Memory Abilities of Typical Children and Adults Retrieving Picture Communication Symbols (PCSs): An Investigation of Object-Location Memory

An Honors Thesis (HONRS 499)

by

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ABSTRACT

Purpose: Many children who use visual-graphic displays for communication have difficulty identifying, locating, and sequencing symbols. Some of these difficulties could be attributed to developmental differences in binding features of objects, locations, and sequences. This study investigated developmental feature binding in children and adults using Picture Communication Symbols (PCSs) with grid displays.

Method: Nineteen typical children from the third-grade and nineteen typical adults from college were asked to recreate a 4 x 4 display using PCSs during a picture memory span task.

Results: Participants’ abilities to identify, locate, sequence, and bind these features were used for data analyses.

Conclusion: The results revealed that both third-grade and college-aged participants had significant difficulty recalling PCSs bound to their locations and sequences on a fixed grid display. Although college-aged participants were able to bind more PCSs, locations, and sequences compared to the third-grade participants, data suggests that this task is very challenging for both children and adults.

1 Picture Communication Symbols (BoardMaker) are manufactured by Mayer-Johnson, Inc., P.O. Box 1579, Solana Beach, CA 92075-7579; phone: 1-800-588-4548; URL: http://www.mayer-johnson.com.
AKNOWLEDGEMENTS

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INTRODUCTION

Many children with complex communication needs often rely on augmentative and alternative communication (AAC) to support their communication needs. Due to complications associated with disorders such as cerebral palsy and autism, these children must use visual-graphic symbols represented on aided communication systems to communicate. Many aided communication systems use Picture Communication Symbols (PCSs), simple colored line-drawings created by Mayer-Johnson, to illustrate the linguistic aspects of spoken language. While the process of communicating with PCSs may appear simplistic, it can become a complex and laborious process, riddled with difficulties and frustrations.

Children who use aided communication systems are required to identify, locate, and sequence symbols to communicate messages. When children struggle to do this, their rate of communication is much slower, resulting in frustrations that can cause children to abandon their communicative attempts. Therefore, it is important for AAC providers to better understand those variables that impact children’s abilities to successfully use visual-graphic displays for communication. Researchers have explained why aided communication is more difficult for children than adults, and furthermore, why neither group communicates as effectively as oral speakers.

While much of the AAC literature has addressed variables related to aided communication systems, children’s visuospatial and temporal memory abilities have not been examined. Difficulties identifying, locating, and sequencing visual-graphic symbols may be attributed to developmental differences in visuospatial memory and not just factors related to the physical display. In order to expand our current knowledge base of visuospatial and temporal abilities, developmental data will be obtained by examining children and adults’ abilities to recall
objects, locations, and sequences as well as integrate these features together. Additionally, this study will address a much-needed area of inquiry by examining variables related to AAC physical displays and human development.

Although there is still much to be learned regarding visuospatial and temporal memory in AAC, numerous researchers have investigated children’s abilities to use current aided communication systems. Drager, Light, and colleagues examined the performance of two-to-five-year-old children when locating symbols on dynamic displays. Results of their studies revealed that children had significant difficulty locating symbols regardless of the language organization presented (schematic grid, taxonomic grid, iconic encoding, and integrated scenes) (Drager, et al., 2004; Drager, et al., 2003; Drager & Light, 2010; Light et al., 2004).

Because children have difficulty locating symbols, researchers have used color cuing with visual-graphic symbols to ease the search process. According to Thistle and Wilkerson (2009), preschoolers were more accurate locating symbols when they were unique colors, and when similarly colored items were grouped together within a grid display (Wilkinson, Carlin, & Jagaroo, 2006; Wilkinson, Carlin, & Thistle, 2008). We will now present a review of literature pertinent to human development and visuospatial and temporal memory.

Using visual-graphic symbols to represent language requires children to first remember an object’s identity using target memory. *Target memory* taps into an object’s identity by recalling a particular object. Once a user remembers an object’s identity, contextual memory can assist in location and sequence of objects. All three features (object, location, and sequence) must be integrated to effectively communicate using aided communication systems. This process of combining objects, locations, and their sequential order together is known as *binding* (Lorsbach & Reimer, 2005). When binding is examined in regards to aided communication
systems, it entails the combination of both visual-spatial and temporal memory together. Binding has been examined in cognitive science to gain insight into children’s visuospatial memory.

Spatial and temporal information are not automatically processed and remembered together (Postma, Van Asselen, Keuper, Wester, & Kessels, 2006; van Asselen, Van der Lubbe, & Postma, 2006). This means that AAC users have to redirect their attentional capacities in order to remember and access the correct locations and sequences of PCSs for communication (Lorsbach & Reimer, 2005; Postma et al., 2006; Wilkinson & Hennig, 2009).

In order to understand the challenges children face when identifying, locating, sequencing, and binding PCSs, each ability must be isolated separately to determine where the developmental breakdown occurs. Previous researchers have indicated that younger children have consistently performed more poorly on binding tasks when compared to older children and adults (Postma et al., 2006; Schumann-Hengsteler, 1996). Schumann-Hengsteler (1996) evaluated the performance of five-to-ten-year-old children and adults during the children’s memory game “Concentration.” Her results showed that children were more likely to remember single features (i.e. object or location), while adults were able to more successfully retrieve the correct objects and locations in combination. The task of remembering the object bound to its location proved to overwhelm children’s visual-graphic and temporal memory capabilities.

Another critical aspect of memory to consider is that of working memory. Working memory is defined as “a brain system that provides temporary storage and manipulation of the information necessary for complex cognitive tasks” (Baddeley, 1992, p. 556). For children using aided communication systems, they must temporarily store their partner’s messages while formulating their response. This ability is especially necessary when communicating with
visual-graphic symbols, as AAC users must store not only their message, but also the process of identifying, locating, and sequencing the PCSs required to construct a message.

In this study, target, contextual, and binding of target and contextual features were assess through object recall (target memory), location recall (contextual memory), object and location recall (target + contextual memory), object and sequence recall (target + contextual memory), and location and sequence recall (contextual + contextual memory). Each feature binding area was examined in the performance of third-grade children and college-aged adults during a visual search task in order to examine their memory abilities, and whether developmental differences in performance exist. These age groups were chosen based on prior cognitive science studies that have shown differences in binding abilities (Kessels, Hobbel, & Postma, 2007; Lorsbach & Reimer, 2005; Postma et al., 2006; Schumann-Hengsteler, 1996; Wagner, Shaffer, & Swim, 2012). Based on the developmental memory differences displayed in the aforementioned studies, it is hypothesized that the college-aged adults will have greater success when sequentially retrieving visual-graphic symbols, and demonstrate more advanced developmental abilities to bind object, location, and sequential information.

The following research questions were addressed:

1. What are the developmental profiles of third-grade children and college-aged adults when retrieving objects, locations, sequences, and the binding of these features together?

2. What are the picture spans (highest number of objects recalled correctly in addition to their corresponding locations and sequences) of third-grade children and college-aged adults?
METHODOLOGY

Participants

Third-grade children were drawn from a public school located in northeast central Indiana. The pool of participants included 12 males and 7 females, for a total of 19 participants after 1 student moved to a different school. The chronological ages for the third-grade students ranged from eight years and four months to ten years and nine months (mean age = 8;8, SD = 0;6).

College-aged adults were drawn from multiple different majors at Ball State University. This helped eliminate concerns regarding previous exposure to PCSs. The pool of participants included 4 males and 15 females, for a total of 19 participants. The chronological ages for the college participants ranged from 19 years and 11 months to 23 years and 3 months (mean age = 21;6, SD = 0;10).

Inclusionary criteria for both groups of participants included no prior experience with AAC technologies; no identified speech, cognitive, or physical disabilities; and parental consent and/or participant assent to participate. All participants were within normal limits in vision and auditory acuity (or vision corrected to within normal limits) as reported by teachers.

In order to qualify for participation in the experiment, each participant had to score within +/- 1 standard deviation on receptive vocabulary and nonverbal intelligence. Form A of the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4) (Dunn & Dunn, 2007) and Form B of the Test of Nonverbal Intelligence-Fourth Edition (TONI-4) (Brown, Sherbenou & Johnsen, 2010) were used following standard administration practices. These standard scores reflect normal one-word receptive vocabulary and cognitive abilities. After the initial criteria, 20 out of 26 third-grade students (PPVT-4 mean total score = 99.84, SD = 5.96; TONI-4 mean total score
= 103.16, SD = 7.09) and 20 out of 27 college-aged adults (PPVT-4 mean total score = 104.37, SD = 7.13; TONI-4 mean total score = 101.00, SD = 9.20) qualified to participate in the visual search task experiment.

Materials

Picture Communication Symbols (PCSs)

This is a symbol set designed for children to express their communication needs. PCSs used in this experiment depicted common single-noun words (i.e. “doll, flag, kite”) and were shown on a white background. In total, 296 different PCSs were presented throughout the course of the experiment. This was comprised of 184 stimulus PCSs and 112 distracter PCSs. The size of each PCS was 2.85 cm in width and 1.90 cm in height.

Stimulus and Response Boards

Stimulus and response boards were created, consisting of four vertical columns containing four boxes and four horizontal rows containing four boxes (also known as 4 X 4 fixed communication display). The size of each cell was 4.76 cm in width and 3.17 cm in height. The stimulus and response boards were created with Macromedia Director 2004 MX\(^2\) and Photoshop 7\(^3\). Two stimulus and response boards were created for the practice trials. Twenty-six stimulus and response boards were created for the experimental task. PCSs appeared on the stimulus board one at a time, ranging from one to thirteen PCSs within a given trial. Trials 1 and 2 consisted of 1 stimulus PCS and 4 distracter PCSs each, and trials 3 and 4 consisted of 2 stimulus

\(^2\) Macromedia Director 2004 MX software was published by Macromedia, Inc. Address: 2548 Zanker Road, San Jose, CA 95131-9849. Phone: 1-800-470-7211. Web site: http://www.macromedia.com.

\(^3\) Adobe Photoshop 7 was published by Adobe Systems, Inc. Address: 345 Park Avenue, San Jose, CA 95110-2704. Phone: 408-536-6000. Web site: http://www.adobe.com.
PCSs and 4 distracter PCSs each, and so on. Once all PCSs were displayed, a screen appeared displaying a blank response board, the previously presented PCSs, and 4 distracter PCSs.

The PCSs at the bottom of the response boards were initially presented at a smaller size and separated from the response board by a black line. This design was implemented to maximize space availability for the PCSs on the response boards.

*Symbol Displays*

The stimulus and response boards were displayed on an Elo 1000 Series 1515L Touch Screen LCD Monitor, connected to a 15-inch Gateway laptop computer.

*Procedures*

All participants were seen individually, and testing was conducted in a quiet environment. Each participant met with the primary investigator for two sessions. During the first session, initial evaluation including Form A of the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4) (Dunn & Dunn, 2007) and Form B of the Test of Nonverbal Intelligence-Fourth Edition (TONI-4) (Brown, Sherbenou & Johnsen, 2010) was completed. Participants who scored within the normal range were asked to continue on to the experimental search task, which was completed during the second session.

Each participant was verbally presented with basic directions (Appendix C) and began by completing 2 practice trials using the 15-inch colored Elo Touchmonitor. The practice trials allowed for additional instruction when needed, as well as a modeled example of how to start over. In addition to the initial directions, participants were instructed to remove all PCSs from the response board and place them below the black line if a mistake was made. Participants were asked to use their index finger to select a PCS on the touch screen, and then drag it to the correct location and in the correct sequence as when the stimuli originally appeared. This
process was repeated until the participant felt that all correct PCSs had been placed on the
response board in the correct location and order. Lastly, the researcher used the Gateway
computer to control the transition from a completed response board to the following stimulus
board. Responses were automatically saved, and later scored individually.

The experimental search task was designed so that participants observed a
4 x 4 fixed grid stimulus board for 5 seconds per PCS, as PCSs appeared on the touch screen one
at a time. Participants were then asked to recreate the stimulus board on a response board,
placing each PCSs in the exact cell it was previously shown in, and in the same sequential order.
When selecting PCSs to place on the response board, participants were presented with all of the
PCSs previously shown on the stimulus board, in addition to 4 distracter PCSs. Participants
completed between 20 and 26 experimental trials using the touch screen monitor, depending on
their level of accuracy. To assess whether and how developmental differences exist between
third-grade children and college-aged adult's abilities to sequentially retrieve PCSs, an
increasing number of PCSs of varied arrays were presented after two trials of the same number
of PCSs. For example, all participants began with two trials with one PCSs presented, followed
by two trials with two PCSs presented. This progression continued until two trials with 10 PCSs
each were presented.

Each participant’s picture span was determined as the highest trial level at which one of
the two trials was completely correct (i.e. all objects, locations, and sequences were accurate). If
a participant had not reached his or her picture span at the 10 PCSs presentation level, stimulus
boards were presented until a picture span was determined, or the computer program ended. The
software allowed for 2 practice trials and 26 stimulus and response trials, amounting to a
maximum of 13 PCSs presented in a given stimulus board. One college student was not included in the data, as a picture span was still not determined at the 13 PCSs stimulus level.

RESULTS AND DISCUSSION

Data were analyzed based on means and standard deviations obtained from the two trials past a participants’ picture span, determined as the level at which participants’ abilities to identify, locate, sequence, and bind PCSs failed. Looking at abilities on the trials past the picture span allows for the analysis of when and where visuospatial and temporal memory abilities broke down. The following results and corresponding figures illustrate descriptive statistics pertaining to the participants’ development. For third-grade participants, the results revealed that performances were significantly better for target than contextual memory, successfully recalling more objects than their locations. While the participants were over 75% accurate in both trials when using target memory to recall objects, they were less than 10% accurate when binding those objects to their place in sequence. This same low level of performance was also evident in binding correct locations to sequence. Figure 1 provides descriptive statistics for features correctly recalled for third-graders, for both trial 1 and trial 2.
For college-aged participants, results revealed that their performance was also significantly better for target and contextual memory, as well as combined target and contextual memory for binding objects to their locations. However, combined target and contextual memory is also used when binding objects and sequence, yet objects and sequence were bound together correctly less than 30% of the time. Figure 2 provides descriptive statistics for features correctly recalled for college-aged adults for both trial 1 and trial 2.
When comparing the performance of third-graders to that of college-aged adults, results show that while college-aged participants showed a greater ability to bind objects and sequences, sequencing is significantly challenging for both age groups. Both groups performed comparably when recalling objects and locations separately, although college-aged adults recalled locations with a slightly higher level of accuracy. Figure 3 provides descriptive statistics for features correctly recalled for both third-grade children and college-aged adults, for both trial 1 and trial 2.
For both third-grade and college-aged participants, picture spans were calculated to determine the highest level at which objects and their corresponding locations and sequences were recalled. As hypothesized, college-aged participants were able to remember more, with a mean picture span of 6.53, and a standard deviation of 2.52. Third-grade participants had a mean picture span of 3.68 with a standard deviation of 1.70.
These developmental trends suggest that visuospatial memory abilities develop over time, beginning with target memory, then contextual memory, with the ability to bind them developing last. While the data suggests that developmental differences exist between children and adults when recalling two features, it also shows that even when development is complete, binding objects and locations to sequences is still a formidable challenge. Data suggests that spatial and temporal order information are not automatically encoded in memory, nor does the automatic integration of target and contextual information occur readily for young children. Though implications are currently limited, this data confirms that identifying, locating, and sequencing taxes visuospatial and temporal memory abilities.

Data from this study suggests that the ability to bind objects to locations and sequences is challenging even for typically developing children and adults. AAC practitioners should be mindful of the demands binding places on children with complex communication needs, and set reasonable expectations when introducing communication with visual-graphic displays. Initially, practitioners should provide a limited number of PCSs, to facilitate a child’s early understanding of binding. Further studies using cognitive science paradigms can investigate the demands children encounter when using visual-graphic displays to communicate, and better inform AAC practitioners’ strategies.
References


APPENDIX A

Stimulus Board

[Images of various objects arranged in a grid]
APPENDIX B

Response Board

Click Mouse Button to Select/Move Picture; Press Enter or Return to Advance to Next Screen
APPENDIX C

Instructions Provided to Participants

Today we’re going to play a computer game where we look at pictures. First, you will see the pictures on screen, then they will disappear. After the pictures go away, you have to remember the pictures, the boxes the pictures went in, and the order you saw them come on to the screen. You will move the pictures with the tip of your pointer finger. Let’s practice!

Start program

See how the picture gets big when you move it with your pointer finger? We want the picture to be big when we put it in the box. The pictures will only move when they are big. Make sure each picture is big before you go on to the next picture.

Demonstrate task

If the child is correct with the two-picture practice sequence:

Great job! You remembered the pictures, the boxes they went in, and the order they came on the screen.

If the child is incorrect with the two-picture practice sequence:

You did a great job keeping the pictures big, but let’s try one more time. It’s important that you remember the pictures, the boxes they went in, and the order they came on the screen.

For all children:

If you ever change your mind, you need to put all the pictures back below the black line and start again, like this.

Demonstrate task
Now we are going to start our game! Try to remember all the pictures, the boxes they went in, and the order they came on the screen.

*After every 4th response, the clinician says, “I like the way you're working.”*
APPENDIX D

IRB Documentation

Institutional Review Board

DATE: October 10, 2011
TO: Olivia Swim
FROM: Ball State University IRB
RE: IRB protocol # 272655-1
TITLE: Memory Abilities of Typical Children and Adults Retrieving Picture Communication Symbols (PCSs): An Investigation of Object-Location Memory
SUBMISSION TYPE: New Project
ACTION: APPROVED
DECISION DATE: October 10, 2011
EXPIRATION DATE: October 9, 2012
REVIEW TYPE: Expedited Review

The Institutional Review Board has approved your New Project for the above protocol, effective October 10, 2011 through October 9, 2012. All research under this protocol must be conducted in accordance with the approved submission.

Editorial Notes:

1. Approve

As a reminder, it is the responsibility of the P.I. and/or faculty sponsor to inform the IRB in a timely manner:

- when the project is completed,
- if the project is to be continued beyond the approved end date,
- if the project is to be modified,
- if the project encounters problems, or
- if the project is discontinued.

Any of the above notifications should be addressed in writing and submitted electronically to the IRB (http://www.bsu.edu/irb). Please reference the IRB protocol number given above in any communication to the IRB regarding this project. Be sure to allow sufficient time for review and approval of requests for modification or continuation. If you have questions, please contact Jennifer Weaver Cotton at 765-285-5034 or jmweavercott@gmail.com.