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Using an iPad Application to Promote Early Literacy Development in Young Children With Disabilities

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Abstract

This investigation evaluated the effects of using an iPad application to teach young children with developmental delays to receptively identify initial phonemes through 0- to 5-s constant time delay procedures in the context of a multiple-probe design across three sets of behaviors and replicated across three students. The dependent variable was the percentage of unprompted correct receptive identification responses for target phonemes during instruction and probes. All students mastered their target phonemes, generalized the skills across materials, and maintained the skills at or above 50% of accuracy 4 and 7 weeks after the intervention was completed. This study expands the knowledge on using touch screen iPad application for early literacy instruction of young children with disabilities.

Keywords

iPad instruction, young children with disabilities, phonological awareness, constant time delay

With reading as a critical element for educational advancement and community engagement, deficits in literacy negatively impact the quality of life of people with disabilities (Erickson, 2005). Phonological awareness (PA) skills are a component of early literacy instruction and essential in helping children become independent readers. Students' PA skills predict later reading achievement (Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Failure to acquire PA skills is one reason why students with disabilities perform worse in reading than their peers with stronger PA skills (Conners, Rosenquist, Sligh, Atwell, & Kiser, 2006). However, like their typically developing peers, students with disabilities benefit from specific training in PA skills (Conners et al., 2006; Lemons & Fuchs, 2009; Macaruso, Hook, & McCabe, 2006; Macaruso & Walker, 2008; Saunders, 2007). Improved PA skills lead to better decoding skills (Macaruso et al., 2006), which help students read more fluently and better comprehend the text (Wise, Ring, & Olson, 2000).

Technology, if used appropriately, can assist students with disabilities in participating in the same activities as their typically developing peers (National Association for the Education of Young Children, 2012). Computer-assisted instruction (CAI) has been used successfully to teach PA skills to students with disabilities (e.g., Campbell & Mechling, 2009; Lonigan et al., 2003; Macaruso & Walker, 2008). Early results of computer-assisted PA training show that students who received computer-assisted PA training scored significantly higher than the control groups on trained and untrained PA skills (Barker & Torgesen, 1995). When compared with teacher-directed instruction (TDI), students in the CAI condition significantly outperformed those in the TDI condition (Mioduser, Tur-Kaspa, & Leitner, 2000), and those low-performers made more gains in PA skills in the CAI condition (Macaruso et al., 2006; Macaruso & Walker, 2008). Unfortunately, there are a limited number of studies that use CAI to teach PA skills to young children with disabilities, and most only involved those at risk of reading disabilities.

When constructing any sort of CAI instruction, designers have options for incorporating evidence-based methods. Constant time delay (CTD) procedures are effective and efficient for teaching young children with disabilities. CTD is an errorless procedure involving two parts. During the first part, immediately after the task direction is presented, the student receives a controlling prompt guaranteeing a correct response. During the second part, after presenting the task direction, a fixed amount of time is inserted before

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the prompt is given (Wolery, Ault, & Doyle, 1992). CTD procedures have been used in computer-assisted academic instruction to teach sight words (Lee & Vail, 2005), letter names and sounds in a small group setting (Campbell & Mechling, 2009), and early academic skills (Hitchcock & Noonan, 2000). The results show that CTD procedures were more effective when combined with CAI than with TDI (Hitchcock & Noonan, 2000). Students did not only master the target skills, but also maintained (Hitchcock & Noonan, 2000; Lee & Vail, 2005) and generalized them across materials (Lee & Vail, 2005). However, the small number of CAI studies with CTD procedures indicates that more empirical research is needed.

The first version of iPad was released in 2010. Many applications have been developed to teach different skills to people with disabilities (Shuler, Levine, & Ree, 2012), but few of them have been supported by research. Studies on using mobile devices such as iPads, iPods, and iPhones to teach people with developmental disabilities have received positive results (Kagohara et al., 2012); however, the majority of them focus on students older than 8 years of age. The purpose of the current study was to develop and evaluate the effectiveness of using an iPad application "Touch Sound" with 0- to 5-s CTD procedures to teach PA skills to young children with disabilities. This investigation extended the literature on PA skills instruction to young children with disabilities, furthered our knowledge on using the CTD procedures in CAI, and expanded our understanding on the possibility of using the iPad application to teach early literacy skills to young children with disabilities.

Specifically, this study addressed: (a) What are the effects of using an iPad application that incorporates 0- to 5-s CTD procedures to teach young children with disabilities to receptively isolate initial phonemes? (b) If young children with disabilities acquire the PA skills through the iPad application, will they generalize the target behaviors across positions and across materials? (c) If young children with disabilities acquire the PA skills through the iPad application, will they maintain the target behaviors after the intervention ends?

Method

Participants

Participants included three young children, two in kindergarten and one in second-grade (two girls, one boy), attending a rural Title I primary school in a southeastern state of U.S. Teachers recommended them as potential candidates because they had Individualized Education Program (IEP) goals related to improvement of PA skills. They ranged in age from 5 years 1 month to 8 years 8 months at the beginning of the study. Two students were African American and one was Caucasian. They all had experiences with computers but not with an iPad nor with CTD procedures. Prerequisite skills for inclusion in the study were: (a) visual ability to see the pictures displayed on the iPad, (b) ability to hear the directions, (c) ability to verbally imitate target phonemes, (d) ability to follow a one-step direction, (e) ability to operate an iPad independently by touching the screen with their index finger, (f) ability to wait for 5 s, and (g) ability to attend to a teacher-selected task for at least 10 min. Prior to the intervention, students were also tested using Peabody Picture Vocabulary Test–III (PPVT-III) and Test of Early Reading Ability (TERA-3) to establish a general profile of their literacy development.

Sarah was a 5-year, 1-month-old African American girl diagnosed with Significant Developmental Delays (SDD). She received special education services in a collaborative kindergarten class. She scored 79 on PPVT-III (−1.4 *SD*) and 83 on TERA-3 (−1.1 *SD*). Her performance was below average on the Alphabet and Convention subtests of TERA-3, and was average on the Meaning subtest. She did not recognize any letters of the alphabet except for the initial letter of her name. Sarah played appropriately with toys in her class, interacted with her peers, and adapted well to new teachers. She got frustrated easily and also had difficulty staying involved in an activity for a long time.

Zach was a 6-year, 3-month-old African American boy diagnosed with SDD. He was repeating kindergarten in a collaborative class. Zach scored 93 on PPVT-III (−0.5 *SD*) and 70 on TERA-3 (−2 *SD*). He scored "Poor" on Alphabet and Convention subtests, and "Below Average" on the Meaning Subtest. Zach could not name all the letters and sounds, and he had a difficult time blending sounds to make words and distinguishing between a letter, word, or sentence. Zach demonstrated poor impulse control. He had trouble paying attention in a large or a small group setting. Following directions was a primary concern.

Lucy was an 8-year, 8-month-old Caucasian girl diagnosed with SDD and reading disabilities. She spent most of her day in a collaborative second-grade class, and received intervention in speech in a separate class. She wore eye glasses and a hearing aid regularly, and had success wearing them. Lucy scored 71 on PPVT-III (−2 *SD*), and 43 on TERA-3 (−3.8 *SD*). She scored "Very Poor" on all three subtests of TERA-3. Lucy exhibited voice and fluency skills within normal limits, and she produced most speech sounds correctly. Lucy loved to look at books and listen to stories, but she was reading well below grade level. She had trouble segmenting sounds in words, and she was highly distractible and often lost focus on the word she was trying to decode.

Settings and Materials

The school where the study was conducted served 807 students from Pre-K to 2nd grade, of which 1% were Asian, 5% were Hispanic, 31% were African American, and 60% were Caucasian. All intervention sessions were conducted

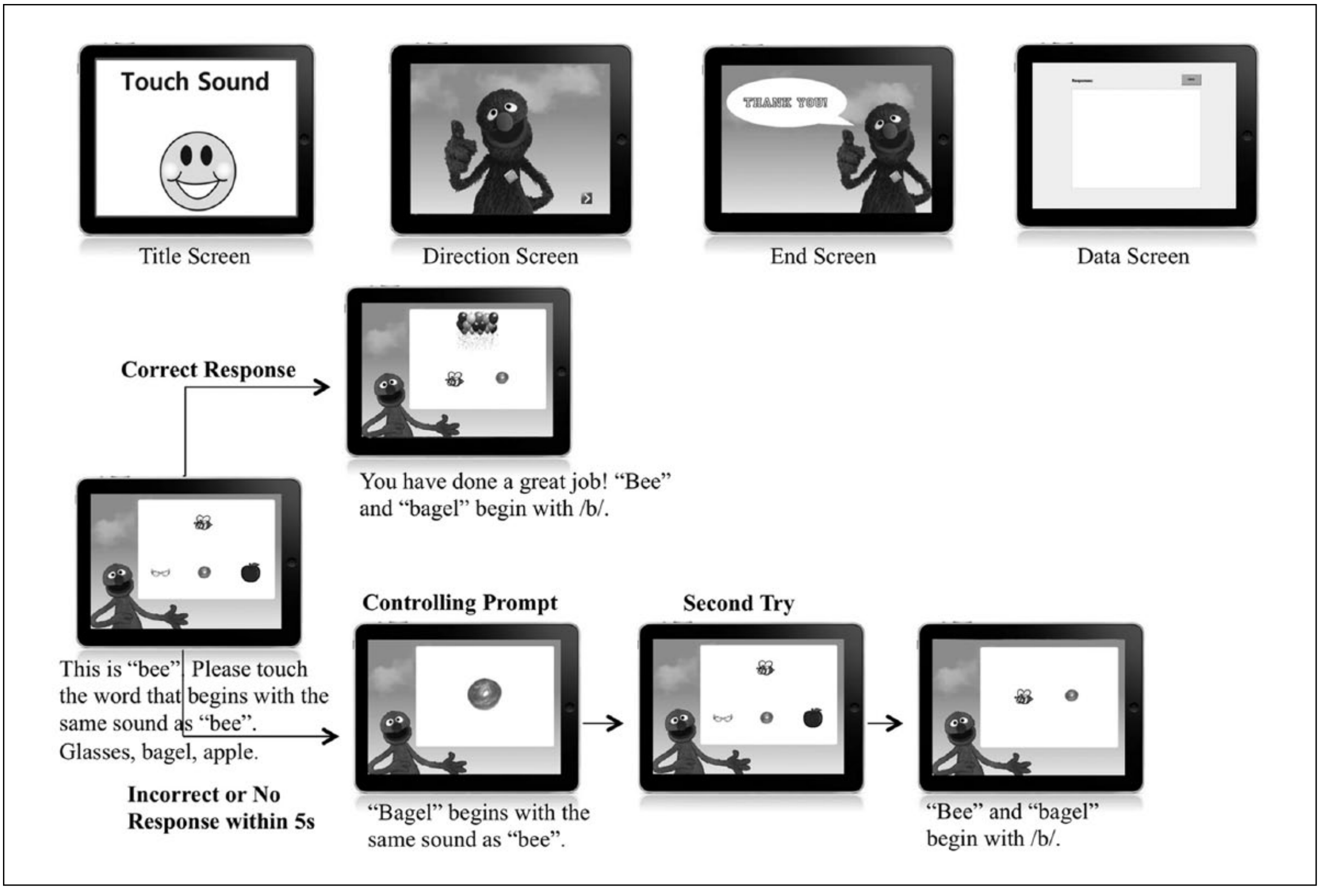

Figure 1. Major screens of touch sound.

in a 1:1 instructional arrangement in an unoccupied room of the school. During intervention, probe, and generalization across position sessions, the student sat facing the iPad, which was located on a child-sized table. The researcher sat beside the student to observe and provide technical support if necessary. During screening, pre-intervention assessments, and generalization across mode sessions, the student sat diagonally across the table from the researcher.

An interactive iPad application "Touch Sound" was developed by the first author for the purpose of this study. Major screen shots of "Touch Sound" are presented in Figure 1. LiveCode® software was used to develop the application. LiveCode® uses natural programming language to develop applications for a range of computer platforms including iOS (i.e., Apple mobile devices). It allows the incorporation of sound, text, pictures, and videos. The audio directions were read by a native English speaker (the second author) and were recorded using Audacity® 11.3 Beta with the MacBook built-in microphone. During intervention and probes sessions, a 16 GB iPad 2 running iOS 5 was used to present the tasks.

Screening and phoneme selection. Each student was screened on 21 initial consonant sounds printed on 5 in. × 8 in. index cards. Each index card included four pictures, with one picture representing an object whose name started with a target phoneme on the top row and three choices on the bottom row. The researcher read the task direction (i.e., "This is *bus*. Please point to the picture that starts with the same sound as *bus. Bee, cup, watch*."), and student was given 5 s to respond. Each target phoneme was randomly presented 3 times in each session, with different pictures, over three consecutive days. The target phonemes were defined as those that a student made no more than 33.33% correct responses over three consecutive sessions. Six target phonemes (see Table 1) were identified for each student. The identified target phonemes were divided into three sets based on difficulty. Each set included a phoneme with the lowest percentage of accuracy and a phoneme with relatively higher percentage of accuracy.

Dependent Measures and Response Definitions

The target behavior was defined as the student receptively touching the picture that had the same initial phoneme as the given picture. The dependent variable was the percentage of unprompted correct receptive identification responses for the target phonemes for each session.

Table 1. Target Phonemes for Instruction and Generalization Across Positions.

Student	Target phonemes	Generalization across position
Sarah	Set 1: /b/, /k/ Set 2: /f/, /g/ Set 3: /l/, /m/	/k/, /l/, /f/
Zach	Set 1: /k/, /dʒ/ Set2: /θ/, /p/ Set 3: /l/, /z/	/k/, /l/, /p/
Lucy	Set 1: /k/, /dʒ/ Set 2: /g/, /t/ Set 3: /l/, /p/	/k/, /l/, /p/

Five potential responses were recorded automatically by "Touch Sound" during the intervention: (a) unprompted correct (touching the correct answer within 5 s after the task direction was given, and before the prompt was shown), (b) unprompted incorrect (touching an incorrect answer within 5 s after the task direction), (c) prompted correct (touching a correct response within 5 s after the prompt was shown), (d) prompted incorrect (touching an incorrect response within 5 s after the prompt), and (e) no response error (failure to touch any answer within 5 s after the prompt). The criterion to move to next set of phonemes was that student reached 100% unprompted corrects over three consecutive sessions.

Experimental Design and Conditions

A multiple-probe design across behaviors (three sets of phonemes) replicated with three students was used to evaluate experimental control (Gast & Ledford, 2010). Experimental conditions included probe, CTD on an iPad, generalization, and maintenance.

Probe procedures. A probe session was conducted with every student prior to the introduction of intervention, and following the session during which each student reached the predetermined criterion for one set of target phonemes. Each probe session consisted of 18 trials. The six phonemes for each student were intermixed and randomly presented 3 times with different pictures. At least three sessions were conducted over 2 days or until the data were stable. The first probe also served as the baseline data for the first set of phonemes.

Probes were delivered through the iPad application. After the student's attention was secured, the researcher presented the iPad in front of him or her, and loaded the application. The student touched the smiling face to start the probe. During the probe, on each screen the student saw one picture (i.e., the picture of an object whose name started with the target phoneme) at the top row and three picture choices at the bottom row. The iPad application read the task direction (e.g., "This is bee. Please touch the word beginning with the same sound as bee. Cat, bagel, flower."). The student had 5 s to respond. With an unprompted correct, the application delivered a general verbal praise statement along with a graphic (e.g., fireworks) and then advanced to the next trial. Unprompted incorrects were ignored (the application moved to the next trial). Data were collected automatically by the iPad application.

CTD on an iPad. Intervention included two phases: 0 s delay sessions and 5 s delay sessions. Each intervention session began by securing the student's attention. The researcher started the application and it asked the student to touch the smiling face when he or she was ready to work. This brought the student to the direction page on which a cartoon character stated the task expectations, and presented an example. Then, the student touched an arrow button to start the instruction.

The first screen contained four pictures. One picture (e.g., a picture of a bee) that started with the target phoneme placed at the top row and three pictures placed horizontally at the bottom row (i.e., a picture of an object whose name started with the same target phoneme as the picture of object on the top row, and two distractors that were pictures of common objects for the student to recognize). Different pictures of objects that begin with the target phonemes were used from trial to trial to facilitate generalization. "Touch Sound" read the task direction. For example, "This is kite. Please touch the word that begins with the same sound as kite. Kitchen, bee, ice."

During 0 s delay sessions, the application immediately showed the controlling prompt, on which only the picture of the correct answer was presented, and "Touch Sound" said, for example, "Kitchen begins with the same sound as kite." The third screen was the same as the first screen, and the student had a second try. The student started 5 s delay sessions when he or she reached 100% prompted corrects in one 0 s delay session.

Subsequent sessions were conducted using 5 s delay until students reached the criterion of 100% unprompted corrects over three consecutive sessions. After "Touch Sound" delivered the task direction, the student had 5 s to respond before the prompt was provided. Every unprompted correct led the student to a new screen, on which pictures of two objects whose names began with the same target phonemes were presented, and descriptive verbal praise was given (e.g., "Nice job! Cat and cup begin with /k/."). An unprompted incorrect resulted in the prompt screen. On the prompt screen, only the picture of the correct answer was shown, and "Touch Sound" said, for example "Cat begins with the same sound as cup." After that the student had a chance to answer the question again. Either prompted correct or prompted incorrect led the student to the screen, on which pictures of the two objects whose names began with the same sound were presented, and at the same time, a verbal prompt was delivered by the application (e.g., "Cat and cup begin with /k/.").

Each session lasted for about 10 min and included six trials, three trials for each target phoneme. Students received two intervention sessions every day. Five similar lessons were developed for each set of target phonemes, different pictures of different objects were used in the five lessons to foster generalization, and students never saw the same pictures of objects over two consecutive days. At the end of each intervention session, students were allowed to play games on the iPad for 10 min.

Generalization assessments. Generalization assessments were conducted individually before intervention started and again once the student reached the criterion on one set of target phonemes. Generalization assessments evaluated whether students could generalize the skills across materials, and if students could correctly isolate trained phonemes when they appeared at the end position in words.

Generalization across materials. Worksheets were printed in color on a piece of 8.5 in. × 5.5 in. white paper. The six target initial phonemes were randomly presented 3 times with different pictures on the worksheet. For each phoneme, the first row was a picture of an object whose name began with the target phoneme, and the second row was three pictures of objects placed horizontally. The researcher named each picture, and asked the student to use a pencil to circle the picture on the second row that started with the same sound as the picture named on the first row. A correct response was recorded when the student circled the correct picture within 5 s after the task direction, and an incorrect response was recorded when the student circled an incorrect answer, or did not respond within 5 s after the task direction.

Generalization across positions. Discrimination of consonants in the end position is generally considered a more difficult task than the discrimination of consonants in the onset position (Kochetov, 2004; Redford & Diehl, 1999). These assessments evaluated if students could generalize the skills learned in an easier task to a more difficult task. The procedure was identical to the probes. Pictures of objects whose names ended with the target phonemes were selected. Instead of isolating initial phonemes, students had to isolate the final phonemes. Because not all phonemes can serve at the end position, only three phonemes were selected for each student for generalization across positions assessment (see Table 1). Each session consisted of nine trials, and each phoneme was randomly presented 3 times with different pictures.

Maintenance. Maintenance data were collected 4 weeks and 7 weeks after intervention on Set 3 was completed. Maintenance assessments were delivered through the iPad application. Format and procedures were identical to those of probe sessions.

Reliability

Inter-observer reliability (IOA) data on the dependent measure and procedural fidelity data were collected for 31% of all sessions for all students, at least once per condition, per student. Two trained observers viewed videotapes of the sessions. Data from observers were compared. The IOA was calculated by point-by-point method in which the number of agreement is divided by the number of agreement plus disagreement, multiplied by 100 (Cooper, Heron, & Heward, 2007). The IOA equaled 100% across all sessions collected and across all three students. Procedural fidelity was collected on researcher's behaviors and iPad application functions. Elements assessed included whether students' attention was secured, if task direction was presented, if students had 5 s to respond, and if correct prompt or praise was delivered. The mean procedural fidelity was 97.8%, with a range from 92% to 100%. Major errors occurred when researcher prompted students during sessions to gain their attention.

Results

Figures 2 to 4 show the percentage of unprompted correct receptive responses for initial phoneme discrimination for each student across conditions. Tables 2 and 3 display their performance during generalization assessments. Visual analysis of data supported the use of an iPad application with 0- to 5-s CTD procedures to teach young children with disabilities to receptively identify initial phonemes, and most of the skills were generalized and maintained after intervention.

Acquisition and Maintenance Results

Sarah. Sarah reached criterion for all sets of her target phonemes after introduction of intervention (Figure 2). She demonstrated a mean percentage of correct responses of 28.47% for untaught phonemes, which was under the chance level (i.e., 33.33%). Visual analysis reveals a change in level and an accelerating trend after introduction of intervention. The mean percentage of correct responses for Set 1 of her target phonemes was 16.67% and 49.31% during Probe 1 and intervention, respectively. She maintained the performance at 83.33% of accuracy level at 4-week and 7-week follow-ups. For Set 2, the mean percentage of correct responses was 30.95% before intervention and 67.65% during intervention. The performance was maintained at 100% of accuracy during 4-week follow-up, but dropped to 50% of accuracy during 7-week follow-up. For Set 3, Sarah showed a mean percentage of correct responses of 30%

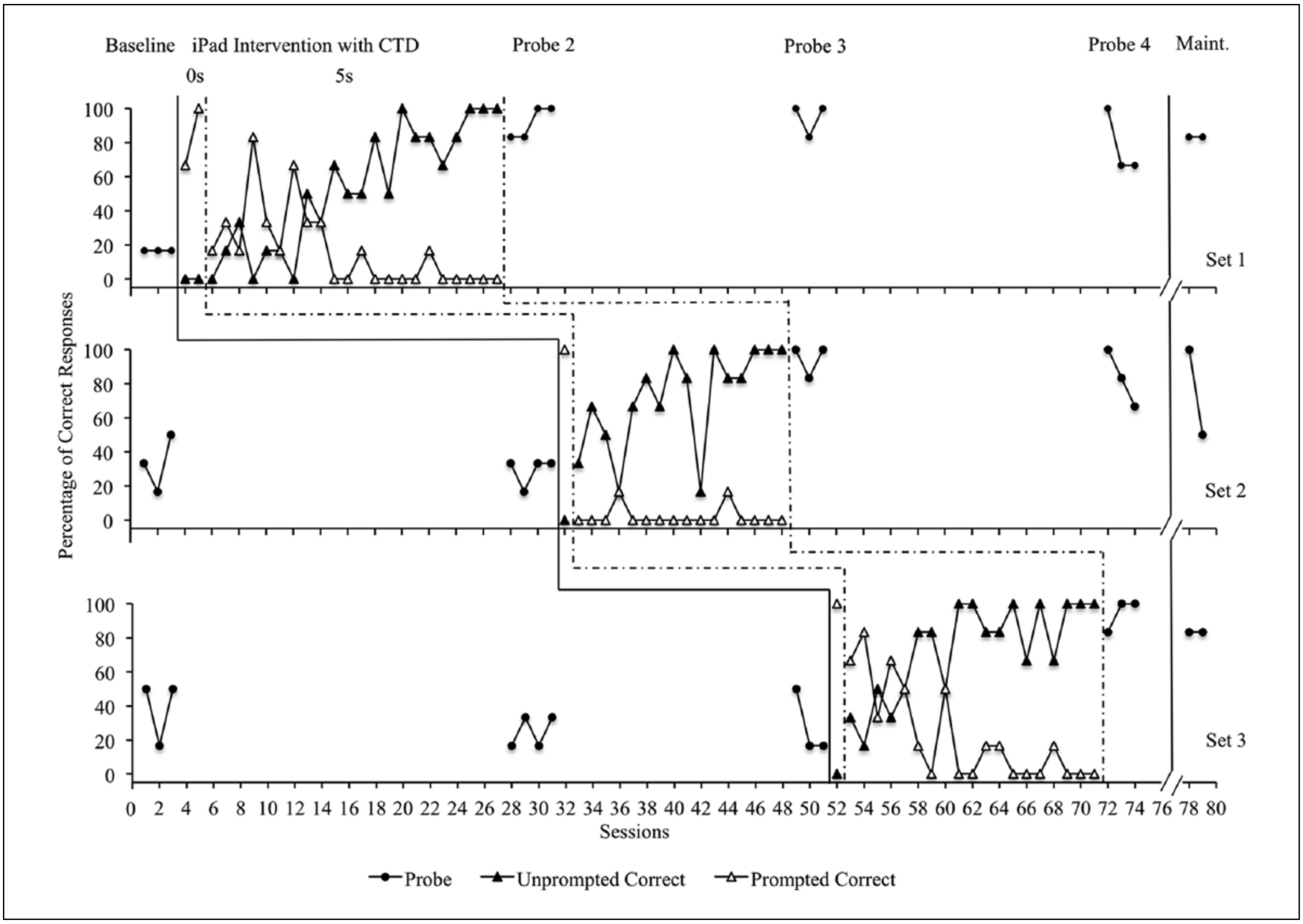

Figure 2. Percentage of correct receptive identification of initial phonemes for Sarah.
Note. CTD = constant time delay.

before intervention and 70% during intervention, and she maintained the performance at 83.33% of accuracy 4 and 7 weeks after intervention ended. Sarah required 22, 15, and 18 instructional sessions to reach criterion for Sets 1, 2, and 3, respectively.

Zach. Zach learned all his target phonemes after intervention (Figure 3). Probe data before intervention indicate an average of 35.1% accuracy for untaught phonemes. This number was very close to chance level. For Set 1, the mean percentage of correct responses was 41.67% before intervention, and 38.45% during intervention, and it was maintained at 100% during 4-week and 7-week maintenance assessments. Zach did not respond to intervention immediately. He needed 10 sessions to get 100% prompted correct during 0 s delay sessions for Set 1 of his target phonemes. His performance had remained at low baseline level for 11 sessions after he was moved to 5 s delay sessions. He sat on the chair, and he touched a picture of choice after task direction without paying attention.

Beginning with Session 26, the researcher modified research procedures in an attempt to improve Zach's attention to task. Prior to each session, the researcher reminded Zach to pay attention and that if he paid attention, he could play games on iPad following the session. Then, after the session, the researcher asked him to rate if he had paid attention during intervention. He was only permitted to play games if the researcher and Zach agreed that he had been focused on the task. Zach demonstrated dramatic improvement after implementation of the attention management strategy, and he reached the criterion for Set 1 after nine sessions. The attention management system was removed beginning with Session 42 when attention was no longer a problem for Zach.

For Set 2 of his target phonemes, Zach showed a mean percentage of correct responses of 30.95% before intervention and 68.84% during intervention, and he maintained the performance at 66.67% correct responses during the two maintenance assessments. For Set 3, he demonstrated a mean percentage of correct responses of 34.85% and 75.44% before and during intervention, respectively. The maintenance data for Set 3 were 50% of accuracy at 4-week follow-up, and were increased to 66.67% of accuracy at 7-week follow-up. It took Zach 21 and 17 sessions to reach the criterion for Sets 2 and 3, respectively.

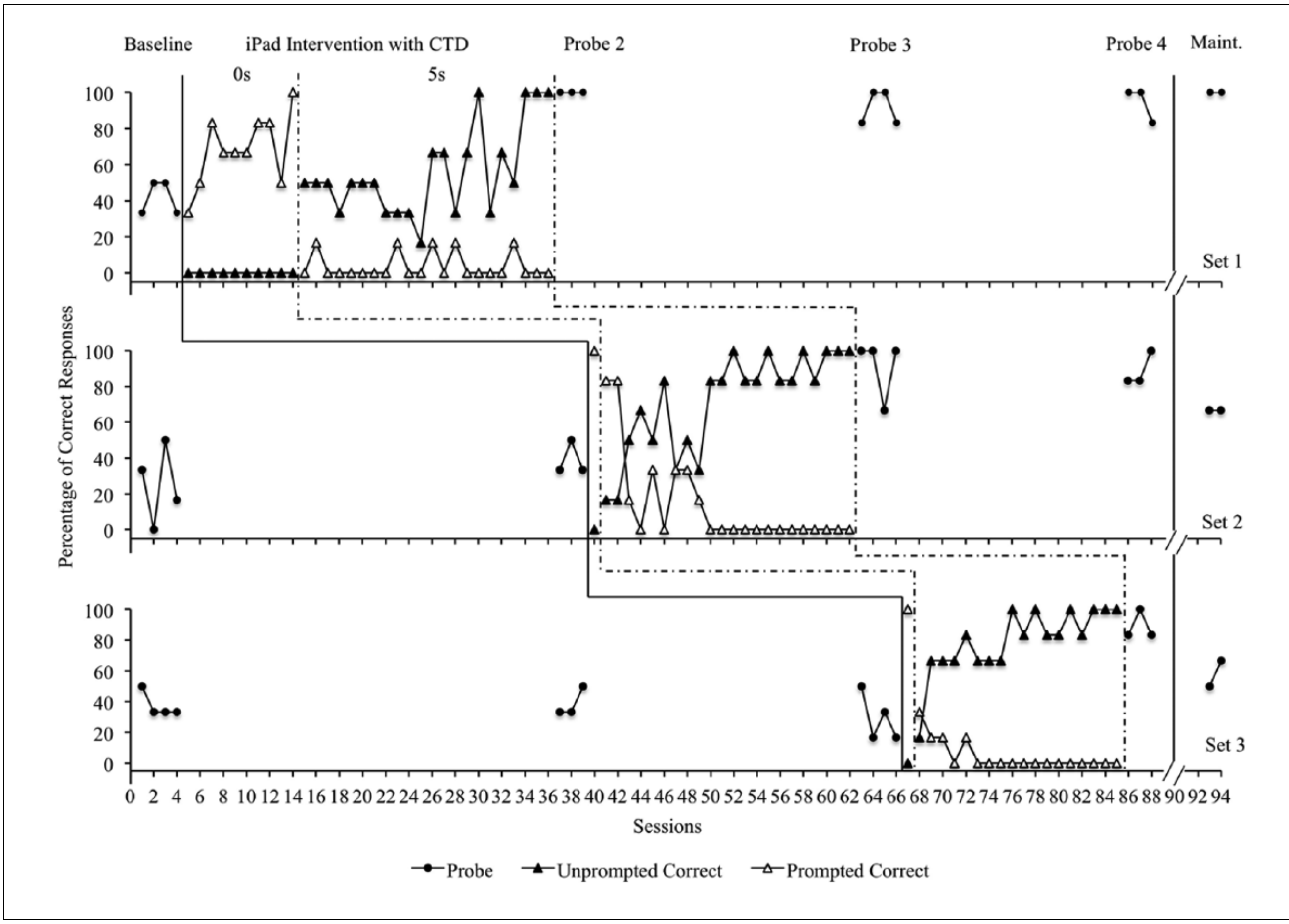

Figure 3. Percentage of correct receptive identification of initial phonemes for Zach.
Note. CTD = constant time delay.

Lucy. Lucy's data are shown in Figure 4. Pre-intervention data revealed an average of 36.13% accuracy (ranging from 22.22% to 50%) for untaught phonemes. Like Zach, Lucy correctly identified some target phonemes before intervention, but her performance was not consistent. Her mean performance remained at approximately chance levels. After introduction of intervention, Lucy's performance on the target phonemes demonstrated a change of level, and the trend was changed from decelerating or zero celeration to accelerating.

The mean percentage of correct responses for Set 1 of Lucy's target phonemes was 22.22% before intervention, and it increased to 46.79% during intervention. During maintenance, her performance remained at an average of 66.67% accuracy during 4-week follow-up, and increased to 100% of accuracy during 7-week follow-up. For Set 2, Lucy demonstrated a mean percentage of correct responses of 47.22% before intervention and 77.78% during intervention. She maintained her performance at or above 83.33% of accuracy during the two maintenance assessments. Her performance on Set 3 showed an average of 50% accuracy before intervention and 78.57% accuracy during intervention, and it was maintained at 66.67% accuracy 4 weeks and 7 weeks after the intervention. Lucy got to the criterion in 24, 19, and 19 sessions for Sets 1, 2, and 3, respectively.

Generalization Results

Generalization across materials. Table 2 summarizes the percentage of correct responses of receptive identification of initial target phonemes when the task was presented on worksheets. The results suggest that all three students improved their performance after the intervention was completed. Sarah generalized the skills across materials with 100% accuracy on Sets 1 and 3 and with 83.33% accuracy on Set 2. Zach showed 100% correct responses on Sets 2 and 3, and 83.33% correct responses on Set 1. Lucy demonstrated 100% accuracy on Set 3, and 83.33% accuracy on Sets 1 and 2.

Generalization across positions. Table 3 presents the data on the percentage of correct responses when the target phonemes appeared at the end of the words. Zach was the only student who showed progress in all target phonemes. He

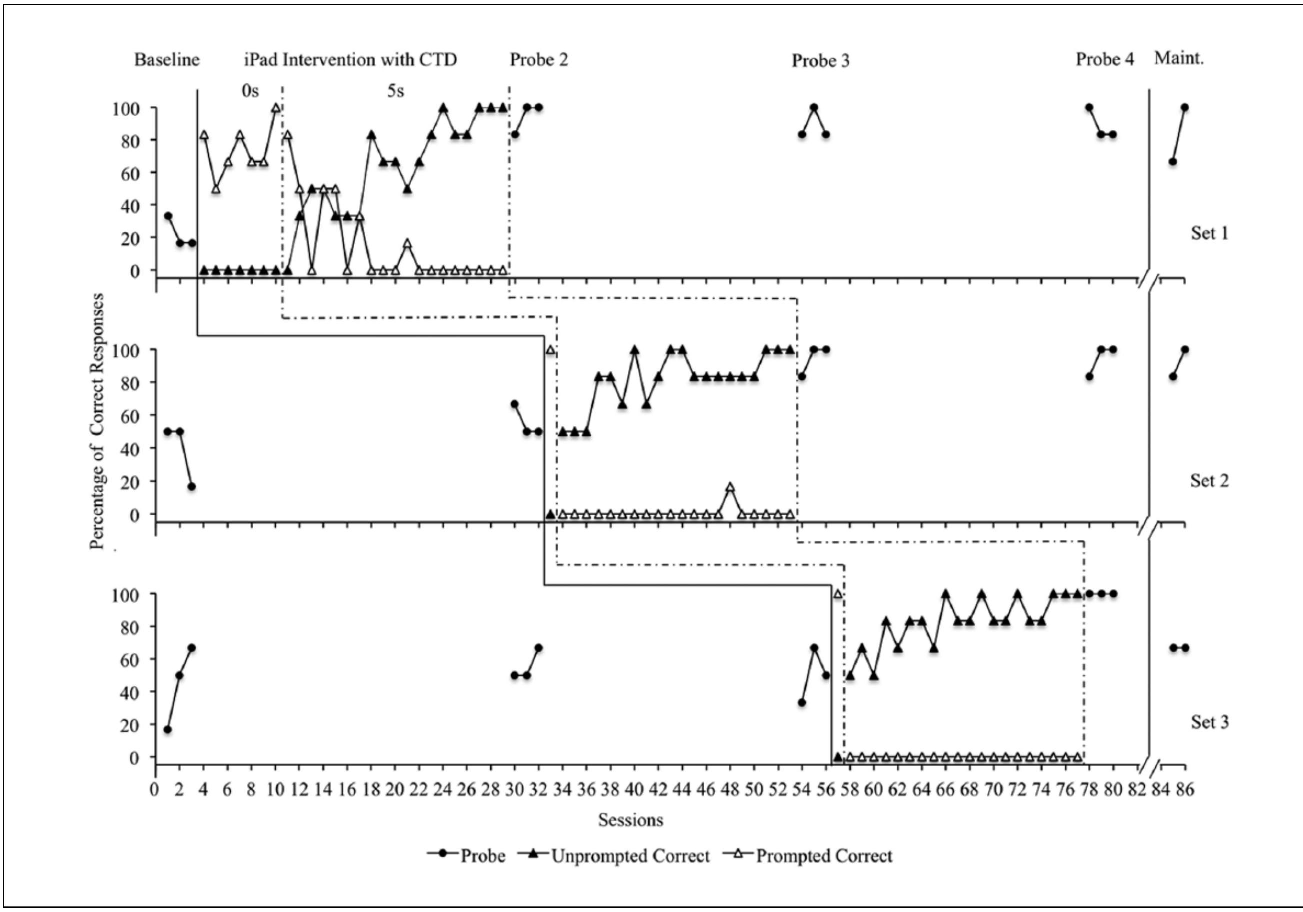

Figure 4. Percentage of correct receptive identification of initial phonemes for Lucy.
Note. CTD = constant time delay.

Table 2. Percentage of Correct Responses of Generalization Across Materials.

Student	Set	Probe 1	Probe 2	Probe 3	Probe 4
Sarah	1	50	**100**	**83.33**	**100**
	2	33.33	50	**66.67**	**83.33**
	3	33.33	33.33	33.33	**100**
Zach	1	0	**66.67**	**100**	**83.33**
	2	0	16.67	**83.33**	**100**
	3	0	33.33	0	**100**
Lucy	1	0	**66.67**	**83.33**	**83.33**
	2	16.67	33.33	**66.67**	**83.33**
	3	16.67	33.33	16.67	**100**

Note. Data in bold were collected after the intervention.

got 100% accuracy on target phoneme /k/ after intervention, and his performance on target phonemes /l/ and /p/ improved from 0% to 33%. Sarah showed improvement on only one target phoneme /p/, and the other target phonemes remained at a low level of accuracy. Lucy was the student who regressed. She performed at 100% accuracy level on /k/ and at 67% accuracy on /l/ before intervention. However, after intervention, the accuracy level dropped to 33% and 0%, respectively. Her performance on /p/ remained at 0% accuracy.

Efficiency Data

The number of sessions to criterion for each set of target phonemes ranged from 15 to 24. All students reached criterion quicker with Set 3 than with Set 1. The total instructional sessions needed to reach criterion for all three sets of target phonemes ranged from 61 to 68.

Social Validity

Social validity of goals and outcomes of the current study was evaluated through a teacher-completed questionnaire and informal interview of students. Three teachers who worked directly with the students on a daily basis completed the questionnaire at the conclusion of intervention. Data were analyzed using content analysis. The findings indicated that all teachers supported that it was a developmentally

Table 3. Percentage of Correct Responses of Generalization Across Positions.

Student	Target phoneme	Generalization Probe 1	Generalization Probe 2	Generalization Probe 3	Generalization Probe 4
Sarah	/k/	0	**33**	**33**	**0**
	/l/	33	67	**100**	**33**
	/f/	0	33	0	**33**
Zach	/k/	33	**67**	**67**	**100**
	/l/	0	33	**33**	**33**
	/p/	0	67	33	**33**
Lucy	/k/	100	**67**	**67**	**33**
	/l/	67	0	**33**	**0**
	/p/	0	33	0	**0**

Note. Data in bold were collected after the intervention.

appropriate goal for their students, and students became more confident in reading related activities, and more focused during learning activities in class. Teachers also reported that they would like to incorporate "Touch Sound" as a center activity to assist students in learning initial sounds. Informal interviews of students revealed all three students enjoyed using "Touch Sound."

Discussion

A multiple-probe design across three sets of target phonemes replicated with three students was used to evaluate the effects of using CTD procedures on an iPad application to teach young children with disabilities to receptively identify initial phonemes. During intervention, students worked on the application and the percentage of unprompted correct identification of initial phonemes was recorded. All students demonstrated an increase in level and an accelerating trend after introduction of intervention.

Relationships to the Existing Literature

Results from this study are consistent with the existing literature. Young children with disabilities can improve their PA skills with appropriate training (Conners et al., 2006; Lemons & Fuchs, 2009; Saunders, 2007); CAI can help them learn PA skills (Macaruso et al., 2006; Macaruso & Walker, 2008; Mioduser et al., 2000); and CTD procedures can be successfully embedded within CAI to teach literacy skills (Campbell & Mechling, 2009; Lee & Vail, 2005).

All participants of this study were eligible for special education services under the category of SDD, and they were below average in intellectual functioning. With about five hours of intervention, they all improved their PA skills. The results add to the limited literature that investigates the effectiveness of PA intervention for young children with disabilities.

Most of existing studies related to using CAI to teach PA skills used a group pretest–posttest experimental design. For students with disabilities, a group design is not sensitive enough to detect individual differences. This study used a single-subject multiple-probe design, in which each student served as his or her own control, and his or her performance before intervention was compared with the performance after intervention (Gast & Ledford, 2010).

Limitations

Some threats to internal validity need to be discussed. The researcher met the participants for the first time at the beginning of the study and students took time to get familiar with the researcher. There may have been an adaptation effect that explains why Lucy and Zach still took 7 and 10 sessions, respectively, to reach the criterion of 100% prompted corrects during the 0 s delay sessions for Set 1 even after the wait/history training and this may have suppressed baseline responding. Students made a lot of unprompted incorrect responses during intervention in the 5 s delay trials. Lucy and Zach seldom waited for the prompt during instruction of Sets 2 and 3 and instead made errors before the prompt. One possible reason might be that 5 s was too long for them to wait. Through observation, the researcher noticed that Zach seemed to rush through the trials to access the games. This should have been addressed in advance with training in a CTD procedure as well as training on using the technology because these students had little experience with tablet computers.

Some problems also arose with generalization across positions. This finding is not surprising because identifying initial sounds is a completely different and more difficult skill compared with identifying end sounds. Training on one kind of PA skills did not necessarily lead to improvement on another kind. The inconsistency in maintenance performance might mean that additional instruction or trials at criterion would have been beneficial. The improvement on the second follow-up probe might have been the result of students receiving instruction on the target phonemes in class or at home during the 3 weeks between the two maintenance probes.

Last, the study was not conducted in a format that is typical in an early education setting. In a natural environment, students seldom get one-on-one attention. However, one of the benefits of technology is that once students learn how to learn from technology, they can access more individualized and one-on-one like instruction as the technology provides corrective feedback and prompting.

Recommendations for Future Research

Using a researcher-developed application like "Touch Sound" allows researchers to embed evidence-based method (i.e., CTD), and to customize intervention based on student's individual needs, which are not available for most pre-existing applications. The first author is in the process of making "Touch Sound" available on iTunes. More studies are needed to evaluate the external validity for the use of this iPad application, for example, using it to teach students with autism, and students who are English language learners. With little adaptation, teachers can also use it as an adjunct to daily instruction, and parents can use it as a supplement at home.

One of the concerns of parents and teachers about young children using technology is that they are learning in front of the computer, so they will not have opportunities to develop social skills. Research has shown that collaborative use of computers can facilitate social interactions between young children, like sharing and turn-taking (Fitzpatrick & Hardman, 2000; Muller & Perlmutter, 1985). Future studies can incorporate peer-tutoring with the use of the iPad application, and record the interactions between the students. Similarly, students taught in dyads or in small group instruction with a SMART Board may also learn from observing their peers as has been shown in studies like Ledford, Gast, Luscre, and Ayres (2008).

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