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A Pilot Investigation of an Autonomous Technology-Based Instructional Program for Teaching Sentence Construction to Students With Extensive Support Needs

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Abstract

In the current investigation, we evaluated the effects of technology-based instructional prototype in teaching eight students with extensive support needs to construct sentences. We employed a concurrent multiple probe research design and determined that the package was effective for seven of the participants. Further, teachers reported favorable perceptions of the prototype. Limitations and areas for future research are discussed.

Keywords

writing, content/curriculum area, intellectual disability, exceptionality, sentence construction, assistive technology, technology perspectives

The field of special education has witnessed a sea change in expectations for the participation of students with extensive support needs (ESN; i.e., autism, intellectual disability, and/or multiple disability) in educational settings. In the last several decades, stakeholders have worked diligently toward increased access to general curriculum, ultimately producing legislative mandates and a movement of the proverbial needle (Individuals with Disabilities Education Act, 2004; No Child Left Behind, 2001). Researchers, propelled by this momentum, established new lines of inquiry into academic instruction for this unique population of students and began to forge a path forward, one investigation at a time. Their work provided demonstrations of effective procedures in reading (e.g., Browder, Ahlgrim-Delzell, Courtade, Gibbs, & Flowers, 2008), mathematics (e.g., Spooner, Saunders, Root, & Brosh, 2017), science (e.g., Jimenez, Browder, & Courtade, 2009), social studies (e.g., Schenning, Knight, & Spooner, 2013), and writing (e.g., Pennington, Collins, Stenhoff, Turner, & Gunselman, 2014). Further, researchers reviewed and evaluated this growing body of literature to extricate evidence-based practices that may be disseminated to guide practitioners in their service delivery (Hudson, Browder, & Wood, 2013; Pennington & Delano, 2012; Spooner, Root, Saunders, & Browder, 2019). Although only a few practices have met the criteria to be deemed as evidence-based for teaching a particular content area (Spooner, Knight, Browder, & Smith, 2012; Spooner et al., 2019), two practices have been consistently and effectively applied as a part of intervention packages to teach academics to students with ESN, response prompting and technology-aided instruction and intervention (TAII).

Response prompting, rooted in applied behavior analysis (Touchette, 1971), involves the presentation of an instructional stimulus, the subsequent delivery of a prompt to evoke the student's correct response, and finally, the delivery of a programmed consequence (e.g., reinforcer, error correction, extinction). Over time, the instructor fades the prompt by inserting a brief delay between the instructional stimulus and the presentation of the prompt or by inserting increasingly or decreasingly intrusive prompts (Wolery, Ault, & Doyle, 1992). For example, Root, Saunders, Spooner, and Brosh (2017) taught students to use a graphic organizer to solve math problems related to finance. After modeling how to use the organizer, they provided an opportunity for the student to use it independently. If the learner made an error or did not complete a step within 10 s, they initiated a prompting sequence that included the delivery of a general verbal prompt, followed by

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a specific verbal prompt, and ultimately a model of the correct response. Response-prompting procedures including progressive and constant time delay, system of least prompts, most to least prompting, simultaneous prompting, and graduated guidance have accumulated substantial research evidence as to their efficacy and been deemed a central component of programming for students with severe disabilities (Browder, Wood, Thompson, & Ribuffo, 2014).

TAII involves the application of any electronic item, equipment, application, or virtual network to facilitate behavior change (Odom, 2013). TAII has been ubiquitous in the recent research literature on teaching academic skills to students with severe disabilities across content areas (e.g., Knight, McKissick, & Saunders, 2013; Mims, Stanger, Sears, & White, 2018; Pennington, 2010; Root, Cox, & Gonzalez, 2019) and its increased accessibility has made it a part of the educational experience of many students with complex needs. For example, Mims, Stanger, Sears, and White (2018) taught students to write about text using a digital app. The app presented a digital reading of modified grade level texts and then guided students through the selection of sentences to construct an opinion text. The app used response-prompting procedures and provided digital feedback. The use of technology offers many potential benefits to the instructional context including the controlled presentation of instructional stimuli (i.e., pacing, limited non-targeted stimuli, feedback), increased implementation fidelity, pairing of instruction with potentially reinforcing digital stimuli, and in some cases, a 1:1 instructional arrangement (Knight, McKissick, & Saunders, 2013; Panyan, 1984; Pennington, 2010). Together, these potent features when combined with response prompting may produce a high-quality instructional environment to facilitate the acquisition of a range of academic skills.

One content area that may be especially suited for the application of a TAII and response-prompting package is written expression. Writing involves the execution of a complex set of skills, many of which may be difficult for students with ESN to acquire and emit. For example, many of these students may have difficulty producing legible written text (Kushki, Chau, & Anagnostou, 2011) or developing a spelling repertoire sufficient to effectively and efficiently generate narratives (Henry & Winfield, 2010). In both cases, educators may use technology to circumvent these potential barriers to writing. In several investigations, researchers have taught students with ESN to generate text by selecting words from a digital array displayed on a computer or tablet (e.g., Basil & Reyes, 2003; Pennington & Rockhold, 2018; Yamamoto & Miya, 1999). Recently, researchers sought to support students with difficulties in sentence construction by having them select complete sentences from an array to construct a narrative about a passage read to them (Mims, Lee, Browder, Zakas, & Flynn, 2012; Mims et al., 2017). These investigations mark a potential pathway for students with ESN to access writing instruction in the absence of key basic writing skills.

The majority of the studies involving TAII to teach writing to students with ESN have included response prompting as the primary method to facilitate skill acquisition. For example, Pennington, Collins, Stenhoff, Turner, and Gunselman (2014) used simultaneous prompting to teach the construction of simple stories to students with autism spectrum disorder. During each instructional session, they asked the student to independently construct a story by selecting words displayed in a computer-based array. Subsequently, they prompted the student to construct three stories by pointing to words on the array. After the completion of each story, the researchers played a digital reading of the story. Similarly, Pennington, Flick, and Smith-Wehr (2018) used the system of least prompts to teach two students with ESN to select words from a word bank displayed on a tablet to construct sentences. During instruction, a classroom teacher presented a request to write a sentence and then waited 5 s for the student to select the first word. If the student made an error or failed to select a word within 5 s of the last selection, the teacher presented a written model. If the student made an error after the presentation of the model, the teacher prompted the completion of the sentence by pointing to the word on the written model and then on the digital array. In the last decade, the majority of experimental research on teaching writing skills to learners with ESN has incorporated similar procedures and have demonstrated their efficacy in facilitating the acquisition of written communication skills in this unique population of students (e.g., Lee, Hawley, Browder, Flowers, & Wakeman, 2016; Mims et al., 2017; Pennington, Delano, & Scott, 2014; Pennington & Koehler, 2017; Pennington, Foreman, & Gurney, 2018). Across these studies, the procedures were implemented by a human change agent (i.e., researcher, teacher).

Recently, advances in technology have permitted researchers to incorporate response-prompting strategies within closed loop software programming. That is, researchers have programmed digital tutors to present instructional stimuli and provide differential feedback contingent on learner responding. For example, in a series of recent studies, researchers used digital tutors to teach reading skills to students with ESN (Saadatzi, Pennington, Welch, & Graham, 2018a, 2018b; Saadatzi, Pennington, Welch, Graham, & Scott, 2017). During instruction, a digital tutor used speech to text technology and constant time delay procedures to respond to students' vocal responses to words presented on digital flash cards. Across all three investigations students acquired the targeted skills, and in some cases, they acquired skills that were not targeted (i.e., a peer's instructional targets). This closed loop technology may be an effective and helpful tool in educational settings as it can offer 1:1 instruction with a high level of preprogrammed implementation fidelity.

To date, there has been only one investigation of closed loop instructional technology to teach writing skills to students with ESN. Mims et al. (2017) designed and evaluated software that provided response prompts and feedback during students' construction of opinion passages about a text they had read. Their results indicated that participants improved opinion passage construction skills. In light of recommendations to provide systematic instruction (e.g., controlled presentation of stimuli,

Table 1. Participant Characteristics.

Participant	Race, Gender	Age (Years)	Disability Category	Intellectual Functioning	General Expressive Communication
Happy	White, female	15	Moderate ID	DAS-2 52	Minimal vocal
Kiki	White, male	17	Moderate ID	RIAS-57	Minimal vocal
Hatman	White, male	21	ASD, severe ID	DAS-2 30	Nonvocal
AKW	Black, female	10	Moderate ID	DAS 49	Vocal
Lucy	Black, female	10	Moderate ID	WISC-5 40	Vocal
Dino	Black, male	8	ASD, ID	DAS-2 57	Vocal
Ian	Hispanic, male	9	ASD, Moderate ID	DAS-2 50	Minimal vocal
Thomas	White, male	8	ASD, Moderate ID	SB 42	Minimal vocal

Note. ASD = autism spectrum disorder; DAS = Differential Ability Scales; RIAS = Reynold Intellectual Assessment Scales; WISC = Wechslers Intelligence Scales for Children; SB = Stanford-Binet.

response prompting) and frequent feedback as students write coupled with the learning characteristics of students with ESN, there is a need for closed loop instructional software designed for use with students with ESN. Therefore, the purpose of this article is to describe a pilot investigation of a closed loop software program, *GoWrite*, for teaching sentence writing to students with ESN. We addressed the following research question*: Is there a functional relation between the use of the GoWrite instructional package and the percent of correct sentences constructed by students with intellectual disabilities?*

Method

Participants and Setting

After obtaining consent from the universities' internal review board, we were invited to attend a summer professional development training held by a local school district in a suburban area of the southeastern United States. During that training, we solicited participation in the study. Teachers interested in participation provided their names and contact information. Following the beginning of the school year, the researchers contacted the teachers and provided inclusion criteria for the selection of students. Ultimately, four teachers decided to participate and sent consent forms to the parents of students who met our inclusion criteria of having (a) moderate to severe intellectual disability (b) a sight word reading repertoire of at least 10 words, (c) experience in manipulating digital technology via a mouse or touch screen, and (d) weaknesses in sentence writing skills. Eight students, ages 8 through 21 with ESN, participated in the study (see Table 1). All participants received special education services in a self-contained or resource classroom.

We conducted all sessions in the participants' special education classroom. During each session, the classroom teacher directed the participants to a potentially less distracting area of the classroom (e.g., desk or table in the back of the room) and presented the tablet with installed app. Sessions lasted approximately 10 min.

Materials

During all sessions, students used an app, GoWrite, that was installed on a portable computer tablet (iPad). We iteratively designed the app using feedback from teachers and students. Prior to the current investigation, we presented an earlier prototype of the app to 32 students with disabilities and their eight teachers. We asked the students to use the app as their teachers observed. Subsequently, we solicited feedback from the teachers. Student observations and teacher feedback indicated a need for fewer trials, longer response intervals, and more reinforcing stimuli. We incorporated those recommendations into the version used in this study.

Prior to baseline sessions, the researcher or classroom teacher helped students develop an avatar with the app. The teacher orally presented choices (e.g., boy/girl) and then directed the student to make a selection by touching the picture. Students were provided opportunities to choose gender, body type, hair color, skin color, and shirt color (see Figure 1). During baseline and intervention sessions, the revised prototype presented a display containing the participant's avatar, a digital instructor (e.g., Robin the robot), a picture stimulus, a nine-cell word bank, and a token system (see Figure 2.). During baseline sessions, the teacher selected an "assessment" toggle which turned off instructional features (e.g., prompting, error correction). When the assessment toggle was not selected, the participants' avatars read sentences aloud as their mouths moved and the digital instructor delivered instructions and feedback as its mouth moved. The software delivered auditory and visual prompts as described below.

In addition, across all sessions, the app presented a picture about which the students were intended to write and a word bank. There were five targeted stimuli (i.e., ball, bus, dog, car, bird) and two pictured exemplars of each. We selected these pictures because of their ubiquity in natural environments and their availability in other software programs made by the designers. Words were centered within each cell in the word bank.

Experimental Design

We used a concurrent multiple probe (MP) design (Horner & Baer, 1978) across participants to evaluate the efficacy of the

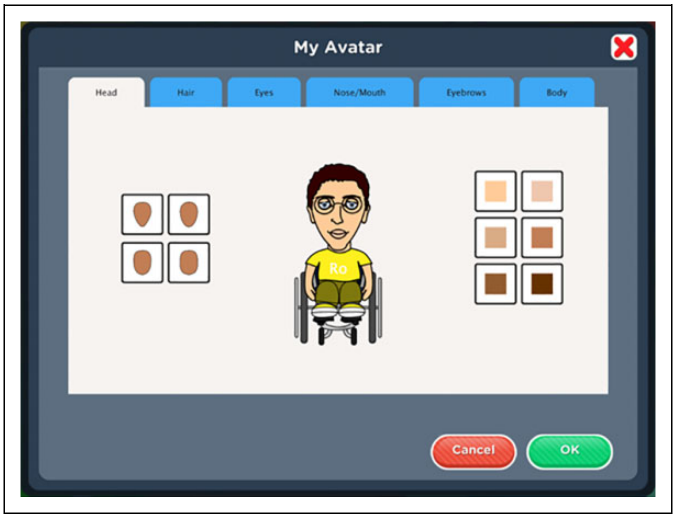

Figure 1. Screenshot of avatar design.

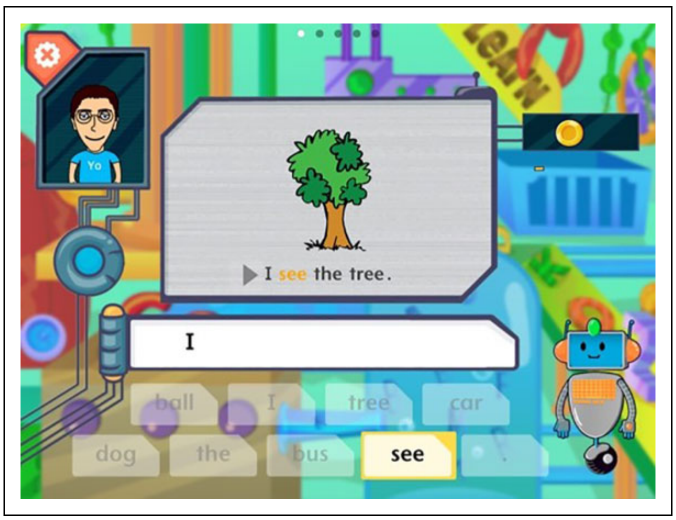

Figure 2. Screenshot of prototype application.

instructional package. Two sets of three participants and one set of two participants were yoked together in an MP arrangement. Prior to introducing intervention to the first participant in a set, we conducted at least three baseline probes across all participants in a set. Subsequently, we introduced the intervention package to each participant, one at a time, following a sustained (i.e., at least three data points) change in responding by the previous participant. We continued instruction until students met a mastery criterion of 80% across three consecutive sessions.

Dependent Variable and Measurement Procedures

During baseline and intervention conditions, the app collected data on the percent of correct sentences constructed and selections made. Data were sent to the primary researcher from the app via an e-mail containing raw data assigned to each student's pseudonym immediately after each session. A sentence was scored as correct if it matched the targeted sentence format (i.e., I see the [noun], The [noun] is [adjective]) and accurately described the picture. We calculated percent by dividing the number of correct sentences written by the number of opportunities (i.e., five trials) and multiplied by 100%.

To reduce instrumentation threats to internal validity, we collected dependent variable reliability data across baseline and intervention conditions. The researcher sat behind the student and collected data as they used the app. We compared the researcher's direct observation data to the data collected the app. We calculated point-to-point interobserver agreement (IOA) by dividing the number of agreements by the number of agreements and disagreements and dividing by 100%. We calculated IOA for 100% of baseline and 37% of intervention sessions for Happy, 60% of baseline and 28% of intervention sessions for Kiki, 50% of baseline and 26% of intervention sessions for Hatman, 66% of baseline and 33% of intervention sessions for AKW, 60% of baseline and 21% of intervention sessions for Lucy, 100% of baseline and 30% of intervention sessions for Dino, 40% of baseline sessions for Ian, and 40% of baseline and 25% of intervention sessions for Thomas. Agreement across all participants was 100%. We also collected procedural reliability data during these sessions by dividing the number of observed teacher steps by the number of total steps and multiplying by 100%. Data were collected on the following steps: (a) teacher presented GoWrite and directed the student to use it, (b) teacher did not prompt the student to make specific selections, and (c) during baseline sessions, the teacher provided general praise at the end of each session or during intervention sessions, the teacher assisted student in accessing coin exchange at the end of the program. Average procedural reliability across participants was 100% for baseline and 97% for treatment sessions.

Teacher Training

Immediately prior to baseline sessions, the researcher demonstrated procedures for accessing the software, individual student sign ins, specific writing tasks, and coin exchange activities. The researcher then provided the teacher an opportunity to ask questions and to practice using the app and receive feedback. During baseline and intervention sessions, teachers provided minimal interaction with students as the application delivered instructional procedures.

Baseline Sessions

During baseline sessions, the teacher selected the assessment button within the app's menu, presented the application in front of the student, and provided the directive, "Work on sentence writing." The app presented five trials per session. During each trial, it presented a pictured stimulus in the center of the screen, a word bank, the request "What do you see? Write a sentence," and then waited 8 s for the student to respond. If the student did not touch a single word within 8 s, or selected five correct or

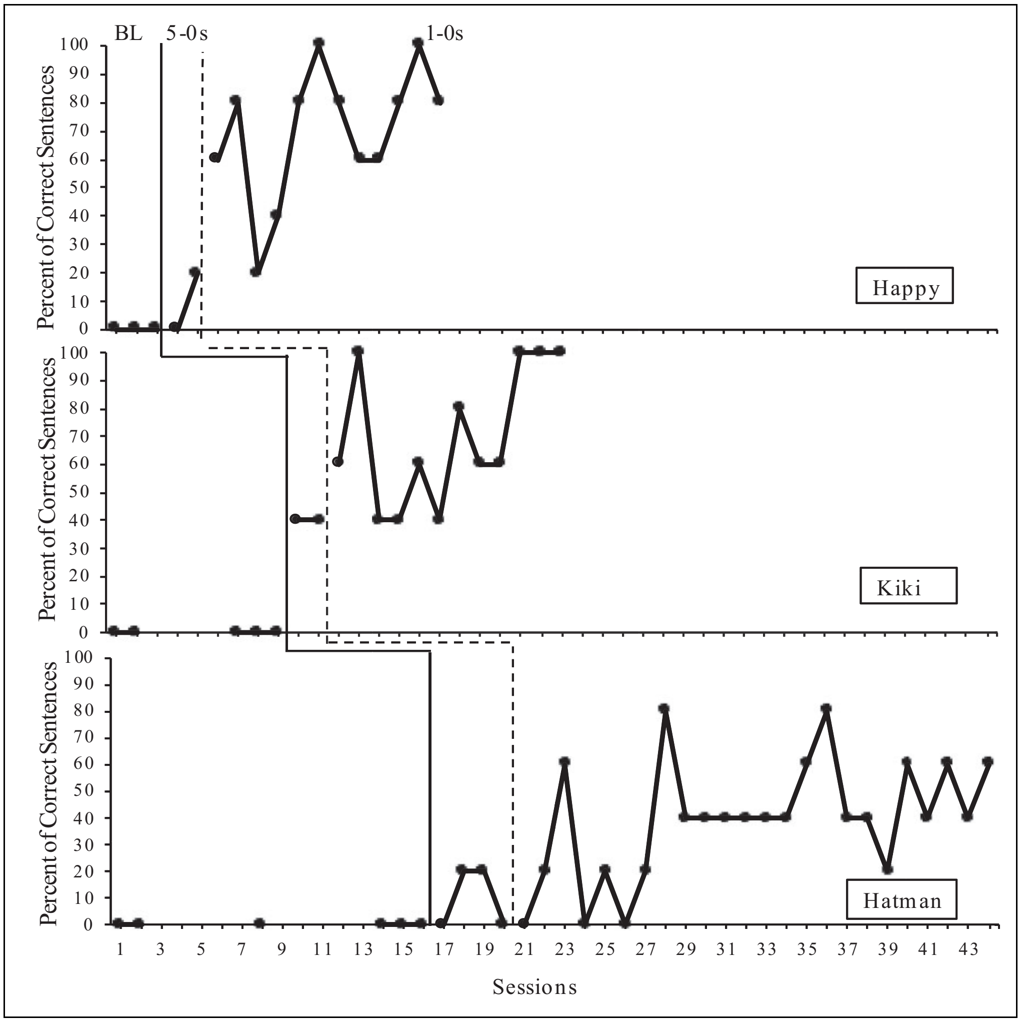

Figure 3. Set 1 results.

incorrectly sequences words, the trial was terminated. The app provided no feedback during each baseline session, but at the end of each session, the teacher provided general praise. During baseline sessions, the app presented pictures and words that would be used during instructional sessions.

Instructional Sessions

At the onset of the first session, a virtual teacher provided directions for using the software and earning digital coins. During the first 2–4 instructional sessions, the app presented five 0-s delay trials followed by five prompt delay trials. The preprogrammed app offered two options for the delivery of 0-s delay trials, five consecutive trials or a single trial. Each participant's teacher decided on the number of these sessions, following observation of the first session. They made determinations based on their prior knowledge of their students and the perceptions related to how quickly their students learned to respond to the software's prompting features. During 0-s delay trials, the app presented a picture with the correct sentence displayed beneath it, a word bank, and the directive, "What do you see, write a sentence." Immediately following the directive, it provided prompts for the correct selection of each word (i.e., highlighted word within the model sentence and highlighted word within bank). All other options, with the exception of the correct word, were shaded and inaccessible, forcing a correct selection. Following the selection of the correct word, the student's avatar stated the word and a coin accompanied by an auditory "ping" appeared in the student's coin bank. During prompt delay trials, the app presented a picture, a word bank, the directive "What do you see, write a sentence" and waited 8 s for the student to respond. If the student selected the correct word, the avatar stated the word and a coin with an accompanying auditory "ping" appeared in the student's coin bank. Subsequently, an 8-s response interval started for selection of the next word. If the student did not respond or selected the incorrect word, the app highlighted the correct word and stated, "Select this word." All other words were shaded and inaccessible. Upon selection of the highlighted word, the avatar orally read the word but no coin appeared in the student's bank. At the completion of each prompted or unprompted sentence, the avatar read the entire

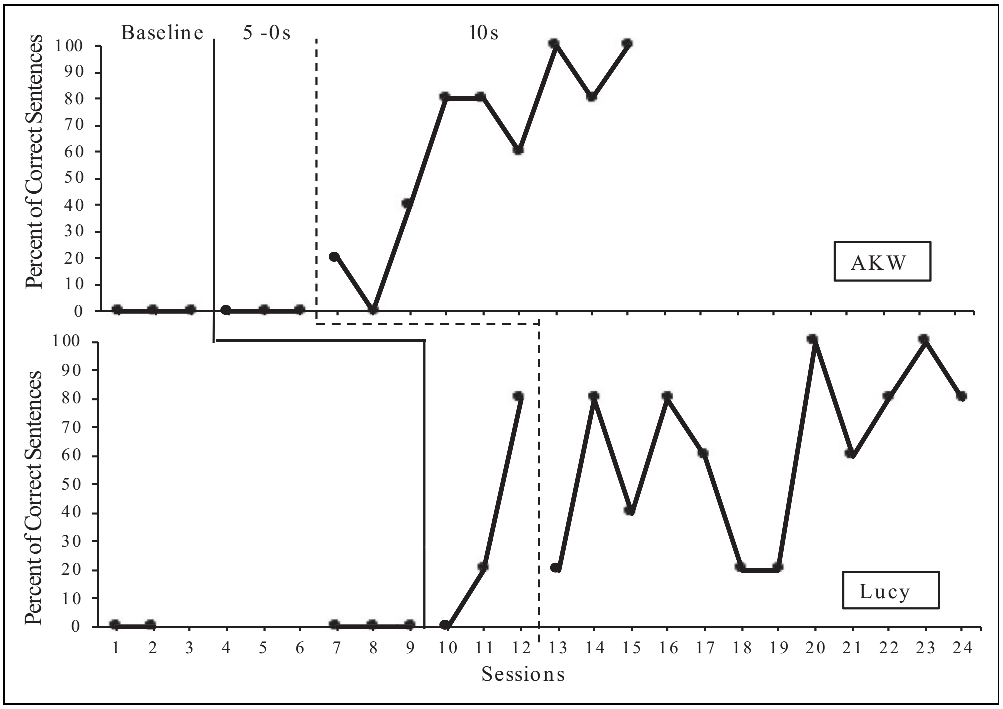

Figure 4. Set 2 results.

sentence aloud as each word in the sentence was highlighted. At the completion of each session, a new screen appeared depicting the coins earned during the session added to the student's total number of coins. Finally, students were presented the opportunity to go to the "Shop" menu and chose to purchase hats for their avatar or play games.

Social Validity Questionnaire

At the completion of the study, the teachers were sent an electronic survey to assess their perceptions of the digital instructional package. The survey was comprised of five 5-point Likert-type scale items that required respondents to rate statements as strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree. In addition, the survey contained three open-response questions to which respondents were directed to describe perceived barriers, strengths, and ways to improve the app.

Results

Set 1

Happy. During baseline sessions, Happy did not construct any sentences (see Figure 3). During sessions in which five 0-s delay trials were presented, she constructed one sentence during the second session. During sessions in which the app presented a single 0-s delay trial, Happy demonstrated an immediate change in performance and a variable but increasing trend to performance levels between 80% and 100% accuracy.

Kiki. During baseline sessions, Kiki did not construct any sentences. During sessions in which five 0-s delay trials were presented, he constructed two sentences during each session. During sessions in which the app presented a single 0-s delay trial, Kiki demonstrated an immediate change in performance, high levels of variability but an increasing trend to consistent performance at 100% accuracy.

Hatman. During baseline sessions, Hatman did not construct any sentences. During sessions in which five 0-s delay trials were presented, he constructed one sentence during two of the four sessions. During sessions in which the app presented a single 0-s delay trial, Hatman demonstrated variable but gradual improvement over time to levels of 40–60% accuracy. It is important to note an error analysis indicated that the majority of errors were a result of him not making a selection within the 8-s response interval.

Set 2

AKW. During baseline sessions or sessions in which five 0-s delay trials were presented, AKW did not construct any sentences (see Figure 4). During sessions in which the app presented a single 0-s delay trial, AKW demonstrated a steadily increasing trend to performance levels above 80% and 100% accuracy.

Lucy. During baseline sessions, Lucy did not construct any sentences. During sessions in which five 0-s delay trials were presented, she constructed between one and four sentences. During sessions in which the app presented a single 0-s delay trial, Lucy demonstrated high levels of variability but an

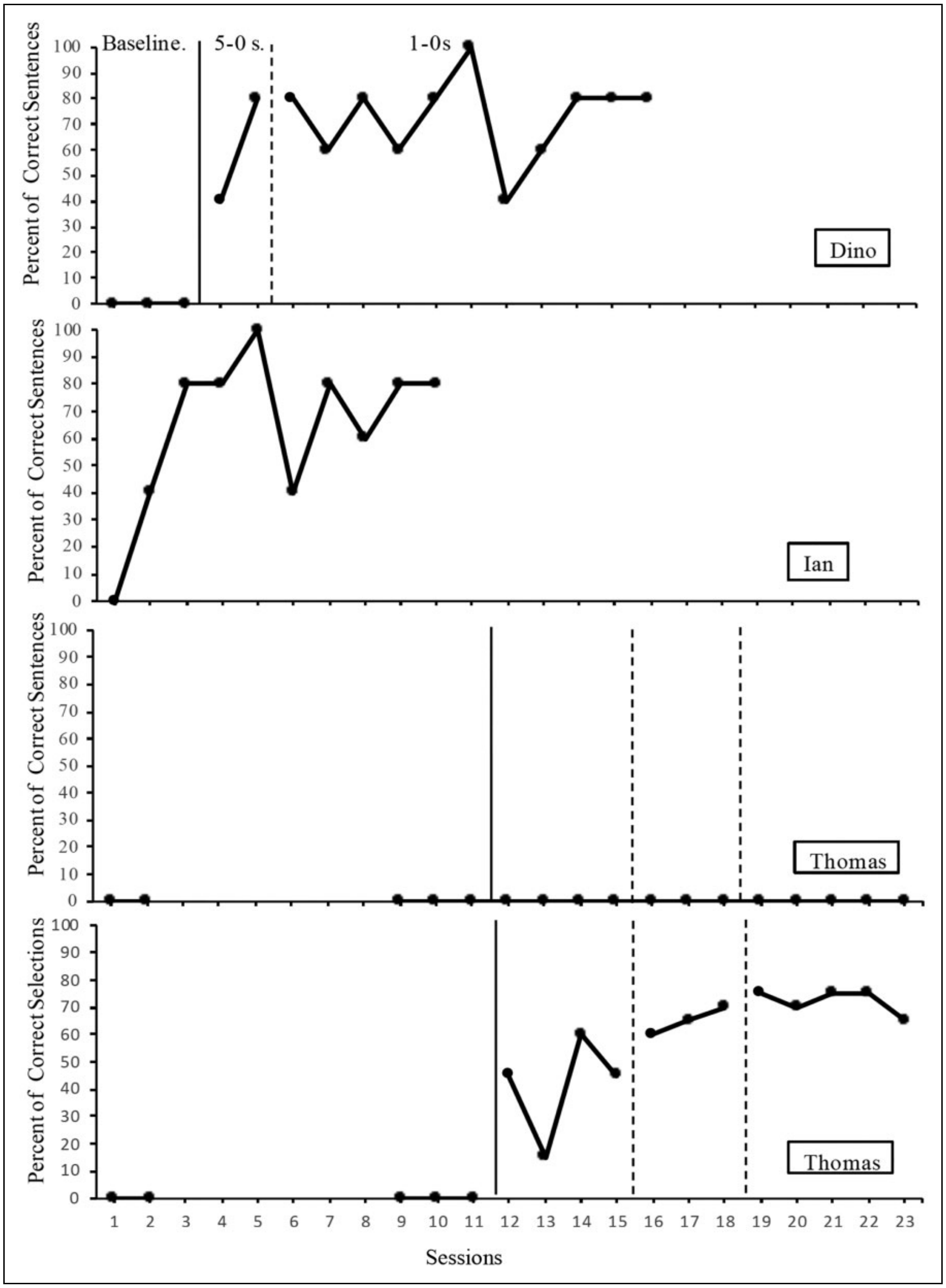

Figure 5. Set 3 results.

increasing trend to consistent performance at between 80% and 100% accuracy.

Set 3

Dino. During baseline sessions, Dino did not construct any sentences. During sessions in which five 0-s delay trials were presented, he constructed between two and four sentences. During sessions in which the app presented a single 0-s delay trial, Dino demonstrated high levels of variability but consistent performance 80% accuracy.

Ian. During baseline sessions, Ian made rapid progress to 80–100% accuracy and then displayed variable performance over time. As a result, the teacher did not present the intervention condition.

Thomas. During baseline sessions or intervention sessions, Thomas did not construct any complete sentences. The bottom graph on Figure 5 depicts the percent of Thomas' correct selections during baseline and intervention sessions (number of correct selections/20 selections). Thomas made no correct

Table 2. Mean Ratings on Social Validity Questionnaire.

Item	Mean
GoWrite was effective in teaching sentence construction to my students	4.75
I would use GoWrite with other students	4.5
I would continue GoWrite after the study concludes	4.25
My students enjoyed using GoWrite	4.75

selections during baseline sessions. During sessions in which five 0-s delay trials were presented, he made selections with an average of 41.25% accuracy. During sessions in which GoWrite presented a single 0-s delay trial, Thomas made selections with an average 65% accuracy. During these sessions, it was noted that Thomas correctly selected "I see the" during each trial but would not touch the final word though he would often state the word. As a result, we conducted two "booster" sessions, during which the teacher physically prompted the final word during each trial. Following booster sessions, his performance improved to a mean level of 72% accuracy, but he still did not select the final word during any trials.

Tau-U

We used Tau-U (Parker, Vannest, Davis, & Sauber, 2011) to provide a nonparametric effect. For Happy, Kiki, and Hatman, we calculated the effect to be .94, 1, .83, respectively. For AWK and Lucy, we calculated the effect to be .61 and 1, respectively. For Dino, we calculated the effect to be 1, and for Thomas, we calculated the effect for sentence construction to be 0 and for correct selections to be 1.

Social Validity

All four teachers completed the social validity survey. For the purpose of summarizing the data (see Table 2), we assigned numeric values to each of the ratings and reported their ratings as means, that is, *strongly agree* [5.0], *agree* [4.0], *neither agree or disagree* [3.0], *disagree* [2.0], or *strongly agree* [1.0]. The teachers rated the statement GoWrite *was effective in teaching sentence construction to my students* as 4.75, *I would use GoWrite with other students* as 4.5, *I would continue GoWrite after the study concludes* as 4.5, *GoWrite was easy to implement* as 4.25, and *My students enjoyed using GoWrite* as 4.75. All teachers scored items as strongly agree or agree. In response to the question, *Describe any barriers to using GoWrite*, one teacher reported that one of the reinforcement games did not work, one reported teacher had to click multiple buttons to change settings, and one indicated a need for more technology so that multiple students could use GoWrite as the same time. In response to the question, *Describe how you might improve GoWrite,* one teacher suggested improving the games and ability to accessorize your avatar. Similarly, another suggested that students should earn enough coins to play the games during each setting and that some of the games should be shortened. One teacher suggested having simpler sentences for students performing at lower levels. Finally, one noted that due to the length of the word monster, that it was displayed in a smaller font within the word bank. Finally, in response to the question, *Describe features of GoWrite you found useful*, one teacher indicated that using patterns, the short length of instructional activities, and reinforcement systems were helpful. One teacher indicated pictures, the assessment toggle, reward systems and prompting to be helpful. Another indicated the use of time delay and the reward system as helpful. Finally, one indicated the ability to change the amount of time a student has to answer.

Discussion

In the current investigation, we sought to evaluate the effects of a novel technology-based instructional package, GoWrite on the sentence writing skills of students with ESN. Our findings indicated that the package produced improved outcomes in seven of the eight participants. Further, social validity data suggest the participants' teachers perceived the package to be effective and that they would continue to use it following the study and with other students. These findings extend the available research literature on teaching writing skills to individuals with ESN in several ways.

First, our findings offer further support that students with more severe disabilities can indeed benefit from carefully designed instruction in the area of written expression. We demonstrated the seven of the eight participants acquired writing skills as a result of the intervention package. Despite being identified for participation due to his lack of sentence writing skills, one participant made gains during a baseline condition. It is plausible that software features within baseline conditions (e.g., selection-based responding, word bank, auditory feedback) may have served to support his writing skills. Together with previous investigations, this study helps to demonstrate that weaknesses presented by struggling writers with ESN are amenable to systematic intervention.

Second, this investigation provided another demonstration of the efficacy of response-prompting strategies in teaching academic skills to students with ESN. These strategies are ubiquitous in the experimental intervention research literature on teaching academic skills to students with ESN, but recent investigations into new content areas such as written expression reflect new and innovative applications of response prompting. In the current investigation, we extended previous literature in response prompting and writing (e.g., Pennington, Flick, & Smith-Wehr, 2018; Pennington, Foreman, & Gurney, 2018; Pennington & Rockhold, 2018: Mims et al., 2017; Yamamoto & Miya, 1999), but others have initiated research lines in the areas of math problem-solving (Root, Browder, Saunders, & Lo, 2017), structured inquiry in social studies (Schenning et al., 2013), and science literacy (Knight, Spooner, Browder, Smith, & Wood, 2013). These new directions in the response-prompting literature have not only extended our understanding of the capacity of these procedures but have extended our expectations for this population students.

Finally, this investigation represents a novel application of autonomous instructional technology for teaching sentence writing skills to students with ESN. The current technology offered teachers and students several potential benefits. Teachers were able to provide 1:1 instruction while working with other students, apply systematic prompting procedures without training, and receive student data without the use of manual collection procedures. Students received 1:1 instruction, dense schedules of instructional feedback, and a personalized digital environment (e.g., avatars, prompting as needed). Interestingly, our findings also suggest some limitations to the digital format. For example, our data reflect high levels of variability indicating the presence of mediating environmental variables. We observed that students were often distracted from using the app by other events in the classrooms (e.g., someone entering the room) precluding their responding within the app's prescribed response interval and resulting in app's recording of an error. Additionally, we found that the some of the shopping items (e.g., games, avatar accessories) did not appear to serve as putative terminal reinforcers for the token system. Future research should address ways to further personalize digital applications regarding the identification and inclusion of stimuli that are reinforcing to and age appropriate for a range of users.

Limitations and Future Directions

Despite overall positive outcomes, several limitations should be considered. First, three of the participants did not meet criterion following the introduction of intervention. As aforementioned, one participant made progress during his baseline condition precluding a demonstration of effect. Two other participants failed to meet criterion. Hatman presented with motor challenges and errors often resulted from him not responding within the response interval. We observed that he often approached the correct word but failed to make a selection within the response interval. Future iterations of our prototype app should provide an opportunity for teachers to schedule longer and shorter wait times. Thomas made rapid progress in word selection but failed to select the final word in the sentence, despite saying the word aloud. It may have been the case that Thomas was tacting/labeling the picture but could not find the written word within the word bank. He might have acquired the "I see a" more quickly because it was repeated across every trial. Since, we wanted to assess the usability of the app for a typical "out of the package" classroom adoption, we decided to not assess student's prior skills in matching or in reading the words presented in the bank during the study. This precluded our ability to ascertain the impact of prior reading skills on student performance during the study. Future investigations should include a preassessment of the vocabulary prior to intervention, or future app iterations might include procedures for teaching vocabulary. For example, the app might provide a match to sample (word to picture) task at the beginning of each session.

Second, the prototype was comprised of several components including (a) response prompting, (b) digital pedagogical agent, (c) avatars, (d) token economy, and (e) selection-based responding. As a result, it is unclear as to the most active ingredients within the package and whether all of the components were necessary. There is a need for further evaluation of the role of each of these components within writing instruction for students with ESN.

Finally, we did not employ a traditional time delay procedure in that during every trial, participants received at least one 0-s delay trial providing a model of the targeted sentence. In previous investigations (e.g., Pennington & Rockhold, 2018), the teacher delivered a controlling prompt comprised of a model of a complete sentence. As participants typed, they observed the entire sentence unit. Since the app in the current investigation prompted by signaling the selection of a single word, we programmed a 0-s delay trial during every session to ensure participants observed at least one model of a correct sentence prior to the opportunity to make errors. Future researchers might evaluate the necessity of the single 0-s delay trial. Since much of the research using constant time delay reflects the complete removal of the 0-s delay trials following a few sessions, it is likely not required.

Conclusion

Written communication is a critical skill toward self-determination in that it serves as a vehicle for increased access in social, educational, and community contexts. Unfortunately, many students with ESN may not receive high-quality writing instruction, as there are limited research data to supported evidence-based practice in this area. In the current investigation, we sought to provide easy access to instructional procedures, rooted in previous research, via an autonomous prototype app. We did not have to train teachers to implement instructional procedures or collect data on student performance. Overall, the prototype produced positive outcomes, suggesting that we were able to circumvent the traditional process of coaching teachers to implement a new procedure and supporting them to maintain fidelity while providing another platform for writing instruction for students with ESN.

Declaration of Conflicting Interests

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References

Basil, C., & Reyes, S. (2003). Acquisition of literacy skills by children with severe disability. *Child Language Teaching and Therapy*, *19*, 27–48.

Browder, D. M., Ahlgrim-Delzell, L., Courtade, G., Gibbs, S. L., & Flowers, C. (2008). Evaluation of the effectiveness of an early literacy program for students with significant developmental disabilities. *Exceptional Children*, *75*, 33–52.

Browder, D. M., Wood, L., Thompson, J., & Ribuffo, C. (2014). *Evidence-based practices for students with severe disabilities* (CEEDAR Document No. IC-3). Gainesville, FL: CEEDAR Center, University of Florida.

Henry, L., & Winfield, J. (2010). Working memory and educational achievement in children with intellectual disabilities. *Journal of Intellectual Disability Research*, *54*, 354–365.

Horner, R. D., & Baer, D. M. (1978). Multiple-probe technique: A variation of the multiple baseline. *Journal of Applied Behavior Analysis*, *11*, 189–196.

Hudson, M. E., Browder, D. M., & Wood, L. A. (2013). Review of experimental research on academic learning by students with moderate and severe intellectual disability in general education. *Research and Practice for Persons with Severe Disabilities*, *38*, 17–29.

Individuals with Disabilities Education Improvement Act of 2004, PL 108-466, 20 U. S. C. §1400, H. R. 1350.

Jimenez, B. A., Browder, D. M., & Courtade, G. R. (2009). An exploratory study of self-directed science concept learning by students with moderate intellectual disabilities. *Research and Practice for Persons With Severe Disabilities*, *34*, 33–46.

Knight, V., McKissick, B. R., & Saunders, A. (2013). A review of technology-based interventions to teach academic skills to students with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *43*, 2628–2648.

Knight, V. F., Spooner, F., Browder, D. M., Smith, B. R., & Wood, C. L. (2013). Using systematic instruction and graphic organizers to teach science concepts to students with autism spectrum disorders and intellectual disability. *Focus on Autism and Other Developmental Disabilities*, *28*, 115–126.

Kushki, A., Chau, T., & Anagnostou, E. (2011). Handwriting difficulties in children with autism spectrum disorders: A scoping review. *Journal of Autism and Developmental Disorders*, *41*, 1706–1716.

Lee, A., Hawley, K., Browder, D. M., Flowers, C., & Wakeman, S. (2016). Teaching writing in response to text to students with developmental disabilities who participate in alternate assessments. *Education and Training in Autism and Developmental Disabilities*, *51*, 238–251.

Mims, P. J., Lee, A., Browder, D. M., Zakas, T. L., & Flynn, S. (2012). Effects of a treatment package to facilitate English/language arts learning for middle school students with moderate to severe disabilities. *Education and Training in Autism and Developmental Disabilities*, *47*, 414–425.

Mims, P. J., Stanger, C., Pennington, R. C., White, W., Sears, J., & Strickler, N. (2017). Opinion paragraph writing intervention for students with significant disability. *Assistive Technology Outcomes and Benefits*, *11*, 29–46.

Mims, P. J., Stanger, C., Sears, J. A., & White, W. B. (2018). Applying systematic instruction to teach ELA skills using fictional novels via an iPad app. *Rural Special Education Quarterly*, *37*, 197–206.

No Child Left Behind Act of 2001, Public Law No. 107-110.

Odom, S. L. (2013). *Technology-aided instruction and intervention (TAII) fact sheet*. Chapel Hill: The University of North Carolina, Frank Porter Graham Child Development Institute, The National Professional Development Center on Autism Spectrum Disorders.

Panyan, M. V. (1984). Computer technology for autistic students. *Journal of Autism and Developmental Disorders*, *14*, 375–382.

Parker, R. I., Vannest, K. J., Davis, J. L., & Sauber, S. B. (2011). Combining nonoverlap and trend for single-case research: Tau-U. *Behavior Therapy*, *42*, 284–299

Pennington, R. C. (2010). Computer-assisted instruction for teaching academic skills to students with autism spectrum disorders: A review of literature. *Focus on Autism and Developmental Disabilities*, *25*, 239–248.

Pennington, R. C., Collins, B. C., Stenhoff, D. M., Turner, K, & Gunselman, K. (2014). Using simultaneous prompting to teach generative writing to students with autism. *Education and Training in Autism and Developmental Disabilities*, *49*, 396–414.

Pennington, R. C., & Delano, M. D. (2012). Writing instruction for students with autism spectrum disorders: A review of literature. *Focus on Autism and Other Disabilities*, *27*, 158–167.

Pennington, R. C., Flick, A., & Smith-Wehr, K. (2018). The use of response prompting and frames for teaching sentence writing to students with moderate intellectual disability. *Focus on Autism and Other Developmental Disabilities*, *33*, 142–149.

Pennington, R. C., Forman, L. H., & Gurney, B. N. (2018). An evaluation of procedures for teaching students with moderate to severe disabilities to write sentences. *Remedial and Special Education*, *39*, 27–38.

Pennington, R. C., & Koehler, M. (2017). The effects of modeling, story templates, and self-graphing in the use of story elements by students with moderate intellectual disability. *Education and Training in Autism and Developmental Disabilities*, *52*, 280–290.

Pennington, R. C., & Rockhold, J. (2018). A brief report: An evaluation of an instructional package for teaching sentence writing to students with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *48*, 301–306.

Root, J. R., Browder, D. M., Saunders, A. F., & Lo, Y. Y. (2017). Schema-based instruction with concrete and virtual manipulatives to teach problem solving to students with autism. *Remedial and Special Education*, *38*, 42–52.

Root, J. R., Cox, S. K., & Gonzalez, S. (2019). Using modified schema-based instruction with technology-based supports to teach data analysis. *Research and Practice for Persons with Severe Disabilities*, *44*, 53–68. doi:10.1177/1540796919833915

Root, J., Saunders, A., Spooner, F., & Brosh, C. (2017). Teaching personal finance mathematical problem solving to individuals with moderate intellectual disability. *Career Development and Transition for Exceptional Individuals*, *40*, 5–14.

Saadatzi, M. N., Pennington, R. C., Welch, K. C., & Graham, J. (2018a). Small-group technology-assisted instruction: Virtual teacher and robot peer for individuals with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *48*, 3816–3830.

Saadatzi, M. N., Pennington, R. C., Welch, K. C., & Graham, J. (2018b). Effects of a robot peer on explicit acquisition and observational learning of sight words in young adults with autism spectrum disorder. *Journal of Special Education Technology*, *33*, 284–296.

Saadatzi, M. N., Pennington, R. C., Welch, K. C., Graham, J., & Scott, R. (2017). The use of an autonomous pedagogical agent for teaching sight words to students with autism spectrum disorder. *Journal of Special Education Technology*, *32*, 173–178.

Schenning, H., Knight, V., & Spooner, F. (2013). Effects of structured inquiry and graphic organizers on social studies comprehension by students with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *4*, 526–540.

Spooner, F., Knight, V. F., Browder, D. M., & Smith, B. R. (2012). Evidence-based practice for teaching academics to students with severe developmental disabilities. *Remedial and Special Education*, *33*, 374–387.

Spooner, F., Root, J. R., Saunders, A. F., & Browder, D. M. (2019). An updated evidence-based practice review on teaching mathematics to students with moderate and severe developmental disabilities. *Remedial and Special Education*, *40*, 150–165.

Spooner, F., Saunders, A., Root, J., & Brosh, C. (2017). Promoting access to common core mathematics for students with severe disabilities through mathematical problem solving. *Research and Practice for Persons with Severe Disabilities*, *42*, 171–186.

Touchette, P. E. (1971). Transfer of stimulus control: Measuring the moment of transfer. *Journal of the Experimental Analysis of Behavior*, *15*, 347–354.

Wolery, M., Ault, M. J., & Doyle, P. M. (1992). *Teaching students with moderate to severe disabilities: Use of response prompting strategies*. White Plains, NY: Longman.

Yamamoto, J. I., & Miya, T. (1999). Acquisition and transfer of sentence construction in autistic students: Analysis by computer-based teaching. *Research in Developmental Disabilities*, *20*, 355–377.

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