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A Comparison of Digitized and Synthetic Speech Outputs to Teach Requesting to Children With Autism Spectrum Disorder

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ABSTRACT

Few studies have compared different augmentative and alternative communication (AAC) intervention components (e.g., symbol sets, instructional strategies) involving individuals with autism and other developmental disabilities. This study compared the relative efficacy of digitized and synthetic speech outputs using voice output communication aids (VOCA) with two children, ranging from 3-5 years old with autism spectrum disorder (ASD) and limited functional communication. This study utilized an adapted alternating treatments design, aimed at teaching basic level requesting skills in two different settings. Visual analysis of the results indicated a divergence in the rate of skill acquisition for speech outputs, and the overall outcome emphasized the need for individualizing AAC intervention packages by taking AAC component options such as speech outputs into consideration. Implications for both special educators and speech-language pathologists working with children with ASD, limitations, and directions for future research are provided.

Key Words: Augmentative and Alternative Communication (AAC), Voice Output Communication Aids (VOCA), Autism Spectrum Disorder (ASD), Digitized speech, Synthetic speech

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INTRODUCTION

Persistent deficits in communication across multiple contexts is one of the defining features of autism spectrum disorders (ASD) [1]. It is estimated that approximately 25-30% of individuals diagnosed with ASD are minimally verbal [2]. Although there exists heterogeneity in communicative abilities of individuals diagnosed across the spectrum, the majority of children who are minimally verbal frequently fail to develop speech and functional communication [3]. Many children with ASD who do not have functional communication compensate their communicative deficits by engaging in pre-linguistic forms of communicative behaviors such as pointing, reaching, and eye gazing [4]. Additionally, they may also engage in higher levels of aberrant behaviors such as self-injury, self-stimulation, tantrum, and aggression [5].

Researchers have found that functional language use by school age consistently predicts better long-term social and adaptive outcomes for individuals with ASD [6,7]. Further, spontaneous functional communication enables children to access and learn from their environment [2].

For the past 50 years, several comprehensive augmentative and alternative communication (AAC) intervention programs have been designed to meet the complex communication needs of children with ASD. Initially, unaided AAC tools such as Makaton signs, sign language, and gestural symbols were used to augment communication. Soon after, aided AAC systems such as Object of Reference (OOR), picture exchange communication system (PECS), voice output communication aids (VOCAs), speech generating devices (SGDs) with preloaded software programs, and AAC applications that would be accessible across different platforms (e.g., Apple, Android) and cloud-based AAC applications that would be accessible across multiple devices were developed. One of the most important areas of educational service of these developments is the amelioration of communication problems in part because of the significance of early functional communication with the support of effective communication modalities.

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Among the AAC systems, VOCAs and SGDs are types of electronic aids that can support communication with prerecorded messages. The users can be trained to press the buttons on the device interfaces to facilitate communication [8]. Some VOCAs and SGDs use human natural speech outputs that are electronically stored in a compressed form (digitized). Some other devices use synthetic speech output which refers to the mechanical conversion of written language into an auditory form using the rules of correspondence between written words and sounds [9]. With the development of AAC applications with digitized and synthesized speech output capabilities for diverse operating systems (e.g., iOS and Android) and common household electronic items such as iPods, iPads, personal computers, tablets, etc., VOCAs are becoming increasingly prevalent within the ASD population [10].

Speech as an output mode, whether digitized or synthesized, has been investigated in order to understand its effectiveness on spontaneous utterances [11], learning how to spell [12,13], making requests [14], and comprehending

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speech [15]. For instance, Parsons and La Sorte [11] investigated the effectiveness of synthetic speech output on the frequency of spontaneous utterances in children with ASD and found that computer-assisted intervention without speech condition did not produce any changes in the frequency of spontaneous utterances. When the synthesized speech was added, children with ASD produced a higher number of spontaneous natural speech utterances. While some of these studies are promising and demonstrate divergence in the pattern of responding in speech output vs. non-speech output, studies that incorporate and compare both digitized and synthesized speech outputs are necessary to further understand the role of speech output in learning and skill acquisition. Among AAC pioneers, there exist opposing arguments to support that one speech output is better than the other speech output in facilitating learning in individuals with ASD. For instance, Parsons and La Sorte [11] and Romski and Sevcik [16] argue that synthesized speech output can be more advantageous to children with ASD. Their premise is that synthesized speech is better understood by individuals with ASD who have auditory processing issues, and difficulty segmenting the words available in natural speech into meaningful word units. Romski and Sevsik [16,17] further argue that the lack of variability and inherent consistency present in the synthetic speech could prove beneficial to children with ASD. On the other hand, researchers such as Haring, McCormic & Haring [18] assert that children with ASD show cognitive characteristics such as working memory deficits, limited attention span with increased distractibility, which may prove detrimental in comprehending synthesized speech output.

The present study aims to contribute to the VOCA literature by further evaluating the role of type speech output in facilitating the acquisition of requesting skills in young nonverbal children diagnosed with ASD. Specifically, the goal of the current study was to train two young, non-verbal children to use VOCA that emitted digitized and synthesized speech output to make communicative requests in two natural settings (i.e., snack time and play). The specific purpose of this study was to investigate if there were differences in the rate of acquisition for making requests trained using VOCA devices with digitized vs. synthetic speech output?

METHODS

This study was conducted after obtaining approval from the relevant human subject research/ ethics committee and obtaining consent from parents/ guardians. We used an alternating treatment design to evaluate the relative effectiveness of digitized and synthesized speech output on requesting skills. Systematically controlled, alternating treatments were delivered in 10-trial sessions for 3 to 4 times per week.

Participants

Participants were recruited based on five pre-determined inclusionary criteria: (1) age between 3 to 8 years old, (2) diagnosis of autism, (3) no physical and or sensory abnormalities that could preclude them from using a VOCA, (4) less than 10 expressive vocabulary words, and (5) no previous training in using VOCA. Two boys, Henry and John (pseudonyms) met all the five inclusionary criteria and were included.

Henry was a 4 year 1-month old Hispanic boy. He was recruited from a private behavior therapy autism center, about 20 miles outside of a major metropolitan area in the southwestern region of the United States. He was diagnosed with autism when he was two-years-old. He used no spoken words at the start of this study. He exhibited moderate levels of stereotypic behaviors such as rocking back and forth, lifting arms and reaching for therapists, mouthing (e.g., thumb and objects) and whining. He also exhibited diurnal bruxism. He did not imitate sounds, point to body parts, or use names to identify familiar people and objects. He had attended a preschool program for children with disabilities, and had also received early intervention services prior to the onset of this study.

John was a 3 year 6 months old African American boy with a diagnosis of autism. He used no spoken words, nor did he imitate sounds. He had not been trained to use any form of augmentative and alternative communication. He did not respond to his name, point to body parts, or use names to identify with familiar people and objects. John had moderate-levels of challenging behaviors such as crying, screaming and repetitive behaviors such as body rocking, slapping flat surfaces with both hands, and object mouthing.

Setting and Materials

The settings for both participants were chosen based on the preference of teachers and parents. For Henry, this study was conducted in a clinical setting (i.e., therapy room and playground) and for John, the study took place at home (i.e., living room). VOCA training occurred in the context of two activities namely, snack time and play time. In both activities, children were taught to use voice output devices with digitized and synthesized speech output to request preferred items (e.g., snack, toy/ play activity).

The therapy room for Henry included a table, chairs, and the intervention materials appropriate to his treatment goals (e.g., pictures of preferred snack items and play items/ activities, Tech/Talk® device, targeted item, etc.). The therapist, participant, and data collectors were present in the room for all the sessions. For Henry, materials included were his preferred snack items (i.e., gluten-free chips, gluten-free brownies, and juice) and play items/activities (i.e., movie, spin-chair, and swing).

For John, the intervention was conducted at his house in the living room with two couches. For all sessions, the therapist, participant, data collectors and the legal guardian were present. For John, materials included were his preferred snack items (i.e., sugar-free gummy, raisins, and strawberries) and preferred play items were (i.e., ring, slinky, and koosh-ball).

For both participants, color pictures of the preferred stimuli items were obtained using a Sony® digital video camera. Using the color picture of the actual items, overlays were constructed for SGD called Tech/Talk® and Big Mack® single-switch communication device. For Henry, Tech/Talk® devices were used to provide instructions, and for John, Big Mack® single switch devices were used to provide instructions. Voice output devices were selected based on individual treatment goals and objectives.

Independent and Dependent Variables

The main purpose of this study was to understand the effectiveness of a specific speech output in teaching basic level requesting skills to children with ASD. Thus, Tech/Talk® from Advance Multimedia Devices Inc (AMDI) and Big-Mack® single-switch communication device were programmed to generate communicative requests in either digitized or synthetic speech output. The external speakers along with recording jacks available in these devices provide increased flexibility to program messages in either digitized or synthetic format. Communicative requests were programmed in a sentence format (e.g., May I have preferred item, please?) in order to give ample time for participants to understand the underlying differences between digitized and synthetic speech in terms of intonation, prosody and the quality of speech. Further, communicative statements with punctuations (e.g., ?) were selected to give the participants opportunities to differentiate speech outputs in terms of intonations and prosody. A Speech-generating device that generates synthetic speech was programmed using Microsoft speech synthesis engine®. The voice output responses were played at the rate of 115 words per minute (WPM), and with a constant pitch setting of 15. Microsoft speech synthesis engine with the default female voice was chosen because of its its robotic quality and to facilitate speech discrimination in selected participants. In order to program synthetic speech output in the Tech/Talk® and Big-Mack® speech-generating devices, first the communicative request statements of the preferred items (e.g., May I have gummy, please?) were created in a textual format using a software called Kurzweil-1000®. Later the created texts were converted to speech using Microsoft® speech synthesis engine and saved as MP3 files. The MP3 files were played using Windows media player® and manually recorded into the selected devices. The device that generated digitized speech output was programmed with a human voice at a constant intensity level with normal speech rate (SPR). Female therapists who provided instruction on a given day programmed the selected device with their own voice. If male therapists were selected to provide instruction, then one of the female therapists working in the clinic was allowed to program the device with their voice. This step was taken to ensure that both of the devices were programmed to provide speech outputs in a female voice.

Two dependent measures were collected in order to measure the rate of skill acquisition for a device with specific speech output and the difference in the rate of acquisition across two types of speech output. The measures were (a) percentage of correct responses, and (b) number of trials taken to reach mastery criterion.

Data Collection Measures

To measure the rate of acquisition, three types of responses made by the child were calculated (1) independent response, (2) prompted, and (3) no response. Further, prompted responses were coded based on the type of prompts needed to make a request (i.e., verbal prompt, gestural prompt, partial physical and full physical). Real-time data were collected for 100% of the sessions.

Percentage of correct responses was calculated for each session and a session involved one block of 10 trials.

Percent of correct requesting was calculated by totaling the number of independent responses divided by the total number of trials in that session and multiplying by 100 to obtain a percentage. For both participants, correct responses were defined as independently touching the correct picture displayed on the device within 6 seconds of the therapist delivering the directive. Data were graphically plotted for both Henry and John. The number of trials required for each participant to reach the mastery criterion (e.g., 60% of trials performed correctly for three consecutive 10 trial sessions) was calculated to compare the speed of acquisition for each speech output condition. Only independent responses were taken into consideration to calculate the percent of correct responses towards mastery criterion.

Inter-observer Agreement

Inter-observer agreement (IOA) was collected for 40% of videotaped sessions for both participants by two independent observers. Prior to data-recording, operational definitions of the dependent variables were scored and observation procedures were provided to the observers. Observers were provided with opportunities to practice recording procedures by watching videotapes with the investigator. During the reliability sessions, both observers recorded the type of responses (i.e., independent, prompted, no response) for all the participants on a trial-by-trial basis. The data collected by the observers were compared with those real-time data collected by the investigator. An agreement was calculated when the two observers agreed on occurrence or non-occurrence of a response. Any discrepancy in scoring between the observers resulted in disagreements. IOA was calculated at the end of each observational session by dividing the agreements by agreements plus disagreements and multiplying by 100 to obtain a percentage. For Henry, mean IOA for correct responses was 97% ranging 80-100% and for John, mean IOA for correct responses was 98%, ranging from 90-100%.

Fidelity of Implementation

Two independent graduate student observers were trained to collect treatment fidelity data for 40% of sessions for both participants. After receiving training, observers recorded therapist behaviors including: (1) initiation of requesting opportunities, (2) amount of time provided for the participant to respond, (3) whether the therapist provided designated amount of prompt, and (4) whether the reinforcement was contingently delivered. Observers provided their responses by indicating "Yes", "No", or "N/A" (Not applicable). By calculating the percent of "Yes" responses agreements obtained and calculation of "No" responses resulted in disagreements. For Henry, the mean percent of agreement for baseline condition was 100% and in the treatment condition was 91%. For Chris, the mean percent of agreement for baseline condition was 100% and in the treatment condition was 98%.

Intervention Procedures

First, a paired-choice preference assessment [19] was conducted to identify the most-to-least preferred snack and play items/activities for both Henry & John. After the identification of the preferred snack and play items, baseline sessions were conducted.

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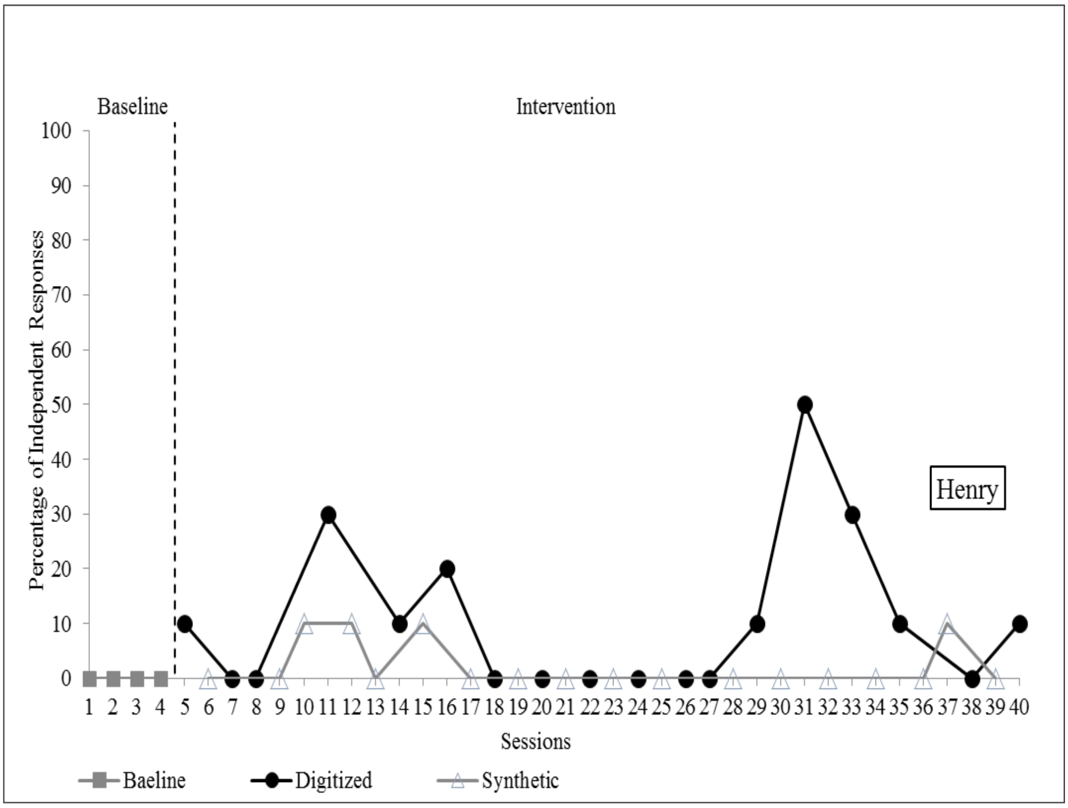
During baseline sessions, the participant was seated at a desk across the therapist. The therapist initiated communication by saying that it was time to have snack or play and provided an opportunity for a communicative request by showing/pointing towards the most preferred item. Each session typically involved 10 requesting opportunities (i.e., trials) and lasted approximately 15 minutes; although the length of the session and the number of trials varied depending on the participants' level of challenging behaviors (e.g., elopement) and factors such as individualized therapeutic goals and other requirements. Depending on a given session (i.e., play/snack), the preferred item was placed within the view of the participants but out of reach. The therapist waited 10 seconds for the child initiate a request by pressing the right panel on the device. Children were given access to the item requested when they used pre-linguistic forms of communicative repertoires such as reaching, pointing or other behavioral indications. No prompts or model behaviors were given during baseline phase.

During intervention sessions, participants were allowed to freely explore the device (e.g., pressing the panel, and listening to messages) for approximately two minutes. The participants were taught to use VOCA during 15-minute training sessions, two to four times per week. SGD training continued until the participant reached mastery criterion (i.e., 60% or higher independent responses for three consecutive sessions). The children learned to press the right panel on a given device, and the therapist subsequently provided access to the preferred item as reinforcement. An appropriate requesting behavior (i.e., pressing the right panel) resulted in access to the targeted item. If no attempt to request the object was made or a request attempt was made using inappropriate behaviors (e.g., banging on the device, touching the wrong panel), the therapist then prompted the child to use the VOCA. VOCA use was taught using a most-to-least prompting hierarchy. This prompting hierarchy included four prompting levels: full physical (i.e., hand-over-hand), partial physical (i.e., hand on the participant's upper-arm or light-touch and or shadow by the elbow), verbal and or gestural prompt (i.e., pointing the right panel or asking the participant to touch the picture of the preferred item), and no response. The criterion for reducing the prompt level was two consecutive correct responses at the designated prompt level. Two consecutive errors resulted in increasing the intrusiveness of the prompt level.

RESULTS

Both participants showed increases in requesting in both experimental conditions (i.e., synthesized and digitized) as compared to baseline. The digitized speech condition produced greater increases in level of percentage of independent responses for both participants, with no overlapping data observed for John. Figure 1 shows a graphical representation of independent requesting responses emitted by Henry during baseline and intervention sessions. Closed circles represent the data obtained from sessions involving digitized speech and the open triangles represent the data obtained from sessions involving the device with synthetic speech Correct requesting was not observed for Henry during any baseline sessions, which indicated that he did not have any previous training in using VOCA. Instead, he engaged in certain pre-linguistic forms of communicative behavior to access the preferred snack or play items (e.g., reaching, grabbing).

Henry participated in a total of 40 sessions (22 play sessions and 18 snack sessions with a total of 400 trials, 220 trials in play sessions and 180 trials in snack sessions). Henry showed an increased percentage of correct independent



responses during intervention sessions (i.e., sessions 5 through 40), but the rate of acquisition failed to stabilize. In VOCA training sessions 5 through 40, Henry's independent requesting responses increased from 0% to 50% in training sessions with the device with digitized speech output and 0% to 10% in training sessions with the device with synthetic speech output. Overall, visual inspection of the data-paths for digitized speech output vs synthetic speech output reveals differences in the slope level and trend between two speech outputs and demonstrates that with digitized speech output Henry produced a higher percentage of independent responses. Using the original mastery criteria of requesting at 60% or a higher percentage of independent responses for three consecutive sessions, it was determined that Henry had not fully mastered the skill to make a basic level communicative request by using the voice output device. Due to some failure in maintaining the acquired skill repertoire, and some health-related and other ethical reasons, intervention sessions with Henry were terminated prior to him reaching the preset mastery (60% over 3 sessions) over the targeted skill.

Figure 2 illustrates John's rate of skill acquisition across baseline and intervention probe sessions. John participated in a total of 14 sessions (i.e., 8 play sessions and 6 snack sessions) and in a total of 126 trials (i.e., 55 snack trials and 71 play trials). Even though he accidentally emitted one correct response during baseline, in the intervention sessions 5 through 14, John's skill acquisition was rapid and his independent response rate increased from 10% to 100%. Divergence in data-paths for digitized and synthetic speech output was observed with digitized speech output producing a higher percentage of independent requesting responses.

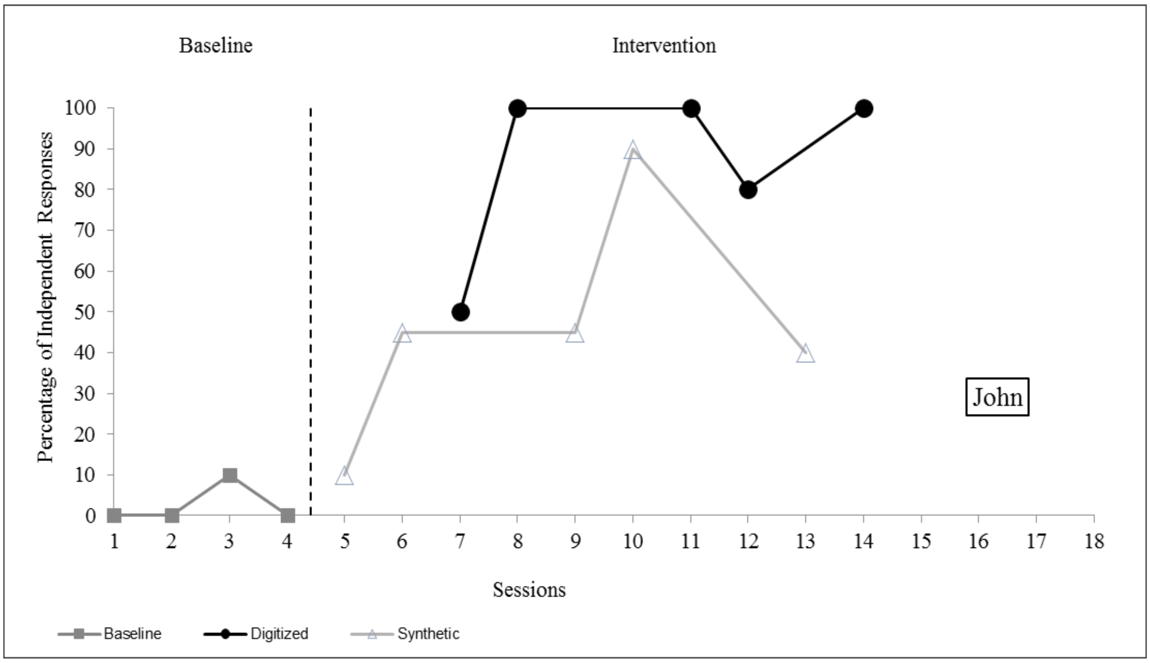


Figure 2: Percentage of Independent Responses across Baseline and Intervention for John

Overall findings obtained from this study demonstrated differences in the rate of acquisition between Henry and John and both participants differed in terms of their skill acquisition across speech outputs with both participants producing higher percent of independent responses in digitized speech output condition.

Even though both participants produced a higher percentage of independent responses in the digitized speech output condition, it is difficult to draw a firm conclusion to claim that one speech output is superior to another speech output to teach basic level communicative requests using VOCA because of the following reasons. First, this study is limited in terms of its generalizability to a larger number of children diagnosed with ASD because the total number of participants (n=2) and there were no female participants. Generalizability is also limited because there were individual differences in terms of the devices used, and the differences in terms of the therapists who provided the intervention and the voices we utilized to produce digitized voice tags.

Despite the limitations, this study has important implications. First, by individualizing the AAC training provided using VOCA and speech generating devices based on specific components like speech outputs, we can maximize success and minimize frustrations. For parents, special educators, speech-language pathologists and other related service professionals, this study provides new information about a specific component (e.g., speech outputs), and future studies can investigate individual cognitive characteristics (e.g., memory, auditory discrimination, etc.) and establish the role of speech outputs in supporting children with ASD in acquiring targeted skill. Additionally, studies should also investigate children's preference for a specific speech output in order to ascertain the role of preferred speech outputs in skill acquisition, but this study suggests that it would be important to include preference testing during the initial AAC evaluation.

CONCLUSION

The overall results obtained from this study suggest that with the support of proper prompting techniques and instructional strategies, children diagnosed with ASD and who do not have spoken language can learn to use VOCAs at their own pace. Choosing any type of augmentative system in general and VOCAs and SGDs in particular, should be based on children's learning preferences and abilities, along with their physical and cognitive characteristics at any given point. This study demonstrates that the immediate verbal feedback that is present when using a voice output switch may enhance responses when compared PECS or selecting icons on a static display, which do not provide immediate verbal feedback. It is worth considering the implications of the results of the present study when selecting a communication system.

Generally, teachers and other practitioners select an appropriate SGD based on symbol displays, durability and the portability of the device, available training and technical assistance, and funding resources. Speech language pathologists and professionals who complete AAC evaluations investigate many aspects of the devices, and they also request trial periods with desired devices prior to purchase of SGDs. There is a required 30-day trial period by Medicaid prior to funding the requested device. There is also a requirement to prove that more basic technology, such as sign language, PECS, and lower tech AAC devices are not appropriate for the potential AAC user. The preliminary outcomes obtained from this study, provides data that speech output is an important component that plays a significant role in contributing to the success of the intervention. Special educators and speech-language pathologists who consider recommending SGDs for children with autism should take speech outputs into their consideration when making this important and potentially costly decision. However, it should be noted that decision making related to selection of a specific speech output is a complex and challenging endeavor and requires careful assessment and individualization. Although the theoretical arguments for both and against digitized and synthetic speech outputs exist, there are no comparative research studies currently available to inform clinical practice in this area. Future studies should develop guidelines and protocols for decision making that are based on sound research.

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