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The Effect of Responsiveness to Speech-Generating Device Input on Spoken Language in Children with Autism Spectrum Disorder who are Minimally Verbal

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Abstract

The use of speech-generating devices (SGD) in early interventions for children with autism spectrum disorder (ASD) can improve communication and spoken language outcomes (Muharib & Alzrayer, 2018). The purpose of this study was to describe children's responsiveness to SGD input modeled by a social partner during adult-child play interactions over a 24-week intervention trial and explore the effect of that responsiveness on spoken language growth. This secondary analysis consisted of 31 children with less than 20 functional words at study entry who received a blended behavioral intervention (JASPER+EMT) as part of a randomized controlled trial (Kasari et al., 2014). Significant improvements were seen in rate of responsiveness to both adult SGD models and adult natural speech models; only rate of responsiveness to SGD models at entry was a significant predictor of frequency of commenting and was a more robust predictor of number of different words post-intervention. Lastly, at entry, children with more joint attention and language responded to SGD models at significantly higher rates. Attention and responsiveness to SGD output may be important mechanisms of language growth and children who have more joint attention skills may particularly benefit from use of an SGD.

Keywords

Augmentative and alternative communication; Autism spectrum disorder; Language; Minimally-verbal; Speech-generating device

Expressive language delays often present in the first years of life in children with autism spectrum disorder (ASD; Lord et al., 2012). Current interventions can successfully improve the language trajectories of individuals with ASD (Kasari et al., 2008; Smith &

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Iadarola, 2015). This is significant, as strong expressive language skills during preschool predict positive social communication and adaptive outcomes in adolescence and adulthood (Anderson et al., 2009; McGovern & Sigman, 2005). Despite these positive trajectories for some individuals, there is a subgroup of around 30% of children with ASD who do not develop fluid, functional language by the age of 5. These children are often referred to as being minimally verbal (Tager-Flusberg, & Kasari, 2013). The vast majority of intervention research has focused on young children with ASD (toddlers and preschoolers) with fewer interventions developed for and tested with older children who are minimally verbal; thus, much less is known about how to teach spoken language skills to children who are older than 5-years and who are minimally verbal (Brignell et al., 2018; French & Kennedy, 2018; Sandbank et al., 2020).

Interventions aimed at this subgroup have had the most success with children who are between 5- and 7-years-old and when targeting requesting language (Pickett et al., 2009; Logan et al, 2017). A positive development in interventions for this subgroup has been the focus on speech-generating devices (SGD) to facilitate the acquisition of spoken language (Schlosser & Koul, 2015). SGDs display graphical symbols that produce synthesized or recorded speech outputs when the symbol is pressed. These devices have grown in popularity both in clinical practice and in research trials (Lorah et al., 2015; Schlosser & Koul, 2015; Van der Meer & Rispoli, 2010). The focus of a number of very recent trials in young children has been on evaluating the effects of aided augmentative and alternative communication (AAC), such as an SGD, on the production of vocal skills (Alzrayer et al., 2021; Bishop et al., 2020; Gevarter et al., 2016).

In other clinical populations such as individuals with childhood apraxia of speech or developmental disabilities more broadly, aided AAC systems (including SGDs) have been found to be effective in improving children’s vocabulary use (Allen et al., 2017) and other expressive communication modalities (Biggs et al., 2018). However, one limitation of this body of evidence is that little attention has been given to the influence of pre-treatment characteristics such as receptive language and symbolic understanding on SGD use and the benefit provided by an SGD (Allen et al., 2017). There is evidence that pre-treatment cognitive ability, joint attention, language use and comprehension, and imitation skills may be predictive of progress in children who use aided AAC systems (Sievers et al., 2018).

Overall, most studies examining SGD use specifically in children with ASD report positive outcomes (i.e., 86%; Van der Meer & Rispoli, 2010), which include children learning to successfully operate SGDs (Durand, 1999; Franco et al., 2009), preferring devices over other communication methods such as picture exchange systems (Sigafoos et al., 2005), using devices to communicate for the purpose of requesting (Olive et al., 2007), and improving vocal speech production more broadly (Schlosser & Wendt, 2008). While these interventions show promise, they also have a number of limitations. Most of these studies were single-case experimental designs without systematic replication, which limits their external validity (Horner et al., 2005; Van Der Meer & Rispoli, 2010). Additionally, protocols and teaching techniques utilized varied greatly across SGD studies, making it difficult for clinicians and families to extrapolate a clear message about the effectiveness of SGD interventions for their children with ASD. Furthermore, they have primarily targeted requesting behaviors.

Requesting behaviors represent one function of language and are important for making sure children's needs and wants are met but other functions, like commenting, may be more challenging to teach (Paparella et al., 2011). Interventions less often focus on developing spontaneous social language, used for the function of commenting, or question asking; therefore, improving social language in children who are minimally verbal remains a high priority for SGD intervention researchers (Pickett et al., 2009).

One randomized controlled trial found that minimally verbal children with ASD between 5 and 8 years of age gained spoken language (including commenting language) faster if they received an SGD in the context of an evidence-based social communication intervention rather than the same intervention without the SGD (Kasari et al., 2014). The behavioral intervention in that trial was a combination of the Joint Attention, Symbolic Play, Engagement and Regulation (JASPER) intervention and Enhanced Milieu Teaching (EMT), which will be referred to as JASPER+EMT. These interventions focus on improving children's spontaneous social communication through play routines and create opportunities to teach new skills through systematic prompting and milieu episodes. The interventions are discussed in more detail in the sections that follow. Of note, children also had more improvements in spoken language if they received aided input from an SGD from the beginning, rather than delaying introduction to the SGD 3-months into treatment.

While these are intriguing findings, it was not clear from the original data *why* the SGD led to more spoken language or for whom the SGD was most beneficial. Hypotheses suggest that children may benefit from the additional visual cues afforded by the SGD, the pairing of visual and auditory cues that remain the same each time they are heard (unlike the human voice that can change intonation), and the motor action of pressing the icon along with the visual and auditory cues (Blischak et al., 2003; Schlosser, 2003; Schlosser & Blischak, 2001). The data from the previous trial (Kasari et al., 2014) showed that when the therapists' paired natural speech along with models on the SGD (additional visual and auditory cues), the child may or may not have responded to that input with communication (spoken or SGD) of their own. Indeed, children's device use was limited – only 10% of child communication initiations and responses were solely using the SGD (Kasari et al., 2014); thus, a much greater percentage of child initiations and responses were via spoken language with or without the pairing of the SGD (Kasari et al., 2014).

Because children's device use was limited and there was variability in response to input from the SGD in Kasari et al (2014), it is important to further unpack the role of language input from the SGD (Allen et al., 2017). From the previous study (Kasari et al., 2014), it remains unclear whether children were more likely to speak after the adult's natural speech model or after the adult's natural speech augmented by additional input from the SGD. While the children randomized to the SGD condition of the behavioral intervention (JASPER+EMT+SGD) produced more socially communicative utterances (a combination of spoken language involving requesting and joint attention language and gestures), it is not known whether the adult input provided on the SGD was a significant intervention element. There is some preliminary evidence in the literature that the language input that children receive is an important element in the success of augmented intervention for non-speaking toddlers (Binger & Light, 2007; Romski et al., 2010).

The aims of the current study were to examine dyadic interactions between children who were minimally verbal and their therapists to (a) better understand if they responded (e.g., imitated or commented) at greater rates to augmented language (i.e., natural speech + SGD) from adults compared to natural speech only from adults, (b) determine whether rate of response to natural or augmented language at entry was related to language growth during the intervention and lastly, and (c) characterize those who responded to the device at higher rates at entry in order to better understand which children appeared to most benefit from access to the SGD.

Method

This study analyzed a subset of children who were part of a previously reported randomized controlled trial. That trial tested the effects of a blended behavioral and developmental intervention and the inclusion of an SGD on language of minimally verbal, school-aged children with ASD (Kasari et al., 2014). With the exception of the coding of video clips from the intervention sessions, no new data were collected for the current study beyond what was collected in the original RCT. The current study used a correlational design and was an extension of the previous trial and therefore used the same data collection procedures.

Participants

This study analyzed a subset of 31 children, 25 males and six females, with a mean age of 6.44 years (*SD* = 1.23) and an average number of different words observed in a naturalistic language sample of 17.23 (*SD*=16.44). See Table 1 for more information. The original randomized trial, which took place in university clinics, included 61 participants, with a mean age of 6.31 years (*SD*=1.16). To be included in the secondary analysis, the children must have been in the treatment arm that was given access to the SGD from the start of the study. The children were recruited across three sites, each within large metropolitan areas. Inclusion criteria in the original study were (a) must have a confirmed diagnosis of ASD using the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000), (b) must be between 5- and 8-years-old at entry into the study, (c) must use fewer than 20 spontaneous words during the Natural Language Sample (NLS), (d) must have had received 2-years of behavioral interventions prior to entry, and (e) must have had at least a 24 months' receptive language age. Exclusion criteria were (a) a serious medical condition, (b) deafness, (c) motor disability, (d) seizures, and (e) proficient use of an SGD. Informed consent was obtained from all participating families.

Research Design

The SGD intervention was embedded within a Sequential Multiple Assignment Randomized Trial (SMART) that involved two separate treatment phases that each lasted 12 weeks. In Phase 1 randomization, half of the children received a blended developmental/behavioral intervention (JASPER+EMT), and half received that same intervention with the addition of an SGD (JASPER+EMT+SGD). In Phase 2, early-responders remained in the same treatment for an additional 12-weeks whereas slow-responders in the JASPER+EMT+SGD were given increased dose and slow-responders in the JASPER+EMT condition were re-randomized to increased dose or access to an SGD (Kasari et al 2014). The current study is a correlational analysis of those originally randomized to the JASPER+EMT+SGD condition, this design was chosen because of our specific interest in children who had access to an SGD throughout the entire trial. The research was approved by each site's Institutional Review Board.

Researchers—After being randomized, children were assigned a therapist who had achieved a treatment fidelity rating of greater than 90% prior to seeing study participants; their backgrounds included speech therapy, special education, and child psychology. Assessments were administered and coded by staff who were blind to the treatment condition and hypotheses of the study and who were trained to fidelity of over 90% on administration of all assessments.

The first author initiated the idea for the current study, coded the data with support from research assistants, and conducted data management. The first and second authors analyzed the data with the co-authors. The first, second, and senior authors wrote the manuscript, with edits and contributions from all other authors.

Materials and Measures

Autism Diagnostic Observation Scale (ADOS; Lord et al., 2000)—The ADOS is a play-based standardized assessment administered by trained and reliable assessors and coded for a number of behaviors that are related to ASD. The ADOS has been shown to have strong psychometric properties, particularly in research contexts (Lebersfeld et al., 2021). Each of the participants included in the analysis completed Module 1 of the ADOS, which is specifically designed for children with little to no language.

Leiter International Performance Scale-Revised (Leiter-R; Roid & Miller, 1997)—The Leiter is a standardized assessment of non-verbal cognitive ability that can be used with a wide age range of children (2-20 years) and takes about 45 min to complete. It includes four subscales, reasoning, visualization, memory, and attention, which are used to obtain the non-verbal Brief IQ (BIQ). The Leiter has been explicitly validated for use in children with autism and is particularly useful for this study population as neither the assessor nor child are required to speak at any point (Tsatsanis et al., 2003).

Natural Language Sample (NLS; Kaiser & Roberts, 2013)—The NLS is a semi-structured observational assessment in which an adult and child engage around a standardized set of toys. The basic procedure involves the presentation of a number of different engaging toy sets (e.g., blocks and play food). The adult responds to all communication attempts (e.g., says *ball* if the child says *ball*) but never models new. This context allows the spontaneous expressive language of children to be estimated. All NLS assessments lasted exactly 20 min. NLSs are sensitive to change over time in populations of children with neurodevelopmental disabilities (Barokova & Tager-Flusberg, 2018) and avoid potential practice effects common of standardized assessments (Abbeduto et al., 2020).

Early Social Communication Scales (ESCS; Mundy et al., 2003)—The ESCS is a structured observational assessment that is used to measure children's early communication skills. The assessment is approximately 15-min long, uses a standard set of toys, and provides systematic opportunities for children to initiate both joint attention and requesting communication skills. For the purposes of this study, children's frequency of initiations of joint attention (IJA) was coded from the administration of the ESCS. IJA refers to children's use of gestures with and without eye-contact and language to share an object or event. The ESCS has been used as the outcome of a number of clinical trials of young children with autism and is a valid measure of early communicative abilities (Hansen et al., 2018).

Structured Play Assessment (SPA; Ungerer & Sigman, 1981)—The SPA is a semi-structured measure of children's play skills. Children's total types of play is calculated from the SPA. The types of play variable refers to the number of different spontaneous play acts within a level of play that the child demonstrated during the assessment. For example, putting a doll on a chair is one play act and brushing the doll's hair is another, both play acts occur within the "child as agent" level of play. Each specific play acts can only be counted towards total types once. Symbolic play measured through the SPA has been associated with later expressive and receptive language (Chang et al., 2018).

NLS Coding during Intervention Sessions—Ten-minute video segments of the recorded 60-minute intervention sessions were coded following the same conventions as the NLS. These clips were from Minute 2 to Minute 12 of the sessions in order to allow a few minutes for the child to transition and settle into the session. Two, 10-minute sessions were taken from entry (Week 1), midpoint (Week 12) and exit (Week 24). On occasion two sessions were not available in these weeks due to missing or corrupted videos. In these cases, the next weeks sessions were used (e.g., Week 2 for the entry timepoint).

Procedures

Data Collection—Assessments were administered prior to the first intervention session (entry), at 12-weeks (midpoint) and following the final intervention session at 24-weeks (exit). Following the completion of the treatment phase, data from intervention sessions and assessments were coded.

Natural Language Sample (NLS).: NLS videos were transcribed using the Systematic Analysis of Language Transcripts (SALT; Miller & Iglesias, 2012). The transcripts were coded for both natural speech and augmented communication using the SGD. Spontaneous child language was coded for its function, such as requesting or commenting. Four variables were produced: (a) total number of spontaneous comments (Comments); (b) total number of spontaneous requests (Requests); (c) total spontaneous communicative utterances (Total Language/TSCU), which included Comments and Requests (including protests) and excluded scripted and nonsocial utterances; and (d) number of different word roots (Number of Words/NDWR). Spontaneous here is operationalized as language that was not prompted or elicited by the adult, for example, language not in response to a question or time delay. Also not counted as spontaneous were scripted utterances such as rote recitation of lyrics from a song.

Intervention Transcripts.: Six sessions (two entry, two midpoint, and two exit) were coded for each child. Each instance of adult language modeling that was contingent with a play act was classified as either natural speech (NS) only or augmented (NS+SGD). This generated a frequency count of the amount of language input that was provided to the child during the session, coded to indicate whether the instances of input were adult natural speech only models or NS+SGD models. Next, the child's responses during the 5 s following the adult language models were coded. Two child codes were possible: (a) a response, including functional and contingent natural speech and/or SGD use; or (b) no response. Responses could include imitations of adult language and approximations of words such as responding with *buh* [natural speech] if the adult said "*block*" [synthesized speech] on the SGD while playing with blocks. Examples of non-functional and non-contingent responses included stereotypic or repetitive language (e.g., repeating a word prior to the adult model and continued to say the same word after) or language not directed towards the adult (i.e., singing a song after an adult language model). Next, the percentage of child responses to each type of adult model was calculated. This was done by dividing the number of child responses to each type of model (i.e., NS only or NS+SGD models) by the number of adult models in each respective category. The result was two proportions, the proportion of response to adult NS only and to NS+SGD models. The two sessions at each time point were averaged to create a single proportion at entry, midpoint, and exit.

Intervention Sessions—The Joint Attention Symbolic Play Engagement and Regulation (JASPER; Kasari et al., 2010) intervention is a targeted early social communication intervention that focuses on children's engagement, play and communicative gestures through play routines and strategies such as modeling new language and play and following children's interests and motivations. Enhanced Milieu Teaching (EMT; Hemmeter & Kaiser, 1994) is an early language intervention that takes place in natural contexts such as play and focuses on responding, expanding children's language while arranging the environment to elicit and prompt for spoken language.

JASPER+EMT intervention sessions targeted joint attention, symbolic play, and spontaneous language within the context of child led play routines. These routines help to facilitate children's engagement and provide opportunities to scaffold children towards developmentally appropriate communication and play targets. For example, if the child only spoke in word approximations the adult would label clear and salient actions with one- to two-word phrases to expose the child to appropriate and contextually relevant language (e.g., child put a block onto a tower they were building together and said, *Block on!* [natural speech]. Additional strategies used include environmental manipulations to elicit language and prompting strategies such as time delays (pausing at motivating moments in the play routines).

Children were given free access to the SGD during each play session, but adults were also required to pair at least half of their natural speech with language on the device (e.g., adult said, *Block on* [natural speech] while simultaneously pressing *BLOCK* [graphic symbol] on the device). The adult paused after their utterances to give the child time to reply or take a turn and to maintain a balance of turns. For low-rate talkers (less than one utterance per min), adults modeled on average up to five utterances per min. For moderate rate talkers (less than three utterances per min) adults modeled on average up to three utterances per min. Adults also used prompting strategies such as time delays to elicit device use during motivating moments in the play routines. Device use was not required of the children, but the adult continued to model its appropriate use even if children were not using the device. The SGDs used in the study were either iPad[1] or DynaVox[2] devices and typically had approximately 12 symbols displayed on a page, though this could vary based on needs of the child. The protocols in the current study align with evidence-based clinical recommendations on the density (Binger & Light, 2007) and latency of communication input for SGD devices (Drager et al., 2006). For full descriptions of the JASPER and EMT interventions please refer to Kasari, et al. (2014) and Kaiser et al. (2000).

Reliability Measures—The overall NLS intra-rater reliability was calculated by averaging the exact-agreement ratings across each individual code. Agreement in the original RCT across the three coders was very high (88.1%). For the new intervention transcript codes, intraclass correlation coefficients calculated separately for adult's language model codes and children's response codes. The average ICC was .989 for adult natural speech models, .99 for adult natural speech models paired with augmented speech, .988 for natural speech responses and .966 for non-responses.

Treatment and Procedural Fidelity—All interventionists achieved greater than 90% fidelity prior to working with children in the study. All NLS, ESCS, and SPA were administered by staff who were trained to fidelity of over 90% on a pre-specified administration checklist.

Data Analysis—To answer the primary research question, a linear mixed effects model with a random intercept was fit to the data to determine whether the proportion of response varied differentially over time (entry, midpoint and exit) as a function of adult language model type. Four separate ANCOVA models were fit to examine the influence of the independent variables (i.e., child response to NS only and NS+SGD models at entry) on post-intervention scores across the four language outcomes of interest: Comments, Requests, Number of Words, and Total Language. The models controlled for cognitive ability (Brief IQ scores), site and entry scores of each respective outcome (e.g., entry Requests when predicting exit Requests).

The next step involved investigating whether particular child characteristics were associated with response to adult NS and NS+SGD models during the first intervention sessions. The relationship of the variables at entry (prior to direct intervention) was of interest in order to better understand the characteristics of the children who would benefit from access to an SGD with little explicit support. Two multiple linear regression models were used to examine which child characteristics were related to rate of response to adult NS and to NS+SGD models. The independent variables in both analyses were child frequency of IJA, cognitive ability (BIQ), play skills (total play types) and Total Language.

[1]The iPad is a product of Apple Computers Inc., Cupertino, CA. www.apple.com
[2]Dynavox is a product of Tobii Dynavox, https://us.tobiidynavox.com/

Results

Response Rate

On average the children received 38.00 (*SD*= 20.96) NS and 19.88 (*SD*= 12.90) NS+SGD models across the 10-min sessions. At entry, the mean response rate to NS models was 28% (*SD*=14%), increased to 37% (13%) by midpoint and to 38% (*SD*=16%) by exit. The mean response to NS+SGD models was 25% (*SD*=16%) at entry, increased to 37% (19%) by midpoint and was 35% (*SD*=23%) by exit. There was a significant effect of time from entry to midpoint X^2 (1, 31) = 17.10, p <.001 and from entry to exit, X^2 (1, 31) = 12.01, p < .001. The main effect of adult model type and the adult model type by time interaction were non-significant (p >.05). These results indicate that the proportion of response to both models (NS only and NS+SGD) increased from entry to midpoint and the gains maintained at exit, but the rate of increase over time did not differ between the two types of adult language models.

Relationship Between Response Rates and Language Trajectories

Response rate at entry to NS+SGD models was significantly related to post intervention Comments (p=.002) and Number of Words (p<.001). Response rate to NS-only models was not related to post intervention Comments (p=.33) but was related to Number of Words (p=.04). Neither children's response rates to NS+SGD nor NS only models were related to post intervention Total Language (p=.06 and p=.94, respectively) or Requests (p=.52 and p=.38, respectively). See Tables 2-5 for full model summaries.

Predictors of Response Rate

The overall regression model was significant for NS+SGD, F(4,18) =6.59, p=.002. Total frequency of IJA and Total Language were related to response to NS+SGD models (p=.03 and p=.04, respectively). Children with higher IJA and more communicative language at study entry responded at greater frequency to adult NS+SGD models during the early intervention sessions. The overall regression model was not significant for response to NS models alone, F(4, 20) p= .97, p=.44. Additionally, none of the predictors, BIQ, Total Language, play and IJA, were related to response to NS models (all p>.10).

Discussion

There have been a growing number of studies evaluating the efficacy of SGD use with children with ASD (Fletcher-Watson et al., 2015; Gilroy et al., 2018; Lorah et al, 2015; Thiemann-Bourque et al., 2018; see Schlosser & Koul, 2015 for a scoping review), apraxia (Ballard et al., 2015), and other developmental language disorders (Ganz et al., 2017; Romski et al., 2010). Despite the amount of research evaluating their efficacy, there has been a notable lack of empirical research exploring the role of SGDs within behavioral therapies for children with ASD , specifically, which components are necessary and sufficient for spoken language growth. This is largely a result of inconsistent reporting of intervention protocols, the large number of varied protocols that exist, and varied terminology across those protocols (Allen et al., 2017).

A number of theoretical mechanisms of expressive language growth from SGD use have been proposed. These mechanisms can broadly be classified as those related to children's speech output (the language that children produce) or speech input (what children hear and see). Examples of mechanisms related to speech input include the consistency of the presentation of the device (i.e., input sounds the same each time with no changes in vocal intonation or volume), the increased quantity of language models (i.e., more input), and the pairing of the speech with a corresponding visual representation (Binger & Light, 2007; Blischak et al., 2003; Drager et al., 2006). This current, secondary exploratory analysis specifically emphasized the role of language input (the language that children hear) and children's attention to that input operationalized through responsiveness in the context of a social communication intervention for children with ASD.

First, on average, children's responsiveness to adult bids improved over the course of the intervention period; however the rate of this increase did not depend on the type of model (NS only or NS+SGD). The lack of difference in response to the types of model may reflect that the behavioral component (i.e., JASPER+EMT) of the intervention likely drove the observed changes in overall responsiveness. Although the operationalization in the current study is slightly different, this finding is consistent with other clinical trials showing the effectiveness of behavioral interventions on children's social engagement and communicative capacity (Kasari et al., 2006, 2015). High-quality behavioral interventions may augment the observed benefits of using SGD to teach social communication skills to young children with autism.

Next, controlling for cognitive ability and entry language levels, children's responsiveness to utterances produced on the SGD during the first intervention sessions was strongly associated with improvement in spontaneous comments and a larger vocabulary. There was no association between responsiveness to utterances produced on the device during baseline intervention sessions with later spontaneous requests or total language; total language did increase over the course of the study. Although the JASPER+ EMT intervention encourages all communication, it explicitly targeted commenting language and language diversity (see Kasari et al., 2014). The fact that improvement in commenting language and vocabulary were most strongly associated with responses to NS+SGD models supports that this approach was successful in encouraging this type of language development. Specifically, interventionists were trained to model commenting language using a diverse vocabulary, a technique shown to be effective in a recent review (Sennott et al., 2016). The language input from the SGD may have been particularly potent in this behavioral intervention due to the emphasis on turn-taking and shared engagement within play routines. The idea of turn-taking (both an adult and child use the device concurrently) within routines has been used as a method of instruction mostly within the context of book-reading paradigms (Binger et al., 2008; Nunes & Hanline, 2007). Nunes and Hanline (2007) measured both children's responses (imitated and generative) across AAC, verbal, and gestures and found large increases in AAC responses within play routines and moderate gains in gestural and vocal responses. While the original study (Kasari et al., 2014) demonstrated that access to SGDs improved social language development, the current study adds to the literature by demonstrating an association between improvements in children's vocabulary and commenting and adults' comments on the SGD during the intervention.

The predictive strength of responsiveness to NS+SGD models over and above NS models alone has implications for the use of SGD within behavioral therapies. The language input children are exposed to was related to expressive language outcomes, but only when that language was paired with SGD use and when children were responsive to the input. The device itself did not make children more responsive (as evidenced by the comparable rates of response to NS and NS+SGD models) but those who were responsive to the SGD from the beginning of intervention saw more positive outcomes. They may have been more attuned to the input from the device right from the beginning and thus benefitted more from SGD access.

Lastly, characteristics of the children who responded to the device at higher rates prior to intervention were explored. At entry, more frequent initiations of joint attention and more language were related to responsiveness to the NS+SGD models while none of the predictors (language, joint attention, cognitive ability, or play skills) were related to NS models. One potential explanation is that the ability to reference the device, toys, and social partner simultaneously requires a high level of joint attention and some baseline language abilities. As a result, those children with little joint attention or language skills at entry likely needed more support to benefit from access to the device, while those with higher levels of joint attention benefited from immediate access to an SGD. Overall, these findings further support the idea that a sub-group of children who are minimally verbal with ASD may be processing language input differently than other children (Bavin et al., 2014) and that input from the device may be particularly suited to their unique learning style.

Clinical Implications

Though these data should be taken as preliminary due to the correlational nature of the analyses and small sample size, they provide preliminary evidence that for some children little explicit training is needed to benefit from access to an SGD in a clinical setting. Furthermore, there may be some benefit for including SGD within behavioral interventions even if the child is not using the device to produce speech themselves. Because there were increases in responsiveness to adult speech input, behavioral interventions such as JASPER and EMT may be important supplements to other established interventions that directly teach children to use SGD. Lastly, for those children who are not responding initially to the inclusion of an SGD within their sessions, targeting non-verbal communication skills like initiations of joint attention, may improve their ability to engage successfully with an SGD.

Limitations and Future Directions

Given the relatively small sample and the correlation nature of the study design, these results should be considered exploratory. Furthermore, while the coding scheme for children's responsiveness to adult utterances on the SGD was highly reliable, validation of the coding scheme with a second and larger sample of school-aged minimally verbal children with ASD is still needed. Furthermore, the average receptive language age equivalent scores for the sample was approximately 2 years-old. Prior reviews have emphasized the importance of receptive language to SGD device use (Barker et al., 2019). In order to promote generalizability, future studies should seek to replicate these findings in a sample with a wider range of receptive language ability. It will also be important in future studies to evaluate how other interventions specifically developed at verbal language can be supplemented by the inclusion of an SGD.

Conclusion

The findings of the current study suggest that some minimally verbal children with ASD may benefit from the addition of an SGD into behavioral interventions targeting spoken language outcomes. Children with more initiations of joint attention and more words to begin with, appeared to benefit the most, although it should be noted that all children had little spoken language at entry. Further research is needed to explore the mechanisms of SGD and for whom these interventions are best suited.

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Table 1

Participant Demographics at Baseline (N= 31)

Characteristics	%	*n*
Sex		
Male	79%	25
Female	21%	6
Race		
White	48%	15
African American	25%	8
Asian American	16%	5
Hispanic	7%	2
Other	4%	1
Mother's education		
High school or less	8%	3
College	27%	8
Graduate school	65%	20
Site		
UCLA	39%	12
Vanderbilt University	32%	10
Kennedy Krieger Institute	29%	9
Age (years)	6.44 (1.23)	

Table 2

Predicting Comments at Study Exit

Model	Estimate	Standardized slope	Standard error	*t* value	*p* (>|t|)
Intercept	−46.04	0.000	13.91	−3.31	0.005
Proportion of response to natural speech + SGD	94.36	0.84	24.42	3.86	0.002
Site: UCLA	11.34	0.33	7.72	1.47	0.163
Site: Vanderbilt	−2.22	−0.06	7.99	−0.28	0.785
Proportion of response to natural speech models	−26.73	−0.23	26.33	−1.02	0.326
Total comments at entry	−0.51	−0.10	0.97	−0.52	0.608
Leiter Brief IQ	0.60	0.63	0.18	3.38	0.004

Note. Reference group for site is Kennedy Krieger Institute.

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Table 3

Predicting Number of Words at Study Exit

Model	Estimate	Standardized slope	Standard error	*t* value	*p* (>|t|)
Intercept	−81.52	0.000	16.24	−5.02	0.0002
Proportion of response to natural speech + SGD	157.24	0.94	33.99	4.63	0.0003
Site: UCLA	27.88	0.55	8.10	3.44	0.0036
Site: Vanderbilt	12.71	0.24	6.65	1.90	0.076
Proportion of response to natural speech models	−70.97	−0.41	31.32	−2.27	0.039
Entry: Number of Words	−0.04	−0.02	0.33	−0.14	0.892
Leiter Brief IQ	1.12	0.79	0.24	4.58	0.0004

Note. Reference group for site is Kennedy Krieger Institute

Table 4

Predicting Total Language at Study Exit

Model	Estimate	Standardized Slope	Standard error	*t* value	*p* (>|t|)
Intercept	−18.99	0.000	23.22	−0.82	0.426
Proportion of response to natural speech + SGD	111.98	0.55	56.24	1.99	0.065
Site: UCLA	22.47	0.36	11.67	1.93	0.073
Site: Vanderbilt	1.07	0.02	11.55	0.09	0.927
Leiter brief IQ	0.25	0.14	0.36	0.69	0.504
Proportion of response to natural speech models	−3.90	−0.02	49.22	−0.08	0.938
Entry: Total language	0.54	0.34	0.34	1.57	0.138

Note. Reference group for site is Kennedy Krieger Institute

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Table 5

Predicting Requests at Study Exit

Model	Estimate	Standardized slope	Standard error	*t* value	*p* (>|t|)
Intercept	9.45	0.000	13.86	0.68	0.505
Proportion of response to natural speech + SGD	−19.18	−0.25	29.07	−0.66	0.519
Site: UCLA	11.24	0.48	7.47	1.50	0.153
Site: Vanderbilt	8.39	0.35	7.37	1.14	0.273
Proportion of response to natural speech models	26.43	0.33	29.47	0.90	0.384
Entry: Requests	0.38	0.33	0.35	1.08	0.296
Leiter Brief IQ	−0.11	−0.17	0.19	−0.58	0.573

Note. Reference group for site is Kennedy Krieger Institute

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Table 6

Predicting Response to Natural Speech +SGD Models

Model	Estimate	Standardized slope	Standard error	*t* value	*p* (>|t|)
Intercept	0.251	0.000	0.097	2.582	0.018
Leiter brief IQ	−0.002	−0.239	0.002	−1.392	0.181
Total language	0.005	0.58	0.001	3.347	0.004
Total initiations of joint attention	0.011	0.539	0.004	2.346	0.030
Diversity of play	−0.006	−0.365	0.005	−1.597	0.128

Table 7

Predicting Response to Natural Speech Models

Model	Estimate	Standardized slope	Standard error	*t* value	*p* (>|t|)
Intercept	0.121	0.000	0.117	1.034	0.313
Leiter brief IQ	0.001	0.18	0.002	0.752	0.461
Total language	0.009	0.12	0.002	0.496	0.625
Total initiations of joint attention	0.004	0.22	0.006	0.108	0.487
Diversity of play	0.0004	0.03	0.005	0.708	0.915