An evaluation of speech production in two boys with neurodevelopmental disorders who received communication intervention with a speech-generating device

Laura Roche a, Jeff Sigafoos a, Giulio E. Lanciai b, Mark F. O’Reilly c, Ralf W. Schlosser d, Michelle Stevens a, Larah van der Meer a, Donna Achmadi a, Debora Kagogara a, Ruth James b, Amarie Carnett a, Flaviu Hodis a, Vanessa A. Green a, Dean Sutherland e, Russell Lang f, Mandy Rispoli g, Wendy Machalicek h, Peter B. Marschik i

a School of Education, Victoria University of Wellington, Wellington, New Zealand  
b Department of Neuroscience and Sense Organs, University of Bari, Bari, Italy  
c Meadows Center for Preventing Educational Risk, The University of Texas at Austin, Austin, TX, USA  
d Department of Speech-Language Pathology and Audiology, Northeastern University, Boston, MA, USA  
e School of Health Sciences, College of Education, University of Canterbury, Christchurch, New Zealand  
f Clinic for Autism Research, Evaluation, and Support, Texas State University, San Marcos, TX, USA  
g Department of Educational Psychology, Texas A & M University, College Station, TX, USA  
h Department of Special Education and Clinical Sciences, University of Oregon, Eugene, OR, USA  
i Institute of Physiology, Research Unit ISDN-Interdisciplinary Developmental Neuroscience, Center for Physiological Medicine, Medical University of Graz, Graz, Austria

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A B S T R A C T

Background: Children with neurodevelopmental disorders often present with little or no speech. Augmentative and alternative communication (AAC) aims to promote functional communication using non-speech modes, but it might also influence natural speech production.

Method: To investigate this possibility, we provided AAC intervention to two boys with neurodevelopmental disorders and severe communication impairment. Intervention focused on teaching the boys to use a tablet computer-based speech-generating device (SGD) to request preferred stimuli. During SGD intervention, both boys began to utter relevant single words. In an effort to induce more speech, and investigate the relation between SGD availability and natural speech production, the SGD was removed during some requesting opportunities.

Results: With intervention, both participants learned to use the SGD to request preferred stimuli. After learning to use the SGD, both participants began to respond more frequently with natural speech when the SGD was removed.

Conclusion: The results suggest that a rehabilitation program involving initial SGD intervention, followed by subsequent withdrawal of the SGD, might increase the frequency of natural speech production in some children with neurodevelopmental disorders. This effect could be an example of response generalization.

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1. Introduction

Many children with neurodevelopmental disorders have limited natural speech production (Lang et al., 2010; Matson et al., 2012). These children are candidates for augmentative and alternative communication intervention (AAC). AAC intervention aims to provide the person with an effective non-speech mode of communication (Beukelman and Mirenda, 2013; Johnston et al., 2012). One increasingly popular AAC option involves the use of tablet computers that are configured with graphic icons and speech synthesizing software (McNaughton and Light, 2013; Sennott and Bowker, 2009). With this system, tapping icons on the tablet screen produces synthetic speech output. For example,
tapping a COLORING BOOK icon might produce the message “I would like the coloring book.” The speech output provides a readily understood message, which is of benefit to listeners. In addition, synthetic speech output might also be of benefit to AAC users as discussed below (Drager and Reichle, 2010; Schlosser, 2003).

Several studies have demonstrated effective procedures for teaching children with neurodevelopmental disabilities to use tablet-based speech-generating devices (SGDs) for functional communication purposes (see Kagohara et al., 2013 for a review; Waddington et al., 2014), for example, taught three boys with autism spectrum disorder and severe communication impairment (expressive language ages of less than 2.5 years) to request access to preferred toys by selecting a sequence of icons from the screen of a tablet-based SGD. The boys were taught a sequence involving: (a) an initial general request (e.g., “I would like a toy please.”), (b) a second specific request (e.g., “I would like the alphabet box.”), and (c) a final “thank-you” response after receiving the requested toy. The teaching procedures involved least-to-most-prompting, time delay, error correction, and reinforcement. With intervention, all three children showed improvement in performing the communication sequence. This improvement was maintained with an unfamiliar communication partner and during the follow-up sessions. These results are consistent with Kagohara et al.’s (2013) conclusion that, with systematic instruction, children with neurodevelopmental disorders and severe communication impairment can be taught to use tablet-based SGDs for functional communication purposes.

While AAC intervention primarily aims to provide children with an augmentative or alternative means to communicate more effectively (Beukelman and Mirenda, 2013; Johnston et al., 2012), researchers have also been interested in whether such intervention might have some facilitative effect on natural speech production – a welcomed bonus to AAC intervention (Greenberg et al., 2013; Millar, 2009; Millar et al., 2006; Schlosser et al., 2009; Schlosser and Wendt, 2008). Blischak et al. (2003) proposed several hypotheses as to why the use of an SGD might enhance natural speech production, including (a) communication effects, (b) motor effects, and (c) acoustic effects. Communication effects might occur when increases in communicative turns, messages, and/or utterance lengths due to SGD use and intervention result in concomitant increases in speech production. Motor effects might stem from a reduction in physical demands (i.e., pointing to a symbol is seemingly less complex motorically compared to producing speech) and pressures to speak, which thus permit a re-allocation of cognitive resources toward the production of speech. Acoustic effects might result from the immediate acoustic output that provides activation feedback to the learner, an increase in the consistency as well as the quantity of the speech output models (which might result in better attention and imitation), and the pairing of graphic symbols with spoken symbolic output that might enhance the development of an internal phonology. In sum, there are plausible reasons why the use of an SGD might be expected to improve natural speech production. Alternatively, synthetic speech output from a SGD might conceivably inhibit natural speech production by preemptioning the need for speech and/or by creating an auditory distraction.

Several studies have investigated the effects of speech output devices on natural speech production in children with neurodevelopmental disorders (for reviews see Millar, 2009; Millar et al., 2006; Schlosser et al., 2009; Schlosser and Wendt, 2008). For example, Parsons and La Sorte (1993) reported an increase in spontaneous vocalizations when the six participating children with autism were using a speech-output device. In another relevant study, Schlosser et al. (2007) monitored the vocalizations of five children during intervention aimed at teaching the children to make SGD-based requests. In this study, the presence or absence of speech output from the device did not influence vocalizations for four of the five children, perhaps because these children evidenced very low levels of vocalizations and vocal imitation. For the other child, a minor and inconsistent facilitative effect was observed. Importantly, this child entered the study with some pre-existing vocal imitation skills. In a third relevant study, Sigafoos et al. (2003) also manipulated the presence and absence of speech output during sessions in which three children used a SGD to request preferred stimuli. Two of these children had autism and one had Leber’s Congenital Amaurosis and intellectual disability. They found that speech output from the SGD did not inhibit vocalizations in the two children with autism. Interestingly, the child with Leber’s began to speak relevant single words (e.g., biscuit, juice) during the latter sessions regardless of whether or not the speech output function of the SGD was on or off.

The varied findings across these studies might stem from differences in the participants’ preexisting vocal/speech skills and from the fact that vocalizations were defined and recorded in different ways across the three studies as noted by Schlosser et al. (2009). Still, the data from existing studies suggest that SGD-based speech output does not inhibit vocalizations/natural speech production and in some cases SGD-based intervention might even facilitate natural speech (Millar, 2009; Schlosser et al., 2009). However, given the relatively few number of studies to date, additional research would seem warranted.

The present study was designed to extend the existing literature in three new directions. The first and primary aim was to provide additional data on the effects of a systematic instructional protocol for teaching children with neurodevelopmental disorders to use a tablet-based SGD for functional communication purposes. An additional demonstration of this type would help to extend the generality of this approach to AAC intervention, which is critical to advancing knowledge regarding intervention effectiveness (Dallery et al., 2013). The second aim was to investigate the effects on natural speech production of teaching two children with neurodevelopmental disorders to use a new generation of tablet computer (i.e., an iPad®) as a SGD. With the proper software, an iPad® can function as a SGD and produce relatively high quality synthetic speech output, which we hypothesized might serve as an effective speech model for the children to imitate. The third direction pursued in this study arose fortuitously when we noticed that the two boys started speaking single words during the initial intervention phase when they were being taught to use the SGD to request access to preferred stimuli. In light of this, we redesigned the study to determine if we might be able to evoke more frequent speech production by removing the SGD, while endeavoring to maintain the need/motivation for communication. The idea is based on the phenomenon of response generalization (Skinner, 1953), whereby reinforcement of one requesting response (e.g., using the SGD to request preferred objects), might increase other requesting responses (e.g., using single words to request those same preferred objects). Thus, in the present study, we predicted that natural speech production would increase by first teaching the alternative (SGD-based) response and then preventing that response by simply removing the SGD, while maintaining the motivation/need to communicate.

2. Method

2.1. Ethical clearance and informed consent

Ethical approval was obtained from the relevant University committee and parents provided informed consent. The children were minors and did not have sufficient receptive and expressive language skills to give informed consent. However, their assent was inferred from their willingness to participate in the sessions and eagerly playing with the preferred stimuli that they were being taught to request.

2.2. Participants

Two boys attending a university-based clinic were recruited for this study because they had neurodevelopmental disorders and severe communication impairment. IQ scores were not available, but an adaptive behavior assessment was
conducted as part of this study using the Vineland Adaptive Behavior Scales, second edition (Vineland-II, Sparrow et al., 2005). The children’s overall (low) level of adaptive behavior functioning was consistent with a classification of developmental disability requiring an extensive level of support, based on criteria established by the American Association on Intellectual and Developmental Disabilities (Schalock et al., 2010). A conservative estimate is that this level of functioning would be consistent with functioning in the moderate to severe range of intellectual disability. Neither child had any physical, hearing or vision impairments and both had adequate motor skills to operate the SGD used in this study as determined by the Vineland-II ratings of motor skills.

2.2.1. Liam

Liam was a 9-year-old boy diagnosed with autism spectrum disorder by a pediatrician. On the Communication Domain of the Vineland-II, his age equivalence scores were 1:6 (years:months) for expressive communication, 1:2 for receptive communication, and 6:5 for written communication skills. His relatively higher score on the written communication domain stemmed from endorsement of several items in the 3 to 5- and 6-year age brackets (e.g., Prints at least three simple words from example. Prints at least 10 simple words from memory). Expressively, Liam was reported to usually make babbling-like sounds and produce sounds and gestures to gain parental attention. He was reported to sometimes use sounds and gestures to indicate that he wanted an activity to stop or continue. He was also reported to usually name at least three objects and sometimes make one-word requests. However, he mainly communicated by leading adults. He engaged in frequent echolalia (e.g., repeating the names of cartoon characters). Receptively, Liam was reported to sometimes turn his eyes and head toward sounds, sometimes look toward a parent upon hearing the parent’s voice, and sometimes look at the speaker when his own name was spoken. He also was reported to usually understand the meaning of yes and no. He engaged in mild self-injurious hand biting that was infrequent (i.e., 1–2 times per hour). Hand biting did not produce tissue damage and was ignored during sessions. He had previous experience in using a tablet computer (i.e., an iPad®) to play games and had previously been taught to request preferred snacks and reject non-preferred snacks using an iPad®-based SGD.

2.2.2. Oliver

Oliver had just turned 3 years old when the study began. Shortly before this, a pediatrician made a diagnosis of global developmental delay. On the Communication Domain of the Vineland-II, his age equivalence scores were 0:4 (years:months) for expressive communication, 0:3 for receptive communication, and 2:5 for written communication skills. His relatively higher score on the written communication domain stemmed from endorsement of only one item (i.e., Recognizes own name in printed form). Expressively, Oliver was reported to usually make babbling-like sounds and sometimes he produced sounds and gestures to gain parental attention and indicate that he wanted an activity to stop or continue. However, he mainly communicated by leading an adult’s hand toward a preferred item or object. Receptively, Oliver was reported to sometimes turn his eyes and head toward sounds, sometimes look toward a parent upon hearing the parent’s voice, and sometimes look at the person speaking when his own name was spoken by that person. He also was reported to sometimes listen to a stimulus for at least 5 min and sometimes he would follow simple action-object instructions (e.g., Bring me the book). Prior to this study, he had received no AAC intervention and had no experience using an iPad® or any other type of SGD.

2.3. Setting and context

This study was conducted in a university-based clinic room. Each child came to the clinic once per week for 1 h. The first and sixth authors (Masters and a Ph.D. student, respectively) implemented the procedures and served as the primary data collectors. Both were studying in the field of Educational Psychology and had at least two years of experience in conducting such interventions. They implemented the procedures on an alternating basis and served as the primary data collectors for the sessions they implemented. Several other authors (Masters and Doctoral students in Educational Psychology) assisted by collecting inter-observer agreement and procedural integrity data. The trainers and observers were not blind to the purpose of the study.

2.4. Materials

2.4.1. Preferred stimuli

Assessments were conducted to identify preferred stimuli that the participants would be taught to request using the SGD. For Liam, a tray containing various toys (e.g., coloring books with crayons, bubbles, toy train, and puzzles) was offered 20 times and he selected each time was recorded. Because Liam most often (75% of the opportunities) selected the coloring books and crayons, these were the stimuli that he was taught to request. Liam independently used crayons to color pictures in the coloring book and he appeared to enjoy this activity. The assessment for Oliver involved setting out various leisure materials (e.g., books, balls, blocks, coloring books with crayons, bubbles, and a set of plastic letters) and recording the amount of time that he played with each object during 10-min sessions. Three such sessions were conducted. Oliver spent most time with the books and the plastic letters. Therefore, Oliver was taught to request these two preferred stimuli. With respect to the books, Oliver appeared to enjoy having the books read to him by his mother. With respect to the plastic letters, Oliver appeared to enjoy putting the letters in their correct (A–Z) order.

2.4.2. Speech-generating device

Both boys were provided with a second generation Apple iPad® loaded with Proloquo2Go® software (Semonti and Bowker, 2009). Each child’s respective iPad® was configured with two icons, representing their preferred stimuli. Each icon measured approximately 6 cm × 9 cm and consisted of a colored line drawing on a white background within a black-lined frame. The two icons were randomly assigned to either the upper right or bottom left quadrant of the iPad® screen. Liam’s icons were COLORING BOOK and CRAYON. Corresponding synthetic speech output (“I would like the book.” and “Crayon please”) was produced when Liam selected the icons from the iPad® screen with a light touch or tap. Oliver’s icons were BOOK and TOY. He used the TOY icon to request the plastic letters and the BOOK icon to request being read a story. Corresponding synthetic speech output was produced when icons were selected. (i.e., “I would like to read a book.” and “I would like to play with the toy”).

2.5. Response definitions

For both participants, reaching was defined as moving one or both hands forward to touch the preferred stimulus within 10 s of the initial verbal cue that signaled the start of each requesting opportunity/trial (see Section 2.7). For Liam, a correct SGD response was recorded when he independently selected the COLORING BOOK or CRAYON icon so as to activate the synthesized speech output within 10 s of the initial verbal cue (see Section 2.7). During sessions when the SGD was not available, a correct response was recorded when Liam used some relevant spoken word (natural speech) to request the offered item (i.e., saying coloring book or crayon). A response was also correct if Liam spoke the color name for one of the crayons (e.g., red crayon). An incorrect/no response was recorded if Liam did not use a relevant spoken word (natural speech) to request the coloring book or crayon or if he made no response within 10 s of the initial verbal cue.

For Oliver, a correct SGD-based response was recorded when he independently selected the BOOK or TOY icon on the iPad® screen so as to activate the corresponding synthesized speech output. The response had to occur within 10 s of the initial verbal cue. A correct spoken response was recorded when Oliver said book, or said the name of the plastic letter held by the trainer. Reaching, SGD use, and spoken responses were not mutually exclusive. An incorrect/no response during the SGD sessions was recorded if Oliver (a) failed to successfully activate the speech output on the SGD, (b) touched the SGD, but did not select the correct icon, (c) reached for the coloring book/crayon without using the SGD, or (d) made no response within 10 s of the initial verbal cue. During sessions when the SGD was not available, an incorrect/no response was recorded if Oliver did not produce any relevant natural speech within 10 s to request the book/plastic letter or if he produced an irrelevant vocalization (e.g., umm, dada).

2.6. Session schedule and experimental design

Liam and Oliver participated in one or two sessions during each clinic visit. Each session lasted 10–20 min and consisted of five discrete trials during which an opportunity was provided to request one of the preferred stimuli. Participants received four sequential phases: (a) baseline, (b) SGD intervention, (c) no SGD, and (d) a final SGD phase for Oliver. The study used single-case experimental designs (Dallery et al., 2011; Kennedy, 2005). Specifically, the sequential phases were introduced in a staggered, time-tagged fashion across the two preferred stimuli in accordance with either a multiple baseline design (for Liam) or a multiple-probe design (for Oliver).

2.7. Procedures

2.7.1. Baseline for Liam

At the start of each baseline session, Liam was given a coloring book and one crayon with the SGD turned on and opened to the correct screen page containing the two icons. The SGD was placed within Liam’s reach. At the start of the session, Liam was allowed to use the coloring book and crayons for approximately 30 s. Following the 30 s, the coloring book was removed and the trainer said, Can I have a look at your coloring? A few seconds later the trainer said Let me know if you want it back. This initial verbal cue (Let me know if you want it back) signaled the start of the first requesting opportunity/trial in the session. Liam’s responses (reaching, SGD use, or
natural speech) were then recorded during the ensuing 10 s. Following this 10 s, the coloring book was returned to Liam. After five such trials, a similar set of five trials was conducted, except that the crayon was removed and the trainer said Let me know if you want another crayon to initiate each 10-s trial. During baseline sessions, Liam received frequent praise (i.e., about one praise statement at the end of each second or third trial) for participation with the intent of sustaining his motivation and attention (e.g., You are doing so well. What lovely coloring you are doing).

2.7.2. Baseline for Oliver
At the start of these sessions, the trainer sat on the floor near Oliver with the SGD turned on and opened to the correct screen page. Oliver’s mother would read to him from a preferred book for approximately 3 min. After 3 min, the book was removed by the trainer who said Can I have a turn with the book? After a few seconds, the trainer said Let me know what you want. This was the initial verbal cue that signaled the start of a 10-s trial. During the ensuing 10-s delay, any reaching, SGD use, and/or natural speech was recorded. At the end of 10 s, the book was returned to him and his mother read to him for another few minutes. After this, the book was removed and the next trial was initiated approximately 3 min later. After five such trials, the book was removed and the five trials of the toy session began. For these five trials, Oliver sat at a table with the plastic letters spread out on the table for him to play with. The SGD was placed within reach and opened to the correct screen page. Oliver was given approximately 20 s to place the letters in order and then the trainer removed the next letter required and said Can I have a turn with the toy? After a few seconds, the trainer said, Let me know what you want and waited 10 s before giving Oliver the required letter, while saying Your turn now. After five such trials, the session was finished and Oliver was given the opportunity to complete the sequencing of letters.

2.7.3. SGD intervention for Liam and Oliver
The procedures used during this phase were identical to the two boys’ respective baseline procedures, except that if the boys did not make a correct SGD-based request within 10 s of the initial verbal cue, then the trainer implemented a least-to-most prompting strategy. This involved the trainer repeating the initial verbal cue while pointing to the correct icon on the SGD. If this did not evoke a correct response within about 3 s, the trainer gently picked up the boy’s hand, isolated his index finger, and physically guided the child’s finger to tap the correct icon from the SGD screen. In addition to using this least-to-most prompting sequence, we also used contingent reinforcement in this phase. Specifically, access to the preferred stimulus was provided only after the child had correctly used the SGD to request that stimulus. This reinforcement was provided if the child made the correct SGD-based request with or without prompting (i.e., independently). However, only requests that occurred without prompting were counted as correct.

2.7.4. 30-s delay for Liam
The procedures in this phase were identical to those of the previous (SGD Intervention) phase except that the use of least-to-most prompting was delayed for 30 s from the initial verbal cue. Because Liam often waited to be prompted in the previous phase, this increased delay was implemented to fade the need for prompting.

2.7.5. Removal of SGD
For these sessions, the SGD was not available. The procedures were similar to baseline, except that any relevant spoken word requests that occurred within 10 s of the initial verbal cue were reinforced by providing immediate access to the preferred stimulus. Relevant spoken words for Liam included saying crayon or pen or red crayon or green pen for example, or saying book or coloring book. Relevant spoken word requests for Oliver included saying book or the name of the correct letter (e.g., A, B, or C).

2.7.6. Final SGD phase for Oliver
This phase was identical to the SGD Intervention phase and was implemented to determine what effects re-introduction of the SGD would have on natural speech production, which had increased in the previous phase. The intent was to then reintroduce the No SGD phase. However, during this final SGD phase, Oliver’s mother withdrew him from the study and enrolled him in an early intervention program.

2.8. Inter-observer agreement
The first and sixth authors served as the trainers and primary data collectors. To check the accuracy of data collection, an independent observer was present during all sessions to collect data on the presence or absence of the dependent variables on a trial-by-trial basis. The resultant data were compared for agreement. An agreement between the trainer and independent observer was scored if the trainer and independent observer had recorded the same child’s response(s) for each trial. Any discrepancies were counted as a disagreement. Percentages of agreement were calculated using the formula: Agreements/(Agreements + Disagreements) × 100 and ranged from 83 to 97%.

2.9. Procedural integrity
The independent observer also used a checklist of the procedural steps to record whether or not the trainer had implemented the procedures correctly (Schlosser, 2002). These checks occurred on at least 50% of the sessions in each phase of the study and for both participants. The checklist allowed for a 3 s discrepancy regarding whether or not the trainer had waited 10 s during each requesting opportunity. Correct implementation was always recorded as being above 80%.

3. Results

Fig. 1 shows the cumulative number of responses for each of the three dependent variables (i.e., reaching, correct SGD-based requests, and relevant natural speech) for Liam. Fig. 2 shows the same data for Oliver.

3.1. Results for Liam
During Baseline Liam received a total of 6 opportunities to request the coloring book and 16 opportunities to request a crayon. For the coloring book, he always reached for the item and never made a correct SGD-based request, nor did he ever produce any natural speech. For the crayon, he reached for the stimulus on 87.5% of the trials, used natural speech on two trials (12.5%) and never used the SGD. During the SGD Intervention phase, Liam received a total of 56 opportunities to request the coloring book and 46 opportunities to request a crayon. For the coloring book, Liam showed increased use of the SGD and a collateral decrease in reaching as the SGD Intervention phase progressed. The first spoken word appeared at Trial 41 and by the end of this phase he had produced a total of eight spoken words. For crayon, there was also a decreasing trend in reaching and a modest increase in SGD use during the SGD Intervention phase. However, compared to SGD use, there was more of an increasing trend in natural speech production, which is especially evident during Trials 20–45. With implementation of the 30-s delay procedure, use of the SGD occurred consistently for the coloring book, whereas Liam was recorded to have used natural speech to request a crayon during the crayon trials of this phase. In the final phase, when the SGD was removed, Liam consistently used natural speech to request the coloring book and crayon.

3.2. Results for Oliver
During baseline, Oliver had seven trials to request the book and three opportunities to request the plastic letters. He consistently reached for the book, but never made any SGD or natural speech responses. During the SGD Intervention phase, he had 33 trials to request a book and 28 opportunities to request the plastic letters. For the book, Oliver showed a rapid increase in SGD-based requests. This was followed by consistent SGD use during the intervention phase. Reaching occurred infrequently and no natural speech was recorded during the SGD Intervention phase. When the SGD was removed, reaching showed a resurgence, but natural speech also increased, especially as a request for the plastic letters. In fact, for the plastic letters, reaching and natural speech occurred simultaneously during all but one of the trials in this phase. In the final phase for both the book and plastic letters, reaching decreased, SGD use increased, and natural speech did not occur. His participation in this study ended at this point due to his being withdrawn from the study and enrolled in an early intervention program.

4. Discussion

For these two children, the systematic instructional procedures implemented during the SGD Intervention phase appeared to be effective in teaching them to use the tablet computer-based SGD to make requests for preferred objects. The effect was less evident for Liam with respect to requesting crayons as he more often used speech to request crayons even during the SGD Intervention phase. Still, the fact that correct SGD use increased only when
Fig. 1. Cumulative number of responses (reaching, correct iPad use, and natural speech production) across successive requesting opportunities/trials and study phases for Liam.

Fig. 2. Cumulative number of responses (reaching, correct iPad use, and natural speech production) across successive requesting opportunities/trials and study phases for Oliver.
the intervention procedures were implemented suggests that these procedures were responsible for the increase in correct SGD-based requesting. This positive intervention effect is consistent with previous studies in which similar types of systematic instructional tactics have been successfully used to teach children with neurodevelopmental disorders and severe communication impairment to use tablet computer-based SGDs for functional communication purposes (Kagohara et al., 2013; Waddinton et al., 2014). The present study can thus be seen as adding another positive demonstration of using a tablet computer-based SGD in AAC intervention for children with neurodevelopmental disorders and severe communication impairment and thus helping to extend the generality of the existing evidence (Dallery et al., 2013).

With respect to the effect on natural speech production of the SGD intervention, both children showed increases in natural speech production after learning to use the SGD. This effect was most evident for Liam during the No SGD phase, but it could also be seen with Oliver during the No SGD phase, especially for opportunities to request the plastic letters. Liam also showed an increase in natural speech during the phase when he was being taught to use the SGD to request crayons. Interestingly, Liam’s increases in speech production for the coloring book (the first request taught) occurred only in the very late stages of the intervention phase, whereas the increases for requesting crayon (the second request taught) were more immediate. Blischak et al. (2003) argued that reduced physical demands and increased natural speech production would likely be realized only if and when automaticity in message selection and production is achieved. Perhaps it was not until the late stages of the intervention that the process of selecting and activating the correct symbol became automated for Liam.

There are several possible explanations for why natural speech production increased for Liam during the SGD Intervention phase and then for both boys when the SGD was removed. One possibility is that by teaching them to use the SGD to make requests, natural speech also increased because relevant spoken responses were also reinforced as requests. The two response forms (i.e., SGD use and natural speech) could thus be seen as members of the same response class. It is known that reinforcing one member of a response class often leads to increases in other members of that response class without explicit instruction, an effect known as response generalization (Skinner, 1953). Liam’s use of natural speech to request crayons during the SGD Intervention phase might be seen as an example of generalization from the prior SGD Intervention phase with the coloring book. Alternatively, Liam’s performance in relation to requesting the crayon allow for an alternative explanation related to his pre-existing use of speech. That is, during baseline he used speech already for 12.5% of the opportunities. It appears that during SGD Intervention, he simply continued to use speech because it was reinforced and that is perhaps why correct SGD use during the SGD Intervention phase did not show more of an increase.

Of course, for any such generalization to occur, both responses had to be already in the repertoire. The specific SGD-based requests targeted in this study did not occur during the Baseline phase, but were acquired fairly quickly with intervention. With respect to natural speech, Liam had some echolalic speech and Oliver spoke a few single words prior to the baseline phase of this study. Natural speech might have increased due to the exposure to the synthetic speech output along with the spoken input of the trainer that occurred during the SGD Intervention phase. Compared to baseline in which the model was restricted to the spoken input provided by the trainer, during the intervention phase the participants received an additional speech model from the SGD. According to Blischak et al. (2003), it has yet to be investigated whether this is a mere issue of quantity of input as opposed to differential quality or differences in other characteristics between natural and synthetic speech. Speaking of quality, synthetic speech output might have provided a consistent and high-quality model for the children to imitate or it might have served as a prompt (Blischak et al., 2003) that increased the likelihood that speech would occur during a trial, which was then strengthened by reinforcement. Furthermore, the additional model via synthetic speech was under the control of the learners themselves given that this model was produced when the children selected icons from the tablet’s display. During the No SGD condition, the children no longer had access to the device, but spoken requests could be used to gain access to the preferred stimuli. While reinforcement of natural speech is a plausible explanation for the increase in natural speech, it is also possible that repeated exposure to the pairing of graphic symbol selections with the associated speech output helped to develop the children’s internal phonological representation (Blischak et al., 2003). This, in turn, may have facilitated the children’s ability to retrieve the spoken label from memory simply by viewing the graphic symbols.

With respect to the third direction pursued in this study – the initial SGD intervention, followed by removal of the SGD – this approach could be seen as one way to increase natural speech production in children with neurodevelopmental disorders and severe communication impairment. The intent was to first establish an effective, yet relatively simple, requesting response that enabled the children to access highly reinforcing stimuli. Unlike an intervention that focuses only on teaching speech, initial use of an alternative mode, such as a tablet computer-based SGD, offers the advantage of enabling correct responses to be easily prompted, thereby ensuring a high rate of success/reinforcement to facilitate learning and ensure a high level of motivation to communicate (Fitzer and Sturmey, 2009). After the requesting response was well established, the SGD was then removed, while the motivation to communicate was maintained by temporarily removing/withholding the preferred stimuli. Removal of the SGD during the No SGD phase was expected to evoke speech because speech then became the only way to gain reinforcement. In practice, however, clinicians would need to monitor the impact of removing the SGD carefully in terms of any unwanted side effects, such as the appearance of problem behavior. Clinicians should also be ready to reintroduce the SGD at a moments notice if any such problems or decreases in successful communication were observed. In other words, in practice this might involve gradually fading out, rather than abruptly removing, the SGD.

Alternatively, given that this study was conducted over several months, it is possible that the increase in natural speech production was due to the inevitable exposure to language models that these children experienced at home and school. Most likely it was some combination of these factors. Specifically, both boys entered the study with some existing vocalizations and speech, but the specific words they uttered during intervention sessions were relevant to the specific context of this study and appeared to function as requests for the specific preferred stimuli we were offering. Nevertheless, our use of individual multiple-baseline designs to evaluate intervention effects provides a convincing demonstration of experimental control for such external variables and thus offers support to the existence of a functional relation between the intervention and increased use of the SGD and increases in natural speech production.

Although the approach for teaching SGD use in the present study is sufficiently evidence-based to recommend for clinical practice, the approach we used to induce speech must be seen as tentative because the evidence for it is limited to the present two cases. Indeed, this appears to be the first study to have first taught SGD use and then withdrawn the SGD in an effort to increase natural speech production in children with neurodevelopmental disabilities and severe communication impairment. Also, the within-participant replication was limited to two, rather than the typically expected
three, replications (Horner et al., 2005). Independent replications with additional children will be necessary before this approach could be recommended. Future replication efforts would be improved by scheduling additional phases where the SGD is alternately present or absent. This would help to more fully isolate the effects of SGD presence or absence on natural speech production. While AAC intervention is primarily intended to provide an effective means of functional communication for people with limited or unintelligible speech (Beukelman and Mirenda, 2013), there would be obvious benefits to the child if ways could be found to increase natural speech production within an AAC intervention. If the effect can be replicated, the approach evaluated in the present study might be indicated for children who demonstrate some level of natural speech production prior to and during AAC intervention.

5. Conclusion

Two boys with neurodevelopmental disorders and severe communication impairment learned to use a table computer-based SGD to request access to preferred stimuli and also began to utter relevant single words during intervention. In an effort to induce more speech, the SGD was removed during subsequent requesting opportunities. With this manipulation, both boys began to respond more frequently with natural speech. This effect suggests that initial SGD intervention, followed by subsequent withdrawal of the SGD, might increase the frequency of natural speech production in some children with neurodevelopmental disorders. This effect could be an example of response generalization.

Conflict of interest

The authors report no conflicts of interest. The authors alone are solely responsible for the content and writing of this paper.

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