frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 09 October 2023
DOI 10.3389/feduc.2023.1190838

OPEN ACCESS

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RECEIVED 21 March 2023
ACCEPTED 19 September 2023
PUBLISHED 09 October 2023

CITATION
Linder A-L, Geyer M, Atzemian M, Meuli N, Martinet C, de Chambrier A-F and Sermier Dessemontet R (2023) Effects of adaptations of a phonics-based reading intervention program on reading and spelling skills of students with intellectual disability who require augmentative and alternative communication.
Front. Educ. 8:1190838.
doi: 10.3389/feduc.2023.1190838

Effects of adaptations of a phonics-based reading intervention program on reading and spelling skills of students with intellectual disability who require augmentative and alternative communication

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Introduction: This study is an examination of the effects of a series of adaptations made to a phonics-based reading intervention program for students with an intellectual disability (ID). The adaptations were designed to make the program more accessible to augmentative and alternative communication (AAC) users. They consisted of using a pointing-response modality to allow participants to give their answers as well as the use of internal speech, which involved performing certain tasks in one's head because students with complex communication needs could not perform them aloud. Participants also completed reading and spelling activities on an iPad® application.

Methods: A multiple-probe-across-participants design was used. Specifically, the adapted reading program's effects were assessed on reading and spelling skills of three students with ID who were AAC users.

Results: The outcomes indicate that all three participants improved their reading skills, and two participants also improved their spelling skills.

Discussion: The results and implications for future research are discussed.

KEYWORDS

intellectual disability, augmentative and alternative communication, complex communication needs, reading, spelling, phonics, intervention

1. Introduction

The ability to read and spell enables individuals to participate successfully in education and society, make decisions, access the job market, and use technology (Light and McNaughton, 2012; Mandak et al., 2018). Literacy skills are therefore crucial for improving the quality of life, self-determination, and social participation of people with an intellectual disability (ID; Forts and Luckasson, 2011). Over the past two decades, research on reading intervention for students with ID has increased. These studies were not restricted to sight word instruction and have shown that students with ID can learn reading skills through intensive and systematic

instruction. The interventions implemented in these studies focused on phonics instruction (Heller et al., 2002; Tucker Cohen et al., 2008; Finnegan, 2012) or phonics instruction combined with other reading components, such as phonemic awareness training (Joseph, 2002; Fallon et al., 2004; Lemons et al., 2012, 2015), comprehension instruction (Ahlgrim-Delzell et al., 2014, 2016), vocabulary instruction and/or fluency instruction (Allor et al., 2010; Burgoyne et al., 2012). In their meta-analysis, Sermier Dessemontet et al. (2019) conclude that systematic and direct phonics instruction (consisting of modeling the required skills and then providing guided practice with feedback and independent practice) can be considered an evidence-based practice to teach reading skills to students with ID.

Researchers have conducted most studies examining how to teach students with ID to read with students who can express themselves verbally (Sermier Dessemontet et al., 2019). However, about a third of the students with ID are unable to meet their daily communication needs through verbal language. These individuals are referred to as displaying complex communication needs (CCN; Short-Meyerson and Benson, 2014; Beukelman and Light, 2020) and exhibit widely varying communication skills (Short-Meyerson and Benson, 2014; Mims, 2020). Some individuals' communication can be described as pre-intentional. They produce behaviors that caregivers interpret as having meaning even if the person is expressing no intention (e.g., facial expressions, crying, vocalizations). Others communicate intentionally with conventional or non-conventional behaviors, either non-symbolically (e.g., holding out hands to ask for more, turning head to finish the task, pointing) or symbolically, using language or some type of symbol to communicate (e.g., photographs, pictograms, hand signs; Short-Meyerson and Benson, 2014; Mims, 2020). Students with ID and CCN who have developed intentional and symbolic communication are typically provided augmentative and alternative communication (AAC) systems (Mims, 2020). AAC systems can be of various types, depending on the user's cognitive, communicative, and motor abilities (Beukelman and Light, 2020). They are generally divided into two main types: unaided and aided systems. Unaided AAC systems do not require the use of any physical equipment (e.g., hand signs, eye blink codes). Aided systems are referred to as either low-tech or high-tech. Low-tech AAC systems typically include robust picture exchange systems and communication boards. High-tech AAC systems include speech generating technologies based on tablets and phones and can be accessed using touch screens, keyboards, switches, or eye tracking (Wilkins and Ratajczak, 2009). They use symbols or letters to generate meaningful words and sentences with either a prerecorded or a synthesized voice. Among students with ID who use aided AAC to communicate effectively in everyday life, some use oral language in a restricted and/or unintelligible way and some relay solely on AAC devices.

Acquiring literacy skills can greatly broaden all AAC users' horizons in terms of communication, education, career, and social interactions. This makes the development of literacy skills extremely crucial for their growth and success in life. Unfortunately, approximately 90% of individuals with ID and who use AAC enter adulthood without functional literacy skills (Foley and Wolter, 2010; Mandak et al., 2018). Underestimation of their literacy potential, inappropriate teaching practices, and the lack of intervention programs tailored to the needs of this group of students contribute to this phenomenon. Some qualitative studies that have focused on teachers' perceptions indicate that many of them consider learning to read too complex a task for students with ID who are AAC users (Ruppar, 2015, 2017; Linder et al., 2020). These students therefore seem at particular risk of receiving substandard reading instruction because teachers' expectations of these students are particularly low and they are rarely given the opportunity to participate in literacy lessons (Ruppar, 2015, 2017; Linder et al., 2020).

Intervention studies for students with ID who are AAC users are too scarce to identify evidence-based interventions. Furthermore, they have been conducted only with English-speaking students (Machalicek et al., 2010; Sermier Dessemontet et al., 2019). However, a recent systematic review of reading interventions designed for individuals who require an AAC highlight the importance of using direct instruction (Yorke et al., 2021). In some studies, researchers have adapted the response modality by focusing on a modality other than oral. Therefore, students participated in a multicomponent reading intervention program by pointing to correct answers (displayed among distracters) in paper format or on a tablet. The results indicated that nonverbal students with ID improved their early-phonics skills (Browder et al., 2012) and reading skills (Ahlgrim-Delzell et al., 2014, 2016). In two single-case studies (Heller et al., 2002; Coleman-Martin et al., 2005), researchers encouraged students with ID who are AAC users to verbalize phonemes silently using internal speech while the teacher (Heller et al., 2002) or a computer with voice output (Coleman-Martin et al., 2005) sounds out the words. The use of internal speech to read words, i.e., requiring students to perform the task in their head, seems promising because these two studies' results show that all students made progress in reading. Studies on spelling are even more scarce with students who have ID and those who also have CCN (Truxler and O'Keefe, 2007; Johnston et al., 2009; Joseph and Konrad, 2009). More research is therefore needed to improve our understanding of how to teach spelling effectively to these students.

The purpose of the present study was to investigate the effects of adaptations of a phonics-based instructional reading program on word reading and spelling skills of individuals with ID who are AAC users. The instructional reading program (De Chambrier et al., 2021) that was adapted in the present study is designed to teach French-speaking students with ID to read and spell. In a randomized controlled study, this program was shown to have a positive effect on word and non-word reading skills of verbal students with ID as well as a marginally significant positive effect with a medium effect size on spelling skills (Sermier Dessemontet et al., 2021). The aim of the present study was to examine the effects of a series of adaptations of this instructional reading program paired with training on an iPad® application related to the program on the development of reading and spelling skills of students with ID who are AAC users. Adaptations included (1) providing opportunities for students to give their responses by pointing and (2) the use of internal speech, especially when one is reading syllables and words. The following research question was therefore considered: What are the effects of an intervention combining adaptations of a phonics-based instructional reading program paired with training on an iPad® application on the ability of students with ID who are AAC users to read and spell words?

2. Methods

2.1. Participants

Teachers were recruited from the special education departments in three French-speaking regions of Switzerland. Teachers who

agreed to participate in the study were asked to identify students who met the following inclusion criteria: (a) diagnosis of intellectual disability, (b) needing an AAC device to communicate effectively, (c) symbolic conventional communication using concrete symbols (e.g., natural gestures, mimes, pictures of objects) or abstract symbols (e.g., isolated words, gestures associated with an object, pictograms), (d) 6 to 12 years old, (e) knowledge of at least eight letter-sound correspondences but inability to read simple syllables or words, and (f) parental permission to participate. Teachers participating in the study were required to schedule at least two individual reading lessons and at least 15 min of training on the iPad® application per week with their student. Eight teachers (including two pairs of teachers in the same class) volunteered to participate and nominated six potential students. To assess eligibility, two members of the research team tested students' abilities in letter-sound correspondence and in reading of syllables and words using a standardized nonverbal reading test developed for assessing students with ID who are AAC users (Meuli et al., 2023). Two students did not meet the inclusion criteria. The first did not know enough letter-sound correspondences, and the second was already able to read several syllables and words. A pair of teachers working in the same class also withdrew from the study because they were unable to schedule two reading lessons per week with their student. Therefore, three students and four teachers were included in the study.

2.1.1. Students

The three participants were Lea, Fadia, and Tim.

Lea was a 9-year-old girl diagnosed with ID (nonverbal IQ = 40, measured with the Leiter-R; Roid and Miller, 1997). Her global adaptive behavior score on the ABAS-II was 51. Her means of communication included natural gestures and the use of pictograms or pictures. She was able to nod her head or verbally express herself to give yes/no answers and used her iPad® equipped with an AAC device, Snap™ Core First (Dynavox, 2021), for further responses and requests. She sometimes produced isolated comprehensible words (approximatively 10 words in total). Lea was bilingual (English-French). She came from an English-speaking family but attended a French-speaking school from the age of 4. Lea was fully included in a general education classroom, where she was supported by a classroom assistant throughout the week and by a special education teacher for 8 h a week. At the beginning of the study, Lea could recognize 11 uppercase and nine lowercase letters and was able to read only one syllable of the non-verbal nonword and word reading subtest (< 10% success; Meuli et al., 2023).

Fadia was an 8-year-old girl with autism spectrum disorder and ID (nonverbal IQ = 62, measured with the Leiter R; Roid and Miller, 1997). She had a global adaptive behavior score of 73 on the ABAS-II. She communicated through natural gestures, the use of pictograms or images, vocalizations, and unintelligible utterances. She was able to use verbal speech to provide yes/no responses. She also used an AAC device, the Proloquo2Go application delivered via iPad® (Assistive Ware, 2019), to communicate. Fadia's family members had little to no knowledge of French and communicated at home in English and Urdu (the official language in Pakistan). She had been taught French at school since the age of 4. Fadia received instruction in a self-contained classroom of seven students with ID. At the beginning of the study, Fadia could recognize 11 uppercase and 12 lowercase letters and was able to read one word of the non-verbal nonword and word reading subtest (< 10% success; Meuli et al., 2023).

Tim was a 12-year-old boy with cerebral palsy and ID (nonverbal IQ = 36, measured with the Leiter-R; Roid and Miller, 1997). He had a global adaptive behavior score of 41 on the ABAS-II. His means of communication included vocalizations, unintelligible utterances, learned gestures, and pictograms of objects or actions that were attached to his wheelchair. He also used his iPad® equipped with an AAC device, Snap™ Core First (Dynavox, 2021), to communicate some messages. Tim had a French-speaking family. He received instruction in a self-contained classroom of five students with ID. During instruction, Tim was regularly off task and exhibited challenging behaviors, such as yelling, refusing to collaborate, and pushing material off the table. At the beginning of the study, Tim could recognize eight uppercase and four lowercase letters and was able to read two words of the non-verbal nonword and word reading subtest (< 10% success; Meuli et al., 2023).

2.1.2. Teachers

Lea's teacher had a master's degree in special education and 8 years of teaching experience with students with ID. Fadia's teacher was a social educator (i.e., professional who provides support and guidance to individuals, helping them enhance their social skills and develop their daily autonomy) and had 7 years of teaching experience with students with ID. One of the two teachers who worked with Tim had training as a nurse and the other as a social educator. They had five and 2 years of teaching experience, respectively, with students with ID.

2.2. Setting

The study was conducted between November 2021 and May 2022. The four teachers who participated in the study were the main interventionists. They delivered reading instruction at least twice a week, with each lesson lasting approximately 20 min. Because Fadia's teacher was absent a few times, a doctoral student, a member of the research team, conducted some reading lessons with this student. All three students also practiced reading with the iPad® app at least once a week for about 15 min. The instruction was conducted in a one-on-one format in a quiet room at each participant's school. Once a week, probes were carried out by a member of the research team (one probe every two to three reading or spelling lessons).

3. Materials

3.1. Literacy program

Reading and spelling lessons from an instructional reading program (De Chambrier et al., 2021) that were adapted to the needs of students who are AAC users were used in this study. The instructional reading program has been developed for French-speaking students with ID. It consists of five levels constructed around the learning of letter-sound correspondences: a, r, u, i (level one); l, o, f (level two); é, j, v (level three); b, ou, t (level four); and ch, m, p (level five). Each time a letter-sound correspondence is learned, a reading and a spelling lesson of syllables and words (consisting of known letter-sound correspondences) is proposed.

The students were also trained on phonemic awareness (e.g., phoneme identification during letter-sound correspondence learning, phoneme blending during reading lessons, and stretching sounds in words during spelling lessons). The complexity of reading and spelling tasks increases progressively from one level to another. In the first level, students learn to read and spell syllables and words with a consonant-vowel (CV) and vowel-consonant (VC) structure. In the following levels, syllables and words with a CVC, CVCV, CCV structure are added. This program adopts a systematic and explicit approach, using a systematic corrective procedure that integrates a constant time delay procedure and a system of least-to-most prompts (described below in the intervention phase).

3.1.1. Adaptations

The original instructional reading program required oral responses. To make the program accessible to students who cannot provide oral responses, members of the research team adapted it to allow for pointing responses and to emphasize the use of internal speech, i.e., verbalizing phonemes silently, especially during the decoding process (Linder et al., 2023).

3.1.2. iPad® application

Our research team developed the iPad® application to intensify instruction for students with ID because many teachers seem to find it difficult to provide their students frequent literacy lessons, especially in a one-to-one format (Sermier Dessemontet et al., 2021). Six activities per letter-sound correspondence are available on the iPad® application to practice memorizing letter-sound correspondences, first-phoneme identification, blending phonemes to form words, reading syllables, reading words, and spelling syllables. The iPad® activities are very similar in content to those proposed in the instructional reading program lessons, offering guided practice with corrective feedback using a constant time delay procedure provided by the application. No oral responses are required to interact with the iPad app.

The manual for the instructional reading program and all materials needed to conduct each lesson were provided to the teachers at the beginning of the study. Intervention materials included cards with pictures, letters, syllables or words, movable letters, a dart card, and Legos (see Tables 1, 2 e.g., of the intervention materials). Teachers were also provided a script describing how to use the adaptations along with the manual for the instructional reading program so they could implement them correctly during the intervention. The booklets with various response options the students could select by pointing were also provided to teachers.

3.2. Data collection procedures

3.2.1. Dependent variables

The two dependent variables in this study were (a) the number of words correctly read and (b) the number of words spelled phonetically correctly (i.e., representing each of the phonemes in the word in the correct order). During probes, the number of words that students were able to spell orthographically correctly (i.e., at this point of the instructional program, written with a silent letter at the end) was also assessed because many French words end in a silent letter.

Once a week, a researcher administered reading and spelling probes separately from lessons (1 or 2 days after each participant's last reading or spelling lesson) to assess the taught skills. No corrective feedback was given during probes, but the researcher could congratulate the students for their efforts. Probes assessed the reading and spelling of 14 words that were taught in the first three levels of the curriculum. Table 3 lists all the target words evaluated. The target words were presented sequentially in a booklet and always followed the same order. In each reading probe, the students were required to read the target word and point to the picture representing the correct word displayed among three distracters. If the word contained a silent letter at the end, it was written in grey. Before the students read each of the target words, the researcher pointed to and named each of the four pictures (the target word and the distracters). The three distracters were selected considering the target word's structure whenever possible (i.e., CV or CVC words). One of the distracters began and another ended with the same phoneme as the target word, and all four words belonged to various semantic fields. The pictures used for the reading probes were different to the ones used during the intervention. If the student made three consecutive errors, the reading probe was stopped and the spelling probes began. The spelling probes required the students to spell a word phonetically correctly (i.e., the correct graphemes in the correct order) using black movable letters that were placed randomly in front of them among two determined additional black movable letters that served as distracters. The researcher asked the student to spell the word using the movable letters while showing a picture of the target word, which was displayed in a booklet. Out of the 14 probed words, 11 ended with a silent letter. For these words, once the student spelled them phonetically correctly (i.e., without a silent letter at the end), the researcher placed three new and grey movable letters in front of the student and asked if they knew which one to add at the end of the word. The two distractors were chosen randomly among four letters likely to typically appear at the end of a French word (e, s, t, z). After three consecutive errors in phonetic spelling, the evaluation was stopped. If the student read or spelled a word correctly in three consecutive probe sessions, it was considered learned and was not assessed in the following probe sessions. To be scored as correct, the response had to occur within 4 s of the researcher's prompt. During the probes, an "I do not know" pictogram placed next to the response options was made available to the student to indicate to the interventionist that they did not know the answer. If the student used it, the answer was recorded as incorrect and the student was presented with the next item. The criterion for mastery was 85% of correct responses on the reading and spelling probe trials during two consecutive probe sessions. Students entered the maintenance phase once they met this criterion. The number of correct responses was recorded, collected, and plotted on graphs during the baseline, treatment, and maintenance phases.

3.2.2. Interobserver agreement

Another member of the research team observed approximately one-third of the probe sessions in the baseline and intervention phases for each student. Using the video recordings of the probes sessions, the second scored each student response using the same data collection instrument as the interventionist. Interobserver agreement was calculated by dividing the total number of agreements by the total number of observed responses and multiplying the answer by 100 (Kazdin, 2011) and was collected during 33% of sessions for Lea, 31% of

TABLE 1 Adaptations of reading lessons.

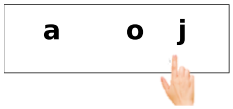
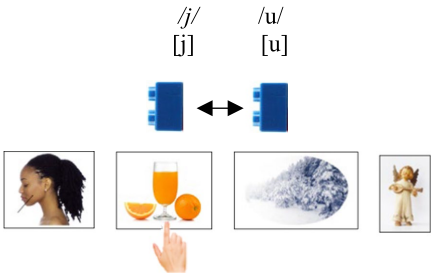
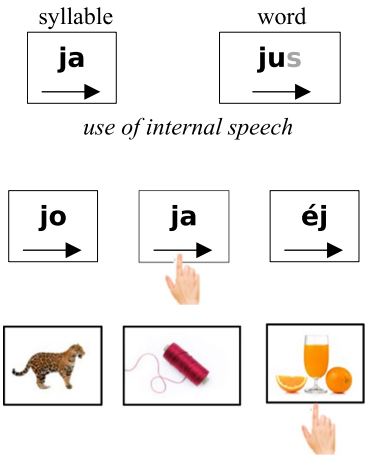
Skills	Description	Material and student's response mode
Letter-sound correspondences review	**Select the letter to match a phoneme orally given.** The teacher places three to four letters in front of the student and asks, *"Show me the letter that makes the sound /j/* [j]*?"*	
Phoneme blending to identify words	**Select a picture to match the blending of (stretching) sounds given one by one orally.** The teacher presents the four pictures of words by pointing at them: *"joue"* [jU] *(cheek), "jus"* [ju] *(juice), "neige"* [nèj] *(snow), "ange"* [Bj] *(angel).* The teacher gives the sounds of a word by stretching them: *"/jjj/* [j] – */uu/* [u]." *What word is?"* To support this activity, the teacher points to a Lego® piece each time a sound is given and assemble the Lego® pieces to represent the blending of the sounds.	
Reading syllables and words	**Read syllables or words with the tree-step decoding strategy.** The teacher places a syllable or a word card in front of the student and asks, 1. *"Say the sound of each letter in your head. What sound? What sound?"* 2. *"Read slowly in your head stretching sounds and blending them together."* 3. *"Read quickly in your head."* After reading, • If a syllable or a non-picturable word is read, the teacher places the syllable/word read among two others (distractors) in front of the student and asks the student to point to the syllable/word: *"Show me "ja""* [ja]. • If a picturable word was read, the teacher places three pictures in front of the student and asks: "Which picture is it?"	

Photo credit: hand: alexkon123 ©123rf.com, Lego® piece: nenovbrothers ©123rf.com, cheek: Mark Adam ©123rf.com, juice: Sommai Larkji ©123rf.com, snow: rtsubi ©123rf.com, angel: Anirut Rassameesritrakoo ©123rf.com, jaguar: Anan Kaewkhammu ©123rf.com, thread: miltoni ©123rf.com.

sessions for Fadia, and 42% of sessions for Tim. The average percentage of agreement between observers in the baseline and intervention probe sessions was 100% across sessions for all participants.

3.2.3. Social validity

After the intervention, the teachers completed a social validity questionnaire to elicit their opinions on the adaptations and on their student outcomes. Teachers were asked to rate six statements on a five-point Likert scale ranging from "*strongly agree*" to "*strongly disagree*" (e.g., "I recommend the use of the instructional reading program and its adaptations to other teachers working with students with ID and who are AAC users," and, "My student has made significant progress with the instructional reading program and its adaptations.").

3.3. Research design

A multiple-probe-across-participants design (Kratochwill et al., 2013; Ledford and Gast, 2014) was used to examine the effects of an intervention combining adaptations of the instructional reading lessons and iPad® training on the reading and spelling skills of students with ID who are AAC users. This design has the advantage of involving few participants and is well known for evaluating reading interventions' effectiveness (Barger-Anderson et al., 2004). All participants entered the baseline simultaneously. Once baseline data for a student was fairly stable, they entered the intervention phase. The order in which participants entered the intervention phase was randomly selected. Therefore, when Lea, the first participant, began the intervention, the remaining participants continued to receive intermittent baseline probes until they entered the intervention phase. When Lea demonstrated progress in reading or spelling, Fadia entered the intervention phase. Our progress criterion was the ability to read or spell two new words on two consecutive repeated measures. When Fadia met the progress criterion, Tim entered the intervention phase.

3.4. Procedures

3.4.1. Baseline phase

During the baseline phase, students received reading instruction as usual. Information on the reading instruction the teachers provided

TABLE 2 Adaptations of spelling lessons.

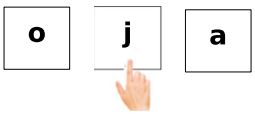
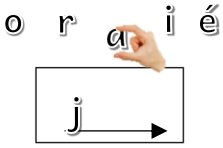
Skills	Description	Material and student's response mode
Letter-sound correspondences review	**Select the letter to match a phoneme orally given**. The teacher places three to four letters in front of the student and asks: *"Show me the letter that makes the sound /j/* [j]*?"*	
Stretching sounds in words	**Say the word while stretching sounds**. The teacher presents a picture of a word and asks: *"Say the word "neige"* [nèj] *(snow) with me in your head by stretching sounds." /nnnnèèèèjjjjjj/.*	 *use of internal speech*
Spelling syllables and words	**Spell the syllable or word given orally**. The teacher places a dart card and movable letters in front of the student and asks: *"Spell "ja"* [ja]*."*	 The student spells the answer using movable letters and places them on the dart card.

Photo credit: hand: alexkon123 ©123rf.com, snow: rtsubi ©123rf.com.

during the baseline was collected through observations of two lessons per student, an interview with the teacher following the observations, and completion of a teacher log. During the baseline, Lea, Tim, and Fadia were taught new letter-sound correspondences or reviewed correspondences that were taught previously. They were also trained on phonemic awareness with a task that involved sorting words according to their first phoneme and participated in read-aloud activities (teacher reading a children's book to the students). Lea and Fadia also received sight-word instruction (assembling identical words and/or assembling words with pictures). During the baseline, Lea and Fadia received two to three lessons per week (respectively, $M = 2.3$ and $M = 3.0$), whereas Tim received one to two lessons per week ($M = 1.6$ lessons per week). At least three baseline probes were conducted with each participant until a stable baseline was observed in reading and spelling words.

3.4.2. Training teachers

Prior to the start of the intervention phase, the four teachers received 3 h of training in which they learned to use the intervention materials with the adaptations and to apply the instructional strategies used in explicit and systematic instruction. Throughout the intervention phase, members of the research team also provided the teachers coaching (two visits per month and exchanges on site or by phone or email).

3.4.3. Intervention phase

The intervention sessions consisted of the reading and spelling lessons in the instructional reading program's first three levels. Tables 1, 2 present the content of these adapted lessons. They both started with a quick review of the known letter-sound correspondences. In this activity, three to four letters were placed in front of the student, who had to show the one corresponding to the sound given orally by the teacher. The teacher provided the student feedback for each question. If the student answered correctly, the teacher praised the student and validated the answer. If the student answered incorrectly or did not answer within the 4-s response time (constant time delay), the teacher showed the correct answer and asked the student again after shuffling the response options. If the student still could not give the correct answer, the teacher physically prompted the student to show the correct response (i.e., took the student's hand and touched the correct letter) and then asked about a new letter-sound correspondence. In reading lessons, a phonemic awareness activity was then proposed to the student. The student was told to blend the stretched sounds given orally by the teacher to form a word and point to its picture. Once the teacher had modeled the task, the student performed the activity in a guided-practice phase, and the same feedback procedure as for the review of known letter-sound correspondences was used. The student was then taught to read syllables and words with the three-step decoding strategy consisting of (a) giving the sound of each letter-sound correspondence, (b) reading the syllable or the word slowly while stretching continuous sounds and blending them together, and (c) reading the syllable or word quickly (Engelmann et al., 1999). The student was asked to complete all three steps using internal speech. During the level one decoding activity, the teacher modeled the three-step decoding of all the syllables and words included in the lesson. Then, during the guided-practice phase, the teacher would ask the student to perform each step of the decoding strategy using internal speech, wait 5 s, and then model the step out loud once again for the student. Modeling was progressively faded once the student progressed through levels two and three of the program. Therefore, the teacher modeled the three-step decoding for only one syllable and then asked the student to read new syllables and words independently using internal speech during the guided practice. To check the reading of a picturable word, the teacher asked the student to point to the picture representing the word among two distracters. For syllables and non-picturable words, the teacher asked the student to point to the correct printed syllable/word among two distracters in response to the teacher's oral presentation. When the student correctly identified a picture or a printed single syllable/word, the teacher praised the student and validated the answer. Moreover, to give the reading meaning, the teacher gave a word beginning with the syllable that was read (i.e., "Well done,

TABLE 3 Target words for the reading and spelling probes.

Probes	Words to read and spell during probes	Pictures used as distracters for the reading probes	Movable letters available for the spelling probe (phonetically spelled)
1	**rat** [Ra] (rat)	**roue** [RU] (wheel),**tas** [ta] (pile),**nez** [né] (nose)	**r a f i**
2	**rue** [Ru] (street)	**rond** [RI] (circle),**jus** [ju] (juice),**bain** [bC] (bath)	**r u l a**
3	**riz** [Ri] (rice)	**roi** [Rw] (king),**scie** [si] (saw),**chat** [Ha] (cat)	**r i j é**
4	**ile** [il] (island)	**hibou** [ibU] (owl),**cil** [sil] (lash),**oeuf** [Ff] (egg)	**i l b a**
5	**lit** [li] (bed)	**loup** [lU] (wolf),**nid** [ni] (nest),**main** [mC] (hand)	**l i f u**
6	**lire** [liR] (read)	**lune** [lun] (moon),**rire** [RiR] (laugh),**bus** [bus] (bus)	**l i r t o**
7	**or** [OR] (gold)	**os** [Os] (bone),**poire** [pwR] (pear),**aile** [èl] (wing)	**o r f é**
8	**rot** [RO] (burp)	**roi** [Rw] (king),**pot** [pO] (pot),**thé** [té] (tea)	**r o s i**
9	**fil** [fil] (thread)	**four** [fUR] (oven),**pile** [pil] (battery),**verre** [vèR] (glass)	**f i l v é**
10	**fort** [fOR] (strong)	**foot** [fUt] (soccer),**port** [pOR] (port),**sac** [sak] (bag)	**f o r l a**
11	**fée** [fé] (fairy)	**feu** [fE] (fire),**dé** [dé] (dice),**veau** [vo] (veal)	**f é r o**
12	**jus** [ju] (juice)	**jeu** [jE] (game),**rue** [Ru] (street),**nain** [nC] (dwarf)	**j u l v**
13	**lave** [lav] (lava)	**lard** [laR] (bacon),**pive** [piv] (pine cone),**jambe** [jBb] (leg)	**l a v r u**
14	**vélo** [vélO] (bike)	**volant** [vOlB] (wheel),**rouleau** [RUlo] (rolling pin),**sapin** [sapC] (fir)	**v é l o i f**

you read 'vo' [vO]. It's the beginning of the word 'volcan' [vOlkB] (volcano)".) or a sentence containing a non-picturable word that was read (i.e., "Well done, you read the word 'vole' [vOl] (fly) as in the sentence 'L'oiseau vole' [l wazo vOl] (the bird flies)".) If the student identified an incorrect answer or did not answer within the 4-s constant time delay, the teacher showed the correct answer.

In spelling lessons, after a quick review of known letter-sound correspondences, the student was encouraged to stretch sounds in a word by using internal speech while the teacher performed the task aloud. Then, the teacher taught the student to spell syllables (level one) and words (levels two and three) using movable letters to place on a dart card. This activity does not require any adaptation because students give their responses by placing the movable letters on a dart chart to form syllables or words. However, due to Tim's motor difficulties in grasping the fine movable letters, they were replaced with easier-to-grasp material consisting of small and thick cardboard cards on which each letter was printed. For level one spelling lessons, teachers modeled the spelling of all syllables, and the student was then trained on spelling them in a guided-practice phase. In levels 2 and 3, the teacher only modeled the spelling of one syllable and then asked the student to spell the other syllables and words independently in the guided-practice phase. To support the student's spelling activity, a graduated system of least to most prompts was used. If the student was mistaken or did not provide an answer, the prompting included first a verbal cue that consisted of the teacher repeating the syllable or word to be written and lengthening the target phoneme that the students had to encode (e.g., "What do you hear first in '/aaav/ [av]'?"). If the student selected the correct letter, the teacher could, if necessary, verbally indicate where to place the letter on the dart card (e.g., "Put the letter at the beginning of the dart"). If the student failed or did not respond within 4 s constant time delay, the teacher modeled the expected response and asked the student to complete the task. Finally, if the student still could not complete the task, the teacher used physical guidance to select the target letters and place them in the right order on the dart card. To give the syllable-spelling activity meaning, the teacher would refer to a word that starts with the syllable the student correctly spelled (i.e., "Well done, you spelled 'av' [av]. It's the beginning of the word 'avion' [aviI] (plane)".)

During the intervention phase and at least once a week, the student practiced activities on the iPad® application. Four activities were offered: (1) a phoneme-blending activity in which the student must blend the sounds of a word that are given orally and touch the picture of the word among two distracters, (2) a syllable-reading activity in which a syllable is given orally and the student must touch the corresponding written syllable among two distracters, (3) a word-reading activity in which the student must read a word and select the corresponding picture among two distracters, and (4) a syllable-spelling activity in which a syllable is given orally and the student must select each of the letters needed from several to spell the syllable. The students first used the application under teacher supervision for 2–3 sessions until they knew how to use the program and then used it independently.

3.4.4. Fidelity of implementation

The reading lessons' implementation fidelity was assessed using a checklist that listed each lesson's components and the actions required of the teacher. A member of the research team recorded procedural fidelity data for 40% of all intervention sessions for all three students during the intervention phase. Fidelity was calculated by dividing the number of steps the teacher performed correctly by the total number of steps required in the lessons and then converting the result to a percentage by multiplying it by 100. During the intervention, the teachers conducted an average of 2.3 lessons per week with their students (SD = 0.18). Percentages of procedural fidelity were 95% for Lea, 96% for Fadia, and 90% for Tim. The students also completed an average of 3.5 activities per week (SD = 2.55) using the iPad® application, which corresponded to around 20 min of independent activity per week ($M = 22.7$; SD = 14.01).

3.4.5. Maintenance phase

After participants had completed all the lessons scheduled in the intervention phase, intermittent probes were conducted 2 weeks after

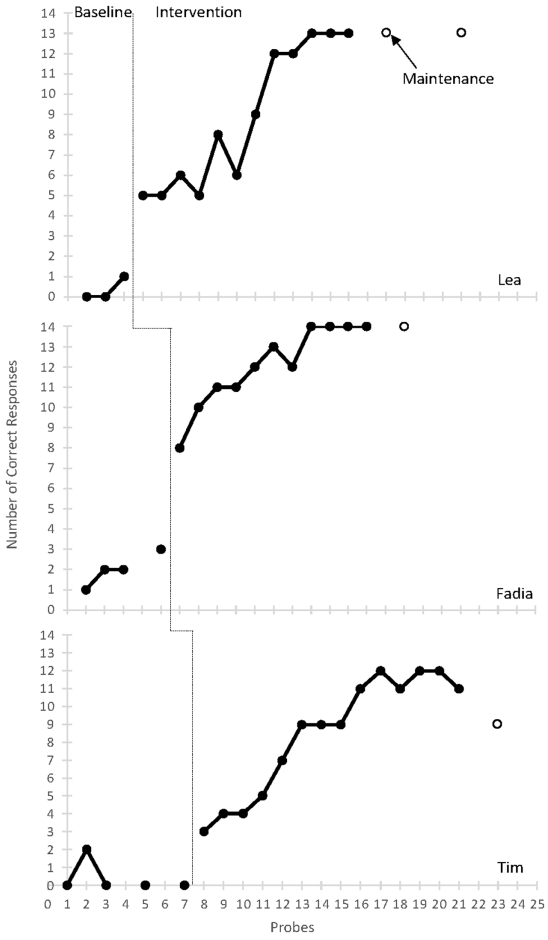


FIGURE 1
Number of correct responses on reading probes.

the end of the intervention to ensure that students had maintained their reading and spelling skills. Lea underwent an additional maintenance probe 6 weeks after the end of the intervention. Fadia and Tim only underwent one maintenance probe because Fadia was absent at the end of the school year and Tim finished the intervention phase shortly before summer vacation. During the maintenance phase, Lea and Fadia's teachers taught them new letter-sound correspondences. The two students learnt to decode and spell words with these new letter-sounds correspondences. The targeted syllables and words of the intervention were not reviewed. Tim received no literacy instruction during the maintenance phase since it was the last 2 weeks of the school year, a period in which teachers do extra-curricular activities with their students.

3.5. Data analysis

Visual analysis was used to determine whether a functional relationship existed between the intervention and the dependent variables and to characterize the magnitude of these relations (Ledford and Gast, 2014). To supplement visual analysis of the intervention, statistical analysis of effect size was conducted. The Tau index (Parker et al., 2011), a non-overlapping measure defined in terms of comparisons between pairs of data points (one data point from the baseline phase and one data point from the intervention phase), was calculated. The Tau values that show the required improvement in the intervention phase compared to the baseline phase can be interpreted as follows: values of less than 0.30 might be characterized as "weak," values between 0.30 and 0.84 as "medium," and values larger than 0.84 as "large" (Brossart et al., 2018). The LRR-increasing form of the log response ration (Pustejovsky, 2018) was also calculated. This index allows for quantification of functional relationships in terms of proportionate change. Tau and LRRi values were computed online using the calculator (Pustejovsky et al., 2022).[1]

4. Results

Figure 1 shows the students' results on the reading probes, and Figure 2 presents their results on the spelling probes. The x-axis represents the number of probe sessions, and the y-axis represents the number of correct responses on the reading and spelling tasks. All three participants demonstrated a low and/or stable trend on their baseline scores in word reading. Lea, Fadia, and Tim demonstrated an increase in reading level after receiving instruction with the adapted reading lessons of the instructional reading program. All the students met the criterion of a score of 85% (12 words correctly read) for two consecutive probe sessions, requiring a mean of 9.3 sessions (range = 6–13 sessions). Students' performance on the spelling task showed mixed results. All participants presented a low and/or stable baseline trend in their baseline scores in word spelling, but only Lea and Fadia demonstrated an increase in level and trend after receiving instruction with the adapted spelling lessons of the instructional reading program. They both met the criterion of a score of 85% (12 words phonetically correct spelled) for two consecutive probe sessions.

4.1. Student performance in reading words

4.1.1. Lea

Lea correctly read between 0 and 1 word ($M = 0.3$) during baseline sessions. During the intervention, Lea achieved an immediate change in level and an overall change in trend, with scores ranging from 5 to 13 ($M = 8.9$). In the 9th session, she met the criterion of 85% correct responses for two consecutive probe sessions. The Tau score indicates a strong effect size from baseline to intervention ($\tau = 1.0$), and the LRRi estimate was 2.79 (95% CI [0.82, 4.77]), which indicates a very significant improvement from baseline (1,533% change). At the end of the intervention, Lea was able to read 13 of the 14 words assessed and maintained her level 2 and 6 weeks after the intervention.

4.1.2. Fadia

Fadia's baseline scores ranged from 1 to 3 words ($M = 2$). With the introduction of the intervention, her level increased rapidly, and a steep accelerating trend was observed, with scores ranging from 8 to 14 ($M = 12.1$). Fadia met the criterion of 85% correct responses in the

1 https://jepusto.shinyapps.io/SCD-effect-sizes/

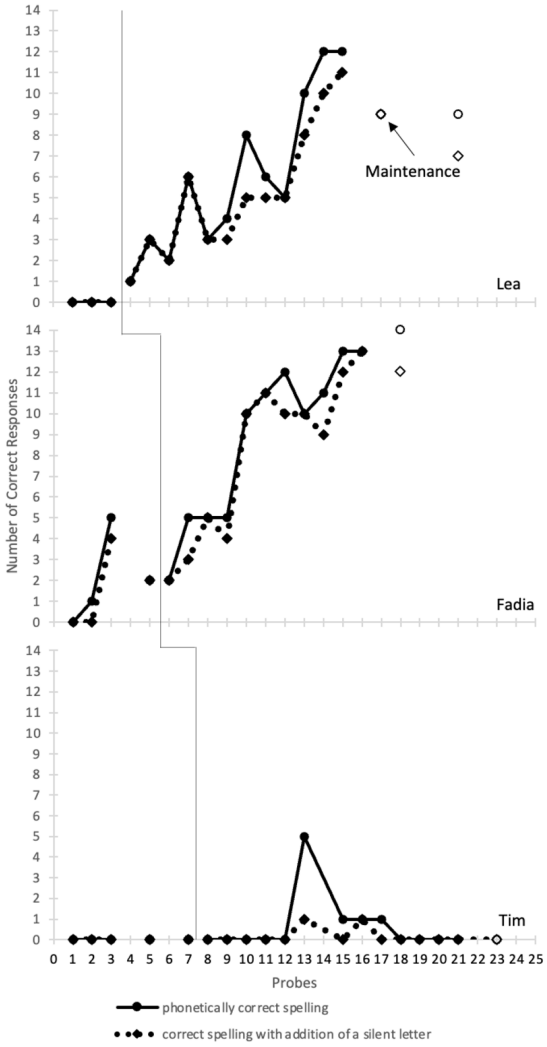


FIGURE 2
Number of correct responses on spelling probes.

6th probe session. The Tau score indicates a strong effect size from baseline to intervention (τ = 1.0), and the LRRi estimate was 1.78 (95% CI [1.37, 2.19]), which indicates a significant improvement from baseline (493% change). During the last four sessions of the intervention, Fadia was able to read all the words and maintained this score 2 weeks after the intervention.

4.1.3. Tim

During baseline sessions, Tim read between 0 and 2 words (M = 0.4). When the intervention was introduced, Tim's scores immediately change in level and trend. The data showed a gradual accelerating trend, with his scores ranging from 3 to 12 (M = 8.5). At the end of the intervention, Tim was able to read 12 of the 14 words and met the criterion of 85% correct responses in the 13th probe session. The Tau score indicates a strong effect size from baseline to intervention (τ = 1.0), and the LRRi estimate was 2.56 (95% CI [0.59, 4.53]), which indicates a very significant improvement from baseline (1,196% change). Two weeks after the end of the intervention, Tim was able to read 9 words correctly, indicating that he had partially maintained his reading skills.

4.2. Student performance in spelling words

4.2.1. Phonetically correct spelling

4.2.1.1. Lea

During baseline probe sessions, Lea failed to spell any words phonetically correctly. During the intervention phase, she showed an increase in the number of words correctly spelled, with scores ranging between 1 and 12 (M = 6). Visual analysis of the graph revealed a positive trend with gradual acceleration. At the end of the intervention, Lea was able to spell 12 of the 14 words phonetically correctly, and she met the criterion of 85% correct responses in the 12th and final probe session. The Tau score indicates a strong effect size from baseline to intervention (τ = 1.0), and the LRRi estimate was 3.38 (95% CI [2.02, 4.73]), which indicates a very significant improvement from baseline (2830%). Lea partially maintained her spelling skills, correctly spelling nine words 2 and 6 weeks after the end of the intervention.

4.2.1.2. Fadia

The intervention's effect was not immediate in Fadia's performance because her scores overlapped with her baseline scores during the first four intervention sessions. However, visual analysis of the graphed data indicates that she quickly demonstrated an increase in level and an upward trend after these first four sessions. Indeed, Fadia's scores improved, her scores ranging from 0 to 5 (M = 2) in the baseline probe sessions to ranging from 2 to 13 (M = 8.8) in the intervention probe sessions. In the 11th and final probe session, she met the criterion of 85% correct responses. At the end of the intervention, Fadia was able to encode 13 of the 14 words phonetically correctly. The Tau score indicates a strong effect size from baseline to intervention (τ = 0.86), and the LRRi estimate was 1.35 (95% CI [0.26, 2.44]), which indicates a significant improvement from baseline (284%). Two weeks after the intervention, Fadia further improved her skills by spelling all 14 words phonetically correctly.

4.2.1.3. Tim

Visual analysis of the graphed data suggests that the intervention did not affect Tim's spelling skills despite the adaptation made to the material used to assess word spelling to facilitate manipulation. The Tau score was 0.31, and the LRRi estimate was 1.93 (95% CI [0.48, 3.39]).

4.2.2. Correct spelling with addition of a silent letter

4.2.2.1. Lea

Despite slightly lower scores, an upward trend similar to that of the spelling of phonetically correct words can be observed for the spelling of words with a last silent letter. At the end of the intervention, Lea was able to spell 11 words correctly by placing the correct silent letter at the end of the word. The Tau score indicates a strong effect size from baseline to intervention (τ = 1), and the LRRi estimate was 3.22 (95% CI [1.88, 4.58]), which indicates a very significant improvement from baseline (2421%). She partially maintained her spelling skills 2 and 6 weeks after the end of the intervention, spelling nine and seven words correctly, respectively.

4.2.2.2. Fadia

Fadia made similar progress in spelling words with a last silent letter compared to her spelling of phonetically correct words. At the end of the intervention, she was able to spell 13 words correctly by placing the correct silent letter at the end of the word. The Tau score indicates a strong effect size from baseline to intervention ($\tau = 0.86$), and the LRRi estimate was 1.49 (95% CI [0.21, 2.77]), which indicates a significant improvement from baseline (345%). She maintained her spelling skills 2 weeks after the intervention, spelling 12 words correctly.

4.2.2.3. Tim

Given the results of his spelling of phonetically correct words, no interpretation could be made of Tim's spelling of words with a last silent letter. The Tau score was 0.15, and the LRRi estimate was 0.58 (95% CI [−0.96, 2.12]).

4.3. Social validity

All four teachers completed the social validity questionnaire and gave their opinion on the instructional reading program and the adaptations for students who are AAC users. Three teachers agreed that it would be easy for other teachers to conduct adapted instructional reading lessons if the adaptations were freely downloadable online. One teacher neither agreed nor disagreed with this point, noting that ongoing training would help them use the lessons properly. All four teachers indicated that they would recommend the adapted instructional reading program to other teachers. They similarly agreed that they would continue to use the adapted instruction reading program with their student who participated in the study and with students with similar profiles. Regarding their opinion on the impact of the adapted instructional reading lessons on their student, all the teachers agreed that the skills targeted in the instructional reading lessons were important skills to work on with their students. All of them also agreed that the adapted instructional reading lessons were beneficial for the student and that their student made significant progress thanks to the adapted instructional reading lessons.

5. Discussion

The purpose of this study was to determine whether adaptations of a systematic and explicit instructional reading program for students with ID, enhanced with practicing skills on the iPad® application, were effective for teaching reading and spelling skills to students with ID who are AAC users. As the visual and statistical analysis of effect size showed, the improvement in word reading was very clear for Lea and Fadia since the beginning of the intervention. Maintenance data showed that these two participants were also able to maintain a high performance level after the intervention. Tim's reading skills also improved as soon as he started the intervention phase, but his scores increased more gradually. Tim maintained his reading skills relatively well after the intervention. These results indicate that the reading intervention was successful in teaching the three students to read the targeted words. In this study, in addition to the use of direct reading instruction (Yorke et al., 2021), adaptations of the reading lessons were made to support students in reading by encouraging them to use internal speech and to allow them to demonstrate competence by using a pointing response modality. Similar to Coleman-Martin et al. (2005), the current study extended research on the use of internal speech (i.e., soliciting students to perform a task in their head), specifically to perform the three steps of the decoding process. It seems important to encourage students regularly to use internal speech to complete this process. If students do not have the opportunity to be active during training, their reading progress is likely to remain small (Truxler and O'Keefe, 2007; Ahlgrim-Delzell et al., 2016). Furthermore, to teach reading skills to students with ID who are AAC users, it is essential to consider their communication needs. In the present study, allowing participants to demonstrate their skills using a pointing response modality is another adaptation that was indispensable. When the students read picturable words, the pointing response modality consisted of showing the image corresponding to the word read. For non-picturable words and syllables, the pointing response modality consisted of showing the target printed syllable/word among an array of two distractors. As research has shown, the opportunity for students who are AAC users to respond by pointing is an effective way to test their reading skills (Browder et al., 2012; Ahlgrim-Delzell et al., 2014, 2016). Promising results in reading support the idea that students with ID who are AAC users can develop reading skills with a phonics-based reading intervention program using strategies that allow them to participate in activities and show their skills (Browder et al., 2009).

During the intervention, two participants (Lea and Fadia) seemed to improve their pronunciation skills. They started using the oral modality even if they were instructed to use internal speech. They progressively managed to utter the sounds of the letters during the first step of the decoding process in an intelligible manner. They also attempted to read some words orally during the other two steps of the decoding process. Most of their responses were not entirely intelligible, but some of them became progressively intelligible. Our findings are consistent with the results of Erickson and Geist (2016) study which show that having some oral language skills is related to better reading and spelling skills among students who are AAC users.

The present study provides an interesting insight into the effects of phonics-based reading instruction on the spelling skills of students with ID who are AAC users. Though the results for spelling were not as clear as they were for reading, visual and statistical analyses of effect size showed that the intervention allowed Lea and Fadia to develop skills in this area. The joint work on reading and spelling throughout the intervention may have allowed these two skills to reinforce each other (Ehri, 2000). However, the intervention did not allow Tim to improve his spelling skills. Several hypotheses can be made to explain Tim's lack of progress in spelling. First, unlike the other two participants, Tim was the only one unable to produce phonemes orally. It is possible that this lack of oral language had an impact on his spelling skills, in line with the findings of Erickson and Geist (2016). Second, Tim is the student with the most severe cognitive limitations (nonverbal IQ = 34). He may not have been able to mobilize the cognitive resources necessary to perform the spelling task because it is more demanding that the reading task, especially in terms of working memory (Gabrieli et al., 1994; Fleischman and Gabrieli, 1998; Gabrieli et al., 1999). Indeed, spelling a word requires more complex cognitive processing. It requires the speller to keep the

word in the phonological loop of working memory, process the various sounds making up the word to isolate phonemes, identify the associated graphemes, and then produce the motor response necessary to encode the word (i.e., by writing or by selecting a movable letter and placing it on the paper). Third, Tim has cerebral palsy. His form of cerebral palsy rarely causes uncontrolled physical reflexes. Still, his motor difficulties may have further complicated the spelling task because his attention was also heavily engaged in performing the gestures necessary to pick up the movable letters and place them side by side to form a word. It is likely that this motor activity's high attentional demands impeded his spelling skills despite the easier-to-grasp material (cardboard cards on which each letter was printed) that was offered to him during the intervention. To overcome the motor difficulties associated with the use of movable letters, future studies could evaluate the use of other response modalities, such as pointing to letters or dragging them on a tablet, eye-gaze responses and eye-tracking technology, for students with ID who are AAC users and have motor difficulties. To facilitate the spelling task for students resisting the intervention like Tim, it would be interesting to determine whether the addition of a visual aid could be a useful support, such as using tokens to symbolize a word's phonemes and guiding the student in the spelling task by referring to them. Joseph (2002) showed that students with ID can improve their CVC-word spelling skills by using the word box method. This method consists of asking a student to spell a CVC word by putting a letter in each compartment of a rectangle-shaped box divided into three section. This could be an interesting way to support spelling skills.

6. Limitations

As in any study, limitations can be found in the present investigation. First, it would have been more methodologically solid if five data points had been collected during the baseline probes for all participants (Ledford and Gast, 2014). This was not the case for the first two participants, for whom only three and four data points were collected for ethical reasons. Indeed, this allowed us to avoid delaying the beginning of the intervention too long for the participants because probes were performed only once a week. We also wanted to avoid multiplying probes on skills that had not yet been taught to the students and that they tended to fail repetitively. Therefore, only the minimum required data points were collected for the first two participants. Second, use of technology for the spelling activity could have been an interesting approach. Indeed, the use of a keyboard may have been an easier way to work on spelling for the student who had motor difficulties and showed difficulties using the movable letters. This familiarization with technological tools would also have been an opportunity for participants to understand the usefulness of spelling to transmit a message and to imagine in the long term being able to enhance their communication possibilities. Third, the intervention was delivered individually to the three students. This one-on-one instruction is not representative of how instruction takes place in a classroom. Indeed, the organization and functioning of a classroom leaves little opportunity to offer one-on-one instruction, especially because it is important to provide frequent reading and spelling lessons for students to improve their skills. To allow for more efficient instructional situations, it would be interesting for future researchers to examine whether an intervention with larger groups of participants is possible and effective for all students to develop reading and spelling skills. It would also be interesting to examine whether the instructional reading program (De Chambrier et al., 2021) could be used jointly with students who can express themselves orally and students who are AAC users while adaptations of the program are incorporated only for the latter or as support for students with mild language disorders (e.g., difficulty to pronounce some sounds). Finally, it would have been interesting to carry out generalization probes with new, untaught words. This would have made it possible to assess whether participants were able to use the three-step decoding strategy and internal speech to read these novel words.

7. Conclusion

The present study contributes to the state of knowledge on reading instruction for students with ID who are AAC users. It demonstrates that with some adaptations, research-based reading instruction programs for students with ID can be used effectively with these students. Still, studies conducted with this group of students remain scarce. This group of students is characterized by high heterogeneity. More studies are clearly needed to identify strategies that enhance reading and spelling instruction for students with ID who are AAC users who have different competence profiles. Indeed, the present study was conducted with students who already knew many letter-sound correspondences and used pointing to symbols effectively to communicate in their everyday life. This is not the case for all students who are AAC users. Many are unable to respond by pointing as a result of complex physical and/or sensory impairment. Studies are also needed on teaching the foundations of reading to students with lower literacy and communication skills. Increasing the research knowledge on effective instructional strategies for students with ID who are AAC users and disseminating them to professionals working with them is urgent to address the extremely high level of illiteracy in this group. This is crucial because knowing how to read and spell could help expand their educational, cultural, social, and professional opportunities.

Data availability statement

The datasets presented in this study can be found online via the following link: https://doi.org/10.48573/ns3k-em13.

Ethics statement

Ethical approval was not required for the study involving human samples in accordance with the local legislation and institutional requirements because the Swiss Ethics Commission of State of Vaud considered this research to be pedagogical and therefore outside the scope of the Swiss Federal Act on Research Involving Human Beings. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RS, CM, and A-FC conceived the study and obtained the funding. All authors contributed to the refinement of the study design and the data collection methods. A-LL created the adaptations of the instructional program for AAC users with input from RS, NM, CM, and A-FC. A-LL and NM managed participant recruitment. A-LL organized the data collection, conducted the visual and statistical analyses, and wrote the first draft of the manuscript. A-LL, MG, and MA collected the data, assessed the implementation fidelity, and coached the teachers. All authors provided critical feedback and helped shape the final version of the manuscript. RS supervised the project. All authors contributed to the article and approved the submitted version.

Funding

The Swiss National Science Foundation research grant SNF no 100019_192562 provided funding for this study. Open access funding was provided by the University of Teacher Education of State of Vaud (Haute école pédagogique du canton de Vaud).

Acknowledgments

We are grateful to the participants and teachers who participated in this research project. We also thank the reviewers for their constructive feedback.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

Publisher's note

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