Effects of an AAC App with Transition to Literacy Features on Single-Word Reading of Individuals with Severe Autism Spectrum Disorders who have Minimal Speech

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Abstract

The purpose of this study was to investigate the effects of an augmentative and alternative communication (AAC) app with transition to literacy (T2L) software features (i.e., dynamic text and speech output upon selection of a graphic symbol within the grid display), on the acquisition of 12 personally relevant sight words for individuals with severe autism spectrum disorder (ASD) who had minimal or no speech. The study implemented a single-subject, multiple-probe, across word sets design with four participants. All four participants in this study demonstrated increased accuracy reading sight words and results from this study provide preliminary evidence that the T2L features can positively impact the sight word learning of individuals with ASD who have minimal speech and limited literacy skills.

Keywords: Augmentative and Alternative Communication (AAC); Autism Spectrum Disorder (ASD); Minimal speech; Literacy; Apps

Effects of Dynamic Text and Speech Output in an Augmentative and Alternative Communication App on Single-Word Reading of Individuals with Severe Autism Spectrum Disorders who have Minimal Speech

Communication impairments are inherent with an autism spectrum disorder (ASD) diagnosis (Kasari et al., 2014). As many as 30-50% of individuals with ASD do not develop functional speech (Shane et al., 2015). These individuals have significant communication impairments characterized by having a very small repertoire of spoken words or fixed phrases that are used communicatively (Kasari, Brady, Lord & Tager-Flusberg, 2013). In addition, the spoken words or phrases are often restricted within contexts and functions and likely include scripted phrases that have been highly trained. For example, the individual may only use spoken words for requesting preferred food items with a familiar adult (e.g., I want X) (Kasari et al., 2013). To support communication and increase opportunities for participation, augmentative and alternative communication (AAC) (e.g., sign language, picture communication boards, AAC apps on mobile technology) may be required for individuals with ASD who have minimal speech. Currently, AAC systems are used with these individuals with the purpose to decrease challenging behaviors, increase social participation (e.g., turn taking, social initiations), make requests, and participate in academic activities (e.g., spelling). More specifically, research demonstrates that aided, graphics-based AAC systems are successfully and frequently used with individuals with ASD and complex communication needs (Ganz, 2015; Ganz et al., 2012; Holyfield et al., 2017; Mirenda & Erickson, 2000). Individuals with ASD who require AAC often select high-tech devices when offered choices among high-tech speech generating devices, low-tech picture exchange-based systems, or manual sign language (Ganz, 2015).

With prevalence rates for ASD continuing to increase (Wright, 2018), more individuals with severe ASD and who have minimal speech are entering school than ever before. Subsequently, changes in federal policy have mandated and promoted an emphasis on inclusion and positive educational outcomes for all students (Knight, Browder, Agnello, & Lee, 2010). These mandates include those who require AAC to communicate and participate. These learners must have access, be involved, and progress in the general curriculum. Therefore, instruction must be adapted to meet their needs (Knight et al., 2010; Light & McNaughton, 2013). Assistive technology, including the use of an AAC system, then becomes a critical component to full educational participation.

Individuals characterized as having severe disabilities, including those with minimal speech and ASD, have historically been viewed as incapable of developing literacy skills (Morgan, Cuskelly & Moni, 2011). Therefore, literacy instruction has often either been denied to them or provided in ways that did not meet their learning needs. A growing body of research has demonstrated that individuals who use AAC can learn to read when provided with appropriate evidence-based instruction (e.g., Blischak et al., 2004; Fallon et al., 2004; Johnston, Buchanan, & Davenport, 2009; Light & McNaughton, 2009b; Millar et al. 2004), yet the overall outcomes remain poor (Mirenda & Erickson, 2000).

Although there are several components to literacy, one critical component is learning sight words. Sight word learning involves instruction that teaches students word recognition instead of a relationship between sounds and letters in a word (Browder & Xin, 1998). Word recognition skills are essential to become a skilled reader, as these skills can help students build a foundation in literacy and provide a sense of accomplishment and motivation (Mandak, Light, & Boyle, 2018; Spector, 2011; Broun, 2004; Light & McNaughton, 2013). Sight word instruction allows students to see a relationship between words and meaning (Broun, 2004) and opens the door to meaningful reading experiences (Mandak et al., 2019). Sight word learning may also increase an individual's ability to participate in functional tasks (e.g., grocery lists, reading directions) and can support improved communication and access to leisure activities (e.g., YouTube watching and searching) (Browder & Xin, 1998; Caron & Light, 2016).

Sight word interventions are common approaches used in literacy instruction for individuals with moderate and severe disabilities (Browder et al., 2006; Browder & Xin, 1998), yet again, limited research includes individuals with severe ASD and minimal speech (Spector, 2011). Spector (2011) reviewed single-subject research from 1980 to 2009 for sight word instruction with individuals with ASD. Spector (2011) found only nine single-subject sight word studies for individuals with ASD. Of the nine, six of these studies included individuals with ASD who used speech and therefore instructional and/or assessment tasks that required spoken responses.

Traditionally, sight word instruction uses pictures and/or text to teach sight words in various tasks including matching tasks (Fossett & Mirenda, 2006), computer-based instruction (Hetzroni & Shalen, 2005), flashcards and games (Crowley, McLaughlin & Kahn, 2013), and mobile technology with systematic instruction (van der Meer et al., 2014). Interventions most commonly includes words that are identified as frequently occurring, yet often with irregular spelling (e.g. Dolch Word List[1]), as well as words related to daily living (e.g., household items, food items, clothing items) (Fossett & Mirenda, 2006; Hetzroni & Shalem, 2005).

Although explicit literacy instruction is vital, current AAC technologies and features within high-tech speech generating devices, could also be used to complement instruction and possibly even incorporate literacy into everyday communication. Individuals with ASD who have minimal speech who use AAC, typically have systems with graphic symbols (i.e., photographs, line drawings) to represent words or concepts for communication. These graphic symbols are often paired with a static text label located above the image; however, this static pairing of text and graphic symbols, may interfere with sight word learning (Fossett & Mirenda, 2006; Erickson et al., 2010). Emerging research has begun to explore redesigning of AAC systems to better support literacy, with Light, McNaughton, Jakobs, and Hershberger (2014) proposing the incorporation of a transition to literacy (T2L) feature into AAC technologies. The T2L feature pairs voice output messages with corresponding orthographic output, upon selection of a graphic symbol within an AAC display (Light et al., 2014) (see https://tinyurl.com/rerc-on-aac-T2L for a video example of the feature).

The T2L feature has been incorporated into both visual scene display applications and AAC systems that use grid-based displays. Mandak, Light, and McNaughton (2019) investigated the effects of the T2L app features in a visual scene display application with preschoolers with ASD and some speech. All participants demonstrated successful acquisition of the 10 targeted sight words (range: 77-100% accuracy) during shared reading of the book *Brown Bear Brown Bear*. In a study by Caron and colleagues (2018), the T2L app feature was investigated using a grid-based display within an AAC application. All five participants with ASD demonstrated increased accuracy reading 12 sight words through exposure the T2L feature during a structured matching task. These participants, who were described as minimally verbal with some literacy skills (e.g., could not decode, yet were able to identify more than 100 sight words), were also able to transition from a 15 location graphics-based grid display, to a 15 location text-only grid display during generalization tasks.

Study Aims

The purpose of this study was to further investigate the effects of dynamically displaying text along with speech output (T2L feature) within a graphics-based grid display AAC app, in order to support the acquisition of targeted sight words, with individuals who have severe ASD who had minimal speech. Individuals with severe ASD and minimal speech are often not included in research studies on sight words, despite this being one of the main ways they participate in literacy instruction. In addition, in the previous studies using the T2L feature, the participants had an ASD diagnosis and had minimal speech, yet had more literacy skills (e.g., over 100 sight words) (Caron et al., 2018), or the participants had diagnoses of moderate ASD, were young, and primarily used speech (e.g., Mandak et al., 2019). Although gains were observed with both studies, the researchers speculated that intrinsic factors including speech abilities, age, severity of diagnosis, as well as prior literacy skills may have played a role in the rate of acquisition, as well as the positive benefits of the T2L feature. Additional research with individuals who have severe ASD, minimal speech, and more minimal literacy would expand understanding of who the T2L feature could benefit. Subsequently, the research questions for the proposed study were: (a) What is the effect of the AAC app with T2L software feature on the acquisition of sight word reading of 12 words, during a structured matching task, by individuals with severe ASD who are minimally verbal and have very limited literacy skills? (b) Are the effects maintained once exposure to the AAC app with T2L feature is terminated? (c) Do the participants generalize the sight word reading skills to different stimuli?

Method

Participants

Participants for this study were recruited through outreach to teachers and speech-language pathologists in Pennsylvania schools who worked with students with severe ASD. The inclusion criteria used to select participants required that individuals: (1) had an ASD diagnosis based on the DSM-V criteria and a CARS-2 rating of severe (Childhood Autism Rating Scale Second Edition, CARS-2; Schopler, Van Bourgondien, Wellman, & Love 2010), (2) were ages 5-21 years old, (3) were unable to meet daily communication needs through speech, (4) were able to follow one step directions, (5) could communicate symbolically with a minimum of 10 spoken words, signs, or graphic symbols, (6) had English as the primary language used at home, (7) had hearing and vision that were unimpaired or corrected per teacher or parent report, (8) were not decoding and recognized less that 50 sight words, per teacher report.

Participant profiles. Four boys with ASD ranging in age from 9;7 (years; months) to 18;7 (M = 14;0) participated in the study. All of the individuals scored a severe ASD rating on the CARS-2 and scored below the 1st percentile on the PPVT-IV (i.e, they received a Standard Score of 42 or below, corresponding to an age equivalent of 3.2 years or below). They all attended educational programs with substantially separate ASD support services, including 1:1 supports throughout the school day. All participants had functional hearing and vision, and were able to follow routine one-step directions. Three out of four participants had very limited to no speech; they primarily used physical communication, gestures, vocalizations, sign approximations, and AAC apps with graphic symbols within grid-based systems on the iPad. The fourth participant also used physical communication and gestures; however, he primarily used 20 spoken word approximations and rote phrases (e.g., “I want that”) to communicate. Previous literacy instruction for each participant had primarily focused on letter-sound correspondences and sight word recognition skills, yet with minimal progress (see Table 1).

Research Design

The current study implemented a single-subject multiple-probe, across word sets design with four participants. The study included four participants with severe ASD, each of who participated in three of their own word sets. The acquisition of sight words was evaluated across four phases for each of the three word sets, including: baseline, intervention, generalization, and maintenance.

Measures and Data Analysis

The dependent variable for the study was the percentage correct during the single-word reading probes. Specifically, the correct identification of a graphic symbol selected from a field of four, when provided with a target written word, across 8 trials (each target word presented twice). Probes were conducted across all study phases. A correct response during the probe tasks was defined as an independent selection, of the correct graphic symbol, within 5 seconds of the researcher's presentation of the word. An incorrect response was defined as selection of the wrong graphic symbol or lack of response within 5 seconds of the researcher's presentation of the written word.

Data on the accuracy of reading the target words were graphed separately for each individual across the four phases and three word sets. The level, slope, and variability of the data in the intervention condition were compared to those at baseline to determine the effectiveness and efficiency of the introduction of an AAC app with T2L software features. Additionally, Tau-U effect size was calculated (Parker, Vannest, Davis, & Sauber, 2011). A Tau-U score ranges from 0-1 and can be interpreted using the following criteria: .20 or lower is a small effect; between .20 and .60 is a moderate effect; between .60 and .80 is a large effect; and between .80 and 1 is a very large effect (Vannest & Ninci, 2015).

All sessions were videotaped, and probe data were recorded live. In order to ensure the reliability of the data, coding from the video-taped sessions by the graduate student was compared to the data sheets collected live by the researcher. The graduate student coded a randomly selected sample of 30% of the baseline and intervention sessions and all of the generalization and maintenance sessions, for each of the participants, across each word set. Interrater agreement was calculated by determining the number of agreements divided by the number of agreements plus disagreements plus omissions. The mean interrater reliability per participant, per phase was 100%. See Supplemental Table 1 for more information.

Materials

Target Words. Twelve personally-relevant motivating sight words were selected for each participant. These targeted sight words were selected based on discussions with the participants' parents and teachers, as well as a review of the participants' AAC systems. The 12 words were grouped into three sets of four words, for each participant. To select and organize these words, the following criteria was used; (a) words had to be 3-9 letters in length, (b) words had to be imagable (e.g., pizza, legos), and (c) words had to contain, within a set, at least two words that shared the same initial letter (e.g., jeep, juice, bike, mickey). Additionally, all sight words were presented with lower case letters. The targeted sight words selected for each participant are listed in Supplemental Table 2.

Probe Materials. Assessment probes were used throughout the study to evaluate the participants' accuracy in recognizing the targeted sight words. The materials for the assessment probes included laminated graphic and orthographic representations of the target words. The graphic representations included SymbolStix[2] icons. Screenshots of the AAC application were taken to obtain these graphic symbols. The graphic symbols were printed in color and cut into 2"x2" squares. Assessment probes for generalization included photographs of the targeted sight words. The photographs selected for the probe were not seen during instruction. For the orthographic representations, laminated text cards were created by printing the word in black, 72 pt. Arial font on yellow paper

AAC hardware and software. During the intervention phase, the AAC technology with the T2L feature was introduced to the participants. The T2L software feature was used on a NOVA Chat 124 TM device. A 15-button display was programmed with graphic symbols (i.e., symbols for the 12 target words and three words for models). The T2L feature occurred in a sequential manner. First the dynamic presentation of text appears. It emerges from the selected graphic symbol. Then, the grid display is slowly replaced by a black background and the word. The word stays on the screen for 3s. While the text is on the screen, it is paired with speech output (matching the text exactly). After 3s is over, the text shrinks back into the graphic symbol and disappears. See *Figure 1* as an example for the sight word *swim*. Additionally, refer to https://tinyurl.com/rerc-on-aac-T2L for a video demonstration of the T2L feature.

Individualized photo books. Three books were created for each sight word set using Microsoft Powerpoint, then printed for intervention. Each of the books included one photograph or AAC symbol without text per page. The first picture book used the SymbolStix icons from the device, creating an "exact match." Participants were prompted to match the picture from the book to the symbol in the device. The second book used photographs, representative of the same concepts as the AAC symbols on the device (and the targeted sight words), but no longer a direct match to the AAC symbols on the device. These photographs were different from the photographs used during generalization. Participants were prompted to match the picture from the book to the symbol in the device. The third picture book also used photographs, representative of the same concepts as the AAC symbols on the device and the targeted sight words. However, these photographs were combined with characters or other objects of interest (e.g., SpongeBob with the targeted sight word jeep). Participants were prompted to follow the same procedure, to match the picture from the book to the symbol in the device. Each book included three pages of photograph symbols for each sight word. The photo books did not include any written words.

Procedures

All of the sessions were conducted by the first author and took place in a classroom. Three to four sessions occurred each week, with each session lasting approximately 20-30 min. Due to scheduling challenges, two sessions were sometimes schedule on the same day, yet a break occurred between each session. The procedures for each of the phases (symbol training prior to baseline, baseline, intervention, maintenance, and generalization) are outlined in more detail below.

Symbol Training. Prior to baseline, all participants were assessed on their accuracy in symbol identification of the target sight words and foils. They were presented with of four graphic symbols and the spoken instruction, "*point to_____.*" If errors were made and training was required, the researcher completed the following procedures, per concept: first, the researcher would place four graphic symbols in front of the participant and state "show me" and verbally label the target concept (e.g., swim), then the researcher would implement systematic instructional procedures. The instruction used most-to-least prompting procedures including the researcher first identifying the correct image for the participant and having the participant touch that image as well, then, providing a verbal prompt plus 3 sec. time delay, and then providing only a verbal prompt (i.e., saying "touch (target item)"). Corrective feedback (i.e., showing the correct response) was provided as required. Three trials per concept were completed in this order, with feedback and graphic icons rearranged per trial. Once participants consistently identified the symbols with greater than 90% accuracy over two consecutive sessions, baseline for all sets began.

Baseline. During baseline probes, the participant was presented with one text card and four Symbolstix picture cards. The researcher pointed to each picture card and labeled the picture aloud. Then, the researcher stated, "Read the word, find the picture that goes with this word." To demonstrate the probe task, two models were provided using sight words not targeted within this study. After the models, the four target words were each probed twice, for a total of eight trials per sight word set. No feedback was provided during the eight trials per set. Probes of all three word sets began on the same day. Once a stable baseline was established for Word Set 1, for each participant, the participant began intervention for Set 1, while Word Sets 2 and 3 were held in baseline. Due to severity of ASD diagnoses and reported challenges with task participation in academics, participants worked on one word set at a time, intervention for each subsequent set began once the participants reached the minimum treatment criterion for the previous set (i.e., 6 out of 8 on probes for three consecutive sessions).

Intervention. Each instructional session included two parts: (1) probes to measure the participants' accuracy of reading the targeted sight words, and, (2) structured matching tasks with photo books (described above) and the AAC device with transition to literacy (T2L) features. The probes followed the same procedure as the probes during the baseline phase. The probes were completed as the first task in every session to measure sight word learning from previous instructional sessions. After the probes, the participants chose two of the three picture books to use for the matching task with the AAC app and T2L feature. Per book, the participants matched the representation of the sight word in the book to the SymbolStix on the AAC device.

Upon selection of the SymbolStix within the AAC system, the T2L features were activated (i.e., dynamic text appeared on the screen for three seconds, paired with speech output). The researcher modeled the task for two words, after the models, the researcher did not label the target words (letting the speech output on the device be the only auditory output the participant received) nor point to the text when it appeared (letting the dynamic nature of the text attract the visual attention). The researcher assisted in activation of the graphic symbol on the device if the participant did not make a selection on the device after 3 secs, or if the participants selected the wrong icon. The participants were instructed to select the same SymbolStix icon from the AAC device twice in a row, per page of the book. Overall, the participants had 12 exposures to the sight word per session, six from each matching photo book. No additional instruction was provided on these words, other than exposure to the T2L feature.

Generalization. Generalization data was also collected during baseline and after intervention ended in order to determine whether participants generalized their sight word reading skills to different graphic representations of the targeted sight words. The sight word assessment probes for generalization followed the same procedures used for all other probes. However, new photographs (not seen during intervention) were used to represent the targeted sight words.

Maintenance. The sight word probes for maintenance followed the same procedures used for all probes. Maintenance occurred at different times across sets and participants, due to constraints related to school schedules and time of acquisition. Maintenance data ranged from two to ten weeks from the last intervention session. Because of the nature of the research project, participants did not have access to the tablet and app after the intervention concluded. Yet, at the end of the study, the app and commercially available options (e.g., NOVAChat by Saltillo[5]; SnapScene by TobiiDynaVox[6]) were discussed with each participants' team.

Procedural reliability. To ensure consistency of the procedures, all probes and instructional sessions were video recorded. Procedural reliability was completed for the probe and intervention procedures across all phases. To assess procedural fidelity, a graduate student in Communication Sciences and Disorders was trained in the use of two checklists: one for probe, and one for intervention sessions. First, the first author and graduate student watched and scored a video (using the checklists) per phase together, discussing scoring while watching. The researcher and graduate student then watched an additional video from each phase, independently and compared their checklist scoring, and then discussed any discrepancies. Once the researcher and graduate student agreed on >90% of the completed steps, for three videos, the graduate student began coding independently. The graduate student then reviewed a random sample of 20% of the probe and intervention sessions for each participant, per set. For both the probes and the intervention sessions, steps in the procedures correctly implemented were divided by the total number of procedural steps then multiplied by 100 to yield a percentage of fidelity. The fidelity means of probes sessions and the intervention procedures, for each of the participants, was calculated across sets and ranged from 85% to 100%. The findings are summarized in Supplemental Table 1.

Results

Results for participants' correct responses on the three sight word sets (total of 12 sight words) are represented in Figures 2 (Nick and Jake) and 3 (Cole and Curt). The results are presented, per participant, according to: (a) the effect of transition to literacy feature (T2L; dynamically presenting text, paired with speech output, upon selection of a specific graphic symbol in the device) on the acquisition of 12 personally relevant sight words; (b) the rate of acquisition (e.g., number of exposures); (c) the generalization to different graphic representations of the targeted sight words; and, (d) the maintenance of these effects. Overall, all participants demonstrated low and stable baseline performance, across word sets. Once the T2L feature was introduced, increases in correct responses were observed for all participants. Generalization and maintenance of skills were observed for three out of four participants and were not completed for one of the participants as he left the study early due to health issues.

Acquisition of Sight Words

Nick demonstrated considerable improvement as a result of intervention across all three word sets (Figure 2). Gains were calculated by comparing the average of baseline to the average of the last three intervention sessions. Gains across sets included: +59% for Set 1 (almonds, crackers, swim, stop), +58% for Set 2 (bird, read, run, gym), and +63% for Set 3 (scooter, help, computer, horse). According to Tau-U calculations the size of the effects were very large, with a Tau-U value of 1.0 for Set 1 ($p=0.006$), 1.0 for Set 2 ($p=0.000$), and .97 for Set 3 ($p=0.000$).

Jake also demonstrated significant improvements across all three word sets, as a result of the intervention (Figure 2). Gains across sets included: +77% for Set 1 (washer, wrench, baler, shovel), +81% for Set 2 (harrow, hose, pliers, litter), and +72% for Set 3 (camping, camo, pager, lure). According to Tau-U calculations the size of the effects were medium to very large, with a Tau-U value of 1.0 for Set 1 ($p=0.006$), .52 for Set 2 ($p=0.116$), and 1.0 for Set 3 ($p=0.000$).

Similar results were seen for Cole, with improvements from baseline across all three word sets as a result of participating in the intervention (Figure 3). Gains across sets included: +79% for Set 1 (frito, bunny, potty, pizza), +73% for Set 2 (pool, pretzel, cars, ipad), and +54% for Set 3 (jeep, juice, bike, mickey). According to Tau-U calculations the size of the effects were very large, with a Tau-U value of 1.0 for Set 1 ($p=0.002$), 1.0 for Set 2 ($p=0.002$), and .88 for Set 3 ($p=0.007$).

Figure 3 displays the percentage of sight words in each set identified correctly by Curt during the baseline, intervention, and generalization conditions. The participant experienced medical issues (including seizures) during the study and subsequently left school. Due to this, intervention probes were completed for word Sets 1 and 2 and generalization probes were completed for word Set 1 only. No maintenance probes were completed. For sight word Set 1 (cheetos, minecraft, computer, water), Curt demonstrated a notable gain of +52% (calculated by comparing the average of baseline to the average of the last three intervention sessions). According to Tau-U calculations the size of the effects were large, with a Tau-U value of .79 for Set 1 (p=0.000). For Set 2 (marker, milk, legos, eraser), improvement was seen as a result of intervention. Baseline mean percent accuracy was 16% (range 0 to 25%), with improvement to a mean accuracy of 50% for the last three interventions that Curt participated in. A stable baseline was established for Set 3 (spin, run, candy, cut) with a mean percent accuracy of 21% (range 0% to 38%), however, intervention probes were not completed due to illness.

Rate of Acquisition

Participants ranged in exposures per word from 60 to 348. More specifically per participant, Nick averaged 152 exposures (range: 60 to 228) per word. Jake averaged 68 exposures per word (range: 60 to 72). Cole averaged 68 exposures per word (range: 60 to 84). Curt only met criterion for Set 1 words. He participated in 29 sessions, for a total number of 348 exposures, per word. See Supplemental Table 3 for a more detailed summary of rate of acquisition and exposure data.

Generalization

Generalization data was also collected during baseline and after intervention ended in order to determine whether participants generalized their sight word reading skills to different graphic representations of the targeted sight words. Generalization occurred immediately after criterion was reached for Nick, Cole, and Curt. Due to school breaks and some health issues, Jake's generalization occurred right before maintenance. During generalization new photographs (not seen during intervention) were used to represent the targeted sight words. Nick demonstrated notable gains of +69% (Set 1), +50% (Set 2), and +58% (Set 3) for pre and post-intervention generalization measures. Like Nick, Jake demonstrated notable gains of +79% (Set 1), +100% (Set 2), and +63% (Set 3) for pre and post-intervention generalization measures. Cole demonstrated similar generalization results, with pre-intervention generalization scores at low levels (range: 6% to 25% and scores were significantly increased (range: 94% to 100%). These changes from pre to post-intervention resulted in large gains: +75% (Set 1), +75% (Set 2), and +88% (Set 3).

Maintenance

Maintenance data ranged from two to twelve weeks from the last intervention session of the Set, with Set 3 having the least amount of time between intervention and the final maintenance measure. Maintenance probes were conducted at different times across the Sets and will be reported per participant's data. No maintenance measures are available for Curt, as he left the study early due to illness.

Nick's mean percent accuracy for maintenance was 69% (Set 1), 75% (Set 2), and 75% (Set 3). Set 1 was measured eight and 12 weeks from the last intervention session, Set 2, four and eight weeks, and as previously stated Set 3 was measured at two weeks from the last intervention session. Jake's mean percent accuracy for maintenance was 100% (Set 1), 63% (Set 2), and 75% (Set 3). Set 1 was measured eight and 12 weeks from the last intervention session, Set 2, four and eight weeks, and Set 3 was measured at four and six weeks from the last intervention session. Cole demonstrated the strongest maintenance means. His percent accuracy for maintenance was

94% (Set 1), 100% (Set 2), and 100% (Set 3). Set 1 was measured four and 12 weeks from the last intervention session, Set 2, four and 12 weeks, and Set 3 was measured at two and eight weeks from the last intervention session.

Discussion

Students with ASD are likely to require specialized instruction for literacy and communication in order to experience greater post-school outcomes (Caron et al., 2018; Tager-Flushberg & Kasari, 2013). With federal mandates that schools achieve improved outcomes in reading for all students (Knight et al., 2010), including those with severe disabilities, research to support access to literacy instruction for individuals with minimal or no speech who require or benefit from AAC, is vital to accomplish this goal. The current study aimed to improve literacy outcomes, specifically sight word reading, with four individuals had severe ASD and minimal or no speech, through the use of AAC technology.

Results from this study provide preliminary evidence that redesigning AAC apps with literacy support features (i.e., T2L feature) can positively impact the sight word learning. The four participants in this study demonstrated increased accuracy reading as many as 12 sight words, with the introduction of an AAC app with T2L features. The positive gains observed were a result of no practitioner instruction, just the AAC system alone; the gains were observed after a range of 60 to 348 exposures to the targeted sight words. Though no research to date has evaluated the impact of AAC apps with the T2L feature with older individuals with severe ASD who have minimal speech and very limited literacy skills, the results from this study are notable given the participant's challenges and previous literacy history. In addition, the results contribute to the growing body of research that demonstrates the effectiveness of the T2L feature in AAC apps to support literacy learning for individuals with complex communication needs (e.g., Caron et al., 2018; Mandak et al., 2018; Holyfield et al., 2019).

Extrinsic and intrinsic factors that may have contributed to the effectiveness of sight word instruction and positive gains made by the participants.

Extrinsic Factors

The T2L literacy feature, within the AAC application, was likely a contributing factor to the positive gains made by the participants. Specifically, the T2L feature (Light et al., 2014) included the use of: (a) dynamic text to attract the learner's visual attention to the written word, (b) active linking of the written word to its spoken referent (via the speech output), (c) targeting of motivating and meaningful vocabulary known to the learner (Light, McNaughton, & Caron, 2019). The combination of these features resulted in the direct and active pairing between the text label (i.e., the sight word) and graphic symbol, as well as, text and speech output - consistent with the principles of effective sight word instruction (e.g., Browder & Xin, 1998; Fossett & Mirenda, 2006).

In addition, personally-relevant and motivating sight words were selected and grouped into three sets of four words, for each participant. Individuals learn sight words more rapidly when the words are more familiar, real (vs. nonsense, like "fim" or "bol"), and appear more frequently (e.g., cake vs. sake) (Roberts, Christo, & Shefelbine, 2011). In addition, using words with meaning to the individual have greater potential of fostering intrinsic motivation and increasing engagement in the literacy activities (Light & McNaughton, 2013). Thus, selection of personally-relevant and highly motivating words may have been an important factor to positive gains.

Despite the gains demonstrated in this study, the individuals have previously experienced very limited literacy success. Low expectations and inadequate instruction have contributed to poor literacy outcomes, generally, for individuals with severe disabilities (Ruppar, 2017; Spooner, Dymond, Smith, and Kennedy, 2006). These issues may be due to teachers' (and related service providers like speech-language pathologists) training experiences; training may not have emphasized the means for adapting instruction when individuals have minimal or no speech (Spooner et al., 2006). Limited to no training for providers is required for use of the T2L feature, as the feature presents the sight words to the individual through AAC system activation and the AAC system becomes the vehicle for a means of learning. Subsequently, the AAC system as the means for learning the sight words, may have also contributed to positive gains. Although parallel instruction in literacy is recommended, for example direct instruction in phonological awareness like letter-sound knowledge or decoding, the T2L feature may have the potential to provide a means for access to some literacy instruction that inherently incorporates many best-practices (e.g., un-pairing of text and graphic symbols).

Intrinsic Factors

Three studies, including the current study, have investigated the use of the T2L feature with participants with ASD. The participant's age, diagnosis, and current literacy skills likely played a part in the different outcomes observed. Caron, Light, Holyfield, and McNaughton (2018) introduced the T2L feature in the same AAC app as used in this study, to five school-aged students with ASD (ages 6-14), in structured one-on-one sessions targeting 12 sight words. Mandak, Light, and McNaughton (2018) investigated the effects of the T2L feature within a visual scene AAC application, targeting 10 sight words, during shared reading of the storybook *Brown Bear Brown Bear* with three preliterate preschoolers with ASD (ages 3-4). Each of these studies offer promising results for use of the T2L feature with individuals with ASD, with all three studies showing positive gains for the participants and moderate to very large effects. Yet, there are differences across the three studies.

All individuals with ASD, across the studies, have made some progress with target sight word acquisition after exposure to the T2L feature. Although caution should be taken when comparing these findings, the number of exposures required in order to support acquisition varied; this provides potentially important considerations for future interventions. The preschoolers in the study by Mandak and colleagues (2019) acquired the sight words with 55 to 135 exposures. In the study by Caron and colleagues (2018), the participants learned to recognize the sight words in 20 to 32 exposures. The participants who completed the current study learned the sight words in 60 to 228 exposures. The participants in the study by Caron and colleagues (2018) required considerably less exposures. The participants in that study had acquired 26 letter-sound correspondences and demonstrated greater knowledge of sight words. With this level of phonemic awareness, and more literacy success, these individuals were likely able to use partial visual and phonetic connections to help identify sight words (Ehri, 2005).

Ehri’s phase theory (2005) has application to the study differences. This theory portrays the emergence of skills and strategies that support sight word reading. During the pre-alphabetic phase, individuals mainly rely on salient visual or contextual features to read words. The individuals in this phase may not know letters and lack phonemic awareness skills (Ehri, 2014). In addition, their sight word skills may be described as unreliable and having a number of guessing errors. Nate and Curt, fit this description, and therefore it isn’t surprising that even within this study, that these two individuals needed the most exposures in order to acquire the targeted sight words.

Once individuals learn letter sounds, they can begin to apply this knowledge to remember how to read a word. Ehri (2005) describes individuals with this knowledge as partial alphabetic. The connections in this partial alphabetic phase are still incomplete, as individuals still have no use of decoding skills, and rely on predicting and memorizing words from initial letters and context cues (Ehri, 2014). In this phase, individual's sight word reading is developing yet will often include errors when presented with similar spelled words (e.g., words with similar initial and final constants, like swim and stem) (Ehri, 2014). Jake and Cole, as well as the participants in Caron et al., 2018 fit the description of this phase. These individuals needed half the number of exposures (or less) to acquire their target sight words, in comparison to Nate and Curt, and some of the individuals from Mandak et al. 2019. Although letter-sounds seem to help in terms of rate of acquisition, and these individuals may need less exposures or repetition to acquire words, this knowledge it is not a prerequisite to use of the T2L feature or participate in sight word instruction, as demonstrated by gains made in Mandak et al. 2019 and Nate and Curt in this study.

Limitations and Future Directions

Although this study provides important data regarding the effectiveness of an AAC app with T2L software features (i.e., dynamic text with speech output upon selection of graphic symbol) on sight word learning for individuals with ASD who had minimal or no speech, it does have a number of limitations that should be considered when interpreting the results. First, the study included only a small number of participants (i.e., four). Future research should investigate the effects with a larger number of participants, as well as, individuals across ages and spoken output spectrum.

Additionally, the study targeted a small, closed set of choices that included: only symbols for words targeted within the study, only one other word with the same initial letter as the targeted sight word, varied word lengths, and a limited array of response options (i.e., choice from four photographs). The closed set of responses may have simplified the reading task (Barker, Saunders & Brady, 2012); future research is required to investigate varied sets of words, the impact of foil choices, as well as, larger word sets to determine the effectiveness of T2L features.

The current study isolated introduction of the AAC app with T2L features as the independent variable in the study. The study design does not allow comparison of the effectiveness of AAC apps with and without T2L features, as well as the relative effectives or efficiency of different design considerations (e.g., animation speech, size of text, color of word). Future research and develop is required to investigated these considerations, as well as the the effects of traditional AAC apps (i.e., static pairing of symbols and text) on sight word learning, as compared with the effects of the AAC app with dynamic T2L features. Furthermore, in order to investigate the effects of the AAC app as the independent variable, no additional literacy instruction with these words was provided in this study and no feedback was provided on reading performance. However, the AAC app with T2L features is designed to supplement, not replace, literacy instruction. Future research is required to determine the effects of the AAC app with T2L features when used as a supplement to literacy instruction. In addition, the app was also introduced in a highly structured task. The app clearly contributed to the acquisition of sight words in this structured implementation, but future research is required to investigate the effects of the T2L features on literacy acquisition when utilized in daily communication interactions with a range of communication partners to observe if this intervention context if feasible, or if the feature is best to use in a more structure learning environment.

This study also focused on an isolated skill, sight word reading. Sight word reading is a skill that is important to literacy development, however, learning to read and write requires a complex process of integrating and applying a wide range of component skills and knowledge, as well as, integrating background experience, knowledge, and language understanding (Mirenda & Erickson, 2000). Therefore, future research and development is required to investigate the effects of T2L feature on other literacy skills, like letter-sound knowledge and decoding (Light, McNaughton, & Caron, 2019).

Additionally, future research and development is required to investigate how to support the transition to traditional orthography from symbol-based AAC displays. This may include investigating the number of exposures required for acquisition and the total number of words to target during instruction. With built-in system features, the AAC system could prompt service providers to test acquisition of the word and offer the option for removal of the graphic icon, thus slowly fading graphic icons and supporting the transition to more of an orthographic system.

Conclusions

Literacy skills are vital for all individuals. Many individuals who have minimal or no speech have been viewed as incapable of developing literacy skills (Morgan, Cuskelly & Moni, 2011), thus contributing to poor literacy outcomes. Yet once an individual can read even a few words, this skill can open doors to more meaningful communication, education, and literacy experiences. Once a set of sight words are mastered, these words can serve as a foundation for further literacy development, and can support the beginning of a transition from an AAC system that utilizes mainly graphic symbols to orthography (Caron et al., 2018). This study provides preliminary evidence that redesigning AAC apps with transition to literacy (T2L) features (i.e., dynamic text with speech output upon selection of graphic symbol), results in improvements in sight word reading for individuals with severe ASD who have minimal or no speech and who have had limited literacy opportunities or success. With mandates that schools improve outcomes in reading for all students, including those with severe disabilities and minimal or no speech, research with innovative solutions like the T2L feature provide one potential solution to contribute towards accomplishing this important goal.

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Endnotes

[1]Dolch word list is a list of frequently used English words. The list contains 220 words that have to be easily recognized in order to achieve reading fluency in English. The lists are divided by grade and it is common that children are required to learn these words through memorization. A list can be found at https://www.mheducation.com

[3]SymbolStix is an icon library that includes of 25,000 symbols. More information can be found at https://www.n2y.com/symbolstix-prime/

[4]NOVA Chat 12 is a voice output communication device available from Saltillo Corporation. https://saltillo.com/products/print/nova-chat-12

Table 1
Participant Demographics

	Nick	Jake	Cole	Curt
Age	18 years; 7 months	17 years; 1 month	9 years; 7 months	10 years; 10 months
Gender	Male	Male	Male	Male
Disability	Autism spectrum disorders (ASD)	ASD	ASD	ASD; Seizure Disorder
Childhood Autism Rating Scale (CARS-2)[a]	Severe	Severe	Severe	Severe
Grade and Educational Placement	11th grade; Substantially separate Autism Support classroom; no inclusion	10th grade; Substantially separate Multi-disability classroom; no inclusion	4th grade; ½ day of therapies and ½ day of 1:1 virtual charter school; no inclusion	5th grade; Substantially separate Autism Support classroom; included for gym and art
Communication Modes	Physical communication; low-tech communication notebook with 8 to 12 line drawings (icons or photographs) per page	Physical Communication; 10 sign approximations; limited use of an iPad with GoTalk Now[7] (9 icons per page)	Physical Communication; 10 sign approximations; iPad with [8]Proloquo2Go	Physical communication; rote spoken utterances (I want + object); low-tech supports for task completion and schedule
Peabody Picture Vocabulary Test (PPVT – IV, Form A)[b]	Standard Score: 40 Percentile Rank: <0.1% Age Equivalent: 3.2 Description: Profound impairment	Standard Score: 40 Percentile Rank: <0.1% Age Equivalent: 2.3 Description: Profound impairment	Standard Score: 40 Percentile Rank: <0.1% Age Equivalent: 2.9 Description: Profound impairment	Standard Score: 42 Percentile Rank: <0.1% Age Equivalent: 3.11 Description: Profound impairment
LSC (out of 26)[c]	12	26	26	10
Dolch Word Screening[d]	3	15	10	2
Estimated total sight word inventory[e]	10	20	25	15

Note. [a]Childhood Autism Rating Scale (2nd ed.; CARS-2), helps to identify and distinguish severity of Autism. [b]Peabody Picture Vocabulary Test (4th ed.; PPVT-4) is an assessment of understanding of spoken language. No test modifications or adaptations were provided. All participants scored < 1 %ile. [c]LSC (Letter-sound correspondences) were assessed by presenting four letter tiles and the researcher stating the target letter sound. Each letter-sound was targeted three times, if the participant identified the letter-sound correctly in 2 out of 3 trials (or more), then the sound was considered known. Scores are presented as total correct out of 26. [d]Number correct out of 40, based on pre-primer word list. Written words were presented in groups of four and words were read aloud. The participants pointed to a word. [e]Sight word inventory is estimated based on (a) screening of Dolch words (*N*=40) and (b) teacher report. The total includes the Dolch words read successfully plus personally relevant words like names, places, foods, movies, etc.

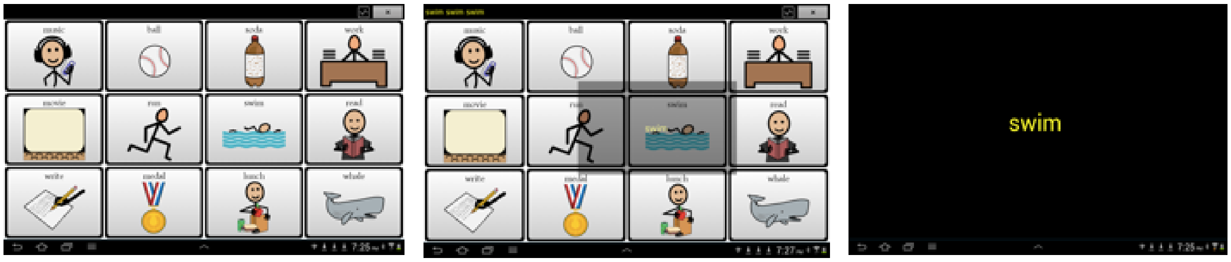

Figure 1: Example of the dynamic text feature within the graphics-based AAC grid display within the NOVA Chat 12. Upon selection of the graphic symbol with static text label (image on left), the text alone zooms out from the graphic symbol (image in the middle); the text then fills the screen for 3 seconds and the word is spoken (image on the right) before fading back into the graphic symbol. Refer to https://tinyurl.com/rerc-on-aac-T2L for a video demonstration of the feature

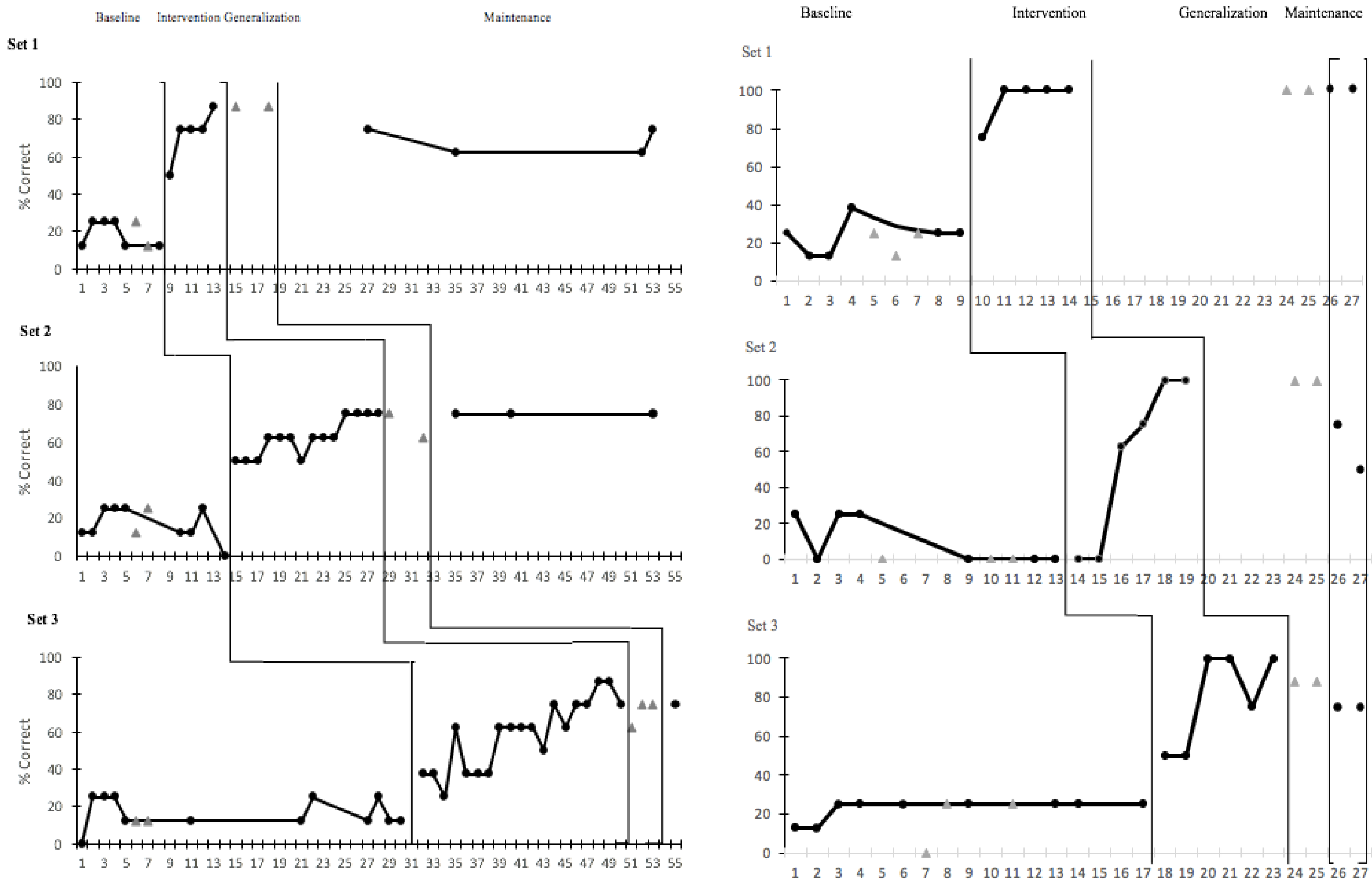

Figure 2: Percentage of single-words read correctly, by Nick (left) and Jake (right), out of 8 trials, in the probes at baseline, during intervention, and during maintenance and generalization.

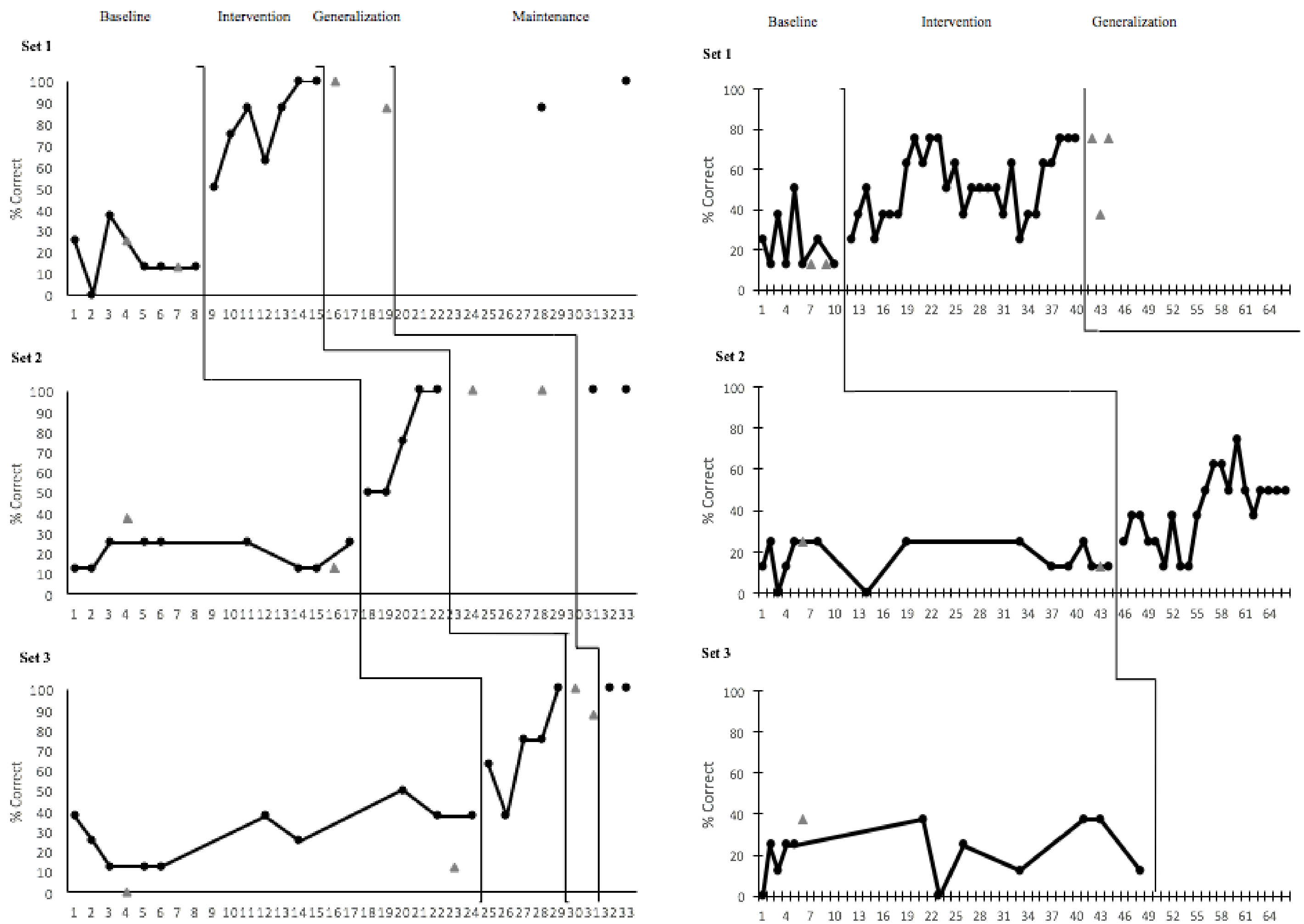

Figure 3. Percentage of single-words read correctly, by Cole (left) and Curt (right), out of 8 trials, in the probes at baseline, during intervention, and during maintenance and generalization.

Supplemental Table 1
Procedural and treatment fidelity

	Baseline probes	Intervention probes	Generalization probes	Maintenance probes	Intervention	Data
Nick	Set 1: 93; Set 2: 94; Set 3: 89	Set 1: 99; Set 2: 98; Set 3: 89	Set 1: 100; Set 2: 89; Set 3: 97	Set 1: 89; Set 2: 89; Set 3: 89	Set 1: 100; Set 2: 100; Set 3: 95	Set 1: 100; Set 2: 100; Set 3: 100
Jake	Set 1: 100; Set 2: 100; Set 3: 100	Set 1: 99; Set 2: 100; Set 3: 100	Set 1: 100; Set 2: 100; Set 3: 100	Set 1: 100; Set 2: 100; Set 3: 100	Set 1: 97; Set 2: 100; Set 3: 100	Set 1: 100; Set 2: 100; Set 3: 100
Cole	Set 1: 100; Set 2: 100; Set 3: 100	Set 1: 98; Set 2: 99; Set 3: 94	Set 1: 100; Set 2: 100; Set 3: 98	Set 1: 89; Set 2: 89; Set 3: 100	Set 1: 100; Set 2: 100; Set 3: 100	Set 1: 100; Set 2: 100; Set 3: 100
Curt	Set 1: 99; Set 2: 97; Set 3: 99	Set 1: 99; Set 2: 91	Set 1: 98; Set 2: 98	Left study early	Set 1: 100; Set 2: 85;	Set 1: 100; Set 2: 100; Set 3: 100

Note. Mean fidelity (reported in percentages) of probes sessions, intervention, and, the data, for each of the participants, across Word Sets and study phases

Supplemental Table 2

Individualized word lists, per participant, for each of the three Sight Word Sets

	Set 1	Set 2	Set 3
Nick	almonds, crackers, swim, stop	bird, read, run, gym	scooter, help, computer, horse
Jake	washer, wrench, baler, shovel	harrow, hose, pliers, litter	camping, camo, pager, lure
Cole	frito, bunny, potty, pizza	pool, pretzel, cars, ipad	jeep, juice, bike, mickey
Curt	cheetos, minecraft, computer, water	marker, milk, legos, eraser	spin, run, candy, cut

Supplemental Table 3

Number of Exposures and Total Time of Exposure to the Dynamic Text During Intervention for the Participants, per Set of words

Participant	Total number of intervention sessions per set	Total # of exposures to dynamic text per set	Total dynamic text exposure time[a] per word, per set
Nick	Set 1: 5; Set 2: 14; Set 3: 19	Set 1: 60; Set 2: 168; Set 3: 228	Set 1: 3 min; Set 2: 8 min, 24s; Set 3: 11 min, 24s
Jake	Set 1: 5; Set 2: 6; Set 3: 6	Set 1: 60; Set 2: 72; Set 3: 72	Set 1: 3 min; Set 2: 3 min, 36s; Set 3: 3 min, 36s
Cole	Set 1: 7; Set 2: 5; Set 3: 5	Set 1: 84; Set 2: 60; Set 3: 60	Set 1: 4 min, 12s; Set 2: 3 min; Set 3: 3 min
Curt	Set 1: 29; Set 2: 21; Set 3: did not complete	Set 1: 348; Set 2: 252; Set 3: did not complete	Set 1: 17 min, 24s; Set 2: 12 min, 36s; Set 3: did not complete

Note. [a]Exposures are counting the amount of time with the text on the screen (3s per activation)