inches x 1.0 inch. Each symbol was also printed in the equivalent size and placed onto a flashcard with a white background.

The examiner knelt approximately 15 feet directly in front of the participant and held up each of the nine flashcards one at a time. The participant was directed to touch the matching line drawing on the DynaVox Vmax™ display or to speak the name of the object shown on the flashcard being held by the examiner. Each participant was successful in matching at least eight of the nine line drawings during this vision screening task, which was considered passing.

Fine motor screening.

A fine motor screening was conducted using the DynaVox Vmax™ to ensure that participants could accurately activate a button equal to the smallest height and width of any of those used in this experiment. The participant was shown a screen that displayed a 3 inch x 3 inch square button and was directed to touch the button. When the participant touched the button the device spoke, “Get me!” and the page advanced to a second display with a 0.5 inch x 0.5 inch button placed at the opposite side of the screen. This target was smaller than the smallest button used in the experiment. When the button was touched, the device spoke, “You got me!” Each participant successfully activated this sequence of buttons three consecutive times demonstrating that they had adequate range of movement and fine motor abilities to participate in the study.

Hearing screening.

A hearing screening using a portable audiometer was attempted. However, the participants repeatedly refused participation. Given that the task utilized in the experimental condition did not rely on auditory competence, the experimenter queried the participants' parent who confirmed that hearing had not been a concern during any recent medical checkups. One participant had pressure equalization tubes and her hearing was found to be within normal limits during a recent medical visit. The participants' responses to the device's, siblings' and interventionists' speech output, as well as responses to environmental sounds, all suggested hearing function within normal limits.

Language comprehension screening.

The Receptive One Word Picture Vocabulary Test-3 (ROW-PV-3; Brownell, 2000) was performed to screen vocabulary comprehension. Each participant achieved a standard score between 85 and 115 on the vocabulary comprehension screening.

Parent interview.

A parent interview was conducted to assess other variables that may threaten internal validity. These included primary language spoken in the home, cognitive and/or emotional delays, fine and/or gross motor delays, speech and language delays, hearing loss, and any prior experience with touch screen computers or AAC devices. Based on the parental report each participant spoke English as the primary language, had no known emotional, cognitive, fine motor, or gross motor delays, demonstrated typical speech and language development, and had hearing within normal limits. Participants did not have previous experience with touch screen computers or AAC devices.

Comprehension Pretest of Experimental Vocabulary.

A non-identity match-to-sample pretest was conducted to ensure that each participant comprehended the vocabulary and photographic symbols used in the experiment. This allowed the interventionists to be sure that learner performance could be attributed to navigational skills and not to lack of comprehension of vocabulary items. The photographs representing each experimental vocabulary item were printed, removed from the visual scene in which they appeared on the device, and displayed on a white background in a field of six. The interventionist directed the participant to point to a photograph by delivering the prompt, "Put your finger on the [vocabulary item]." To prevent the participant from benefitting from process of elimination, the interventionist only presented three of the six vocabulary items on a page before advancing to the next page where the process was repeated. Thus, to screen all vocabulary items each page was shown to the child twice. No reinforcement was given and error correction was not provided. Attention and participation in the task were reinforced. The participants identified an average of 72% of the experimental vocabulary items during this pretest.

General Developmental Screening

During the maintenance session, the mother of the subjects completed a portion of the Child Development Inventory (Ireton, 1992) to confirm that each participant was typically developing. Only the portions that would affect the performance in the research study (social development, fine motor, expressive language, language comprehension, and possible problems) were completed and scored. All areas were within normal limits for each participant.

Dynamic Screen Display and Speech Output

The DynaVox Vmax™ SGD was set to use the AT&T Natural Lab Voice, Crystal, throughout the investigation. The speech output volume and the speech rate were set at 40 (out of 100) throughout the entire investigation. Before each experimental session, the interventionist played a sample and asked the participant to confirm audibility of the speech output.

Procedural Overview and Design

A within participant alternating treatment design comparing embedded and non-embedded VSDs was implemented. Participants found symbols within VSDs on the DynaVox Vmax™ that matched the vocabulary item given by the interventionist. Participants were not given corrective feedback, but participation and attention were reinforced. A familiarization session was conducted along with 10 experimental sessions and a maintenance session that occurred 6 ½ weeks after the final experimental session. Accuracy of selections and latency of correct symbol selections were compared across embedded and non-embedded scenes for all participants individually and as a group.

Independent Variables

Embedded versus non-embedded VSDs served as the independent variable.

Dependent Measures

Dependent measures included response accuracy for selection of the correct VSD and response latency for correct responses only. All latency data were computed using only the participants' accurate responses. A response was considered accurate when the participant independently located the VSD on the main page that contained the target vocabulary item. Response latency was recorded to the nearest hundredth of a second using the data logging feature on the DynaVox Vmax™ device. Latency was recorded from the time that the final syllable of the prompt was spoken by the interventionist and stopped when the participant touch-activated the correct symbol.

Procedures

Familiarization session.

Before beginning experimental sessions, each participant was familiarized with the DynaVox Vmax™ device and the operation of its touchscreen. Participants were shown a main page that contained two embedded VSDs and one non-embedded VSD. These VSDs were not used in the experimental sessions. The vocabulary items that were used in the familiarization session were produced by 60% of two-year-olds according to the MCDI (Dale and Fenson, 1996). In the familiarization session, interventionists introduced the DynaVox Vmax™ device by saying, "This is my talker. If I want it to say *house* I put my finger on this picture. See? Now if I want it to say *house* I put my finger on the house." The interventionist used this process to demonstrate one embedded and one non-embedded symbol and then invited the participant to locate a different embedded and non-embedded item. The interventionist used verbal, visual, and physical prompts until the child successfully located the symbols. The child's participation was reinforced.

Experimental sessions.

Participants were asked to locate each of the 36 symbols during each session. There were six symbols per VSD with three embedded VSDs and three non-embedded VSDs. The embedded and non-embedded target symbols were presented in a randomized order. Sessions were conducted a mean of three days apart (range of two to seven days).

Each session began with the interventionist drawing attention to the DynaVox Vmax™ and confirming that the volume of the device was audible. During each session the interventionist prompted each vocabulary item one at a time with one of three prompts: "Find the *item*," "Put your finger on the *item*," or "Touch the *item*." If the participant did not attempt to locate the symbol within three seconds, the investigator implemented a least-to-most prompting hierarchy that included a light physical prompt (interventionist lightly directed the participant's arm toward the device), visual prompt by a point to the general area (interventionist gestured to the device), visual prompt by a close point (interventionist gestured to the correct area on the device), and finally hand over hand assistance.

If the participant chose the wrong VSD on the main page, the interventionist activated the "Go back" arrow to return to the main page. Once at the main page, the interventionist implemented the prompt hierarchy to help the child find the correct VSD. If the participant chose the correct VSD on the main page, the interventionist gave the spoken prompt, "Find it," to remind the participant to locate the symbol that represented vocabulary item. The same prompt hierarchy was used for the second page if the participant did not respond within three seconds. If the participant did not locate the correct symbol on the second page, the "Go back" arrow was used and prompts were delivered until the voice output matched the interventionist's target word. If the "Go back" arrow was used or if any prompts other than the non-specific "Find it," were required, the vocabulary item was scored as incorrect.

After a symbol was chosen on the subordinate page, a white screen appeared. The interventionist would prompt the next vocabulary item while on this screen. On the final syllable of the prompt, the interventionist touched the center of the screen, which linked to the main page set-up with all six VSDs.

Maintenance Session.

A maintenance session was conducted 6 ½ weeks after the final data collection session. This session was conducted identical to all experimental sessions. Both experimental conditions were implemented, and all 36 symbols that represented vocabulary items were administered.

Procedural and Response Reliability

Researchers ensured that all factors other than the independent variables remained constant by collecting procedural fidelity and interobserver-agreement data during 33% (10/30) of the experimental and maintenance sessions, across participants, conditions, and interventionists. Two interventionists were trained prior to the investigation until at least 95% of procedures were correctly completed by both interventionists and until at least 95% interobserver agreement was reached during practice sessions. A third investigator was trained to collect interobserver agreement and procedural fidelity data. This investigator also reached the 95% criterion with both of the other interventionists before working in the field. While one interventionist worked with the participants, another observed and scored the procedural fidelity and participant responses. Overall interobserver agreement and procedural fidelity were computed using the formula agreements divided by agreements + disagreements x 100. Latency was recorded automatically by the DynaVox Vmax™.

Data Reduction and Analysis Procedures

Data were organized by each participant. Because the research question compared embedded and non-embedded VSDS, only selections made from the main page (visual scene selection) were included in the analysis. The criteria for a correct response on the main page included two parts: the VSD selected on the main page contained the symbol that represented the prompted vocabulary item and the selection was made independently within five seconds of the last syllable of the spoken word being delivered.

Accuracy, Latency, and Percent Non-overlapping Data (PND) for Each Participant.

Mean accuracy and mean latency of a correct visual scene selection were calculated for each subject in each of the two experimental conditions. Mean accuracy was calculated by dividing the total number of correct scene selections by the total number of opportunities. Mean latency was calculated by dividing the sum of all latency values for correct scene selections during a session by the total number of correct scene selections made during that session. As an indicator of effect in single subject design, the percent of non-overlapping data (PND) was computed for accuracy and latency of correct responses used in this study for each participant individually. All PND calculations were performed using the method of Wolery, Gast, and Hammond (2010). PND is used to compare the consistency of one condition being superior to another condition. The number of sessions where a participant was more accurate with embedded VSDs was divided by the total number of sessions completed. PND values within the range of 75 to 100 reflect a notable level of consistency. When calculating PND on the dependent measure of accuracy, the number of sessions in which accuracy with embedded VSDs was superior to accuracy with non-embedded VSDs was divided by the total number of sessions. This number was multiplied by 100 to calculate each participant's PND. When calculating the latency PND, the number of sessions in which a participant had a faster average time of response when choosing an embedded VSD over a non-embedded VSD was divided by the number of sessions where there was at least one correct embedded VSD response and one correct non-embedded VSD response. This number was multiplied by 100 to calculate each participant's PND for latency data.

Performance on First 12 Stimuli of Each Session Compared to Last 12 Stimuli of Each Session.

The mean accuracy of response for the first 12 items administered during a session was compared to the mean accuracy of response for the last 12 items administered for each participant individually. This was done to determine whether participants had more difficulty successfully navigating the SGD as the session progressed. Mean accuracy of response was reported by total accuracy, embedded VSD only accuracy, and non-embedded VSD only accuracy.

Maintenance Data Analysis

The mean accuracy and mean latency of response were calculated for each individual. Mean accuracy and mean latency of response were reported by accuracy and latency for all selections, mean accuracy and mean latency for only embedded VSD selections, and mean accuracy and mean latency for only non-embedded VSD selections.

Overall Accuracy and Latency Aggregated for All Participants.

Data for each of the three participants was combined to compare accuracy between the two experimental conditions. The total number of correct scene selections was divided by the total number of opportunities for each of the two experimental conditions. Accuracy of all responses, embedded only responses, and non-embedded responses were calculated. Response latency was calculated for all correct responses, embedded only correct responses, and non-embedded only correct responses. The total latency of all correct scene selections was divided by the total number of correct scene selections to determine the average latency of response.

A correlation coefficient was computed to quantify the relationship between the score obtained from the adult rating of vocabulary items and participant accuracy in selecting the correct visual scene display during the experimental sessions. This was completed to see if adult perceptions of the scene were related to learner performance during the experimental sessions. A second correlation coefficient was computed to quantify the relationship between the participants' performance on the baseline probe and accuracy of selecting the correct visual scene display during the experimental sessions. This was completed to see if the performance on the baseline probe task was related to learner performance during the experimental sessions. A paired two sample t-test was used to compare differences in the mean accuracies of scene selection for embedded and non-embedded VSDs by all participants.

Results

Procedural Fidelity

All procedural fidelity and interobserver agreement measures were computed as agreement/agreements + disagreements x 100. Using this formula, overall procedural fidelity was computed to be 99.8% (661/662).

Experimental Sessions.

Procedural fidelity for the experimental sessions was calculated from a procedural checklist used during interventionist training sessions. Procedural fidelity during the experimental sessions was 99.8% (557/558).

Maintenance Session.

Procedural fidelity for the maintenance session was calculated from the same procedural checklist used during interventionist training sessions. Procedural fidelity during the maintenance session was 100% (104/104).

Response Reliability

Experimental Sessions.

Interventionists collected data on the dependent measure of accuracy of response during experimental sessions. Interobserver agreement for accuracy of response was 100% (304/304).

Maintenance Session.

Interventionists collected data on the dependent measure of accuracy of response during the maintenance session. Interobserver agreement for accuracy of response was 100% (54/54).

Overview of Results

Each participant's performance during experimental sessions and the maintenance session will be discussed individually followed by an aggregated comparison.

Participant 1: Accuracy and Latency for All Opportunities

Accuracy During Experimental Sessions

Throughout all experimental sessions, Participant 1 was 12.3% accurate (40 correct responses out of 324 opportunities) when choosing a VSD from the main page. As shown in Table 2, participant 1 had similar accuracies for embedded and non-embedded VSDs with 13.0% accuracy (21/162) with embedded VSDs and 11.7% accuracy (19/162) with non-embedded VSDs.

[Insert Table 2]

As shown in Figure 3, over 10 comparison sessions, Participant 1 performed more accurately locating symbols in embedded scenes on 5 of 10 sessions yielding a PND of 50%.

[Insert Figure 3]

As shown in Table 3, when looking at only the first 12 opportunities in all sessions, participant 1 was 9.17% accurate overall (11/120), 9.5% accurate (6/63) on embedded VSDs, and 8.8% accurate (5/57) on non-embedded VSDs.

During the last 12 prompts given during all sessions, participant 1 was 11.9% accurate overall (10/84), 16.3% accurate (7/43) on embedded VSDs, and 7.3% accurate (3/41) on non-embedded VSDs.

[Insert Table 3]

Accuracy During Maintenance Sessions

As shown in Table 4, during the maintenance session, participant 1 was 47.2% accurate (17/36) when locating the correct VSD on the main page. She was 66.7% accurate on embedded VSDs and 27.8% accurate on non-embedded VSDs during the maintenance session.

[Insert Table 4]

Latency During Experimental Sessions

Participant 1 took an average of 3.453 seconds to select the correct VSD from the main page. As shown in Table 2, participant 1 was faster in finding the correct VSD for embedded than non-embedded VSDs with respective mean latencies of 3.206 seconds compared to 3.727 seconds.

The PND was calculated for latency data of correct VSD selection. Only sessions with at least one correct embedded VSD selection and one correct non-embedded VSD selection were included in the analysis. As shown in Figure 4, participant 1 performed more quickly on embedded scenes over non-embedded scenes on 4 of 5 sessions yielding a PND of 80.0%.

[Insert Figure 4]

Latency values were not calculated for the VSD selection of the first 12 and last 12 items in all sessions due to a large number of sessions where the participants did not choose at least one embedded VSD and one non-embedded VSD correctly. With no correct selections, there was no latency data on scene selection collected.

Latency During Maintenance Sessions

Participant 1 correctly chose the VSD from the main page in an average of 3.443 seconds. Participant 1 took longer finding embedded VSDs with a latency of 3.752 seconds on average compared to a mean of 2.700 seconds with non-embedded VSDs.

Participant 2: Accuracy and Latency for All Opportunities

Accuracy During Experimental Sessions

Participant 2 was 19.0% accurate when choosing a VSD from the main page throughout all experimental sessions (58 correct responses out of 305 opportunities). As shown in Table 2, participant 2 was more accurate with embedded VSDs with 27.0% accuracy (41/152) than with non-embedded VSDs with 11.1% accuracy (17/153). As shown in Figure 5, participant 2 performed more accurately with embedded scenes than with non-embedded scenes on 7 of 10 sessions yielding a PND of 70%.

[Insert Figure 5]

As shown in Table 3, participant 2 was 28.3% accurate (34/120) in locating the correct VSD for the first 12 items during all experimental sessions. Participant 2 was 35.5% accurate (22/62) with the embedded VSDs given in the first 12 opportunities of all sessions and 20.7% accurate (12/58) on non-embedded VSDs given in the first 12 opportunities of all sessions.

During the last 12 opportunities of all sessions, Participant 2 was 6.0% accurate overall (5/84) when choosing a VSD from the main page with 11.6% accuracy (5/43) on embedded VSDs and 0.0% accuracy (0/41) on non-embedded VSDs.

Accuracy During Maintenance Sessions

As shown in Figure 4, during the maintenance session, participant 2 was 58.3% accurate overall (21/36) when choosing a VSD from the main page. Participant 2 was 55.6% accurate on embedded VSDs and 61.1% accurate on non-embedded VSDs.

Latency During Experimental Sessions

Throughout all experimental sessions, participant 2 took an average of 2.971 seconds to select the correct VSD from the main page. As shown in Table 2, Participant 2 took 2.909 seconds to find the correct embedded VSD on the main page and 3.120 seconds to find the correct non-embedded VSD on the main page. As shown in Figure 6, participant 2 located embedded scenes on the main page faster than non-embedded scenes on the main page during 3 of 5 sessions yielding a PND of 60.0%.

[Insert Figure 6]

Latency During Maintenance Sessions

During the maintenance session, participant 2 correctly chose the VSD from the main page in an average of 2.948 seconds. Participant 2 found embedded VSDs in 2.896 seconds on average and non-embedded VSDs in 2.994 seconds on average.

Participant 3: Accuracy and Latency for All Opportunities

Accuracy During Experimental Sessions

Participant 3 was 21.6% accurate in locating the correct scene throughout all experimental sessions (64 correct responses out of 296 opportunities). As shown in Table 2, participant 3 was 23.5% accurate (35/149) with embedded VSDs and 19.7% accurate (39/147) with non-embedded VSDs. As shown in Figure 7, participant 3 performed more accurately on embedded scenes over non-embedded scenes on 5 of 10 sessions yielding a PND of 50%.

[Insert Figure 7]

As shown in Table 3, participant 3 accurately located 28.6% (34/119) of all VSDs in the first 12 opportunities of all sessions. During the first 12 opportunities of each session, she was more accurate locating embedded VSDs with 32.2% accuracy (19/59) compared to 25.0% accuracy (15/60) with the non-embedded VSD condition.

During the last 12 opportunities of all sessions, participant 3 was 19.0% accurate overall (16/84) when choosing a VSD from the main page. Her performance yielded 22.9% selection accuracy (11/48) with embedded VSDs and 13.9% accuracy (5/36) on non-embedded VSDs.

Accuracy During Maintenance Sessions

As shown in Figure 4, participant 3 correctly chose 55.6% of the VSDs from the main page during the maintenance session (20/36). Participant 3 was 50.0% accurate on embedded VSDs and 61.1% accurate on non-embedded VSDs.

Latency During Experimental Sessions

Participant 3 took an average of 3.002 seconds to select the correct VSD from the main page. As shown in Table 2, she was faster in finding the correct symbol for embedded than non-embedded VSDs with respective mean latencies of 2.878 seconds compared to 3.152 seconds. As shown in Figure 8, participant 3 located embedded scenes on the main page faster than non-embedded scenes on the main page during 7 of 9 sessions yielding a PND of 77.8%.

[Figure 8]

Latency During Maintenance Sessions

Participant 3 correctly chose the VSD from the main page in an average of 2.511 seconds. Participant 3 found embedded VSDs in 2.588 seconds on average and non-embedded VSDs in 2.447 seconds on average.

Accuracy and Latency for the Aggregated Data Produced by the Three Participants

Response accuracy during all experimental sessions was calculated for all participants as a group by dividing total number of correct scene selections by the total number of opportunities. Total accuracy was also separated into performance accuracy for embedded and non-embedded VSDs. As shown in Table 2, the total accuracy for all participants as a group was 17.5% (162 correct selections out of 925 total opportunities). Mean response accuracy during the embedded experimental condition was 21.0% (97 correct selections out of 463 total opportunities), and the non-embedded response accuracy was 14.1% (65 correct selections out of 462 total opportunities). Because researchers had no hypothesis about direction of effect, a two-tailed t-test was used to compare embedded and non-embedded mean selection accuracy. The mean embedded selection was greater than mean non-embedded selection, but this difference fell short of our criterion for statistical significance of .05, ($t[2] = 3.12$, $p = 0.089$).

A correlation analysis between adult rating of vocabulary items and experimental accuracy was implemented to examine whether adult perception of the relevancy of vocabulary in certain scenes influenced performance on accuracy. The two variables had a weak negative correlation, $r(1) = -0.02$, $p = 0.41$. This suggests that the adult rating of the goodness of fit of vocabulary items did not have an effect on the learner's performance.

A correlation between baseline probe performance and experimental accuracy was implemented to examine whether comprehension of actual vocabulary items taught prior to intervention influenced performance on accuracy in the experimental task. The two variables had a weak negative correlation, $r(1) = -0.02$, $p = 0.39$. This suggests that the performance on the baseline probe did not have an effect on the learner's performance.

Discussion

Throughout the experimental sessions, the participants had difficulty navigating the SGD. In spite of this basal effect, the three participants were more successful locating embedded VSDs compared to non-embedded VSDs. Additionally, each of the three participants tended to locate embedded VSDs more quickly than non-embedded VSDs. Participants, for the most part, exhibited somewhat due diligence in sampling the array of choices and often took several seconds prior to making a choice (although attention to task varied between subjects and across sessions). Although spoken encouragement and small tokens of reinforcement were offered to participants throughout the sessions, the learners may not have been sufficiently reinforced. No participant showed a steady gain in accuracy over the course of the experiment (See Figures 3, 5, and 7).

The performance of Participant 3 (see Figure 7) deteriorated during the final three experimental sessions even after increased reinforcement during these final experimental sessions. It is possible that fewer teaching opportunities with more frequent sessions may have been more effective than the schedule and length of sessions utilized.

Participants produced a substantially greater number of correct responses in the maintenance task when compared with their performance during the last two acquisition tasks (Figure 4). It is possible that maturation over several months was responsible (maturation was not controlled). Alternatively, the six and a half week break between acquisition and maintenance probes may have addressed the possible issue of task habituation, which in turn, resulted in improved performance.

Previous investigations suggested that two-year-olds were able to successfully navigate SGDs with fewer teaching sessions than the current study. For example, most 2-year-old participants in Olin et al. (2010) reached 75% accuracy in locating 9 symbols in 3 embedded scenes after only 2 to 4 training sessions. In the current study, participants had to locate 36 symbols in six different scenes; three of the scenes were embedded and three were non-embedded. Future research should address the optimal number of symbols and scenes to teach young learners.

To explore the influence of task habituation, performance on the first 12 vocabulary items from all sessions was compared to performance on the last 12 vocabulary items from all sessions. There was a noteworthy difference for two out of three participants. One participant performed 22.3% better during the first 12 items when compared to the last 12 items while another participant performed 9.5% better on the first 12 items. Taken together, this suggests that the number of VSDs and the number of symbols trained to young SGD users at one time can have important influence on learner performance.

Participants in this study performed better six and a half weeks after their last experimental session than they did during most experimental sessions. As shown in Table 4, during the maintenance session, participants found more symbols than they had in the last two experimental sessions. One possible explanation for this is maturation of participants during the break between experimental sessions and the maintenance session. When the researchers presented the DynaVox Vmax™ during the maintenance session, the children showed increased excitement when compared to the final experimental session and eagerly participated throughout the maintenance session. This speaks to the importance of teaching VSD use in highly motivating circumstances. It also speaks to habituation of trials and suggests it is the quality of trials, not the quantity.

[Insert Table 4]

One area of interest in VSD research is how one separates the challenges in learning to navigate compared to the challenges in learning symbols that represent new vocabulary. During the baseline probe comprehension task, the participants correctly identified an average of 72% of the target symbols that were displayed on a white background in fields of six choice symbols when given the clue, "Find the *item*." When these same vocabulary items were presented on the DynaVox Vmax™ in embedded and non-embedded VSDs, the participants' accuracy in identifying the correct scene for each symbol decreased dramatically. Overall the participants identified the correct scene for the symbol with an average of 17.5% (which represents a 54.5% decrement in performance) despite the context provided by the VSD and systematic training and reinforcement provided over 10 sessions.

It is possible that the difficulties associated with young children's ability to navigate a dynamic display device represent a formidable challenge for preschoolers. Thus, there may be some merit in teaching the correspondence between a graphic symbol and its referent prior to teaching the learner to navigate a dynamic display VSD to locate the target symbol. In the baseline probe condition, symbols were presented on a decontextualized static display, which should have further contributed to the difficulty of the baseline condition where no context was available. In the experimental condition, symbols were presented in a contextualized VSD, but the participant had to selected the category (superordinate) VSD to navigate to the page containing the VSD where the symbol that represented the vocabulary item could be selected from the embedded field of six. This was challenging for all participants in this study.

Limitations of Current Research

Although this study provided insight into two-year-olds' ability to use SGDs, there are some limitations. The children who participated were typically developing.

The data collected during this study is helpful to understand the developmental abilities of two-year-olds, but these results may not be applicable to children with disabilities. Also, there were only three subjects involved in this study. The subjects in this study were exposed to identical environments, which equalized experience and increased internal validity; however, because the participants were so similar, the external validity of this study may have been affected. Another limitation of this single-subject design is the lack of a superior-treatment alone condition following this phase of the experiment. Typically, in an alternating treatment design, a superior-treatment alone condition is implemented to ensure performance is maintained in a more effective treatment, and any potential interference from the other treatment is removed (Wollery et al., 2010). Due to participant time limitations, it was not possible to present the embedded VSDs alone without the presence of the non-embedded VSDs.

Implications for Future Research

Continued research is necessary to further our understanding of the best ways to teach and implement AAC strategies to young children. Efforts should be made to better understand whether real-life experience with the scenes and symbols used on a SGD would affect the performance of children when these symbols are placed on a SGD. For example, if a child was able to manipulate the objects in a dollhouse before working with a VSD of a dollhouse, would they be more successful locating symbols within that VSD? The effect on performance of the relatedness of symbols to the learner's natural environment should also be addressed. Also, the effect of performance during vocabulary screening measures on accuracy of selection during experimental sessions should be researched.

Future research may wish to consider shorter more frequent sessions to address habituation. They might look at prompt levels used and the effect on performance across conditions. Also, progress could be indicated by the learner’s increased propensity to use a less intrusive response prompt in selecting a correct choice. A final area that requires further investigation is the task difficulty imposed by the number of symbols on the VSD and where the proper starting point is to allow learners to locate symbols quickly in the initial exposures and add in more symbols as they learn to navigate the SGD. This study could have decreased task difficulty by removing symbols from the VSDs or asking participants to find fewer symbols each session. This study could have also used fewer VSDs on the main page.

Conclusion

The typically developing 2-year-old participants in this study had great difficulty learning to navigate the SGD. Participants located the correct scene for the vocabulary item significantly more accurately and more quickly if the symbol was in an embedded VSD versus a non-embedded VSD. Participants’ performance was not affected by adult ratings of vocabulary or their performance on baseline probe tasks. Although this study had limitations and future research is needed, the results from this study are encouraging and suggest that children can learn to navigate VSDs and that some gains can be provided by using embedded, as opposed to non-embedded, VSDs for young children requiring SGDs.

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Table 1

MacArthur Communication Development Inventories (MCDI) Percentage for Symbols in Experiment, MCDI Mean Percentage for VSDs in Experiment, Mean Adult Survey Rating (5 point rating scale, 1=very unlikely, 5 = very likely) for Symbols in Experiment, and Mean Adult Survey Rating for VSDs in Experiment

Vocabulary Item	MCDI Percentage	Average Adult Rating
Bedroom (Embedded)		
Bed	77.6	3.83
Bug	73.8	1.67
Light	74.8	3.50
Pants	70.1	4.25
Shoe	90.7	4.00
Sock	82.2	3.92
	Mean = 78.2	Mean = 3.53
Foyer (Embedded)		
Door	76.6	4.25
Hat	77.6	3.08
Keys	83.2	4.00
Pizza	68.2	2.08
Telephone	70.1	3.08
TV	74.8	2.58
	Mean = 75.1	Mean = 3.18
Living Room (Embedded)		
Baby	90.7	4.50
Bottle	81.3	4.17
Diapers	79.4	3.67
Foot	78.5	3.25
Kitty	86.0	3.33
Mommy	99.1	4.42
	Mean = 85.8	Mean = 3.89
Bathroom (Non-embedded)		
Bathtub	63.6	4.67
Duck	87.9	3.09
Potty	76.6	4.83
Soap	73.8	4.42
Toothbrush	72.0	4.25
Water	81.3	4.67
	Mean = 75.9	Mean = 4.32
Kitchen (Non-embedded)		
Apple	84.1	4.67
Banana	75.7	4.67
Cheese	84.1	4.58
Crackers	77.6	4.75
Milk	81.3	4.83
Spoon	76.6	3.92
	Mean = 79.9	Mean = 4.57

Playroom (Non-embedded)		
Blocks	64.5	4.00
Crayons	66.4	4.25
Elephant	61.7	3.17
Frog	63.6	3.17
Monkey	68.2	3.17
Paper	65.4	4.17
	Mean = 65.0	Mean = 3.66

Table 2

Mean Accuracy and Mean Latency Data for Individual Participants and Combined Performance of Participants on Embedded and Non-embedded Scene Selection During 10 Experimental Sessions

	Mean Accuracy for Embedded	Mean Accuracy for Non-embedded	Mean Latency for Embedded	Mean Latency for Non-embedded
Participant 1	13.0%	11.7%	3.206 seconds	3.727 seconds
Participant 2	27.0%	11.1%	2.909 seconds	3.120 seconds
Participant 3	23.5%	19.7%	2.878 seconds	3.152 seconds
Total	21.0%	14.1%	2.962 seconds	3.311 seconds

Table 3

Mean Accuracy of First 12 and Last 12 Choices During Each of 10 Experimental Sessions for the Learners' Correct Scene Selection for Both Conditions, Embedded Conditions, and Non-embedded Conditions

	Total Accuracy on First 12 Items	Total Accuracy on Last 12 Items	Percent Difference from First 12 Items to Last 12 Items
Participant 1	9.1% Embedded: 9.5% Non-embedded: 8.8%	11.9% Embedded: 16.3% Non-embedded: 7.3%	+2.8% Embedded: +6.8% Non-embedded: -1.5%
Participant 2	28.3% Embedded: 35.5% Non-embedded: 20.7%	6.0% Embedded: 11.6% Non-embedded: 0%	-22.3% Embedded: -23.9% Non-embedded: -20.7%
Participant 3	28.6% Embedded: 32.2% Non-embedded: 25.0%	19.1% Embedded: 22.9% Non-embedded: 13.9%	-9.5% Embedded: -9.3% Non-embedded: -11.1%

Table 4

Mean Accuracy for Each of Three Participants' Scene Selection During the Final Two Experimental Sessions Compared to Mean Accuracy of Scene Selection During Maintenance Session

	Mean Accuracy During the Last Two Experimental Sessions	Mean Accuracy During Maintenance Session
Participant 1	23.7%	47.2%
Participant 2	27.8%	58.3%
Participant 3	10.3%	55.6%

Figure 1. Example of Embedded Scene Used in Experiment

Figure 1. Embedded bedroom scene used in this experiment. This picture appeared on the main page (superordinate) and also as a vocabulary page (subordinate). Symbols displayed in this scene include bed, bug, light, pants, shoes, and socks.

Figure 2. Example of Non-embedded Scene Used in Experiment

Figure 2. Non-embedded bathroom scene used in this experiment. The picture on the left appeared on the main page (superordinate) and set the context for the subordinate page. The picture on the right was the vocabulary page (subordinate) that was displayed after the bathroom page was selected on the main page. Symbols displayed in the bathroom scene on the right include bathtub, duck, potty, soap, toothbrush, and water.

Figure 3. Accuracy in Making a Correct Selection in Ten Embedded and Ten Non-embedded Experimental Sessions and a Single Maintenance Session (6.5 weeks after session 10) for Participant 1

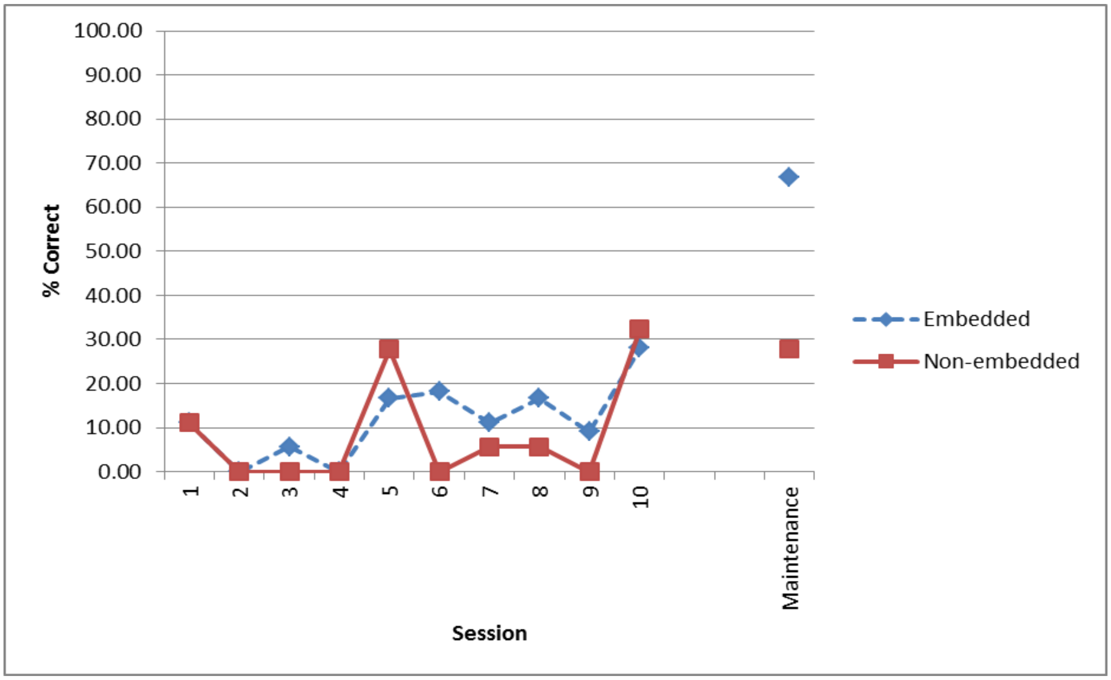

Figure 3. Accuracy of selection for each type of VSD (embedded and non-embedded) from the main page for all experimental sessions and the maintenance session. Participant 1 was more accurate with embedded VSDs during 5 out of 10 experimental sessions.

Figure 4. Latency in Making a Correct Selection in Ten Embedded and Ten Non-embedded Experimental Sessions and a Single Maintenance Session (6.5 weeks after session 10) for Participant 1

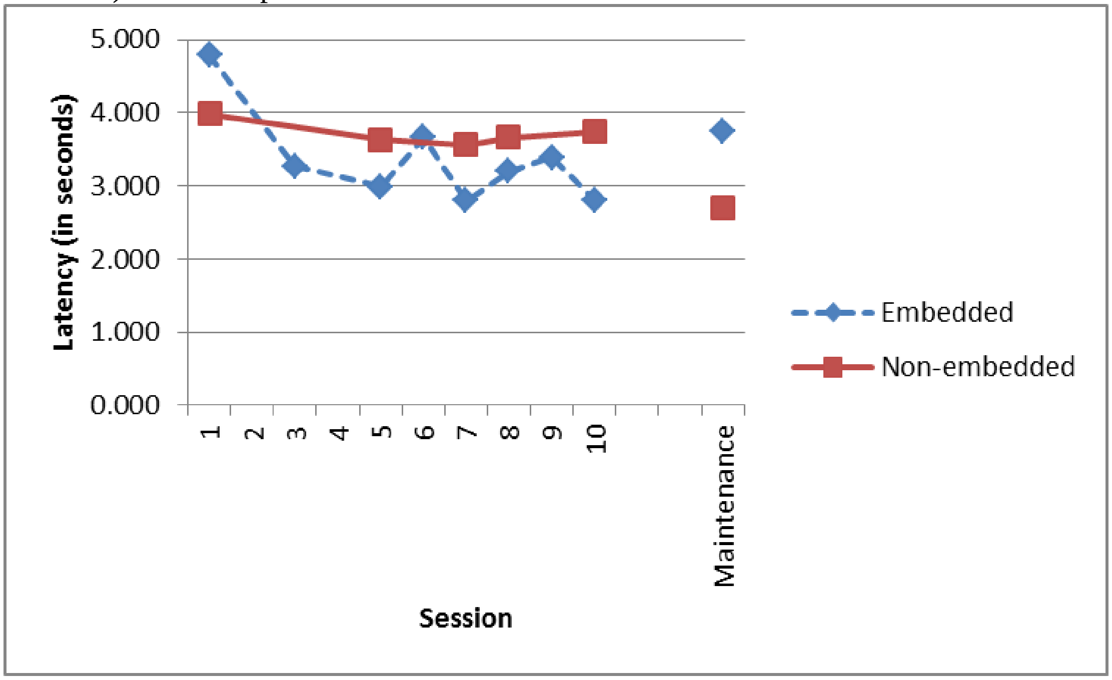

Figure 4. Latency of all correct responses for each type of VSD (embedded and non-embedded) from the main page for all experimental sessions and the maintenance session. Participant 1 chose the embedded VSD faster than the non-embedded VSD during four of the five experimental sessions.

Figure 5. Accuracy in Making a Correct Selection in Ten Embedded and Ten Non-embedded Experimental Sessions and a Single Maintenance Session (6.5 weeks after session 10) for Participant 2

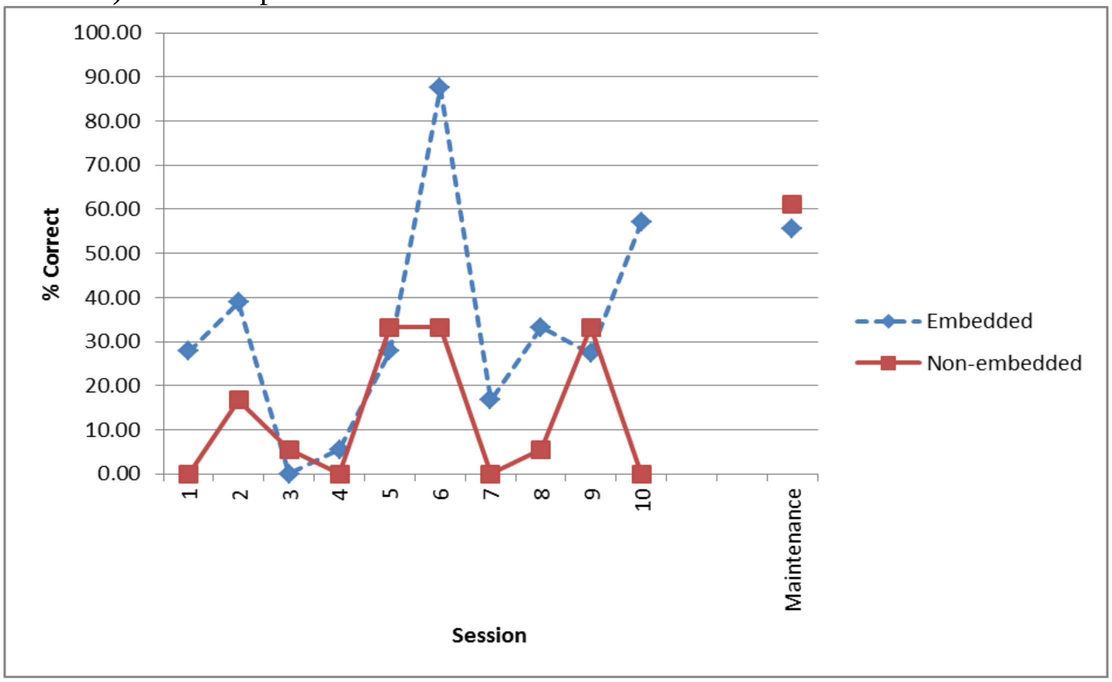

Figure 5. Accuracy of selection for each type of VSD (embedded and non-embedded) from the main page for all experimental sessions and the maintenance session. Participant 2 chose the embedded VSD more accurately than the non-embedded VSD on 7 out of 10 experimental sessions.

Figure 6. Latency in Making a Correct Selection in Ten Embedded and Ten Non-embedded Experimental Sessions and a Single Maintenance Session (6.5 weeks after session 10) for Participant 2

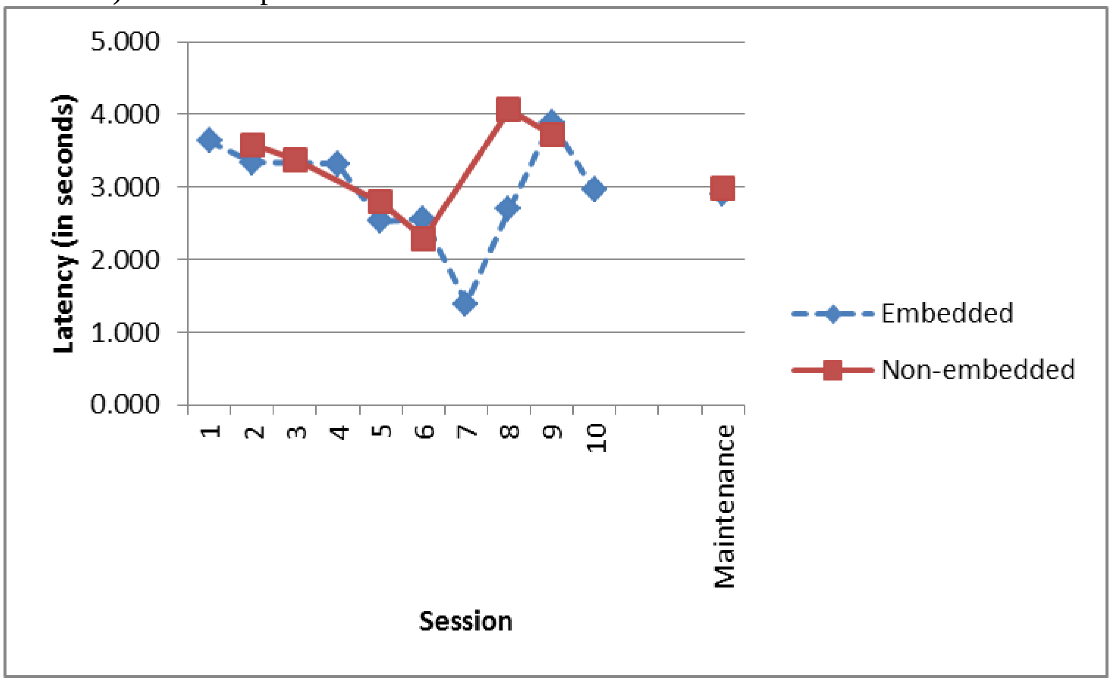

Figure 6. Latency of all correct responses for each type of VSD (embedded and non-embedded) from the main page for all experimental sessions and the maintenance session. Participant 2 chose embedded VSDs faster than non-embedded VSDs during three out of five experimental sessions.

Figure 7. Accuracy in Making a Correct Selection in Ten Embedded and Ten Non-embedded Experimental Sessions and a Single Maintenance Session (6.5 weeks after session 10) for Participant 3

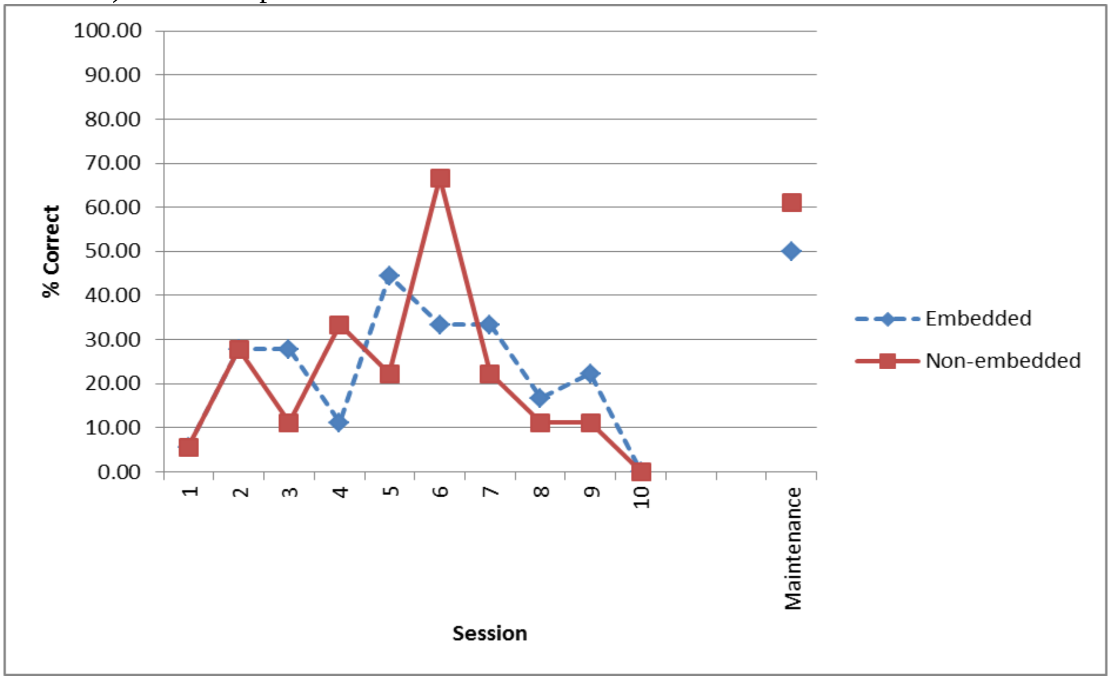

Figure 7. Accuracy of selection for each type of VSD (embedded and non-embedded) from the main page for all experimental sessions and the maintenance session. Participant 3 was more accurate with embedded VSDs during 5 out of 10 experimental sessions.

Figure 8. Latency in Making a Correct Selection in Ten Embedded and Ten Non-embedded Experimental Sessions and a Single Maintenance Session (6.5 weeks after session 10) for Participant 3

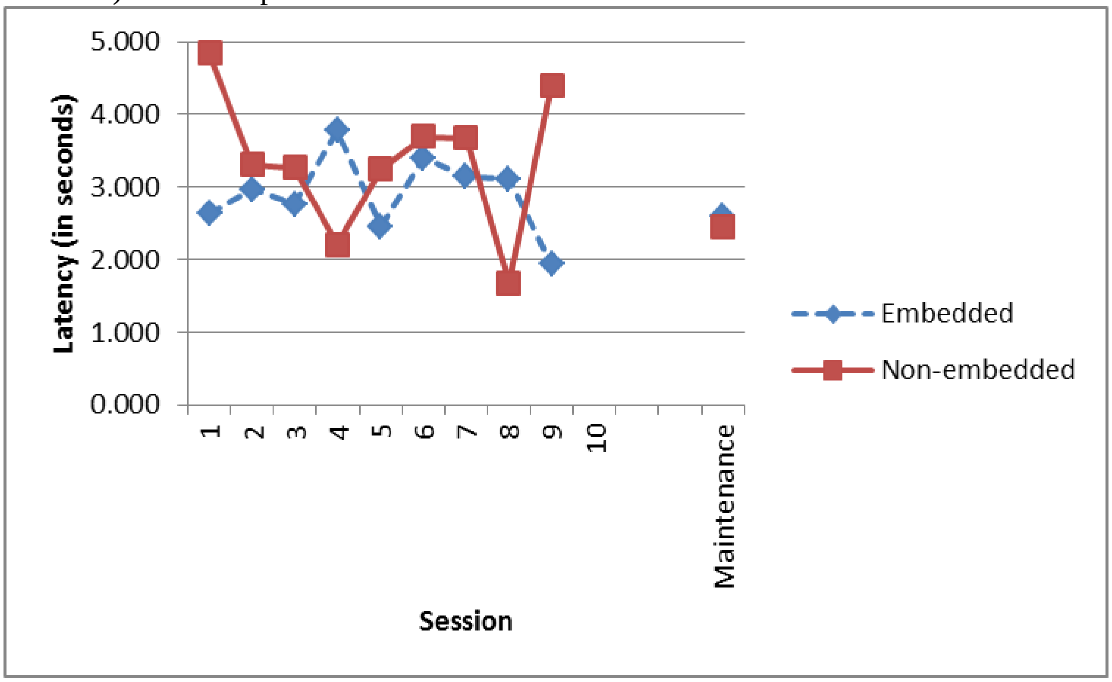

Figure 8. Latency of all correct responses for each type of VSD (embedded and non-embedded) from the main page for all experimental sessions and the maintenance session. Participant 3 chose the embedded VSD faster than the non-embedded VSD seven out of nine trials.