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A Systematic Quality Review of Technology-Aided Reading Interventions for Students With Autism Spectrum Disorder

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Abstract

Technology has been widely used to teach reading skills to students with autism spectrum disorder (ASD), but the quality of research backing up this practice has not yet been fully investigated. The purpose of this review was to examine the quality of research on technology-aided reading interventions for students with ASD and summarize study characteristics of research studies with meeting the What Works Clearinghouse (WWC) design standards. A total of 31 studies using group design ($n = 4$) or single-case design ($n = 27$) were systematically aggregated, and 16 studies (52%) met the WWC design standards. Study features related to participants, intervention, technology usage, and outcome variables were synthesized for these 16 studies. Results indicated that two types of technology (i.e., computer, iPad) were used to deliver reading instruction through software programs or support interventionist-directed reading instruction. Finally, implications for research and practice are discussed.

Keywords

autism, technology, reading, literature review, quality review

Although reading skills are fundamental to accessing written information and expanding one's knowledge (Spooner et al., 2014), students with autism spectrum disorder (ASD) often exhibit unique challenges in reading (Macdonald et al., 2021). According to the Simple View of Reading framework (Gough & Tunmer, 1986; Hoover & Gough, 1990), both decoding and oral language skills contribute to reading comprehension, and poor reading comprehension may result from weakness in either or both. Prior research has reported that impoverished decoding and oral language comprehension skills, as well as social functioning in ASD, may pose extra barriers to successful reading (Lindgren et al., 2009; McIntyre et al., 2017; Ricketts et al., 2013). Students with ASD may demonstrate an average range of decoding skills, but they often encounter difficulties using phonological-based strategies (i.e., sound–symbol/phoneme–grapheme relationships) to decode words (Frith & Snowling, 1983; Macdonald et al., 2021) and exhibit weaker reading comprehension skills as opposed to well-developed decoding skills (Nation et al., 2006). Overall reading comprehension may be impacted by additional challenges due to limited skills in integrating information, understanding anaphoric references, and self-monitoring their comprehension (O'Connor & Klein, 2004). In summary, reading comprehension is considered an area of greater difficulty in ASD than decoding (Ricketts et al., 2013), but it is worth noting that individuals with ASD exhibit various reading profiles, and other subgroups in ASD have challenges in decoding and oral language comprehension as well as reading comprehension.

To ameliorate these reading difficulties, interventions that build on the strengths and interests of students with ASD may be effective in promoting positive outcomes. Given that students with ASD have relative strengths in visual information processing (Ari-Even Roth et al., 2012; Knight et al., 2015) and often prefer content presented on electronic devices over other forms of presentations (Shane & Albert, 2008), incorporating technology may leverage this preference and capitalize on the learning characteristics

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of this group of students (Mayes & Calhoun, 2003). Potential benefits of using technology include increased autonomy, access to alternative modes of responding for students who have limited speaking and writing skills, and additional ways for teachers to work with a larger group of students (Knight et al., 2013).

Technology-aided interventions refer to interventions in which technology is the central feature of an intervention (Steinbrenner et al., 2020; Wong et al., 2014). Technology can be defined as any electronic items, computer or web-based software, applications, or virtual networks, and the evidence base of technology-aided interventions is more focused to the use of technology that are specifically designed or employed to support the learning of learners (Steinbrenner et al., 2020). Recently, Steinbrenner et al. (2020) conducted a comprehensive literature review to identify practices that demonstrate clear evidence of positive effects in individuals with ASD by extending existing literature (Odom et al., 2010; Wong et al., 2014). In this review, methodological acceptability of reviewed articles was evaluated using the protocol that drew from the quality indicators suggested by Gersten et al. (2005), Horner et al. (2005), and What Works Clearinghouse (WWC). Findings of this review suggested technology-aided interventions as an evidence-based practice (EBP) for teaching academic or preacademic skills to students with ASD across age groups.

A number of previous literature reviews were also conducted to examine the specific usage of technology to teach students with ASD. A form of technology-aided intervention that has been implemented to improve academic outcomes of students with ASD is computer-assisted instruction (CAI), which uses a computer as a central feature of an intervention that supports learning (Root et al., 2017). As CAI is designed for instructional purposes, CAI does not simply mean using technology to present materials on a computer screen. It is essential that effective instructional strategies (e.g., prompting, time delay, and reinforcement) are programmed in the CAI programs to improve learning outcomes of students (Hu et al., 2020). Pennington (2010) reviewed articles that applied CAI to teach academic skills to students with ASD. Findings of this review indicated that CAI was effective for teaching a limited set of academic skills, such as basic literacy skills (e.g., picture-word matching), but functional relations were found in a few single-case studies and there was a lack of experimental control. In 2017, Root et al. examined the research base of using CAI for teaching academic skills to students with ASD with more recent evidence. Results of this review indicated that CAI could be considered an EBP for teaching academic skills to students with ASD.

As technological advances led to the development of portable touch-screen devices, the efficacy of other forms of technology-aided interventions, such as iPad-assisted instruction (IAI), began to be investigated. IAI is defined as any instruction that uses an iPad as a primary mode of instructional delivery (El Zein et al., 2016). The difference between CAI and IAI is the type of technology (i.e., computer, iPad) that is mainly utilized for the intervention. Kagohara et al. (2013) conducted a systematic review of 15 studies that included iPads, iPods, and related devices in teaching programs for individuals with developmental disabilities. Although most of the reviewed articles reported positive outcomes, only one of the reviewed articles examined the effects on academic skills.

Knight et al. (2013) broadly examined the use of technology (e.g., computer and tablet) for students with ASD and indicated a low to moderate level of evidence for teaching academic skills to students with ASD. However, as previous reviews have mostly focused on CAI or investigated effects on teaching various academic skills not specific to reading, we have yet to be able to determine how technology has been used to teach reading skills to students with ASD. Given the unique needs of students with ASD in reading and their diverse learning characteristics, a more focused evaluation of the evidence base on the use of technology for teaching reading skills to students with ASD is warranted. It is also worth noting that only a few recent literature reviews (e.g., Knight et al., 2013; Root et al., 2017) examined the experimental rigor of the studies included for review. To increase the likelihood that educators adopt scientifically validated instructional methods, it would be critical to synthesize characteristics of technology-aided reading interventions with high-quality research evidence.

In an attempt to address gaps in the current literature, this study was conducted to determine the quality of the research on technology-aided reading interventions for students with ASD and summarize study characteristics. As a way to disseminate the evidence from research studies that are methodologically sound, the WWC developed a protocol to assess the methodological acceptability of group design and single-case design studies. In this review, technology-aided reading intervention studies were systematically aggregated and evaluated for quality based on the WWC design standards. In addition, descriptive information of high-quality research studies was synthesized to identify study characteristics related to participants, setting, interventionist, technology usage, intervention, and reading outcomes. Specifically, this review sought to answer the following questions:

Research Question 1: What is the quality of the evidence base for technology-aided reading interventions for students with ASD according to the WWC standards?

Research Question 2: What are the study characteristics of technology-aided reading interventions for students with ASD that met the WWC standards?

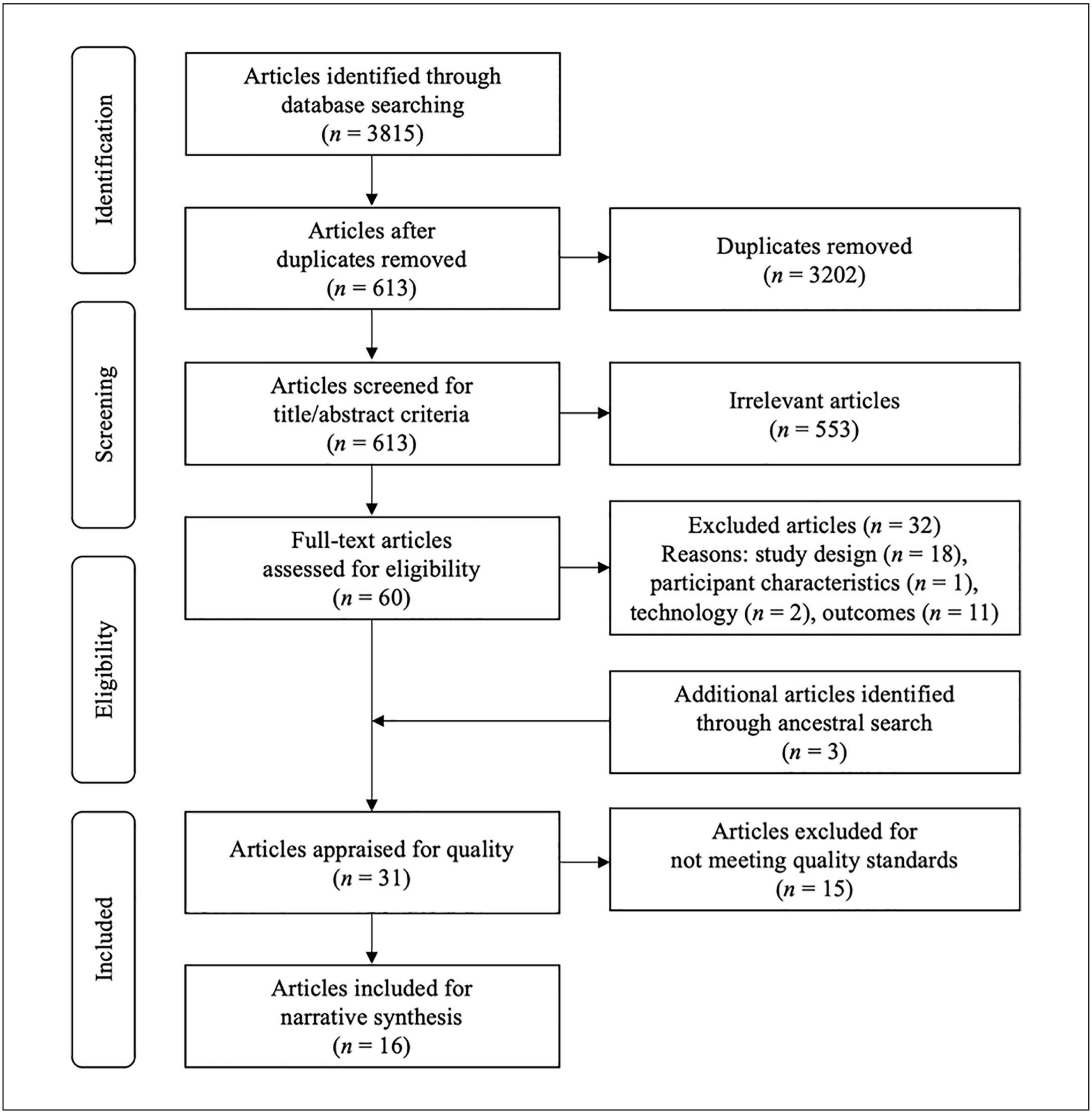

Figure 1. Article search and identification procedures.
Note. The figure was adopted from Moher et al. (2009).

Method

Article Search Procedures

To systematically retrieve literature on technology-aided reading interventions for students with ASD, the following procedures were used (see Figure 1).

Electronic database search. Four electronic databases (i.e., Academic Search Premier, Education Source, ERIC, and PsycINFO) were searched for relevant articles using the following Boolean phrase: "autis* AND (technolog* OR multimedia* OR computer* OR iPad* OR iPod* OR smart* OR tablet* OR AAC OR etext* OR ebook*) AND (reading* OR academic* OR literacy OR comprehension* OR vocab* OR word*)." The electronic search was limited to scholarly peer-reviewed journals, but no restriction was placed on publication date. This search was conducted in January 2019 and yielded 613 articles after duplicates were removed.

Title and abstract review. Titles and abstracts of 613 articles were reviewed to identify studies that (a) were published in English, (b) conducted single-case or group design experiments, (c) included an intervention targeting reading outcomes, and (d) included at least one participant with ASD. If the information was not displayed in the title and abstract, the article was kept for further review. Through this process, 60 potentially eligible articles were screened.

Full-text review. Each of the 60 studies identified in the title and abstract review was further evaluated to determine whether it met the inclusion criteria for this review. To be included for this review, articles had to meet all of the following criteria: (a) utilized experimental research design including a group design or single-case design as defined by WWC, (b) included at least one dependent variable related to reading (e.g., phonemic awareness, phonics, vocabulary, fluency, and comprehension), and (c) used technology (e.g., electronic device and software programs) as part of the independent variable (i.e., reading intervention). In this review, technology was defined as any electronic devices (e.g., computer, smart phone, iPad, iPod, tablet PC, and smart board) or software programs (e.g., GoTalk Now, Classroom Suite, and PowerPoint) including mobile applications and web-based software that were used to increase reading skills of students with ASD. Studies using high-tech alternative and augmentative communication (AAC) were excluded in this review if the AAC was used only to facilitate communication skills. However, if a study applied the AAC device for an instructional purpose, such as presenting sight words and producing sounds to improve sight word reading skills of participants with ASD, this study was included in this review. After reviewing full text, 28 articles were identified for inclusion in this review.

Additional reference search. We conducted an ancestral search of the references of 28 articles, yielding three additional studies. In addition, references in literature reviews on relevant topics were screened to identify potential articles (i.e., Kagohara et al., 2013; Knight et al., 2013; Odom et al., 2015; Pennington, 2010; Root et al., 2017), which did not yield additional studies.

Quality Review

A total of 31 articles were included for the quality review, and the identified group design and single-case studies were evaluated separately based on the *WWC Standards and Procedural Handbooks* Version 4.0 (WWC, 2017), which were the updated version at the time of review. A study may receive one of the three following ratings: (a) meets standards without reservations, (b) meets standards with reservations, or (c) does not meet standards.

Group design standards. Randomized controlled trials (RCTs), regression discontinuity designs (RDDs), and quasi-experimental designs (QEDs) with control groups were eligible to review as WWC recommended. However, no RDD studies were identified through the systematic article search procedures and appraised for quality in this review. WWC also developed separate design standards to review (a) group design studies that assigned individuals to a condition (e.g., assigned a student to the experimental/control group) and (b) studies that assigned clusters to a condition (e.g., assigned a whole classroom to the experimental/control group).

For group design studies with individual-level assignment, the WWC standards include three major domains for review: (a) study design, (b) sample attrition, and (c) baseline equivalence. Group design studies were divided into RCTs and QEDs contingent upon randomized control. Only RCTs with low attrition rates were eligible to meet the standards without reservations. High-attrition RCTs or QEDs were eligible to meet the standards if equivalence was established at baseline for the groups in the analytic sample.

For group design studies that used cluster-level assignment, the WWC standards included seven criteria. The WWC standards initially consider the rigorousness of evidence of an intervention's effects on individuals (i.e., Steps 1–4). If the effects on individuals were not credibly demonstrated, the evidence of the intervention's effects on clusters was reviewed (i.e., Steps 5–7). To meet WWC standards without reservations, the study should be an RCT. Cluster RCTs that have limited potential bias from changes in the composition of clusters and individuals within clusters after the random assignment were eligible to meet the standards without reservations. Cluster RCTs with a risk of bias from high cluster-level attrition, high individual-level attrition, or from unallowable joiners, and all cluster QEDs were rated as meeting the standards with reservations if the study satisfied a requirement for the baseline equivalence of the analytic sample.

Single-case design standards. This review included three major domains of standards for evaluating single-case research recommended by the WWC: (a) systematic manipulation of independent variable (IV), (b) interassessor agreement (IAA), and (c) attempts to demonstrate effects over time and number of data points per phase. Given that a high level of treatment fidelity increases the certainty that study outcomes are the effects of the intended intervention (Bellg et al., 2004), treatment fidelity was included as an additional domain of evaluation but not counted toward the final rating. Treatment fidelity was coded based on author report of (a) the correct operation of technology (e.g., the computer was set up properly), (b) the participant's or interventionist's adherence to protocol of technology use (e.g., the interventionist monitored the participant's engagement in the assigned technology), or (c) adherence to protocol of instructional delivery (e.g., the interventionist used prompting procedures to teach sight words). The single-case design standards used for this review are displayed in the appendix.

Narrative Synthesis

Each of the articles that were rated as methodologically sound was summarized for (a) study characteristics and (b) technology usage.

Study characteristics

Participants. The demographic information of participants was coded in the following four parts based on the description the article provided: (a) gender (i.e., male and female), (b) age (i.e., pre-K = 3–5 years, elementary school = 6–11 years, middle school = 12–15 years, high school = 16–19 years, adult = above 20 years), (c) diagnosis (i.e., ASD = participant with an ASD diagnosis, comorbid ID = participant had both ASD and ID diagnoses or reported IQ was less than 70, others: participant with disabilities other than ASD), and (d) language (i.e., verbal = participant had an ability to verbally communicate or read text aloud, AAC = participant who used any types of AAC [e.g., pictures, signs, iPad] as a primary mode of communication, and ELL = participant who used English as a second language or received educational services for ELLs in school). All participant variables were coded based on author report and coded as *NR* (i.e., not reported) if the information could not be inferred from participant description.

Setting. The intervention setting was coded based on the description the article provided (e.g., self-contained classroom, home, and university laboratory).

Design. The study design was recorded based on the author report (e.g., RCT, QED, reversal/withdrawal, alternating treatment, multiple-baseline, or multiple-probe design).

Intervention. All intervention components that were incorporated into technology-aided interventions were coded based on the author report. If a study compared the effects of two types of interventions (e.g., teacher-directed intervention vs. CAI), only the intervention that used technology (e.g., CAI) was coded for this variable.

Interventionist. The person who delivered the intervention to participants was coded as the interventionist (e.g., teacher and researcher). If a CAI/IAI program delivered reading instruction without any human-delivered instruction, a person delivered initial directions to start the CAI/IAI program or monitored the participants' performance was coded.

Types of text. Reading materials used for the study were coded based on the type of text (i.e., letter, word, sentence, narrative, and expository).

Outcome measures. The dependent variables were coded based on the operational definition (e.g., percentage of correct responses) provided by the author with measurements (e.g., comprehension quiz).

Effects. Intervention effect on each outcome variable was coded as *strong*, *moderate*, or *no effect*. For group design studies, the strength of evidence was coded based on the effect size that the authors provided (e.g., Cohen's *d*). For single-case studies, the strength of evidence was coded based on the functional relations between independent and dependent variables as suggested by the WWC. To provide *strong* evidence, the article had to demonstrate intervention effects 3 or more times with no instances of noneffect. If an article provided three demonstrations of effects but included one or more noneffects, this article was considered to have *moderate* evidence. If an article included less than three demonstrations of effects, this article was rated to have *no effect*. For alternating treatment design studies, each participant's data were rated separately using visual analysis, and a ratio across participants was derived for the final rating. For example, if an alternating treatment design study demonstrated strong effects for three participants and no effect for a fourth participant, this study was rated as moderate based on a 3:1 ratio.

Technology usage. Along with the basic characteristics of technology-aided reading interventions, the use of technology was further investigated. Technology usage was coded for each of the following variables: (a) type (i.e., hardware and software), (b) primary role, and (c) training. First, the use of technology was coded based on the types of hardware (e.g., computer and iPad) and software (e.g., PowerPoint and SMART notebook) that was installed and run on the hardware. Second, the primary role of technology was categorized into one of the two areas: (a) if technology delivered reading instruction without any other supports provided by an interventionist, the role of technology was coded as *delivering instruction*; and (b) if the use of technology was accompanied by a human implementer's instruction as a part of the intervention (e.g., presenting story-map template), the role of technology was considered as *supporting instruction*. Third, training for using technology was coded based on the author report as a way to determine whether the learning history related to the technology was controlled across participants within the reviewed articles. If all student participants were (a) trained to manipulate a specific technology device or software program used for the intervention or (b) screened to ensure that they had an ability to operate a specific technology device or a software program without additional training, this study was coded *Yes* for this variable. If only the interventionists (e.g., teacher and caregiver) were trained or the information could not be inferred from the study description, this study was coded as *NR* for this variable.

Interrater Agreement

Interrater agreement (IRA) data were obtained on all stages of review with one undergraduate student and two doctoral students in special education. The first author, who was certified by WWC and served as an external reviewer for Steinbrenner et al. (2020), was the primary coder, and all secondary coders were trained by the first author until they reached 90% or higher agreement on three consecutive articles. Following the training, each reviewer independently reviewed at least 25% of articles for each stage of review (i.e., 25% of articles for the title and abstract search, 100% of articles for the full-text review and ancestral search, 100% of articles evaluated for quality, and 100% of articles synthesized descriptively). The undergraduate student reviewed articles for the article search procedures (i.e., title and abstract review, full-text review, and ancestral search). Two doctoral students, who were also trained in using WWC design standards to evaluate articles and served as external reviewers for Steinbrenner et al. (2020), reviewed articles for quality evaluation and narrative synthesis in this review.

IRA was calculated using point-by-point agreement (Kazdin, 2011) for all coding variables and Cohen's Kappa (Cohen, 1960) for categorical variables. Kappa is generally considered a more conservative measure of reliability than a simple percentage of agreement as Kappa accounts for an agreement that might occur by chance (Sim & Wright, 2005). Popular benchmarks for substantial agreement are .60, and Kappa values above .80 are considered almost perfect agreement (Landis & Koch, 1977). The calculated IRA was 94% for the article search procedures (Cohen's κ = .79), 100% for the group design quality review (Cohen's κ = 1), 94% IRA for the single-case design quality review (Cohen's κ = .94), and 97% for the narrative synthesis. All disagreements were discussed until the coders reached an agreement.

Results

Quality Review

A total of 31 articles were evaluated against the WWC design standards. The results of quality evaluation of group design studies (n = 2) and single-case design studies (n = 14) that met the WWC design standards without or with reservations are presented in Table 1.

Group design studies. The four group design studies assigned participants to experimental or control group either in an individual-level (n = 3, 75%) or in a cluster-level (n = 1, 25%). Two (67%) of three individual-level group design studies met the design standards with or without reservations, and the one cluster-level group design study (100%) did not meet the standards. One individual-level RCT study (Ahlgrim-Delzell et al., 2014) reported a low attrition rate and met the design standards without reservations. One individual-level QED study (Serret et al., 2017) reported mean scores and standard deviations on pretest across conditions, and only one dependent variable (i.e., word segmentation) met the baseline equivalence criteria suggested by WWC. This QED study was rated as meeting the WWC standards with reservations, and other dependent variables that did not meet the baseline equivalence were excluded from further analysis. The other two group design studies (50%) did not meet the design standards due to high attrition in the experimental group and insufficient information to determine the attrition level or baseline equivalence.

Single-case design studies. About half of the reviewed single-case design studies (n = 14, 52%) met all the WWC design standards with or without reservations. The remaining studies (n = 13, 48%) did not meet at least one of the three standards (i.e., Design Standard 1, 2, or 4).

Design standard 1: IV. All 27 reviewed articles (100%) met Design Standard 1. All studies systematically manipulated the IV (i.e., technology-aided reading intervention) only for the intervention phase and provided sufficient information regarding when and how the IV condition changed.

Design standard 2: IAA. More than half of the reviewed studies (n = 15, 55%) met Design Standard 2 without reservations by reporting 80% or higher IAA that were collected at least 20% of sessions across conditions. Six studies (22%) studies met this standard with reservations because the IAA data were collected at least 20% of the sessions, but the IAA was not measured across conditions or it was not specified. The other six studies (22%) did not meet this standard due to the lack of IAA data (i.e., <20% of sessions or not reported).

Design standard 3: Treatment fidelity. Twenty studies (74%) measured treatment fidelity while seven studies (26%) did not. More than 40% of the studies (n = 11, 41%) met this standard without reservations. Nine studies (33%) met this standard with reservation as it was unclear whether the treatment fidelity was assessed across conditions.

Treatment fidelity was measured differently based on the roles of technology. In the majority of studies that measured treatment fidelity (n = 12, 60%), the use of technology was

Table 1. Results of Quality Evaluation of Articles That Met the WWC Design Standards.

Study	Design	Design standards: Attrition	Design standards: Baseline equivalence	Final rating
Group design studies[a]				
Ahlgrim-Delzell et al. (2014)	RCT	Y	N/A	Y
Serret et al. (2017)	QED	N/A	R (Word Segmentation Only)	R

Study	Design	Design standards: IV	IRA	Treatment fidelity[b]	Phases/data points	Final rating
Single-case design studies						
Alison et al. (2017)	MPD	Y	Y	R	R	R
Armstrong & Hughes (2012)	ATD	Y	R	N	Y	R
Browder et al. (2017)	MPD	Y	Y	R	R	R
Coleman et al. (2012)	ATD	Y	R	R	Y	R
Coleman et al. (2015)	ATD	Y	Y	R	Y	Y
El Zein et al. (2016)	ATD	Y	Y	Y	Y	Y
Ganz et al. (2014)	ATD	Y	Y	R	Y	Y
Lee & Vail (2004)	MPD	Y	Y	Y	R	R
Morlock et al. (2015)	MBD	Y	R	N	R	R
Saadatzi et al. (2017)	MBD	Y	Y	Y	R	R
Smith et al. (2013)	MPD	Y	Y	Y	R	R
Spooner et al. (2014)	MPD	Y	Y	Y	R	R
Spooner et al. (2015)	MPD	Y	Y	Y	Y	Y
Yaw et al. (2011)	MBD	Y	R	N	R	R

Note. RCT = randomized controlled trial; QED = quasi-experimental design; Y = meets the standard without reservations; R = meets the standard with reservations; N = does not meet the standard; N/A = not applicable; ATD = alternating treatment design; MBD = multiple-baseline design; MPD = multiple-probe design.
[a]All group design studies that met the standards used individual-level assignment. [b]Score was not considered for final rating.

paired with interventionist-directed instruction. In these studies, treatment fidelity was measured by ensuring the interventionist's adherence to the protocol of instructional delivery. In the other eight studies that measured treatment fidelity (40%), computer- or iPad-based software programs served as interventionists. In these studies, treatment fidelity was measured using a checklist that describes the protocol of using the technology (e.g., setting up computers, reminding students to participate, and providing verbal directions) or by determining the proper operation of the CAI program during the intervention.

Design standard 4: Number of phases and data points. Of the reviewed single-case studies, 67% met the Design Standard 4 without reservations (n = 7, 26%) or with reservations (n = 11, 41%). Nine studies did not meet this standard (33%) due to the insufficient demonstrations of effects (e.g., multiple-baseline design across two participants) or data points per phase (e.g., less than three data points in baseline).

Although all of the six alternating treatment design studies met Design Standard 4 without reservations, only one (7%) of 14 multiple-probe design studies met this standard without reservations. Half of the multiple-probe design studies (n = 7, 50%) met this standard with reservations. These studies included one to two probes within the first three sessions across conditions, one to two probes prior to intervention across conditions, and/or one probe after the intervention in some conditions not receiving intervention. The remaining six multiple-probe design studies (43%) did not meet Design Standard 4. Four (67%) of six multiple-baseline design studies met this standard with reservations, whereas two studies (33%) did not.

Narrative Synthesis

The 16 studies that met the design standards were synthesized, and overall study characteristics and technology usage are described in Table 2.

Table 2. Study Narratives of Articles With High-Quality Research Evidence.

Study	Participant: Gender; age	Participant: Diagnosis; language	Design	Technology	Intervention (component; interventionist; setting)	Types of text	DVs/measurement	Effects
Ahlgrim-Delzell et al. (2016)	*N* = 17 male = 14 female = 3 5–15 y (K) = 2 (E) = 11 (M) = 4	ASD=8 (w/ ID) = NR (w/o ID) = NR Others: D = 12 DD = 5 AAC = 17 ELL = NR	RCT	iPad *GoTalk Now* – Role: SI – Training: NR	*Phonics Curriculum with Systematic Instruction* Constant TD, text-to speech, least prompts – Teacher – Self-contained classroom	Letter Word Sentence	*Phoneme Identification* – Matching voice phonemes to letters *Blending Sounds* – Matching voice words to written words *Decoding* – Reading word for picture– word matching *Total score* – Total score obtained through the curriculum	Strong Moderate Strong Strong
Alison et al. (2017)	*N* = 3 Male = 3 8–10 years (E) = 3	ASD = 3 (w/ ID) = 3 (w/o ID) = 0 Verbal = 3 ELL = 3	SCR MPD	iPad *GoTalk Now* – Role: SI – Training: NR	*Shared Story* Constant TD, text-to-speech, least prompts – Researcher – Self-contained classroom	Word Narrative	*WH Pairings* – Correct parings of WH words with definitions/examples *Comprehension* – Correct responses to questions	Strong No effect
Armstrong & Hughes (2012)	*N* = 5 Male = 5 7–8 years (E) = 5	ASD = 5 (w/ ID) = 0 (w/o ID) = 5 Verbal = 5 ELL = 3	SCR ATD	Computer *Wynn Wizard* – Role: DI – Training: NR	*Repeated Reading* Reading with a computer, audio voice, highlighted text – Researcher – NR	Narrative	*Comprehension* – Correct responses to comprehension questions *Retelling* – Morrow's retelling scores measured by story elements	No effect (0:5) NA
Browder et al. (2017)	*N* = 3 Male = 2 Female = 1 8–10 years (E) = 3	ASD = 3 (w/ ID) = 2 (w/o ID) = 1 Verbal = 3 ELL = 1	SCR MPD	iPad *SMART Notebook* – Role: SI – Training: Yes	*Story-Mapping* Constant TD, least prompts, audio voice – Researcher – Self-contained classroom	Narrative	*Identification of Story Elements* – Correct pairings of story elements with definitions *Labeling of Story Elements* – Independent labeling of the story elements *Comprehension* – Correct responses to questions	Strong Strong Strong
Coleman et al.(2012)	*N* = 3 Male = 3 10–12 years (E) = 2 (M) = 1	ASD = 1 (w/ ID) = 1 (w/o ID) = 0 Others: ID = 2 Verbal = 3 ELL = NR	SCR ATD	Computer *PowerPoint* – Role: DI – Training: NR	*CAI* Constant TD, audio voice, reinforcement/feedback screen – Intern teacher – Self-contained classroom	Word	*Sight Word Reading* – % of words read correctly – Numbers of trials to criterion	No effect (0:3)
Coleman et al.(2015)	*N* = 3 male = 1 female = 2 9–11 years (E) = 3	ASD = 2 (w/ ID) = 2 (w/o ID) = 0 Others: ID = 1 Verbal = 3 ELL = NR	SCR ATD	Computer *Classroom Suite* – Role: DI – Training: Yes	*CAI* Simultaneous prompting, reinforcement/feedback screen, audio voice – Intern teacher – Self-contained classroom	Word	*Sight Word Reading* – Number of sight words read correctly	No effect (2:1)
El Zein et al.(2016)	*N* = 3 male = 3 9–10 years (E) = 3	ASD = 3 (w/ ID) = NR (w/o ID) = NR Verbal = 3 ELL = NR	SCR ATD	iPad *Space Voyage* – Role: DI – Training: NR	*IAI* Video game designed to identify main idea, reinforcement/feedback screen, token economy – Researcher – University lab	Expository	*Comprehension* – % of correct responses *Task Refusal* – Number of verbal protests, physical refusal, no responses	No effect (0:3) No effect (0:3)
Ganz et al.(2014)	*N* = 3 male = 2 female = 1 8–14 years (E) = 2 (M) = 1	ASD = 3 (w/ ID) = NR (w/o ID) = NR Verbal = 3 ELL = NR	SCR ATD	Computer *iCommunicate* – Role: SI – Training: NR	*Visual Script* Activity/videos related to target vocabulary word, prompting, modeling – Researcher – Empty classroom, home	Word	*Unprompted Noun/Verb Use* – % of unprompted noun/verb use following a question *Average Prompt Level* – Level of prompt to answer *Spontaneous Comments* – Unprompted noun/verb use within a sentence/phrase	No effect (0:3) NA NA

(continued)

Table 2. (continued)

Study	Participant: Gender; age	Participant: Diagnosis; language	Design	Technology	Intervention (component; interventionist; setting)	Types of text	DVs/measurement	Effects
Morlock et al. (2012)	*N* = 3 male = 3 17–18 years (H) = 3	ASD = 3 (w/ ID) = NR (w/o ID) = NR Verbal = 3 ELL = NR	SCR MBD	Computer *GemIIni* – Role: DI – Training: NR	*Video Modeling* Watching videos for each target words 10 times – Researcher – Empty classroom	Words	*Decoding* – % of words identified correctly *Word Pronunciation* – % of words pronounced accurately	No effect Strong
Saadatzi et al.(2017)	*N* = 3 male = 3 19–20 years (H) = 1 (A) = 2	ASD = 3 (w/ ID) = 3 (w/o ID) = 0 Verbal = 3 ELL = NR	SCR MBD	Computer *Vizard* – Role: DI – Training: NR	*CAI* TD, audio prompt, verbal praise/corrective feedback – Researcher – University lab	Words	*Sight Word Reading* – % of words read correctly – Number of sessions to criterion	Strong
Serret et al.(2017)	*N* = 12 male = 11 female = 1 6–11 years (E) = 11	ASD = 12 (w/ ID) = NR (w/o ID) = NR Verbal = 12 ELL = NR	QED	Computer *SEMA-TIC* – Role: DI – Training: NR	*CAI* Game format, animation, reinforcement/feedback – Care giver – Home	Letter Word	*Word Segmentation* – Correct separations in a group of letters to from words	Strong
Smith et al.(2013)	*N* = 3 male = 3 11–12 years (E) = 1 (M) = 2	ASD = 3 (w/ ID) = 3 (w/o ID) = 0 Verbal = NR AAC = 0 ELL = 3	SCR MPD	iPad *Keynote* – Role: DI – Training: Yes	*CAI* Audio prompt, modeling, corrective feedback – Researcher – General education classroom	Word	*Identification of Science Terms* – Correct responses made on assessment items	Strong
Spooner et al. (2014)	*N* = 4 male = 4 8–12 years (E) = 3 (M) = 1	ASD = 4 (w/ ID) = 4 (w/o ID) = 0 AAC = 4 ELL = NR	SCR MPD	iPad *GoTalk Now* – Role: SI – Training: NR	*Shared Story* Constant TD, least prompts, modeling – Researcher – Self-contained classroom	Narrative	*Responses During Shared Story* – Correct responses on 10-step shared story task analysis *Comprehension* – Correct responses to questions	Strong Moderate
Spooner et al.(2015)	*N* = 5 male = 2 female = 3 7–11 years (E) = 5	ASD = 1 (w/ ID) = NR (w/o ID) = NR AAC = 5 ELL = 1	SCR MPD	Computer *GoTalk Now* – Role: SI – Training: NR	*Shared Story* Constant TD, guiding questions, prompting, modeling – Researcher – Teaching office	Narrative	*Responses During Shared Story* – Correct responses on 10-step shared story task analysis *Comprehension* – Correct responses to questions	Strong Moderate
Yaw et al.(2011)	*N* = 1 male = 1 12 years (E) = 1	ASD = 1 (w/ ID) = NR (w/o ID) = NR AAC = 1 ELL = NR	SCR MBD	Computer *PowerPoint* – Role: DI – Training: NR	*CAI* Using Dolch words, audio prompt – Researcher – Self-contained classroom	Words	*Sight Word Reading* – Number of words read correctly within 2 sec	Strong

Note. E = elementary school; M = middle school; H = high school; A = adult; ASD = autism spectrum disorder; ID = intellectual disability; DD = developmental delay; AAC = augmentative and alternative communication; ELL = English language learner; NR = not reported; NA = not applicable; RCT = randomized controlled trial; SCR = single-case research; ATD = alternating treatment design; MBD = multiple-baseline design; MPD = multiple-probe design; SI = supporting instruction; DI = delivering instruction; CAI = computer-assisted instruction; IAI = iPad-assisted instruction; TD = time delay

Study characteristics

Participants. A total of 75 students participated in the 16 studies with high-quality research evidence. Sixty-four students (85%) were male, and the other 11 students (15%) were female. The majority of participants (n = 58, 77%) were elementary school-age students (i.e., 6–11 years old). Nine of the participants (12%) were middle school-age (i.e., 12–15 years old). Only a few participants were high school students (i.e., 16–19 years old, n = 4, 5%), pre-K-age students (i.e., 3–5 years old, n = 2, 3%), or adults above 20 years old (n = 2, 3%). Fifty-seven participants (76%) were students with ASD, and 20 of them (35%) had both ASD and ID diagnoses or had an IQ of <70. Six participants with ASD (10%) did not have ID as a comorbid disorder as they were reported to have high-functioning autism or Asperger syndrome or had an IQ of at or above 70. However, the intellectual ability of 31 students with ASD (54%) could not be inferred from the author report due to the lack of IQ scores or insufficient participant description. The other participants who did not have ASD (n = 18, 24%) were individuals with ID, developmental delay, and multiple disabilities without ASD. The majority of participants (n = 46, 61%) had an ability to verbally communicate and/or read aloud, while 26 participants (35%) used AAC as a primary mode of communication. A total of five participants (5%) were reported as ELLs, but most studies (n = 13, 81%) did not specify the number of participants who were ELLs and who were not.

Setting. The majority of studies (n = 14, 88%) were conducted in separate classrooms without typically developing peers, including the self-contained classroom (n = 8, 50%), empty classroom in school (n = 4, 25%), and university lab (n = 1, 6%). Serret et al. (2017) implemented the intervention at the participant's home. Ganz et al. (2014) implemented the intervention at home for one of the participants. One study (6%) was implemented in a general education classroom during the students' independent work time without involving the typically developing peers (Smith et al., 2013).

Design. The majority of studies (n = 14, 88%) were single-case studies that utilized a multiple-probe design (n = 6, 38%), alternating treatment design (n = 5, 31%), and multiple-baseline design (n = 3, 19%). The other two articles (13%) were group design studies. RCT and QED were utilized in one study each (6%).

Intervention. In more than half of the articles (n = 9, 56%), reading interventions were delivered by computer- or iPad-based programs that included various instructional strategies (e.g., time delay, audio voice, highlighted text, and reinforcement/error correction screen). Seven of those studies (78%) used CAI/IAI programs specifically designed for teaching sight words (n = 5), vocabulary (n = 1), or comprehension skills (n = 1). Repeated reading with a computer (Armstrong & Hughes, 2012) and video modeling for target word recognition and pronunciation (Morlock et al., 2015) were used in one study each.

In three studies (43%), shared story interventions were implemented for teaching comprehension skills to students with ASD who were AAC users. The interventions involved systematic instruction provided by interventionists (e.g., least prompt and time delay), and technology was used to present e-texts with various auditory and visual features and enhance response options. One study (Ahlgrim-Delzell et al., 2016) utilized a phonics curriculum that was embedded in an iPad in conjunction with systematic instruction procedures (e.g., time delay and least prompts). In the other one study (Browder et al., 2017), participants were taught to use an electronic story-map to visualize story structures.

Interventionist. Interventions were implemented by researchers in 12 (75%) studies, by educators in 3 (19%) studies, and by caregivers in 1 (6%) study.

Types of text. Words were used as reading materials in the majority of studies (n = 10, 63%). Paragraphs were used in six comprehension studies (38%). Five of them were used narrative texts (e.g., storybook), and only one study used expository texts (e.g., nonfiction). In one study (6%), letters and sentences were used as reading materials.

Outcome measures. A total of 28 outcomes were measured in 16 articles that met the design standards. Half of the studies (n = 8, 50%) measured decoding skills as one of the dependent variables, five of which (50%) specifically measured sight word recognition. The next common dependent variable was reading comprehension, which was measured in six studies (38%). Four studies (25%) measured vocabulary skills, two of which (50%) targeted correct paring of WH words (e.g., who and when) or story elements (e.g., character, setting, and problem) with definitions. The other two studies targeted science vocabulary acquisition (Smith et al., 2013) or unprompted noun/verb use (Ganz et al., 2014). Phonemic awareness and phonics skills were measured in the fewest number of studies (n = 2, 13%). In three studies (19%), reading-related outcomes were additionally measured as a dependent variable, two of which measured overall performance during intervention sessions using a task-analytic checklist (e.g., identifying book title, select correct vocabulary words, and turn pages), and one study (6%) targeted task refusal and average prompt levels (Ganz et al., 2014).

Effects. A total of 29 reading and nonreading outcomes were targeted, and the effects of the intervention on each outcome variable were coded as *strong*, *moderate*, or *no effect*. Strong effects were most commonly demonstrated across studies (n = 15, 52%), followed by no effect (n = 8, 28%), and moderate effects (n = 3, 10%). Three outcome variables targeted in two (10%) studies were not coded for effects due to the absence of graphs or baseline data.

Technology usage

Type. Two types of technology devices and 12 software programs were incorporated into reading interventions. Half of the studies (n = 8, 50%) used computers, and the other half of the studies (n = 8, 50%) used tablets. GoTalk Now was the most common software program used for technology-aided reading intervention (n = 4, 25%), and PowerPoint was applied in two studies (13%). Wynn Wizard, SMART notebook, Classroom Suite, Space Voyage, iCommunicate, Word Wizard, GemIIni, Vizard, SEMATIC, and Keynote were each utilized in each of the remaining studies (6%).

Role. The use of technology was further categorized into two types based on its primary role: (a) delivering instruction without interventionist-directed instruction and (b) supporting interventionist-directed instruction. In the majority of articles (n = 10, 63%), technology was used to deliver reading instruction without extra interventionist-directed instruction. Seven of those studies (70%) developed individualized CAI programs to provide reading instruction for learning sight words (n = 6) or science vocabulary (n = 1) by using PowerPoint (Coleman et al., 2012; Yaw et al., 2011), Vizard (Saadatzi et al., 2017), and Keynote (Smith et al., 2013). Those researcher-developed CAI programs included key features of presenting texts on screen with audio voice, presenting verbal direction, and providing feedback or reinforcement. Four commercially developed CAI/IAI programs (i.e., Classroom Suite, GemIIni, SEMATIC, Space Voyage) were utilized in four studies (25%) to deliver reading instruction. Morlock et al. (2015) used GemIIni, a website that offers video-modeling materials, to deliver instruction to teach work recognition and pronunciation. One IAI program (i.e., Space Voyage) was used in one study (6%) to improve reading comprehension skills (El Zein et al., 2016). In one study (Armstrong & Hughes, 2012), Wynn Wizard was used to develop e-texts including audio voice and highlighted keywords and used within repeated reading sessions.

In six studies (38%), the use of technology was paired with direct instruction provided by interventionists. Only iPad devices were used for this purpose, and GoTalk Now was the most common software program. Four (67%) of the six studies used the GoTalk Now application within a shared story that included systematic instruction procedures (e.g., time delay and least prompting) to present reading materials on the iPad screen with audio/visual prompts (Alison et al., 2017; Spooner et al., 2014; Spooner et al., 2015). In one other study (Ahlgrim-Delzell et al., 2016), a phonics curriculum blended iPad-based technological speech supports using GoTalk Now was applied in conjunction with systematic instruction including time delay and shaping/fading of model prompts. In one study (6%), iCommunicate was used to present target words with audio voice and providing response opportunities (Ganz et al., 2014). In one other study (6%), the SMART Notebook was utilized to provide participants with a touch-based story-map template (Browder et al., 2017).

Training. Four studies (25%) pretrained student participants to manipulate a specific technology device or software programs (Coleman et al., 2015; Lee & Vail, 2004 Smith et a., 2013) or prescreened participants to ensure that all of them had an ability to operate technology (Browder et al., 2017). However, the majority of studies (n = 12, 75%) did not provide sufficient information regarding pretraining or prescreening procedures.

Discussion

This review included 31 technology-aided reading intervention studies involving participants with ASD. A total of 16 articles met the WWC design standards, and the study characteristics and technology usage in those articles were summarized. Prior to this study, several literature reviews suggested that technology can be successfully used for students with ASD and other developmental disabilities (e.g., Kagohara et al., 2013; Knight et al., 2013). However, no reviews examined the specific use of technology to teach reading skills to students with ASD, and only a few reviews evaluated the quality of research evidence (e.g., Knight et al., 2013; Root et al., 2017). The findings of this study add to the emerging body of research on technology-aided reading interventions for students with ASD.

Quality of Research

Overall, this systematic quality review indicated that more than half of reviewed group design and single-case design studies were high-quality research. In the case of group design studies, the majority of group design studies were initially excluded from further review due to the absence of control groups. To sustain the methodological rigor of group design studies, the WWC design standards suggest that researchers utilize RCTs, RDDs, or QEDs with control groups. Due to the limited number of group design studies included for review, we were unable to draw a conclusion about the methodological rigor of group design studies in this area. Future researchers should refer to research design standards recommended by established organizations (e.g., WWC) to monitor the methodological rigor of their studies, increase the credibility of research findings, and allow a more comprehensive examination or synthesis of research evidence.

Although the majority of studies measured and reported above 80% of IAA and treatment fidelity, in many of those studies, the researchers did not specify whether the data were collected across all conditions (e.g., baseline, intervention, and maintenance) or were collected only during specific experimental phases (e.g., intervention only). This information is critical in determining the internal validity of a study. Future researchers should consider collecting reliability and fidelity data for at least 20% of the sessions across participants and conditions.

Compared with other areas, a relatively small number of articles (n = 7, 26%) met Design Standard 4 (i.e., number of phases and data points). Insufficient demonstration of effects or number of data points does not necessarily mean that the findings of a study are not valuable, but it creates uncertainty in the quality of research evidence and believability of results. Half of the multiple-baseline studies and more than half of multiple-probe design studies did not meet the Design Standard 4, whereas all alternating treatment studies met this standard. Most studies that did not meet substandards for multiple-probe designs did not collect a sufficient number of probe points or overlapping probe points across cases in the baseline. Collecting sufficient baseline data supports a more valid prediction of the participant's future performance and demonstrates better experimental control. Insufficient or variable baseline probe data could reduce the overall validity of the study. However, it should also be noted that demonstrating stable data in baseline may contribute to practice effects. Utilizing multiple-probe design to examine the effects of academic interventions may offer practical value in that participants are exposed to less opportunities for failure without supports in baseline. It is recommended that future researchers balance between collecting a sufficient number of data points in baseline and minimizing practice effects.

Although one of the most common intervention components was CAI/IAI, there is no general consensus on how to measure treatment fidelity if the intervention was delivered solely by technology. Six CAI/IAI studies reported treatment fidelity, yet only a few studies provided sufficient detail of how it was measured. Measuring treatment fidelity during the CAI/IAI sessions requires unique considerations in that learning through the software program requires learners' attention to the program. To deliver CAI/IAI interventions as intended, the study participants would need to demonstrate a high level of engagement throughout the intervention. Varying levels of engagement may be a confounding variable and thus should be monitored closely. Future researchers should identify effective ways to measure treatment fidelity of CAI/IAI interventions and assess engagement. In addition, the role of the interventionist in CAI/ IAI interventions should be described in sufficient detail.

Implications for Research

The National Reading Panel (U.S.) & National Institute of Child Health and Human Development (U.S.) (NRP, 2000) suggested five reading components of reading instruction (i.e., phonemic awareness, phonics, vocabulary, comprehension, and fluency). Previous studies have indicated that reading instructions for students with ASD and other developmental disabilities have focused heavily on teaching sight words, especially when they have moderate to severe educational needs (Browder et al., 2006). While teaching sight words was still one of the most common targeted outcomes in the studies reviewed, it was worth noting that other reading components (e.g., vocabulary and comprehension) were also targeted in many studies. However, there is a general lack of research on phonics or fluency instructions for this population, and more high-quality research is needed to address this gap.

Students with ASD have a wide range of language abilities, which may lead to variability in reading (Davidson & Ellis Weismer, 2014). However, more than half of the reviewed articles did not provide relevant assessment data necessary for determining comorbidity (e.g., IQ scores), and few participants with ASD (n = 6, 10%) were reported to have ASD without ID. The lack of reported information on ID comorbidity did not allow us to compare study outcomes for students with and without ID and make differential conclusions about the effects of technology-aided interventions across different subgroups of ASD. In addition, most reviewed articles (81%) did not specify the number of participants who were ELLs and who were not. Given that having a comorbid ID or learning English as a second language may exacerbate existing challenges that students with ASD have, the participants included in this review may not be representative of the range of difficulties students with ASD and a comorbid diagnosis may encounter. Additional research is needed to make specific recommendations based on varied cognitive or language abilities in ASD.

As there has been an increased emphasis on accessing grade-level academic standards (Every Student Succeeds Act, 2015), a number of technology-aided reading intervention studies taught participants to read age-appropriate materials. However, intervention settings in those studies did not include the inclusive classroom. To increase the generalizability of technology-aided reading interventions for this population, future researchers should investigate how technology can be used within more natural settings rather than pulling students out to provide one-on-one instruction. In addition, fewer participants in secondary education (18%) were involved. Considering that students with ASD have different educational needs in reading across ages, more research is warranted across secondary school-age students with ASD.

In this literature review, six studies compared the effects between technology-aided reading interventions and interventionist-directed reading interventions. The majority of the studies concluded that both interventions led to improved reading outcomes compared with baseline performance, but none of the studies demonstrated differentiated effects in reading outcomes. Delivering reading interventions through CAI/IAI programs may have relative strengths in that it typically involves reduced instructional support from teachers and more flexible pacing in student learning. However, delivering instruction through technology is fairly limited in teaching in-depth comprehension skills and providing in vivo feedback based on the student's verbal responses. In this review, almost all CAI/IAI studies targeted teaching sight words through embedded visual/audio prompts and reinforcement/error correction slides, and there is little evidence on applying CAI/IAI to teach other NRP reading components (e.g., fluency and phonemic awareness). Moreover, despite the wide usage of online learning platforms (e.g., Google Classroom, Blackboard, and WebEx) in the current K–12 educational settings, no reviewed articles investigated the relative effects of distance/remote learning compared with the face-to-face format. Future researchers should examine strategies or models for selecting appropriate modes of reading instruction for students with ASD.

Implications for Practice

There has been an increased awareness of online or technology-aided learning due to unusual circumstances of the past years (e.g., COVID-19 pandemic), and this awareness has led to more educators acknowledging that online learning could have benefits that extend beyond merely an alternative mode of presenting instructional materials. Unfortunately, most of the studies that were identified as high quality in this review targeted more basic reading domains (e.g., sight word acquisition and decoding) reflecting a relative paucity in CAI/IAI that address more complex reading domains (e.g., comprehension). Given that embedded instructional strategies within the CAI/IAI is an essential component of the intervention (Hu et al., 2020), we recommend that educators select and incorporate other EBPs (e.g., prompting, reinforcement, time delay, and visual supports) into CAI/IAI programs when they decide to use technology as a mode of delivering instruction to teach various reading skills other than decoding.

To improve the comprehension skills of students with ASD, educators may consider implementing shared reading (Alison et al., 2017; Spooner et al., 2014; Spooner et al., 2015) or using graphic organizers (Browder et al., 2017). In the reviewed articles, technology was used to provide visual cues, text-to-speech, alternative response modes for answering comprehension questions, and additional tools to visually organize obtained information from the text. Shared reading and story-mapping interventions were implemented as a package that involved various components. Omitting or adding specific components may allow educators to apply the package intervention in natural settings more feasibly, but we recommend that educators monitor the students' progress through data collection to determine the effectiveness of the adapted interventions.

Limitations and Directions for Future Research

Although this systematic quality review adds to the emerging body of research on technology-aided reading interventions for students with ASD, the following limitations should also be considered. First, we interpreted each of the WWC design standards as relevant to the purpose of this review. Our interpretation of the WWC design standards may have resulted in the dismissal of some high-quality research studies. Second, we evaluated the methodological rigor based on the information the researchers provided. If researchers omitted critical information for this review, it may have impacted our quality ratings. Future researchers should report sufficient information to substantiate the methodological rigor of the studies. Third, compared with the other quality indicators suggested by other predominant organizations (e.g., Council for Exceptional Children), the WWC design standards put more weight on the rigorous experimental design (e.g., collecting IAA, number of phases, and data points) than contextual information (e.g., intervention agent and description of practice). To fill the gap between research and practice, future researchers would need to consider not only designing rigorous experimental studies but also providing detailed information for further replications. Fourth, this literature review summarized the effects of technology-aided reading interventions based on narrative synthesis. Future research would need to consider measuring magnitudes of effects of technology-aided reading interventions and comparing the effectiveness across moderating variables through meta-analysis.

Conclusion

Findings of this review suggest that using technology can benefit students with ASD in learning a range of reading skills (e.g., sight word identification, comprehension, and vocabulary). While there is a relative paucity in high-quality research on using other types of technology (e.g., online learning platform) to teach various reading skills (e.g., phonics, fluency, and comprehension) in inclusive settings, technology-aided interventions have received increased attention as an alternative way for delivering instruction due to the unusual circumstances of the past two years (e.g., COVID-19 pandemic). Researchers should continue to investigate novel technology-aided interventions to improve reading outcomes in students with ASD, while educators should continue to direct their attention to the latest research to increase their repertoire of EBPs.

Appendix

Table A1. WWC Design Standards and Rating Criteria for Single-Case Design Studies.

Design standard	Rating
1. Independent Variable (IV)	
1-1. IV was systematically manipulated with researcher determining when and how the conditions changed	– Y: Yes – N: No
2. Interassessor Agreement (IAA)	
2-1. The outcome variable was measured systematically by more than one assessor	– Y: Yes – N: No
2-2. IAA was collected at least 20% of the data points across conditions	– Y: Yes – R: Collected >20%, not across conditions – N: <20%
2-3. The mean IAA was at or above 80% or 0.6 Cohen's κ	– Y: Yes – N: <80% or 0.6 Kappa
	[Standard 2: Overall Rating] – Y: All Y – R: Both Y and R – N: One or more N
3. Treatment Fidelity[a]	
3-1. Treatment fidelity was assessed at least 20% of the intervention sessions across conditions	– Y: Yes – R: Collected >20%, not across conditions – N: <20% or not collected
3-2. The mean treatment fidelity was at or above 80%	– Y: Yes – N: <80%
	[Standard 3: Overall Rating] – Y: All Y – R: Both Y and R – N: One or more N
4. Phases and Data Points	
4-1. Alternating Treatment Design (ATD)	– Y: ≥5 points per condition with ≤2 consecutive points – R: ≥4 points per condition with ≤2 consecutive points – N: ≤3 points per condition with ≥3 consecutive points
4-2. Multiple-Baseline Design (MBD)	– Y: ≥6 phases with ≥5 points – R: ≥6 phases with 3–4 points – N: ≤5 phases or ≤2 points
4-3. Multiple-Probe Design (MPD)	– Y: ≥6 phases with ≥5 points – R: ≥ 6 phases with 3–4 points – N: ≤5 phases or ≤2 points
Additional Standards for MPD	
4-3-1. Probes within first 3 sessions	– Y: 3 probes within first 3 sessions across conditions – R: 1–2 probes within first 3 sessions across conditions – N: No probe within first 3 session in ≥1 conditions
4-3-2. Probes prior to intervention	– Y: 3 probes prior to intervention across conditions – R: 1–2 probes prior to intervention across conditions – N: No probe prior to intervention in ≥1 conditions
4-4-3. Probes after intervention	– Y: 1 probe after intervention in all conditions not receiving intervention – R: 1 probe after intervention in some conditions not receiving intervention – N: No probe after intervention
[Final Rating] Treatment Fidelity scores were <u>not</u> considered for final rating	– **Meet Standards without Reservations** : If all ratings were Y – **Meet Standards with Reservations** : If ratings included both Y and R – **Does Not Meet Standards** : If there was one or more N

[a]Scores were not considered for final rating

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