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Evaluation of a Prototype Application for Supporting Visual-Graphic Symbol Acquisition in Preschool Aged Children with Complex Communication Needs

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Keywords: Augmentative and alternative communication (AAC), Symbol acquisition, Vocabulary, Graphic symbols, App

ABBREVIATIONS

AAC: Augmentative and Alternative Communication
CCN: Complex Communication Needs
PCS: Picture Communication Symbols

ABSTRACT

Young children with complex communication needs can increase their ability to communicate efficiently and effectively through augmentative and alternative communication (AAC) but may experience barriers in acquiring a robust symbol vocabulary which includes learning the relationship between different symbols and their referents. An engaging app that utilizes evidence-based instructional strategies may serve as an efficient and effective tool for supporting vocabulary development and visual-graphic symbol knowledge. The purpose of this study was to design and develop an app to support visual-graphic symbol acquisition. Following development, an initial evaluation of the app was conducted with three young children with complex communication needs. This preliminary study utilized a within-subject; multiple-baseline probe design replicated across participants to examine the effectiveness of the app in teaching visual-graphic symbol acquisition for three target words. Results suggest that the app was an effective and socially valid way to increase visual-graphic symbol acquisition.

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INTRODUCTION

Individuals who have difficulty effectively and efficiently producing or understanding verbal communication are considered to have complex communication needs (CCN). Research has clearly established that individuals with CCN can increase their communicative abilities, oftentimes through the use of augmentative and alternative communication (AAC) [1]. AAC includes all forms of communication (other than oral speech) that are used to express thoughts, needs, wants, and ideas [2] and can include facial expressions, gestures, and selecting picture symbols on non-electronic communication boards and speech generating electronic devices.

Although it is well established that a wide variety of individuals with CCN can increase their ability to communicate efficiently and effectively through AAC, many individuals with CCN experience barriers in their development of communication skills [3-5]. Among these barriers, particularly for individuals with developmental and language delays, are acquiring a robust symbol vocabulary by learning the relationship between different symbols and their referents [6]. A range of empirically validated instructional strategies have been identified for supporting symbol acquisition, including direct instruction [7-10]. However, these strategies rely on communication partners to create opportunities and implement the instructional strategies, and professionals have noted that lack of time and inadequate training create significant challenges [11]. An engaging application (app) may provide an efficient and effective tool for supporting visual-graphic symbol acquisition, particularly if the app is designed based on empirically supported instructional strategies.

Objectives

The purpose of this study was to develop and examine the effectiveness and social validity of a prototype app to support visual-graphic symbol acquisition for preschool aged children with complex communication needs. Information gleaned from this study will be used to improve the app design and develop a more comprehensive app for supporting visual-graphic symbol acquisition.

Justification of Need

A plethora of apps are available that are designed to support individuals with CCN to communicate using a symbol-based communication system (e.g., Proloquo, TouchChat, CoughDrop, etc.), but these apps are designed for communication and not for teaching visual-graphic symbol acquisition. Further, several apps are available that are designed to support vocabulary development (e.g., ABCmouse, Duck Duck Moose, etc.), but these apps are not designed to support learning of the graphic symbols that are used on AAC systems. Although there are no available apps that are designed to support individuals with CCN in acquiring acquisition of the visual-graphic symbols that are used on AAC systems, Sevcik et al [6] did document the effectiveness of computer support for teaching visual-graphic symbol acquisition. However, the software program used by Sevcik et al [6] was specifically designed for the study, is not available to the public, and provided participants with only an observational experience as opposed to providing a systematic instructional strategy that included direct instruction.

MATERIAL AND METHODS

App Development

The prototype app was developed from December 2019 to April 2020 based on an adaptation of the app development model used by White et al [12] with the goal of supporting visual-graphic symbol acquisition for children with CCN. The app was developed through the collaborative efforts of a multidisciplinary team with expertise in AAC, speech language pathology, special education, assistive technology, and therapeutic app design.

The AAC app was developed iteratively using the Unity game development platform by graduate engineering students and staff at the University of Utah's Therapeutic Games and Apps Lab. Development was carried out in accordance with best practices within the app development space, as well as institutional and federal guidelines around HIPAA compliance. All developers were trained in HIPAA compliance and data privacy prior to working on the app. The app used internal device storage to securely store play metrics during a single learning session, after which data was transmitted via secure and encrypted email to the lead investigator for analysis.

The model for the development of the app included four phases. The first phase focused on intervention mapping and included a review of the literature to identify instructional strategies for teaching visual graphic symbol acquisition

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that could be embedded into the elements of the app. The second phase focused on app design and development and included the initial concept design, research team feedback, and consultation with constituent groups.

The third phase focused on the development of the app prototype and included the incorporation of visual design elements and audio recordings. In the fourth phase, prototype app testing was conducted, and iterative revisions were made based upon feedback provided by the research team and constituent groups.

The prototype app developed in accordance with the outlined four-phase methodology aimed to instruct young children with CCN in the visual-graphic symbol acquisition of three target words (PUT, SOME, and ALL). These three words were selected based on their inclusion in the initial 40 core words delineated by the Dynamic Learning Maps Core Vocabulary [13] and their listing among the top 50 words used by nondisabled peers in integrated preschool classrooms [14]. Further, choosing core words extends the current literature demonstrating that children with CCN can learn new symbol-referent relationships with nouns via a computer-based experience [6].

Based upon the literature review to identify instructional strategies for teaching core vocabulary conducted in Phase 1, the instructional design of the application used empirically supported direct instruction strategies [7-10]. Specifically, a visual display featuring elements such as a bee and a tube of lipstick was presented and was accompanied by four Picture Communication Symbols ® (PCS) representing the target core vocabulary words (PUT, SOME, ALL), and one additional core vocabulary word (THAT). The order of presentation of the symbols on the visual display was randomized to mitigate position bias. Subsequently, an auditory instructional cue (e.g., "Put lipstick on the bee") was provided by the app. The visual display and auditory instructional cues varied and were randomized across instructional opportunities (e.g., "Put the cowboy hat on the wombat", "Put the pencil on the desk", "Put the blanket on the fox") to support learning of the target word as opposed to memorizing the visual display or auditory instructional cue. Initially, to support errorless learning, the correct symbol was immediately backlit to provide a visual prompt (see **Figure 1**). A constant time delay method was employed to gradually fade this visual prompt, wherein after three consecutive opportunities of 80% or higher correct responding, no prompt was provided for five seconds, allowing the participant to respond independently. The app also incorporated immediate, contingent feedback to reinforce learning through dynamic on-screen auditory and visual changes for correct responses (e.g., large red lips appeared on the bee paired with a kissing sound; See **Figure 2**). In cases of an incorrect response, the app responded with the auditory message of "No, that's _____" and immediately presented a new opportunity with the target word, accompanied by the backlit correct symbol, ensuring continuous and adaptive learning experiences.

Figure 1: Screenshot of page in app that illustrates a prompted opportunity to respond to the instructional cue of "*Put the lipstick on the bee.*"

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Figure 2: Screenshot of page in app that illustrates the consequence provided contingent upon a correct response to the instructional cue of "*Put the lipstick on the bee.*"

Participants

Approval was obtained from the University of Utah institutional review board (IRB). Written informed consent was obtained from all parents/guardians of participants, who were fully informed about the purposes of the research and how their child's responses would be used and stored.

Three preschool-aged children (Elliot, Maddie, Bella) participated in this investigation. Maddie and Bella were twin sisters. Each participant had an Individualized Education Plan (IEP) with special education and related services provided in the preschool classroom and was identified by the special education classroom teacher as having complex communication needs. No participants had a history of using AAC. All participants attended half-day preschool programs and were enrolled in the same classroom. The vision and hearing for all participants was within normal limits. Observation of participants in their preschool environment revealed that all participants; used eight or fewer spontaneous different verbal utterances, chose desired items/activities by pointing, followed some 1-step directions, and led adults to desired items. Additional descriptive information for each participant is provided in **Table 1**.

Participant	Gender	CA[1]	Race	Batelle[2] Cognitive	Batelle[2] Communication
Elliott	Male	3 yr., 10 mo.	African American and White	1st Percentile	1st Percentile
Maddie	Female	3 yr., 11 mo.	African American	5th Percentile	1st Percentile
Bella	Female	3 yr., 11 mo.	African American	1st Percentile	1st Percentile

[1] CA= Chronological Age
[2] Batelle = Batelle Developmental Inventory 2 [15]

Table 1: Participant Descriptive Information

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Setting

All sessions occurred during free choice play activities in a public preschool classroom located in a metropolitan school district in Utah. During the free choice play period, children in the classroom were allowed to move freely among learning centers. The classroom enrolled four children who were three years old and had developmentally appropriate learning centers and activities. The children attended two mornings per week and the classroom was staffed with one special education teacher and three paraeducators. The special education teacher had a master's degree and license in special education with 10 years of teaching experience. The three paraeducators did not have licenses or degrees and had 8, 3, and 6 years of experience respectively. In addition to these four adults, an occupational therapist, physical therapist, and speech language pathologist provided in classroom, itinerant support.

Materials

During baseline, intervention, and maintenance conditions, the interventionist provided participants with an opportunity to interact with the app on a 10-inch Apple IpadR. During generalization probes, the interventionist provided participants with opportunities to point to symbols on 5 communication displays that were inserted into a 3-ring binder. Each display consisted of 9 colored line-drawn PCS symbols that were 2.25 inches tall X 3.25 inches wide presented in a grid format on 8 ½ X 11 white paper. The symbols on the communication displays included the target core words (put, some, all) as well as 6 additional core words (you, on, can, I, up, stop) that are included in the initial 40 core words delineated by the Dynamic Learning Maps Core Vocabulary [13]. The order of the presentation of the symbols across the displays was randomized to prevent position biased responding.

Interventionist

The first author, a university faculty member and speech language pathologist, provided the intervention for all children. The interventionist joined existing preschool classroom activities to implement the intervention, and invited the target children to play with the app.

Research Design

A within-subject, multiple-baseline probe design replicated across participants was used to assess the effects of the app on supporting visual-graphic symbol acquisition. In a within-subject multiple-baseline probe design, the investigator sequentially applies an intervention across several target skills. Experimental control is demonstrated when there is a change in level and trend of the dependent measure contingent on the staggered introduction of the independent variable. This design is well suited for situations in which reversal of behavior is unlikely and where maturation could be a potential confound [16]. Intermittent baseline probes were used to measure performance across target words prior to the introduction of intervention. Intervention probes were used to evaluate the impact of the intervention. Intermittent probes of post-intervention behavior served as a maintenance check to determine if experimental effects were durable over time. Generalization probes were conducted in baseline, intervention, and maintenance phases to determine if experimental effects generalized to other contexts.

Data Collection

Data to assess the effectiveness of the intervention strategy were automatically collected by the app during baseline, intervention, and maintenance sessions. Participant performance data reflect a consistent presentation of five opportunities per word per session.

Data to assess the acceptability and perceived effectiveness of the intervention strategy to preschool staff were collected through an investigator-developed social validity survey that contained 15 statements. The survey recorded staff opinions about the importance of statements related to (a) instructional strategies embedded into the functioning of the app, (b) the impact of the intervention strategy on the classroom environment (e.g., disruptiveness to classroom routines), and (c) whether it would be difficult to use the strategy while still meeting the needs of the other children in the classroom. All preschool staff in the participants' classrooms completed the survey anonymously during the final week of intervention.

Procedures

In each of the following phases of the study, data was collected in the context of free choice activities in the preschool classroom. The interventionist joined the free choice preschool activity and positioned herself at a child-size table with two chairs. If any participant did not choose to approach the interventionist within the first 15 minutes of free-choice time, the interventionist called the participant over and invited the participant to play on the app.

Baseline: During each baseline session, 5 opportunities (e.g., presentation of the visual display and auditory instructional cue) were provided for the target word and participant responses were automatically recorded by the app following each opportunity. No instruction or differential reinforcement of responses was provided.

Intervention: Intervention occurred in the same setting and during the same period of the day as baseline conditions. Five opportunities per session were provided for the target word and participant responses were automatically recorded following each opportunity. Each opportunity utilized the previously described instructional strategy. A symbol was operationally defined as acquired when a participant achieved an accuracy of 80% (4/5 unprompted opportunities) or higher across three consecutive sessions. Chance level accuracy for a single opportunity was .25. The probability of 80% accuracy in a session with five opportunities was .016.

Maintenance: Maintenance probes began approximately one week after the child met criterion for the target behavior. Intermittent maintenance probes were conducted in the context of the same activities that were used during the intervention sessions. During maintenance sessions, five opportunities were provided for the target word. Participant responses were not differentially reinforced during maintenance probe opportunities.

Generalization Probes: For each participant, generalization probes were conducted 3 times during each completed phase (baseline, intervention, and maintenance) for each target word. Generalization probes were conducted in the context of the same free-choice activity as was used during the intervention sessions, but the participants were asked to point to the target word when provided with paper copies of the symbol displays that were housed in a 3-ring binder. The researcher provided the first opportunity by presenting the first page in the notebook containing symbol displays and saying Show me *target word* (e.g., *ALL*). The interventionist turned the page after each opportunity. Participant responses were not differentially reinforced during generalization probe opportunities and no instruction was provided. Generalization of acquired skills to a low-tech symbol display was assessed because many individuals who use AAC will communicate using symbol displays. Exploring the generalization of acquired skills to symbol displays may provide important information regarding the extent to which skills learned on an app will transfer.

Procedural Fidelity: The preschool special education teacher in the classroom collected procedural fidelity data during at least 30% of experimental condition for each participant. The degree to which procedural manipulations were implemented as planned was calculated by dividing the number of interventionist behaviors exhibited by the number of planned interventionist behaviors and multiplying by 100. Procedural fidelity data included the measurement of the following planned interventionist behaviors: (a) interventionist joined a free choice activity and positioned herself at a child-size table with 2 chairs, (b) if a participant did not choose to approach the interventionist within the first 15 minutes of free-choice time, the interventionist called the participant over and invited the participant to play on the app, and (c) interventionist allowed participant to engage with the app without providing any direction or support. Fidelity data indicated that the interventionist correctly performed the planned behaviors on 100% of prescribed occasions.

Procedural fidelity data was also collected for generalization probes and included the measurement of the following planned interventionist behaviors: (a) interventionist joined a free choice activity and positioned herself at a child-size table with 2 chairs, (b) if a participant did not choose to approach the interventionist within the first 15 minutes of free-choice time, the interventionist called the participant over and invited the participant to play on the app, (c) the interventionist provided the first opportunity by presenting the first page in the notebook containing symbol displays and saying Show me target word (e.g., all), (d) the interventionist turned the page after each opportunity and said Show me target word (e.g., all), (e) the interventionist did not differentially reinforce correct responses and no instruction was provided. Fidelity data indicated that the interventionist correctly performed the planned behaviors on 100% of prescribed occasions.

Reliability: Reliability data for experimental conditions was not collected during baseline, intervention, and maintenance sessions since this data was automatically collected by the app. Reliability data was collected for generalization sessions. Specifically, the first author and an independent observer simultaneously collected data during at least 30% of all generalization sessions for each participant. Interobserver agreement was computed as the number of agreements for correct and incorrect responses divided by the number of agreements plus disagreements and multiplied by 100. Mean interobserver agreement across participants for dependent measures was 100% during baseline, 96% (range = 80%-100%) during intervention, and 98% (range – 80%-100%) during maintenance.

RESULTS

Child Outcomes

Figures 3-5 show the number of correct identifications of symbols representing PUT, SOME, and ALL during baseline, intervention, maintenance, and generalizations conditions for Elliot, Maddie, and Bella respectively. The end of the school year resulted in the need to cease implementation of the study and therefore some participants did not complete all study phases. Visual inspection of the baseline data reveals low and stable rates of correct responding ranging from 0% to 20% correct identification of target word for all participants. Visual inspection of the intervention data reveals a substantial increase in the level and slope of correct responses across all core words for two participants (Elliott and Maddie). Elliot met the pre-established criteria for acquisition for two target words before the end of the school year. Maddie met the pre-established criteria for acquisition for all three target words. Bella met the pre-established criteria for only one target word before the end of the school year. **Table 2** provides a summary of the total number of sessions and total number of minutes needed for each acquired target word for each participant.

During maintenance, Elliot demonstrated an accuracy of 80% correct responding for each of the two words that were acquired (ALL and PUT) prior to the end of the school year. Maddie demonstrated a mean accuracy of 93% correct responding for ALL, a mean accuracy of 100% correct responding for PUT, and a mean accuracy of 90% correct responding for SOME during maintenance. Bella demonstrated an accuracy of 60% correct responding during maintenance for the one word that she acquired prior to the end of the school year.

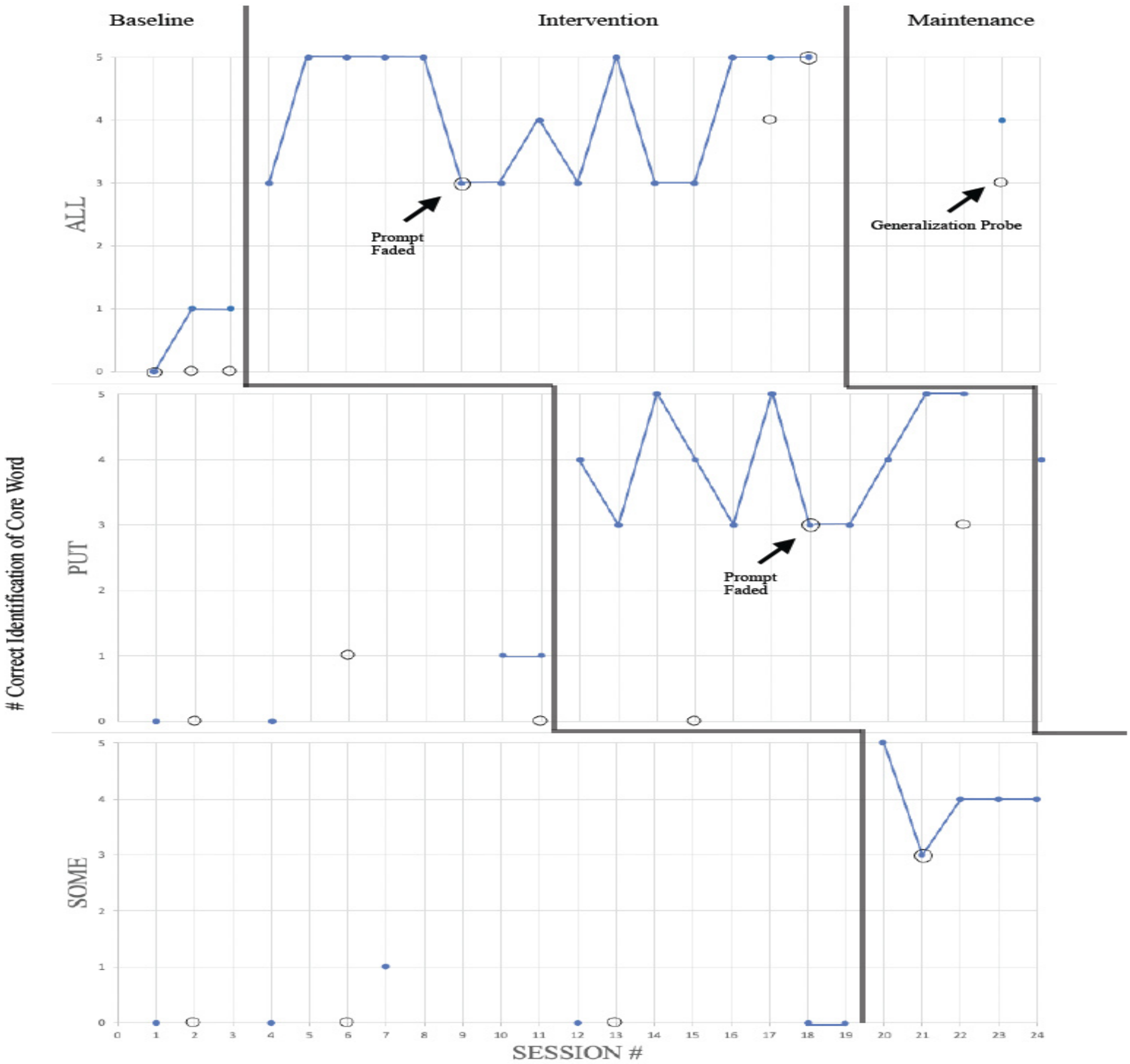

Figure 3: Number of Correct Identification of *ALL*, *PUT,* and *SOME f*or Elliot

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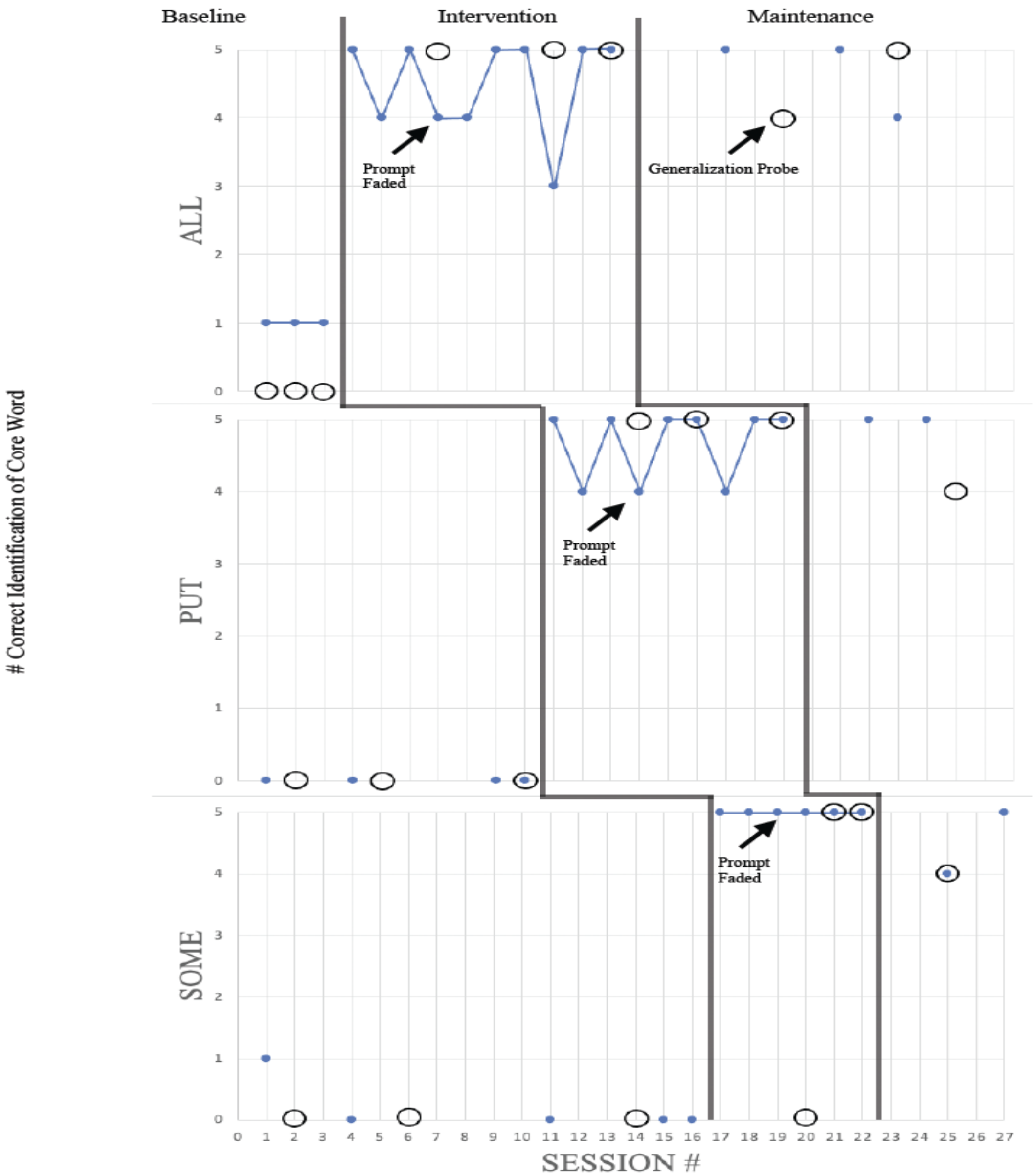

Figure 4: Number of Correct Identification of *ALL*, *PUT,* and *SOME* for Maddie

Generalization probes are also summarized in **Figures 3-5**. During baseline, all participants showed low and stable rates of correct responding (0%-20%) to generalization probes. Generalization probes during intervention revealed a substantial increase in the level and slope of correct responses across all words for Elliot and Maddie. Bella did not demonstrate generalization of target words during intervention. Elliot's performance on a generalization probe for ALL during maintenance dropped slightly (to 60%) while Maddie's performance on generalization probes remained high (80-100%) correct responding across all target words. During maintenance, Bella demonstrated an accuracy of 60% correct responding during a generalization probe for ALL.

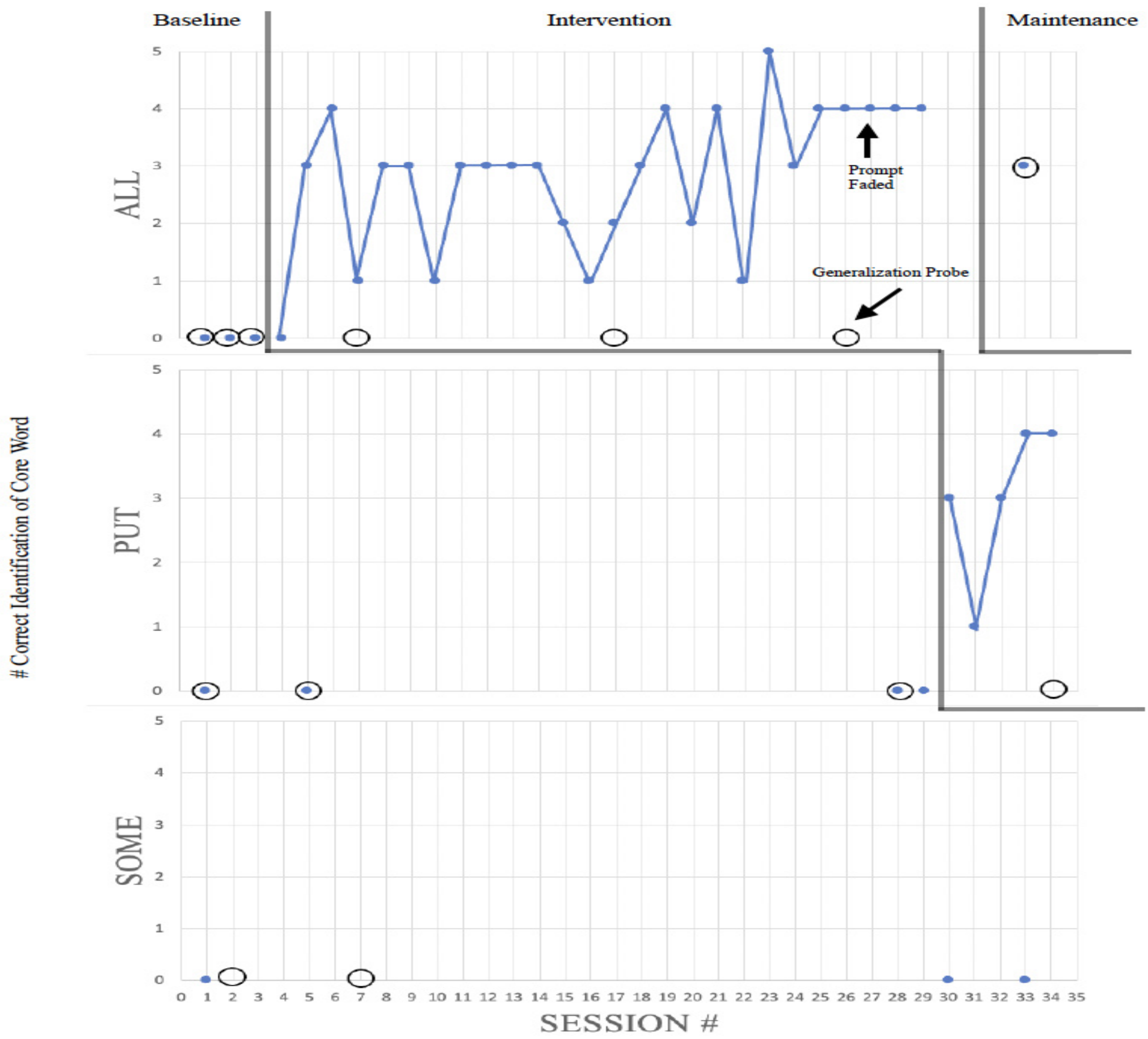

Figure 5: Number of Correct Identification of *ALL, PUT*, and *SOME* for Bella

Participant	Target Word	Total Number of Sessions to Acquisition	Total Number of Minutes[1] to Acquisition
Elliott	ALL PUT SOME	15 11 5	16 10 4
Maddie	ALL PUT SOME	10 9 6	10 9 6
Bella	ALL PUT SOME	26 NA NA	26 NA NA

[1]rounded to the nearest minute

Table 2: Summary of Number of Sessions and Time to Acquisition of Target Words

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Preschool Staff Social Validity

Four preschool staff members completed the social validity survey. All staff strongly agreed (e.g., 5 on a 5-point scale) with statements regarding the importance of teaching visual-graphic symbol acquisition to young children with CCN and the value in using the app to support learning. Further, all staff strongly agreed or agreed (e.g., 4 or greater on a 5-point scale) that (a) the instructional strategies embedded into the functioning of the app (e.g., prompting, feedback on accuracy of child response, time delay to fade prompts) were important and appropriate, (b) the content of the app was appropriate and seemed fun for students, and (c) the use of the app could be easily integrated into the planned activities of a preschool classroom without disruption of activities while still meeting the needs of other students in the classroom. Finally, all staff strongly agreed or agreed (e.g., 4 or greater on a 5-point scale) that they would feel confident using the app with students if given training and support.

CONCLUSION

Results of this investigation provide preliminary data suggesting that the app was successful in teaching visual-graphic symbols to preschool aged children with CCN. Visual-graphic symbol acquisition for two participants (Elliott and Maddie) was obtained quickly with the number of minutes engaged with the app ranging from only 4-16 minutes per word. Further, both Elliot and Maddie generalized their learning of symbol referent relationships to communication displays by pointing to specified symbols when asked. It is important to note that pointing to specific symbols when asked is different from using acquired symbols in functional communication contexts (e.g., in the context play, etc.). Therefore, future studies should examine the extent to which acquired skills generalize to functional use of an AAC system.

Although the third participant, Bella, did demonstrate visual-graphic symbol acquisition for one word before the end of the school year, it took a total of 27 minutes. This suggests that the app in its in current configuration may not be an efficient tool for all students. Future studies should examine if embedding other instructional strategies within the app will produce different results and increase the utility of the app. For example, future versions of the app could be modified by including an option to start with only one symbol choice for each opportunity and then gradually increase the number of symbol choices in the array to support learning.

The findings from this study also support the social validity of the app, with all staff indicating that the skill taught was important, the instructional strategies used in the app were important and appropriate, and that the content of the app was appropriate and seemed fun for students. With regarding to effectiveness of the app, one staff member included the following written response on the survey, "I enjoyed observing the students and the rate at which they were able to learn something new. I believe in this app and the potential for it as a valuable tool for teaching children."

There are limitations associated with this study that affect the extent to which the results might generalize to other individuals, settings, or intervention targets. For example, the study participants shared a number of common characteristics. Consequently, the effectiveness of the app may not be replicable with children that differ in substantive ways. Increased generalizability of the findings could be obtained through replications that extend the use of the app to additional words and with children who have different skills and abilities, including receptive language, cognitive skill, and physical disabilities.

While strong conclusions cannot be drawn from the limited data obtained from only three participants and three target words, results suggest that the use of an app that incorporates research validated instructional strategies can be an effective way to increase visual-graphic symbol acquisition for young persons with CCN and provide preliminary data to support further development of the app and investigation of the effectiveness of the app on a larger scale. Furthermore, the results suggest that preschool teachers view the app and the strategies embedded into the app as highly acceptable. Thus, the use of an app may offer educators an effective as well as a socially valid means of supporting the acquisition of visual-graphic symbols for young children with CCN.

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