

Preliminary Investigation of Context-Aware AAC with Automated Just-in-Time Cloze Phrase
Response Options for Social Participation from Children on the Autism Spectrum

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Abstract

Social participation for emerging symbolic communicators on the autism spectrum is often restricted. This is due in part to the time and effort required for both children and partners to use traditional augmentative and alternative communication (AAC) technologies during fast-paced social routines. Innovations in artificial intelligence provide the potential for context-aware AAC technology that can provide just-in-time (JIT) communication options based on linguistic input from partners to minimize the time and effort needed to use AAC technologies for social participation. This preliminary study used an alternating treatment design to compare the effects of a context-aware AAC prototype with automated cloze phrase response options to traditional AAC for supporting three young children who were emerging symbolic communicators on the autism spectrum in participating within a social routine. Visual analysis and effect size estimates suggest the context-aware AAC condition resulted in increases in linguistic participation, vocal approximations, and visual attention for all three children. While this study was only an initial exploration and results are preliminary, context-aware AAC technologies have the potential to enhance participation and communication outcomes for young emerging symbolic communicators on the autism spectrum and more research is needed.

Keywords: Augmentative and Alternative Communication; Autism; Preschool

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Young children learn early language and socialization skills when they are actively engaged within the context of developmentally appropriate and meaningful social interactions.[1] In contrast, language learning is severely limited in the absence of social interactions.[2] Joint attention (i.e., coordination of attention between a partner and a shared object or event in the environment) is one aspect of language learning that occurs within social routines and has a strong positive relationship to later language learning.[3-4] Social interactions support not only language outcomes, but also outcomes related to participation within everyday routines,[5] contributing to overall well-being and quality of life.[6]

Emerging symbolic communicators (i.e., individuals with less than a 50 word/symbol vocabulary, often referred to as beginning communicators) [7] are one group for whom it is particularly important to embed language learning opportunities within the context of meaningful social routines. This is precisely because early communication development centers around social aspects of language (e.g., intentional communication, use of a variety of communication functions).[7] Furthermore, emerging symbolic communicators' language use is often bound to the immediate communicative context, [8] and language learning opportunities are at their ripest in the immediate moment a new concept appears.[9] Additionally, phrases and words within social routines are often repeated, increasing opportunities for acquisition.[10]

Singing songs is one common example of a social routine with young emerging symbolic communicators that offers opportunities for frequency and regularity of words and phrases. Cloze phrases are often used within these social routines to support language learning and participation.[11] A cloze phrase is one in which the utterance is begun by the partner and

completed by the child. For example, the partner says, “Old McDonald had a ...” and the child participates by completing the phrase saying, “farm.”

Embedding participation and language learning opportunities within the context of social routines is particularly important for young emerging symbolic communicators on the autism spectrum who experience challenges with developing social communication and social interaction skills.[12] Joint attention is one early language skill that is delayed for children on the autism spectrum.[4,13] Due to decreased joint attention and other early social language skills, communication partners may fail to provide adequate opportunities for participation within social routines, [3] thus limiting interactions that play a pivotal role in later language development, such as word/symbol learning.[14]

Augmentative and alternative communication (AAC) technologies (e.g., speech generating devices, mobile technologies with AAC apps) provide an effective means to support this word/symbol learning, along with participation outcomes, within social routines for young emerging symbolic communicators on the autism spectrum.[15-16] A recent review found that high-tech AAC was not only effective, but socially valid, for children on the autism spectrum.[17] Furthermore, recent research has demonstrated that targeting social language in the context of social routines is effective for emerging symbolic communicators.[18-19]

However, participation in social contexts for young children on the autism spectrum who are emerging symbolic communicators is still severely restricted.[20] This may be related to the use of traditional AAC technologies that are not well matched to their developmental skills, resulting in decreased effectiveness and efficiency of communication.[21] Specifically, these technologies often represent vocabulary concepts in the form of isolated line drawings, rather than within the context of the familiar social contexts in which language learning occurs.[15, 22-

23] This representation poses significant learning demands for emerging symbolic communicators for whom language is often context bound (i.e., only related to objects and events that are visible in the environment).[7-9] Furthermore, the representation of each vocabulary concept in an isolated grid cell may pose significant visual-cognitive processing demands for the user to store the target concept in their memory, visually scan through the grid for available symbols, and select the grid cell containing the target symbol.[24]

A growing body of evidence suggests that color photo visual scene displays (VSDs) may be more developmentally appropriate for emerging symbolic communicators.[15] VSDs depict meaningful events within an integrated scene, with relevant concepts programmed as “hotspots” within the scene (i.e., an area of scene that results in voice output when selected).[25] Several characteristics of VSDs that may be better matched to the skills of emerging symbolic communicators include: (1) representation of vocabulary concepts within familiar scenes to provide contextual supports for language learning; (2) “chunking” of key elements in the scene together to reduce working memory demands; (3) capacity for rapid visual processing to quickly identify the key elements in the display rather than scanning through each element.[15]

Additionally, emerging evidence demonstrates the effectiveness of high-tech VSDs for emerging symbolic communicators. Specifically, VSDs can support emerging symbolic communicators in increasing prelinguistic indicators of happiness and engagement including visual attention and vocalizations [26-27] and linguistic communication turns.[28] Used together, social routines and color photo VSDs promote emerging symbolic communicators’ prelinguistic and linguistic participation.[29]

However, like every approach, VSDs have limitations. Given the language use of emerging symbolic communicators is often context dependent,[8-9] either the communication

partner or the child must ensure the VSD matches the current communicative context. As such, navigation to the VSD containing vocabulary related to the current context still presents operational and visual-cognitive processing demands. Alternatively, if the vocabulary concepts are not currently represented within the technology, a photograph could be quickly taken, and vocabulary could be added just-in-time (JIT) to support participation in the social routine.[30-31] Previous research shows that programming VSDs JIT can support linguistic participation from emerging symbolic communicators.[32-33] Still, the time required for the AAC user or the partner to navigate to the target page, or add vocabulary JIT, reduces efficiency and relevance, particularly within the context of a fast-paced social routine with inflexible timing, such as singing along with a song (i.e., the song has already moved on to different lyrics by the time the vocabulary is located or programmed).

With technological advancement in artificial intelligence (AI), new opportunities are arising to make AAC more connected to context in which it is used (i.e., context-aware AAC).[34-35] Context-aware AAC is immediately responsive to the current communicative context by providing contextually relevant vocabulary to the AAC user or otherwise supporting meaningful communication within the immediate context. Interactions are steeped in context,[8-9] containing multitudes of information context-aware AAC feature options could integrate. Previous work has explored how advances in speech recognition AI could integrate the low intelligibility speech of the user into AAC technology [36] or how advances in physiological wearables and AI could integrate physiological data from users into AAC technology.[37]

Given the transactional nature of communication, perhaps the most critical piece of contextual information for AAC to integrate is the linguistic input (e.g., speech) of communication partners. For example, when a communication partner uses the cloze phase “Old

McDonald had a...” in an interaction with a child who is an emerging symbolic communicator, the AAC system automatically generates a VSD for “farm”. That is, a response to a cloze phrase from a communication partner can be offered JIT [30-31] without requiring the child or the communication partner to search for the target concept. Rather, the child has the immediate opportunity to participate in the social routine (by selecting the color photo VSD for farm), while maintaining the natural pace of the social routine. This low effort for both the child and the partner could support linguistic participation for the child and provide an in-the-moment opportunity for language learning.[8-9]

While technological advancements in AI exist to allow for such context-aware AAC feature options,[34,38] this approach is just beginning to be explored. Furthermore, the limited research and development to date has mostly focused on adult and advanced communicators, requiring significant metalinguistic skills and proficient literacy skills.[35,39] Recent work from our research team focused on emerging symbolic communicators is an exception. In a recent paper, we described the development of an AAC prototype that leveraged real-time contextual information (i.e., communication partner speech) to automate augmented input for emerging symbolic communicators on the autism spectrum.[40] Although preliminary, the results suggested that, compared to a standard topic display, the context-aware prototype increased visual attention and linguistic participation.[40]

The Current Study

The goal of the current preliminary study was to complete an initial exploration of the effects of context-aware AAC featuring automated JIT VSDs with cloze phrase responses compared to traditional AAC featuring isolated picture symbols in a grid format with no context-aware capabilities for supporting young children who were emerging symbolic communicators

on the autism spectrum in participating and engaging within a social routine. Specifically, the study asked: (a) What are the comparative effects of two technology options – a standard grid-based AAC app and a context-aware AAC prototype with automated cloze phrase response options – on linguistic participation through high-tech AAC from young children on the autism spectrum who are emerging symbolic communicators? (Research Question #1); (b) What are the comparative effects of the two technology options on participation through vocal approximations? (Research Question #2); and (c) What are the comparative effects of the two technology options on visual attention to the high-tech AAC? (Research Question #3). The authors hypothesized that (a) participants would have higher linguistic participation with access to context-aware AAC given the importance of context for emerging symbolic communicators and the time and use demands of standard grid-based technologies for emerging symbolic communicators; [15,21,24,31,41] (b) participants would have increased vocal approximations with access to context-aware AAC due to the previously hypothesized increased AAC use and the potential for voice output to support vocal communication for young children on the autism spectrum; [17,42-43] and (c) participants would have increased visual attention toward the context-aware AAC prototype as compared to the standard grid display with isolated picture symbols due to the prototype's heightened relevance to the immediate context, the visual salience of color photographs, and the associated movement that is a strong visual attractor. [21,26,44]

Method

This study was approved by the Institutional Review Board of the first author's university before any participants were recruited (protocol approval number 2211433922). A guardian provided informed consent for their child's participation in the study.

Participants

Children were eligible to participate in the study if their parents reported that they were on the autism spectrum; were young children between the ages of 4 to 5; were emerging symbolic communicators using fewer than 50 words to communicate; had hearing, vision, and motor skills functional for making meaningful selections on a touchscreen and hearing the selected output. Three children, Laura, Damien, and Jared (pseudonyms) participated in the study. They were recruited through an on-campus summer clinic for children on the autism spectrum in which they were enrolled. Recruitment occurred by sharing a flyer with study information to parents and guardians who could reach out if interested in their child participating. The same three children who participated completed a previous study evaluating a different prototype for a different purpose.[40] The children all used fewer than 20 words consistently to communicate across any modality (AAC, formal gestures, signs, vocal approximations). The majority of communication from all participants was prelinguistic, and the majority of attention from all participants was directed toward a single object or activity of interest with limited social or joint attention. Table 1 provides more detailed information about the participants.

Setting

All sessions occurred in a large free play preschool classroom within a university clinic-based summer preschool program. Participants sat one-on-one with the interventionist and engaged in the “Row, row, row your boat” song each session. Participants engaged in a simulated version of being on a row boat with the interventionist in one of the following ways, based on their preference: sitting on a bean bag rocked back and forth by the interventionist, sitting on a seesaw moved up and down by the interventionist, or sitting on a chair moved forward and backward by the interventionist.

Design

An alternating treatment design (ATD) was used to evaluate the comparative effects of the two technology options.[45] The two technologies – standard of care technology and a context-aware prototype with automated cloze phrase response options – served as the two study conditions. Technology condition was the independent variable studied. The study had two phases: intervention and maintenance.

Phase Shifts

Each participant began the study in the intervention stage as an ATD compares two alternating conditions rather than comparing a baseline to an intervention.[46] Participants shifted from the intervention stage of the study to the maintenance phase after one session with 66%+ spontaneous cloze phrase completion in one of the two conditions. Whichever condition in which this was achieved served as the only condition carried into maintenance to focus on performance with the more successful technology. In the event of equal performance across conditions, both conditions would be carried into maintenance. Only two of the three participants (Laura and Jared) met the criteria for shifting to the maintenance phase, and the technology condition within which they met the criteria was the context-aware AAC prototype.

Researchers

A licensed speech-language pathologist, the first author, was the interventionist in each session of the study. The second, fifth, and sixth authors controlled the prototype remotely as “wizards” using their mobile phones (see the “Context-Aware AAC Technology” Materials subsection). For each session, the author who served as the wizard also collected live data and procedural fidelity checks for interrater reliability and procedural fidelity to be measured.

Materials

Standard AAC Technology

Proloquo2Go on an iPad Mini was the AAC used in the standard technology condition. This was the standard technology selected because of its ease of programming, its inclusion of color line drawing representations for the target words in the study, and because the participants had access to it outside the context and target words of this study. In an effort for the standard condition technology to reflect the standard of care for many children, a common default user with a grid of 15 was used with all three target words according to the default structure (i.e., “boat” in a “things” folder; “stream” in a “places” folder; and “dream” in an “activities” folder, all located on the user home page).

Context-Aware AAC Technology

A prototype web app housed on the same iPad mini as the standard technology condition developed by the third author in close collaboration with AAC users and communication partners following rigorous human centered design practices [40,47-48] served as the technology in the context-aware AAC technology condition. The prototype featured a blank screen until, responsive to a cloze phrase communicated by the interventionist, a color photo VSD appeared as a JIT option to respond to the cloze phrase without requiring navigation or programming on the part of the participant or the interventionist. Figure 1 depicts what participants saw from the context-aware AAC prototype throughout the song.

The prototype reflected a wizard-of-oz approach [40,49-50] that allowed the research team to create a user experience for participants identical to that which they would experience with access to context-aware, AI-powered AAC without first requiring costly and time-consuming back-end development. This user experience was accomplished by a “wizard” in the background on a separate device controlling what appeared in realtime on the participant’s AAC

device. For example, when she heard the interventionist say “Row row row your _____”, the wizard selected a preloaded color photo image of a young child in the boat that, within 1s of being remotely selected by the wizard, appeared on the participant’s AAC device as a color photo VSD.

Procedures

Participants engaged in one to three sessions a week depending on scheduling and attendance in the autism clinic over the course of 5 weeks. All sessions occurred in the morning.

Intervention

Every intervention session included two halves: one for each technology condition. The technology condition order oscillated each session so that the condition that occurred first in one session occurred last in the next session. Within each condition, identical procedures were repeated by the interventionist. The only difference across conditions was the AAC technology.

Within each condition, the interventionist repeated the same procedural sequence 6 times, singing the “Row row row your boat” song twice. Each time singing the song, the interventionist sang the lyrics using salient social behaviors (SSBs) to promote participant engagement.[18,29,51] Within the lyrics, three lines within each repetition of the song were sang as cloze phrases to encourage linguistic participation from participants.[11] They were: “Row, row, row your _____ (boat)”; “Gently down the _____ (stream)”; and “Life is but a _____ (dream)”. The procedural sequence used for each cloze phrase within the song and therefore a total of six times in each condition per session was: (a) sing the phrase using SSBs; (b) use an expectant delay rather than singing the word that would complete the cloze phrase with wait time of at least 5s or until the participant provides a response; (c) provide a gestural prompt toward the AAC technology if no attempt at linguistic participation is made within the 5s; (d) after the

gestural prompt, wait at least 5s or until a response occurs; (e) respond to accurate linguistic participation (via AAC or vocal approximation) with social praise; (e) respond to inaccurate linguistic participation with an expansion that relates the language communicated to the song; and (f) respond to a no response by singing the word to complete the cloze phrase.

Maintenance

Maintenance sessions were comprised of only one technology condition: the technology condition most supportive of the participant in the intervention phase. A pared down procedural sequence was used in the maintenance phase to eliminate teaching (i.e., prompting and feedback). The interventionist completed the following procedural sequence six times per condition (once for each of the three target words in the song that was sang twice per condition): (a) sing the phrase using SSBs; and (b) wait at least 5s for a response, and (c) if no response occurs, sing the word to complete the cloze phrase before moving on to the next lyric.

Procedural Fidelity

Procedural fidelity was collected live by the session's "wizard" and observing author, all of whom were provided and familiar with study procedures. After each session, the observing author reported the steps to which the interventionist did and did not adhere. Procedural fidelity was a mean of 98.1% for all sessions across participants and conditions (range: 95.8% - 100%).

Data Collection

All data were collected live by the interventionist during study sessions using printed data sheets. Data were also available for review via videorecording of every session.

Measures

The study had three dependent variables for which data was collected each session to evaluate participants' participation within a song-based social routine. The primary dependent

variable was accurate linguistic participation using high-tech AAC (Research Question #1), defined as selection of the correct word to complete a cloze phrase within a song lyric within the allotted wait period.[18] Linguistic participation through vocal approximations (Research Question #2), one of the secondary measures, was defined as vocal production of part(s) of the accurate linguistic response (e.g., the initial sounds) within the allotted expectant delay period.[18] Vocal approximations were counted whether or not high-tech AAC was selected. Visual attention to high-tech AAC (Research Question #3), the other secondary measure and a behavior important to language learning for emerging symbolic communicators,[3-4,52-53] was defined as 3s or more of sustained gaze to the device screen or sustained gaze up until the point when a selection was made during the allotted expectant delay period.[40]

Interrater Reliability

Interrater reliability was collected live by the session's "wizard" and observing author, all of whom were provided and familiar with operational definitions for the study's measures. Immediately after each session, the observing author and the interventionist compared their independent tracking of the data and discussed disagreements. Independent interrater reliability was 92% across all variables and sessions (range: 83%-100%). After discussion, all disagreements but four (99.5%) were quickly resolved. The four disagreements not resolved through initial discussion were quickly resolved after video review of the session.

Data Analyses

Graphs were created of primary and secondary measures for each participant in accordance with single-subject reporting standards.[46] Also in accordance with standards, graphed data were visually analyzed regarding level, trend, slope, and variability. The size of the comparative effects of technology condition was also estimated using the Nonoverlap of All

Pairs (NAP) effect size measures.[54] NAP was calculated by comparing performance on each of the three variables across the two technology conditions in the intervention phase. NAP scores at or above 0.93 were interpreted to estimate a strong effect. NAP scores at or between 0.66 and 0.92 were interpreted to estimate a moderate effect. NAP scores lower than 0.66 were interpreted to estimate a weak effect.

Results

Figure 2 contains all three participants' graphed data across conditions for all dependent variables: accurate linguistic participation through AAC use (Research Question #1), accurate linguistic participation through vocal approximation (Research Question #2), and visual attention toward AAC technology (Research Question #3).

Accurate Linguistic Participation Using High-Tech AAC

Visual analysis showed that Laura immediately used the context-aware AAC to accurately participate in the social song routine at a high level. In fact, only in one procedural sequence did any prompting occur for Laura because of her immediate spontaneous success. Her high level of participation in the context-aware AAC condition stayed consistent after instruction ended. Conversely, Laura never demonstrated accurate participation using the standard AAC technology, spontaneously or with prompting. Technology condition was estimated to have a large effect on accurate AAC use throughout the intervention phase (NAP = 1.00).

Visual analysis revealed that Jared's accurate high-tech AAC use to participate in the social song routine, both spontaneous and prompted, trended upward throughout the intervention phase in the context-aware AAC condition and maintained after intervention. In the standard AAC condition, however, Jared's AAC use was consistently zero across the intervention phase,

even with prompting. The estimated effect size of the technology condition was moderate for Jared's spontaneous and prompted communication in intervention ($NAP = 0.90$).

Visual analysis of Damien's spontaneous and prompted AAC use showed that his accurate linguistic participation in the context-aware AAC condition trended upwards, though at a slower and less consistent rate than it did for Jared. As with the other participants, Damien never used the standard AAC to participate accurately in the social song routine. The effect of technology condition on spontaneous and prompted linguistic participation from Damien was estimated to be large ($NAP = 0.94$).

Vocal Approximations

Visual analysis of Laura's vocal approximation showed that Laura demonstrated higher rates of vocal approximations overall in the context-aware AAC condition than in the standard AAC condition. However, there was a high level of variability in Laura's vocal approximations that seem to follow a downward trend in the final three sessions. Yet, this trend may have been reflective of variability alone given that her vocal approximations in the maintenance phase were again higher in level. Technology condition was estimated to have a large effect ($NAP = 0.94$) on vocal approximations for Laura throughout the intervention phase.

Visual analysis showed that Jared produced vocal approximations at lower levels than Laura in both technology conditions. Still, his vocal approximation level was higher in two sessions in the context-aware AAC condition as compared to the standard AAC condition. His vocal approximations in the maintenance phase using context-aware AAC without instruction were higher overall than vocal approximations across conditions in intervention. The AAC technology used by Jared in the intervention phase was estimated to have a moderate effect on his vocal approximations ($NAP = 0.70$).

Visual analysis shows that after a three-session delay in the context-aware AAC condition and a five-session delay in the standard AAC condition, Damien began to demonstrate increased use of vocal approximations. After the first three sessions, his vocal approximations occurred at a consistently higher level in the context-aware AAC condition than the standard AAC condition. AAC technology condition was estimated to have a moderate effect on Damien's vocal approximations ($NAP = 0.73$).

Visual Attention to AAC Technology

According to visual analysis, Laura's visual attention to the context-aware AAC technology was consistently higher than her visual attention to the standard AAC technology. The condition effect size was estimated to be large ($NAP = 1.00$). Her visual attention to the context-aware AAC technology also maintained post intervention.

Visual analysis of Jared's data showed that he also demonstrated higher visual attention to the context-aware AAC technology than to the standard AAC technology. There was a high level of variability in Jared's visual attention to the context-aware AAC from session to session. Still, the estimated size of technology condition was large ($NAP = 1.00$).

Damien's data, when visually analyzed, showed that his visual attention was also higher overall to the context-aware AAC technology than to the standard AAC technology. Damien's visual attention was variable in the context-aware condition with no clear trend while trending upward toward the end of the study in the standard condition. Technology condition was estimated to have had a moderate effect on visual attention from Damien ($NAP = 0.91$).

Discussion

Social interaction is critical to development for all young children.[1-2,5-6] For young children on the autism spectrum who are emerging symbolic communicators, AAC intervention

is required to support social interaction.[15] Previous research shows that social routines, cloze phrases, high-tech AAC, color photo VSDs, SSBs and evidence-based interaction strategies, and the provision of high-relevance vocabulary JIT can make participation in social interactions more accessible for emerging symbolic communicators and children on the autism spectrum.[17-19,29,32,55]. Advances in AI provide opportunities for AAC technology features to better reflect the evidence base and reduce time and effort on the part of users and communication partners through a context-aware approach.[34-35] For emerging symbolic communicators, one such novel feature opportunity is automated JIT provision of cloze phrase response options, represented by color photo VSDs.

Preliminary evidence from the current study suggests that this approach may provide young children on the autism spectrum who are emerging symbolic communicators with increased access to social interaction within a repetitive, predictable social routine. This study compared linguistic participation through high-tech AAC and vocal approximations, as well as visual attention to AAC, across a context-aware AAC prototype and a standard AAC option. For all three participants, the context-aware prototype appeared more supportive of participation within the routine. The current results align with another preliminary study which found that context-aware AAC that provides automated augmented color photo input to supplement spoken communication partner input can promote participation from young children on the autism spectrum in a group circle time activity.[40] The results align more broadly with research documenting the benefits of context-aware AAC that integrates communication partner speech for other populations.[39]

There are a number of reasons why the emerging symbolic communicators in the current study may have been more successful participating in a social routine with the context-aware

prototype than the standard technology. First, standard AAC technology may not be well suited to their developmental strengths and needs.[15,21] In contrast, the context-aware prototype was designed specifically to support emerging symbolic communicators drawing on theory and evidence to maximize: visual-cognitive-linguistic accessibility through the use of color photo VSDs and JIT high-relevance response options;[31,41] attentional accessibility through the use of motion to attract vision to the response option and elimination of navigational requirements; [24,44] motor accessibility through the use of a large selection space; and errorless participation if the AAC is selected through provision of one communication option at a time. Each of these address common barriers to communication for emerging symbolic communicators on the autism spectrum .[4,7-9,13]. In this study, Laura's effective use of the context-aware AAC with almost no teaching, and all participants' comparatively higher use of the technology with limited teaching, is evidence of the high accessibility of the technological approach.

Implications

Only limited implications can be drawn from this study due to the preliminary nature of the work and the use of a prototype rather than fully developed AAC technology. Still, when considered in the context of previous research, this study offers further support that in intervention with emerging symbolic communicators, clinicians should consider evaluating and, if effective for the individual emerging symbolic communicator client, implementing the use of: high-tech AAC, color photo VSDs, social routines, cloze phrases, SSBs, expectant delays, gestural prompts, and differential feedback including expansions and social praise.

Based on this study and other recent studies evaluating context-aware AAC that integrates communication partner input,[39-40] we suggest that researchers should continue to explore and evaluate the many ways that communication partner input could be leveraged

effectively in AAC technology. Critically, future research is needed to evaluate how context-aware AAC features such as automated cloze phrases response options could be meaningfully included within a robust, comprehensive AAC system. All future research into context-aware AAC should reflect the priorities offered by AAC users and the families and professionals who are regularly their communication partners. Emerging symbolic communicators should be prioritized in this work given the limitations to accessibility of many existing AAC technologies for emerging symbolic communicators [21,24,41] and the critical importance of communication partner input as interaction context for early language development.[7-9] Importantly, AAC technology and instruction must ensure emerging symbolic communicators can initiate as well as respond to interactions, so future research should also explore opportunities for context-aware AAC options to support users in initiating interactions, such as through automated programming from visuals of the immediate environment.[34]

More research is needed before strong implications for technology developers can be offered. This research must continue to evaluate the efficacy of the context-aware technology approach, but must also evaluate the attitudes of users and communication partners toward AAC that is monitoring the linguistic context, and must consider when and how this option is enabled (e.g., in spaces with familiar partners who understand the technology is making suggestions based on speech). Feasibility research is also crucial to understand if and how AAC technology can provide useful response options based on communication partners speech given the realities of interaction contexts (e.g., background noise; multiple communication partners speaking simultaneously) and how they may test technology capability limits. Yet it appears that, for emerging symbolic communicators and other AAC users who are interested, the use of AI for creating context-aware AAC feature options should be explored.

Limitations and Future Research Directions

Given that this study was a preliminary evaluation of a prototype, there were significant methodological limitations that should be considered. First, this study included only three participants within only one context implemented within a short timeframe by a white interventionist from the mainstream culture with AAC expertise and experience. Future research must explore how context-aware AAC could provide response options to cloze phrases within other contexts, such as naturally occurring social and academic contexts, and should include parents, siblings, and professionals who have a long-lasting relationship with the participants and who reflect participants' culture. Furthermore, the two technologies compared differed across multiple factors in an effort to compare standard technology to a theory-and evidence-informed context-aware prototype. Due to the multiple differences (e.g., context awareness, representation, layout), it is impossible to say with certainty which particular aspects of the prototype made it more supportive of participation in social routines for the participants. This initial comparison was just one initial step, and future research is needed to more specifically and incrementally compare the effects of context-aware AAC individual features for emerging symbolic communicators.

In addition to methodological limitations of the preliminary study, there are limitations to the prototyping approach used and the novel technological approach of leveraging AI to make AAC for emerging symbolic communicators aware of and responsive to the communicative context, such as the linguistic input of the communication partner. Regarding the wizard-of-oz prototyping approach,[49-50] the ability to efficiently evaluate a novel approach to AAC came at the cost of necessary evaluation of technical and implementation feasibility. For instance, without developing the AI backend, this study could not address critical questions about: how

and when the contextual awareness should be enabled (e.g., after consent of a communication partner is obtained), how to ensure only safe and meaningful representation is provided, or whether the noise level in a preschool reduces accuracy of capturing communication partner speech.[40] If more comprehensive user evaluation demonstrates the efficacy of this approach, significant feasibility research will be necessary. Regarding the technological approach, many unanswered questions remain. Responding to highly predictable cloze phrases (e.g., words within common song lyrics) in social routines is one small interaction context. Future research must answer critical questions about: how this approach could be situated as one feature within a more comprehensive AAC system, whether familiar communication partners could provide personal information about the emerging symbolic communicator to allow for accurate responses to individualized cloze phrases (e.g., “My name is ____”), how to provide and teach dismissal options when context-aware response options do not reflect what the user wants to say (e.g., appearing as a popup option within a full AAC app and disappearing after 5 s of non-selection), and how to ensure that potentially biased AI algorithms can be made equally effective across the culturally and linguistically diversity that AAC users represent.

Conclusion

Emerging symbolic communicators, including some young children on the autism spectrum, often use and learn new words through their participation in meaningful, reciprocal, repetitive interactions with more expert communicators.[10] Evidence shows that implementing social routines and supportive interaction strategies such as cloze phrases alongside high-tech AAC can promote engagement and communication from beginning communicators.[18-19,29] JIT programming of relevant communication options can also support beginning communicators in interacting within meaningful contexts [32-33] which may also support language learning.[30-

31] Recent advances in AI create the opportunity for AAC to automatically provide a response option to cloze phrases JIT by integrating communication partner speech. Such a technology feature option could increase in-the-moment opportunities for language use from beginning communicators while simultaneously decreasing knowledge and use demands from communication partners. Perhaps most importantly, the technology option also has the potential to support emerging symbolic communicators in engaging in interactions with inflexible pacing (e.g., singing along with a song) that too often move on without their involvement due to the time required to access words that are not made available JIT. The current study provided preliminary evidence that this approach to context-aware AAC during social routines can increase participation and engagement from young children on the autism spectrum who are beginning communicators. Much more work is needed to comprehensively evaluate this approach as one component of a complete AAC technology and intervention. If future research continues to show promise, work is also needed to answer empirical questions about technological implementation to ensure effective, responsible, use-inspired development.[47-48]

Data Availability Statement

All data generated or analyzed during this study are included in this published article.

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Figure 1

Communication partner input	Corresponding AAC interface	Voice output upon selection
“Row, row, row your ____.”		
[Expectant delay]		“boat”
“Gently down the ____.”		
[Expectant delay]		“stream”
“Merrily, merrily, merrily, merrily life is but a ____.”		
[Expectant delay]		“dream”

Figure 2

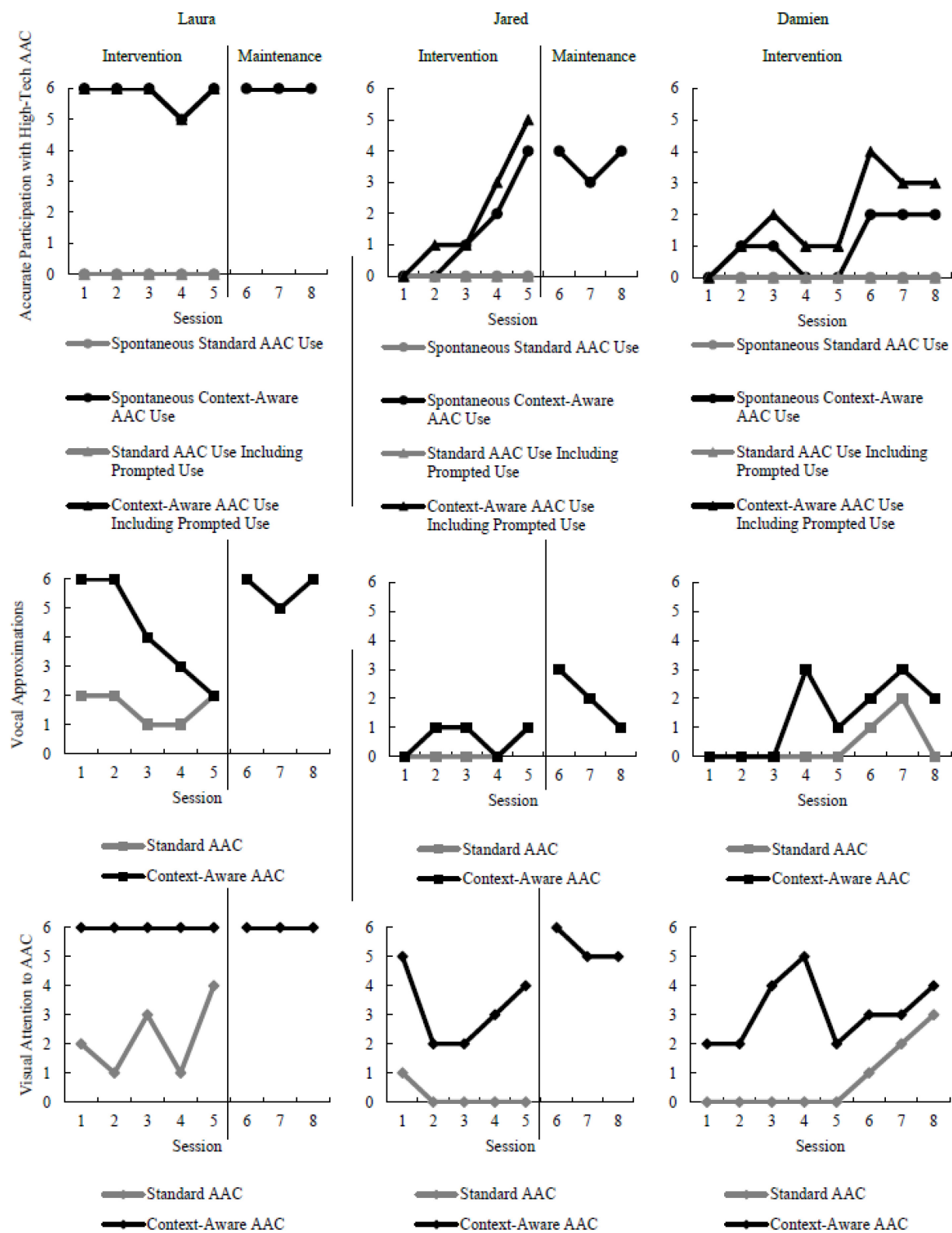


Table 1

Participants' Descriptive Information

Participant ^a	Age ^b	Gender ^b	Race ^b	Diagnosis ^b	Primary communication mode ^c	Primary stage of spontaneous communication ^c	Primary spontaneous engagement ^c	History with AAC ^b
Laura	5	F	White	Autism	Prelinguistic PCBs; high-tech AAC and vocal approximations to request favorites	Preintentional, prelinguistic communication	Object orientation	<1 year of access to a grid-based AAC app; <1 month of access to a VSD-based AAC app
Jared	4	M	White	Autism	Prelinguistic PCBs	Preintentional, prelinguistic communication	Object orientation	<1 month of access to grid- and VSD-based AAC apps
Damien	4	M	Pacific Islander	Autism	Prelinguistic PCBs	Preintentional, prelinguistic communication	Object orientation	<1 month of access to grid- and VSD-based AAC apps

Note. M = male; F = female; PCBs = potentially communicative behavior (e.g., nonspecific vocalizations, reaching or pushing away an object, gaze to a partner); VSD = visual scene display.

^aAll participant names are pseudonyms.

^bBased on parent or guardian report.

^cBased on structured observation across multiple social contexts and the Communication Complexity Scale (Brady et al., 2012); communicative intentionality can only be estimated based on behavior, it cannot be known.

