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TEACHING EARLY READING SKILLS TO CHILDREN WITH AUTISM USING MIMIOSPROUT EARLY READING

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A number of studies have demonstrated positive outcomes for typical learners from the internet-based reading program, MimioSprout® *Early Reading* (MER). In the present study, a preliminary evaluation of MER was conducted with four children with autism who attended an applied behavior analysis educational program in a school setting. The primary aim was to investigate whether it would be feasible to use MER with children with autism and whether any adaptations to the standard teaching procedure would be needed. A secondary aim was to investigate whether completing MER would improve early reading skills. When additional discrete-trial table top activities were designed to supplement each child's progress, every child was able to complete all 80 lessons and showed similar correct performance to that reported for typically developing learners. Results from a standardized test of reading ability showed an improvement in word recognition reading age for all children from 14 months to more than three years over the 14 weeks of teaching. A follow-up test showed that gains were maintained eight weeks after the end of the intervention. MER can be successfully used with children with autism and can improve their early reading skills. Copyright © 2013 John Wiley & Sons, Ltd.

There has been considerable interest in the use of applied behavior analysis (ABA) methods as a comprehensive early intervention model for children with autism in home and center-based or school-based settings. Recent systematic reviews and meta-analyses suggest positive outcome data, especially for cognitive, language, and adaptive skills (e.g., Eldevik et al., 2009, 2010; Reichow, 2012). In addition to a focus on social, language and other adaptive skills, ameliorating academic skill deficits is often a component of ABA programs. A total of 67% of children with an autism spectrum disorder (ASD) have been classified as learning disabled due largely to deficits in the acquisition of specific academic skills (e.g., Dickerson Mayes &

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Calhoun, 2006), and research reviews often report reading disability as the most commonly encountered learning disability (e.g., Osman, 2000; Sattler, 1992). Most published curriculum guides on ABA for children with an ASD include some early reading programs with progressive levels of difficulty (e.g., Leaf & McEachin, 1999; Partington, 2006). Many of these describe how to teach sight word reading. A sight word is any word that is responded to correctly when presented visually and is pronounced without decoding the phonemes (i.e., the sounds) that make up the word. However, learning to read words by sight should not be seen as a comprehensive reading program. If a child is to become an independent reader, then they will likely need to learn how to connect the sounds of the spoken language of the culture (phonemes) with letters or groups of letters and how to blend the sounds of letters together to produce approximate pronunciations of unknown words. Phonemic awareness (i.e., the ability to segment and blend phonemes), along with knowledge of letter-sound correspondence (the alphabetic principle), is a strong predictor of reading and spelling ability (Davidson & Jenkins, 1994). Acquiring these complex early reading skills is difficult for many children who present with no significant learning needs (NICHD, 2000). The challenge to children with autism, with concomitant speech and language difficulties, is thus multiplied.

The National Reading Panel report on effective reading instruction describes five basic, interconnected sub-skills that children should master to become proficient readers (NICHD, 2000). First, *phonemic awareness* or recognizing that all words are made of separate sounds called *phonemes*. Second is *phonics* or sounding out phonemes in a word and blending the sounds back together to read whole words. Third is *reading vocabulary* or understanding that the words they read have meaning just the same as the words they speak or hear. Fourth is *reading fluency* or reading quickly and accurately, and finally, *reading comprehension* or understanding what they read and acting on that understanding. If these skills are critical in teaching reading and preventing reading failure, then it would seem imperative that children with learning disabilities, including ASD, learn these skills.

Although most existing ABA curricula on early reading skills for children with autism may specify targets skills in phonetic reading, such as teaching a child to emit the corresponding sound associated with a letter (e.g., saying 'sss' when shown the letter s) and being able to decode unknown words by blending sounds together, more detailed guidance about how to teach these skills is not usually provided. In addition, there is little research-based evidence about how or when to teach a sequence of letter sounds. One notable exception, used in many ABA settings, is the direct instruction reading program (e.g., Reading Mastery: Engelmann & Bruner, 1995). Furthermore, the non-ABA research literature on teaching early reading skills to children with autism also largely focuses on teaching sight reading rather than decoding and blending skills (see Chiang & Lin, 2007; Joseph & Seery, 2004, for a review). Moreover, most

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research on phonics instruction has focused on teaching typically developing children and not children with developmental disabilities. MimioSprout® *Early Reading* (MER) is a beginning reading program, delivered over the Internet, which provides a complete instructional program package for teaching the five essential reading components identified by the National Reading Panel (see e.g., https://www.mimio.com). It is beneficial to special needs learners because it uses learning principles derived from behavior analysis (see Layng, Twyman, & Stikeleather, 2003, 2004 for detailed descriptions of the program). For example, 'The Right to Effective Education', a position statement of the Association for Behavior Analysis (1990) (Barrett et al., 1991), recognizes that effective instructional methods should include such objectives as specifying mastery criteria that include the dimensions of both accuracy and speed for fluent performance, allowing students to master instructional objectives at their own pace, and providing sufficient practice opportunities to enable learners to master skills at each step of the curriculum. These recommended educational entitlements for students are all incorporated into the MER program.

Specifically, MER incorporates four key learning frameworks, consistent with an ABA teaching methodology that would predict successful learning for all learners and are consistent with the principles of effective instruction (Layng et al., 2004). First, *Reduced Errors*—teaching starts at a simple level, usually with skills that the child already knows. Instruction builds gradually from there, helping to minimize errors. Any errors are used as teaching opportunities, and the child can always repeat a task so that they can finish that task successfully. Second, *Mastery Criterion*—a child does not move to the next part of the lesson (episode) until they have met a specific learning goal in the preceding section. Third, *Guided Practice*—as new words are learned, time criteria are gradually introduced so that children have to identify sound and letter combinations not only consistently and accurately but also quickly (i.e., fluently; see Binder, 1996). Later, these time criteria are also introduced into sentence and story reading. This is consistent with the precision teaching methodologies (Kubina, Morrison, & Lee, 2002). Finally, *Cumulative Review and Application*—here skills taught are revisited and extended several times throughout the program.

One of the most significant features of MER is that instruction in every lesson is tailored to meet the individual needs of each child. In support of its reduced-error framework, the program adapts moment-by-moment based on the frequency and ratio of correct and error responses for each child, rate of responding, or specific error patterns, to offer the most beneficial lesson for that particular learner (e.g., by providing extra practice on tasks, additional instruction, or additional reinforcement). Some of these instructional foundations of MER may be especially beneficial for special needs learners. This is due to MER breaking complex tasks down into the smallest teachable components, an emphasis on active rather than passive responding, the provision of multiple learning opportunities throughout the program, and rich schedules of reinforcement.

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In MER, children learn to sound out and read words through multiple interactions in 80 episodes that last approximately 15–20 min each. The episodes are interactive lessons that use cartoon characters residing in 'worlds' (e.g., space world, undersea world, and jungle world). The program consists of two parts, MimioSprout *Reading Basics* (MRB, Episodes 1–40) and MimioSprout *Reading Independence* (Episodes 41–80). MRB focuses on decoding and beginning comprehension and MimioSprout *Reading Independence* on reading fluency, consolidation, and comprehension skills.

Outcome data are encouraging for typical learners. For example, Layng et al. (2004) investigated the effects of supplementing an existing reading curriculum for 23 children in kindergarten with MRB. At baseline, fewer than 50% of children were reading at their grade level (as assessed by the Developmental Reading Assessment; Beaver, 1997). Following completion of MRB, all 23 children scored above kindergarten level and 82% scored at an early to mid first-grade level. In another study, Twyman, Layng, and Layng (2011) examined the effects of MER on the early reading skills of 65 students when compared with a control group of 60 students who did not receive the MER intervention. When the MER group completed at least 41 lessons ($M = 67$), they showed a greater improvement on reading measures than the control group as measured by the Woodcock Johnson III-R Letter-Word Identification subtest (Schrank, Mather, & Woodcock, 2006) and prescribed subtests from the Iowa Test of Basic Skills (Hoover et al., 2001). Huffstetter, King, Onwuegbuzie, Schneider, and Powell- Smith (2010)) also showed that children using MER made greater gains on standardized tests of early reading skills than a control group who did not received MER.

Although MER has not yet been evaluated with children with autism, there are several reasons why it may be of benefit to them. First, computer-assisted instruction has been demonstrated to be a powerful tool for facilitating the learning of children with autism (e.g., Klin, McPartland, & Volkmar, 2005). Second, MER may also help to overcome inherent difficulties associated with a diagnosis of autism that affect learning (e.g., poor motivation, abnormalities in sensory perception; Daal & Reitsma, 2000). In addition, for many children with autism, unusual sensory features, such as under-responsiveness and over-responsiveness to sensory stimuli, can lead to problems in discriminating relevant information in a learning situation (e.g., Baranek, 2002; O' Neill & Jones, 1997). Concentrating on the computer screen during the MER lessons, where minimal, pertinent information is presented, may help to overcome these problems. Finally, children with autism who have good decoding skills may nevertheless find it difficult to answer questions about what they have just read (e.g., O' Connor & Klein, 2004; Wahlberg & Magliano, 2004). The developers of MER have included frequent use of indicators to test that children can answer questions about the text they have decoded (Layng et al., 2004).

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The purpose of the present study was to conduct an initial evaluation of MER to children with autism. The primary purpose of the study was to investigate whether it would be feasible to use MER with children with autism and whether any adaptations to the standard teaching procedure would be needed. A secondary aim was to investigate whether completing MER would improve early reading skills related to phonemic/phonological awareness and phonics. Evaluating improvements in decoding and word reading only was the focus of this investigation rather than more comprehensive reading skills such as oral reading fluency and comprehension mainly because it was not known how far the children would progress through the episodes. Therefore, it was hoped that change could be detected over the course of the intervention period with a focus on these earlier reading skills.

METHOD

Participants

Participants, hereafter referred to as children, were one girl and three boys; all had a clinical diagnosis of autism and attended an autism unit attached to a mainstream local government-funded school. This educational provision offered intensive behavioral intervention based on the principles of ABA (see Grindle et al., 2012, 2009 for a description of the educational model). Mary was aged 6 years 7 months, Mark was 5 years 11 months, Andrew was 4 years 10 months, and Lenny was 6 years 11 months. All had been in the ABA setting for at least one year. Children were assessed three months prior to starting MER using the Stanford Binet Intelligence Scale: Fourth Edition (Thorndike, Hagan, & Sattler, 1986) and the Vineland Adaptive Behavior Scale—Survey Form (VABS: Sparrow, Balla, & Cicchetti, 1984). These assessments were part of a routine procedure for monitoring each child's overall educational program rather than being carried out specifically for this study (Grindle et al., 2012). At the time of testing, composite full-scale IQ scores were as follows: Mary (88), Mark (90), Lenny (68), and Andrew (64). Vineland adaptive behavior composite standard scores were Mary (79), Mark (79), Lenny (66) and Andrew (64).

MimioSprout® *Early Reading* requires learners to perform a number of key skills as they progress through the episodes, such as repeating out loud sounds and words that are modeled to them, matching words and sentences to corresponding pictures, and following simple instructions. Subsequently, inclusion criteria to participate in the study were related readiness skills considered necessary for the children to benefit from MER: (a) sitting at a computer for short periods of time (up to 15 min) without engaging in challenging behavior and without prompts, (b) following one or two-step teacher instructions (e.g., 'clap hands, and turn around'), (c) responding to feedback

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(praise, or correction), (d) matching nonidentical pictures (e.g., placing a picture of a cup with a picture of another cup), and (e) vocally repeating modeled sounds and words (although they were not always phonemically accurate). In addition, all children were capable of self-initiated speech (typically, communicating using at least three word sentences). All children had received some reading instruction prior to starting MER, but this was limited to them matching identical letters or learning some high frequency words considered appropriate for their school year group. None of the children were able to read words phonetically (i.e., they were not able to 'sound out' words) prior to the study.

Setting

Teaching sessions were conducted mostly in one of the children's regular classrooms. Alongside a wall in the classroom were two computers with chairs where the children practiced MER with an ABA tutor sitting next to them. The ABA tutor had at least 1 year experience implementing ABA programs. Teaching sessions always took place during a time designated for one-to-one instruction for all of the children in the class. While completing episodes, the children and their tutor sat with their backs to other children in class who were working at their desks with an ABA tutor. Occasionally, children were taken to a quieter setting (e.g., the school office, the school computer suite) if noise and activity levels in the classroom environment proved to be distracting (i.e., if children were looking away from the computer screen to the source of the noise).

Materials

MimioSprout® *Early Reading* instructional components were (i) 80 online lessons (episodes) each of approximately 15–20 min in length, (ii) MimioSprout's printable *Sprout Stories*™ (including *MimioSprout Readers*, *Read with Me Stories*, and *Companion Stories*), (iii) *Sprout Cards*™ (about 100 printable flash cards of sounds and words taught in the program), (iv) MER *intensive practice* materials (Sound-Word Frequency Building Sheets with up to 60 sounds/words on each sheet for the child to read in short practice sprints), (v) Progress Maps and Stickers (for children to record each episode that they completed), and (vi) Completion Certificates, which were provided to the children on completion of 80 episodes.

Potential back-up reinforcers, including edible items, toys, and novelties, were also identified for each child based on the teacher's knowledge of their preferences, and on-going preference assessments were included as part of the child's ABA program.

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Measures

Children's early reading skills were assessed using The Dynamic Indicators of Basic Early Literacy Skills (DIBELS; Good, Kaminski & Dill, 2002) and the Word Recognition and Phonics Skills Test (WRAPS; Carver & Moseley, 1994). These assessments were chosen for their use in published outcome studies on reading and for their focus on assessing beginner reader skills (e.g., Coyne & Harn, 2006). The DIBELS primarily measures reading skills that have been shown to be strong predictors of early reading success and can be used to help identify those children who might be at risk of reading difficulties later in life (Good, Gruba, & Kaminski, 2002). For the DIBELS, all children were assessed using the First Grade Scoring Booklet Benchmark Assessment. The child's total score for each measure was how many correct responses they provided in 1 min. The DIBELS assessment consists of five sub-measures: (i) the *Initial Sound Fluency* measure that assesses a child's ability to recognize the initial sound in an orally presented word, (ii) the *Phonemic Segmentation Fluency* measure that assesses a child's ability to segment three and four phoneme words into their individual phonemes, (iii) the *Word Use Fluency* measure that assesses expressive vocabulary skills (i.e., the ability to use words to convey a specific meaning for a particular label or word), (iv) the *Letter Naming Fluency* measure that assesses the child's ability to label letter names (if the child produced the letter sound rather than the letter name this was scored as incorrect), and (v) the *Nonsense Word Fluency* measure that assesses alphabetic principle skills (i.e., the ability to know that letters represent sounds in words and that letter sounds can be blended together to read/ decode words).

The WRAPS is a standardized measure that assesses children's developing word recognition skills. During the WRAPS assessment, one stimulus word at a time is spoken out loud by an examiner and repeated again in a sentence (e.g., 'Orange', 'The Orange that we eat'). The child is asked to select, by pointing, on a sheet the correct word in a row out of an array of five words. The child's total score is how many words, out of 50, they can correctly identify. The WRAPS can be used with children from 4–9 years and provides a standardized score and word recognition age for each child.

Design

The study used a single subject pretest/posttest design replicated across four children in a small series of cases. Assessments were conducted on at least three data collection points for all children: pre-intervention, after 40 MER episodes, and after 80 MER episodes. Lenny, Mark and Mary completed the 80 episodes within the school (academic) year in which they had started MER. Andrew required an

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additional few months into the following school year. Subsequently, posttests of performance were also conducted for Lenny, Mark, and Mary after the summer vacation (approximately 8 weeks in length) to see if early reading skills changed during a period of no intervention. No follow-up was conducted with Andrew.

Procedure

Overview of basic teaching procedure

The MER teaching procedure recommended for typically developing children was followed as closely as possible (e.g., Layng et al., 2004). Children practiced an introductory program ('Mousing Around') prior to starting episode one until they could complete the lesson independently. For some children, additional instruction was needed for them to complete this episode independently (see Adaptations and Additional Instruction). The Mousing Around program taught the instructional language used in MER online lessons (e.g., for negation—'Click on the fish. If it is NOT the fish click on the arrow'; for first, next, and last concepts—'Click on the friend who is FIRST'), but also provided practice in basic computer skills (e.g., clicking and dragging the mouse, tracking on the screen from left to right, top to bottom).

Each child's progress was measured at regular intervals throughout the intervention. A mastery criterion of 90% correct was required on each online episode before moving on to the next episode. In addition, after completing a set of episodes they were required to read colorful story booklets (e.g., 'MimioSprout Readers') correctly and without hesitation (as per the MER implementation guidelines) before children could progress with the online tuition. Finally, in sound/word fluency tests (taken from the intensive practice materials), the children were asked to read from a sheet of paper as many sounds/words as possible in 1 min (all required responses had been taught previously during online instruction). For example, after episode four, the child had to say correctly 25–35 correct sounds in 1 min with <3 errors to be able to progress onto episode five on the computer. Reading the story booklets and completing the sound/word fluency tests helped to support and extend MER online instruction by evaluating transfer of skills from online reading to printed text (as recommended in the MimioSprout guidelines).

Each child practiced MER at least three times a week when they were in school and worked sequentially through the episodes. The type of MER instruction in these sessions sometimes differed depending on the individual needs of the learner. For example, children could complete three different online episodes in a week if they reached mastery criterion each time. Alternatively, if they did not reach criterion, they could practice the same online episode three times in a week until they did reach criterion. Sometimes during the MER sessions, the children did not use the internet

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program at all and teaching instead focused on necessary prerequisite skills at the table using discrete-trial teaching. No other additional reading instruction from teachers or parents was provided during the time period of the study.

Across children, the mean duration of each episode was 16 min. All children celebrated their progress by recording it on the maps and wall charts provided by MER and by receiving stickers and certificates.

Data collection and reliability

Data on each child's performance were collected automatically by the MER program (i.e., number of interactions per episode, duration of interactions in minutes, and percentage correct responses). Tutors also took descriptive data on all problems that occurred during teaching. To calculate inter-observer agreement on assessment scores, four observers scored an average of 65% of assessments for each child (WRAPS—66% of assessments, DIBELS—87%, Decoding Words Assessment—53%, MER fluency tests—54%). Agreement was calculated for response reliability (agreement that a response was correct or incorrect) on standardized assessment scores. Mean reliability was calculated by tabulating agreements and dividing them by agreements plus disagreements and multiplying by 100. It was 97% (range, 94–99%) across the assessments and across children.

Adaptations and Additional Instruction

For all children, adaptations to the standard teaching procedure and some additional instruction were required at some point to support their progression through the online episodes. The decision to implement additional teaching strategies was made when on-going data collection revealed that children had not achieved mastery criterion on particular tasks within a given time frame (e.g., if they had not mastered an online episode within one week, if they were not able to read the MimioSprout Readers correctly and with fluency, as per the MimioSprout guidelines). This emphasis on data-based decision making for individual children meant that it was not possible to decide ahead of time what additional teaching components would be required or to apply these components systematically across children. All children in the ABA provision received one-to-one tutor support for the majority of their instructional hours at school. Therefore, it was not considered unusual for a high level of teaching input to be provided to help the participant's progress through MER. Five main adaptations were developed, and each is described in detail in the following text.

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Tutor sitting with child

During each online episode a tutor familiar to the child sat next to them. It was important that the data collected by the computer were based on the child's unprompted performance of reading ability, so any prompts delivered by the tutor predominantly consisted of reminders to attend to the computer screen or to speak out loud when required to do so by the program. All children initially required prompts from their tutor to speak out loud when instructed to do so by the computer. The tutor also provided prompts, reminders, or encouragement, when necessary for any associated tasks (e.g., reading MimioSprout Readers, performing fluency tests).

Prior to the study, the first author conducted two training sessions with the tutors, describing in detail the teaching procedures and data collection techniques to be used in the study. During the study, the first author sometimes observed MER teaching sessions. During these sessions tutors were provided with direct feedback regarding their supervision skills and further advice provided where necessary. In particular, tutors were given feedback about appropriate prompts to give the children. All tutors received similar training and were assessed periodically throughout the study to ensure that procedures were implemented in a consistent fashion.

Manipulating the motivating operation (MO) for challenging behavior

Although a variety of features are built into the MER program to motivate typical learners (e.g., completing reading tasks usually results in the moving of an animated character to a desired destination and after each correct response, the computer delivers a praise statement such as 'Yeah' or 'You did it'), these were not initially sufficient in decreasing the MO for engagement in challenging behavior throughout the program. For example, during early episodes functional assessments revealed that Mark engaged in avoidance behaviors (e.g., tantrums, running away) when he was told to go on MER and that Andrew engaged in escape behaviors (e.g., climbing under the table) when he received error correction from the computer. Subsequently, for all children, high quality, individually determined reinforcers were delivered intermittently throughout each episode (for attending, following directions, etc.) as well as for episode completion irrespective of reading performance. This intervention appeared to reduce the value of reinforcement through engaging in challenging behavior as on task behavior during episodes subsequently increased as the frequency of challenging behavior decreased.

Increasing on task behaviors

For Lenny, Mary and Andrew, specific strategies were also put in place to increase their *on task* behaviors (e.g., looking at the computer screen, speaking out loud when

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required to do so by the program) during online instruction. By dividing each episode into 2-3 sittings across the day inattentiveness and distractibility were substantially reduced. Certain times of the day were also associated with higher rates of off-task behavior for all children (e.g., the start or end of the school day, immediately before lunch), so episodes were not completed at these times.

Remediating problems through using discrete trial teaching

At times, children did not achieve the 90% mastery criterion on online episodes and needed additional assistance. Given that the program included specific feedback and prompting targeted towards the learners' responses, the child was first allowed to repeat the episode a few times to see if the program's embedded feedback and instruction remediated the problem. Across children, they averaged five repeated episodes to complete up to episode 80 (range, 3–10). A mean of 85 online sessions (including repeated episodes) was needed to complete the program (range, 83–90). A total of 75% of repeated episodes occurred during the first 40 episodes.

If the child continued to need assistance in addition to that provided by the program itself, discrete-trial table top teaching was provided. These additional teaching tasks were not intended to teach reading skills per se, rather they were designed to re-engage the child with the program by teaching key prerequisite skills such as following the instructions that MimioSprout uses.

As a general strategy, once a difficulty was identified, the skill was broken down into several smaller steps (i.e., using a task analysis procedure) and taught first at the table using discrete-trial procedures and related visual stimuli (e.g., picture cards), before the participant was tested again on the online episode. All four children encountered difficulties with certain aspects that were remediated using discrete-trial teaching (see Table 1).

For example, in the 'negation task' during the Mousing Around program, children were required to follow an instruction to click on a picture if that picture appeared on the screen, but to click on an arrow if the picture did not appear (i.e., 'Click on the fish. If it is NOT the fish click on the arrow'), and similar instructions were used during the online episodes for reading instruction (e.g., 'Click on "the", if it is not "the" click on the arrow'). This was a difficult task for all children and they worked through the following steps at the table to master the skill:

Step one: Children were first taught to follow receptive instructions with negation using familiar objects/mastered concepts. For example, 'Show me the one that is NOT the horse' versus 'Show me the one that IS the horse', 'Find the one that is NOT blue' versus 'Find the one that IS blue.' Initially, these instructions were kept short and succinct (e.g., 'NOT blue' and the participant had to touch the red color card),

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Table 1. Examples of difficulties on MER that were remediated through discrete trial teaching (DTT).

Skill area	MER difficulty	Corresponding DTT activity
Negation	Child needed to click on a word if it matched a spoken word or click on an arrow if it did not '*Click on* "*the*", *if it is not* "*the*" *click on the arrow*'	(See text for complete description) Children were first taught negation using mastered tacts. Next, instructions and materials were modeled more closely to those used in MimioSprout. For example, an arrow figure was placed on the table in front of the child (pointing in the same direction as the arrow on the computer screen) with a printed word to the left of the arrow. The child was taught to touch the printed word if the target word matched that word and the arrow when it did not.
Vocabulary comprehension	Child needed to click on the pictures of different characters performing different actions '*Touch Flip slipped*'	Children were first taught at the table, receptive identification of all the different character names used in MER (e.g., 'Touch Flip' when there were two other pictures of characters in the array). Next, they were taught to identify the verbs used in MER (e.g., 'Touch slipped'). Finally, the child was required to discriminate between picture cards depicting the verb and the character name (e.g., Touch Flip Slipped).
Recall	Child needed to read out loud a sound/word and then listen to three characters saying similar sounding sounds. They then had to recall which character had said the target sound/word. '*Click on the one that said* "*b*"'	Children read a target sound. Next, pictures of three characters were placed on the table in front of the child. Under each character was a printed sound which the therapist read to the child as they pointed to each sound. The therapist then asked, 'Which one said……', and the child touched the correct character. Gradually the textual prompt was faded, so that the therapist merely pointed to each character, saying a different sound each time.

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but they gradually become more complicated as the child demonstrated competence. When the children could receptively discriminate these instructions, they were tested again on the relevant episode.

Step two: If they still could not follow the computer directions, they received additional teaching at the table that more closely resembled the computerized instruction (e.g., 'Click on the fish. If it is not the fish click on the arrow.'). During all trials, an arrow figure was placed on the table in front of the child (pointing in the same direction as the

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arrow on the computer screen) with a picture of an animal to the left of the arrow. The child was taught first to touch the picture of the animal that always corresponded to the animal named in the instruction (e.g., a picture of a horse would be placed next to the arrow and they were required to touch it).

Step three: Next, the child was taught to touch the arrow when the named animal *did not* correspond to the picture on the table (e.g., If given the instruction, 'Touch the dog. If it is not the dog touch the arrow' and a cat was placed on the table next to the arrow, they were required to touch the arrow).

Step four: Finally, the child was provided with a series of trials that randomly interspersed instructions where the named animal matched the picture on the table with instructions where it did not (negation).

Importantly, children needed discrete trial teaching (DTT) input early on in their MER instruction (e.g., the first time a particular skill area such as negation or recall was introduced). However, once the skill was mastered, first at the table and then in the online episode, they were usually able to demonstrate that same skill in successive episodes without any further DTT input even though the complexity of problems using the skill increased greatly. Thus, DTT support was mostly needed during the first 10 episodes when skills were introduced for the first time and was used rarely in later episodes.

Improving fluency

Additional instruction was also needed for the children to pass the MER Fluency Tests. Common problems included reading correctly but too slowly or reading with errors. To overcome problems with reading too slowly, the appropriate pace was modeled to children, and they were encouraged to match the model. They were also given additional practice opportunities to increase their speed using flash cards, before being tested again with the words on the sheet of paper. On subsequent practice sessions, after being shown how to graph their performance, some children asked to graph their scores so that they could see if they could beat their previous score. Sometimes children began reading at a fast pace at the start of the interval but slowed down as time progressed. If this was the case, the measured time interval was reduced to 10 s and then gradually increased. To help with scanning the sounds/words on the sheet, the therapist used a ruler to mark the line that the child was reading.

For all errors not corrected via the program itself, the correct response was modeled to the child and additional practice was given using flash cards. One of the fluency tests (after Episode 35) required the child to read nonsensical consonant-vowel-consonant sound-word combinations based on sounds they had already learned (e.g., 'fleel'). Mark and Lenny initially made many errors on this task because they

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attempted to change each nonsensical word into a real word (e.g., feel), possibly because all the fluency tests up to that point had consisted of real words. The target consonant-vowel-consonant combinations were put onto flashcards with different color ink for the different phonetic components, and practiced until the children were fluent (e.g., 25–35 correct with <3 errors).

RESULTS

The MER program-generated data on children's progress as a result of the standard teaching procedure combined with the adaptations described in the preceding section were examined first. Table 2 shows the summary data for program outcomes for each child (mean scores across episodes for percent correct responding, learner interactions, episode duration, number of responses per minute, and the number of weeks each spent on MER). Data are presented separately for Episodes 1-40, 41-80 and for all lessons combined.

The data allow a comparison between the learning profiles of the current participants to that reported for 1000 typically developing children who had completed the first 40 episodes (Layng et al., 2003). The typically developing children averaged 94% correct responding across the episodes and engaged in an average of 190 individual learner interactions (i.e., comprised of a presentation, a response, and a consequence) in each episode. Each episode lasted on average 17 min and learners engaged in nine responses per min across all 40 episodes. The scores from the typically developing children are enclosed in parentheses on the tables, alongside the mean score for the children with autism. The scores for the children with autism are consistent with the learning profiles of the typically developing children and demonstrate a stability of effect across children.

Data were also collected to show each child's learning profile for episodes 41-80, and the scores were averaged across children. For episodes 1-40 and 41-80 there are noticeable differences in the scores for mean number of learner interactions per episode (respectively, 196 vs. 275). This possibly indicates the greater complexity of tasks in later episodes (i.e., more responses required, although at a faster rate since episode length did not increase). Table 2 also shows the number of weeks spent on MER for each child. They averaged 14 weeks to complete up to episode 40 (range, 9-23) and 28 weeks to complete up to episode 80 (range, 22-43 weeks).

Table 3 shows, for each child, the standardized assessment scores for the DIBELS taken at the different time points: pre-intervention (baseline), after 40 episodes (Time 1), after 80 episodes (Time 2), and for Lenny, Mark and Mary at follow-up after 8 weeks with no intervention (Time 3). The data are presented for the total number of correct responses recorded in one minute for each measure. For four of the sub-tests (initial sound fluency, phoneme segmentation, letter naming fluency, and

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Table 2. Summary of MimioSprout program outcomes.

	Mean percent correct			Mean interactions per episode			Mean interactions per minute			Mean episode duration (minutes)			Mean number of weeks on MimioSprout		
	1–40	41–80	1–80	1–40	41–80	1–80	1–40	41–80	1–80	1–40	41–80	1–80	1–40	41–80	1–80
Mary	97	98	97	181	276	228	14	21	17	19	13	16	10	13	23
Mark	95	98	97	204	277	240	15	20	18	14	15	15	9	13	22
Lenny	95	98	97	198	278	234	14	18	16	16	15	16	15	7	22
Andrew	92	98	95	200	267	232	13	18	15	16	16	17	23	20	43
Mean	95 (94)	98	97	196 (190)	275	234	14 (9)	19	17	16 (17)	15	16	14 (na)	13	28

The mean value enclosed in parentheses represents the data from 1000 typically developing children who had completed the first 40 episodes (Layng et al., 2003,). na represents 'not available'.

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Table 3. Standardized test results from the DIBELS

Children	DIBELS sub-tests	Baseline	Time 1	Time 2	Time 3
Mark	Initial sound fluency	(1)	7	25	26
	Phoneme segmentation	(0)	7	22	13
	Word use fluency	5	23	14	33
	Letter naming fluency	(20)	(4)	34	44
	Nonsense word fluency	(6)	18	23	19
Andrew	Initial sound fluency	9	17	28	—
	Phoneme segmentation	(0)	28	47	—
	Word use fluency	0	17	22	—
	Letter naming fluency	(0)	0	31	—
	Nonsense word fluency	(6)	22	25	—
Lenny	Initial sound fluency	9	12	18	31
	Phoneme segmentation	12	14	12	24
	Word use fluency	0	0	15	25
	Letter naming fluency	(2)	(1)	(0)	(0)
	Nonsense word fluency	(6)	41	(10)	25
Mary	Initial sound fluency	28	38	42	51
	Phoneme segmentation	(7)	15	21	23
	Word use fluency	2	40	29	28
	Letter naming fluency	(3)	6	(11)	50
	Nonsense word fluency	23	43	26	48

DIBELS, Dynamic Indicators of Basic Early Literacy Skills.

Values enclosed in parentheses represent scores that show the child to be 'at risk' of later reading difficulties (Good, Gruba, et al., 2002). A benchmark goal and cut-point for Word Use Fluency has not yet been provided. Dashes indicate where follow up data are not available.

nonsense word fluency), values enclosed in parentheses are indicative of the child being at risk of reading difficulties in later grades (Good, Gruba, et al., 2002). This prediction is not possible for Word Use Fluency because a benchmark goal and cut-point has not been provided (due to there being no research available on the relation between this skill and the development of later reading ability).

The number of correct responses recorded in 1 min improved across all measures from baseline to time 2 for Mark, Andrew, and Mary. For Lenny, his phoneme segmentation score remained the same, and his letter naming fluency decreased slightly. For Mark, Lenny, and Mary, posttest scores were also higher than at baseline, with the exception of letter naming fluency for Lenny. On most measures, scores also increased from time 2 to time 3, even after an eight-week period of no intervention. On most available measures, the level of risk following intervention also decreased. At baseline, scores from 69% of the measures, across children, indicated that the child would be at risk for poor reading outcomes later in life (Good, Gruba & Kaminski, 2002). At time 2, this had decreased to 19% of scores, and at time 3 to 8% of scores (only the letter naming fluency test for Lenny indicated that he was at risk).

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Table 4 shows the raw scores for the WRAPS and the corresponding word recognition age (WRA: years, months). For Mark, Andrew and Lenny these scores improved from baseline to Time 2 and from Time 2 to Time 3. Mary scored at ceiling (maximum raw score 50, WRA 8+ years) at baseline and again at all further assessment periods.

DISCUSSION

The present study showed that each child was able to complete all 80 MER lessons and showed similar trials correct to that reported for typically developing learners provided that additional strategies, mostly derived from teaching procedures common in ABA and other special education settings, were developed to help maintain their progression through the lessons. The approach that was taken to solve learning problems that arose for the children as they encountered new tasks in MER was essentially the same approach that was used to solve any learning problem they had in other curriculum areas. The general strategy was to conduct a task analysis of the task required in MER program and transfer this to a table-top task, and this was then presented within a discrete trial format as is typical in an ABA approach. In addition, strategies were also designed as needed for individual children that took into account their transitory interests and difficulties. For example, during some episodes, Andrew focused on stimuli on the screen that were not relevant to the learning task (e.g., the steps on a space ship), and had difficulties shifting his attention away from these stimuli to respond to instruction (i.e., he had problems with stimulus overselectivity). Copying the pictures of the steps and space ship onto small cards and giving him frequent exposure to the cards throughout the day helped to overcome this difficulty.

Table 4. Standardized test from the WRAPS (raw score and word recognition age)

Children	Scores	Baseline	Time 1	Time 2	Time 3
Mark	Raw score	8	42	44	48
	Word recognition age (years, months)	<5	7,5	7,7	7,11
Andrew	Raw score	14	39	50	-
	Word recognition age (years, months)	5,3	7,3	8+	-
Lenny	Raw score	28	40	43	47
	Word recognition age (years, months)	6,4	7,3	7,6	7,10
Mary	Raw score	50	50	50	50
	Word recognition age (years, months)	8+	8+	8+	8+

WRAPS, Word Recognition and Phonics Skills Test.
Dashes indicate where posttest data are not available. Word recognition age is indicated in years, months.

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For Lenny, certain tasks and characters triggered high rates of self-stimulatory behavior (hand flapping) that interfered with his learning. This behavior reduced to near zero levels when he received reinforcement for not performing the behavior for a given period of time during each episode (i.e., a DRO procedure was implemented). The frequency of Lenny making errors also increased during early episodes due to his seeming preference for the feedback he received from the computer when he made errors compared to the feedback he received for correct responses. Subsequently, he was given additional reinforcement for correct responses to compete with the value of the reinforcement he was receiving from the computer for making an error. These adaptations and additional teaching strategies were successful in overcoming obstacles to learning during individual episodes and were essential in maintaining each child's successful progression through MER.

The second exploratory aim of this study was to investigate whether completing MER would improve early reading skills and phonological awareness in children with autism. For each of the children in this small case series gains in key early reading skills were found when MER was used according to the program designers' recommendations of best practice (e.g., MER practiced at least three times a week) and when additional instruction was provided in the early stages. This suggests that MER should be evaluated more systematically as a tool to teach early reading skills to children with significant additional learning needs.

The results of the reading skills tests for each of the four children are encouraging within the time span of the study. If a typically developing child's word recognition age (WRA) was to improve from between 14 months and 3+ years to a WRA above their grade level in 14 weeks of teaching (i.e., the average number of weeks taken to reach episode 40), this would be recognized as a significant improvement in reading skills. The fact that three children with autism were able to achieve such gains is encouraging. Furthermore, a critical skill in functional reading ability is for a child to be able to decode nonsense words (e.g., Good, Baker, & Peyton, 2008). This skill also improved substantially for all children on the DIBELS (as measured by words decoded per minute). Additionally, it is noteworthy that the increases in test scores for most of the children occurred in the first 40 lessons of the program. This might be expected because this is the part of the program that teaches the decoding and blending skills that were measured. The second half of the program concentrates on building fluency, comprehension strategies, and diversifying reading skills—skills less likely to show changes on the outcome measures that focus mainly on the early reading skill of decoding words (e.g., DIBELS and WRAPS). In future research, children with autism progressing through the whole of the MER program should be tested on a broader range of reading skills.

Evidence was also found to show that children maintained their improvements and even continued to show some improvement on key reading skills after the

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intervention had formally stopped for their school summer vacation. For example, some of the scores on the DIBELS measures increased from the posttest to follow-up (see Table 3), as did the scores on the WRAPS for two of the children (see Table 4). This may indicate that the children had acquired sufficient reading skills to access reading materials more generally and also within the context of their everyday life. Anecdotal reports from teachers and parents suggested that this was the case and should be something that future research should investigate or attempt to document. For example, following MER, Andrew's parents reported that he started spontaneously sounding out printed words that he saw on signs in his neighborhood. Lenny also started to spontaneously point to words from left to right as his parents read to him. Thus, it is possible that Lenny learnt new words by connecting the spoken word he heard with the printed word at which he was pointing. The reduction in the number of at risk scores on the DIBELS also supports the suggestion that MER had taught the children functional reading skills that were not only being used outside of the structured MER teaching sessions but may also be those skills likely to prevent future reading problems.

Some exceptions to the general trend of skill increases were evident for some of the DIBELS sub-measures. For example, the Nonsense Word Fluency Score decreased from Time 2 to Time 3 for Mark and from Time 1 to Time 2 for Lenny. In both cases, errors made occurred when the child attempted to change the nonsensical letter combinations into a real word. This was a similar error to that described previously for one of the fluency tests. The Phoneme Segmentation score also decreased for Mark from Time 2 to 3. In this task he was required to segment three and four phoneme words into their individual phonemes (e.g., say 'b' 'a' 't' for 'bat') but he just repeated the whole word (e.g., 'bat'). Possibly, the emphasis on 'real' words in HER and in reading generally confused the children with what was expected of them for these sub-measures of the test. The Letter Naming Fluency task remained low for Lenny because he said the sound of the letter rather than the letter name which was the requirement of the task. The emphasis in MER is on saying phonics rather than the letter name so this may have contributed to this score remaining more or less unchanged. Again, future studies could usefully examine improvements in reading skills following MER using a range of different reading assessments.

Another consideration is that it was possible that the WRAPS scores for each child may have been influenced by their previous learning of sight words. All children had learned some high frequency word lists deemed as appropriate for their school year group prior to starting MER (Mary: Word lists for kindergarten through to fifth grade; Mark: up to and including third grade; Lenny: kindergarten and first grade; Andrew: kindergarten only). The percentage of words in the WRAPS that had been pre-taught as sight words was as follows: Mary, 30% (15/50 words); Mark, 28% (14/50 words); Lenny, 18% (9/50 words); Andrew, 12% (6/50 words). Thus, their previous learning

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of sight words would have especially affected baseline performance making it harder to achieve an increase on this outcome measure.

The primary aim of this study was to investigate whether it would be feasible to use MER with children with autism and whether any adaptations to the standard teaching procedure would be needed. Further research is needed to extend the current findings by examining the effectiveness of MER with larger samples of children and including a control group in the study design. Another consideration would be to assess other possible changes of interest. For example, although standardized measures at baseline and posttest were used to measure improvements in early word reading tasks related to phonological/ phonemic awareness and phonics, improvements in more advanced reading skills such as oral reading fluency and comprehension were not assessed. Future larger scale investigations could also examine how receptive and expressive language abilities might be related to the acquisition of key reading skills, or the impact that an additional developmental disability might have on learning to read for children with autism. Finally, it would be interesting to examine in more detail the effects of the additional table-top teaching provided during the first 10 episodes. Although it is unlikely that these additional tasks contributed to any changes in reading ability (they were meant to re-engage the child with the program rather than teach reading skills per se), it is possible that the children would not have been able to progress through the online episodes without these additional tasks and learning materials. Future research could perhaps manipulate this aspect of the intervention by comparing a MER model with or without this additional teaching. Finally, it would be interesting to assess whether MER could be used in standard special educational settings that are not ABA-specific and may not have the kind of staff student ratios or the expertise in behavioral methodologies (e.g., discrete trial teaching, task analyses) common in these settings. It is possible that the additional teaching identified in this study as being beneficial, mostly based on discrete teaching, would be more difficult to implement in a non-ABA context.

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