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Computer-Assisted Instruction for Teaching Academic Skills to Students With Autism Spectrum Disorders: A Review of Literature

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Abstract

Although legislation mandates that students with autism receive instruction linked to the general education core content, there is limited research supporting the effectiveness of interventions for teaching core content to these students. In this study, the author reviewed research conducted between the years 1997 and 2008 using computer-assisted instruction (CAI) to teach academic skills to students with autism. The author concluded that CAI was effective for teaching a limited set of academic skills to individuals with autism; however, functional relations were found in few of the single-case designs and none of the group designs included a control group. Future researchers should explore the use of CAI in various instructional arrangements, identify critical technology components, and evaluate commercially available software.

Keywords

computer-assisted instruction, autism spectrum disorders, academics, evidence-based practices

Autism spectrum disorders (ASD) are developmental disabilities characterized by deficits in communication and socialization accompanied by engagement in stereotyped and repetitive behaviors. By most recent estimates, the prevalence of ASD has increased to 1 in 110 children (Centers for Disease Control, 2009). In addition, these children present deficits across a broad continuum of severity. Consequently, educators are confronted with an urgent need to develop individualized and effective programming for this increasing population of students.

The most recent development in the evolution of educational programming for children with ASD has been an increased interest in technologies for facilitating access to general education core content. This shift in focus was precipitated by federal legislation that mandated that students with disabilities be provided with access to the general education curriculum (Individuals With Disabilities Education Act, 1997; No Child Left Behind Act, 2001). Furthermore, the No Child Left Behind Act stipulated that states assess students with disabilities, even those with significant intellectual disabilities, using measures that are directly linked to core content standards (Browder et al., 2007). This presumptive change in paradigm has outpaced researchers' abilities to investigate the effectiveness of instructional technologies in the context of the general education curriculum, thus leaving educators to teach core content while drawing from a paucity of resources.

Generally, researchers have approached core content instruction for individuals with moderate to severe disabilities by investigating the effectiveness of evidenced-based technologies traditionally used to teach functional skills on the acquisition of general education content. For example, response-prompting procedures (e.g., time delay, simultaneous prompting) have been demonstrated to be effective in teaching general education content to students with significant intellectual disabilities (e.g., Morse & Schuster, 2004; Riesen, McDonnell, Johnson, Polychronis, & Jameson, 2003). Researchers are only beginning to extend their investigations to other instructional technologies. One practice, the use of computer-assisted instruction (CAI), has been suggested to have unique potential for learners with ASD (Blischak & Schlosser, 2003).

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CAI refers to the use of a computer technology to present learning materials and/or check learner's knowledge (Anohina, 2005). Several researchers have suggested that CAI is compatible with the characteristics of individuals with ASD. D. Moore, McGrath, and Thorpe (2000) described how CAI might serve to ameliorate the social deficits that are a cardinal feature of ASD. They suggested that an adherence to social rules that are a part of any educational context could be taught through the use of multimedia programs designed to increase the salience of crucial social stimuli. Computer programs can be designed to highlight, slow down, and repeat critical social cues, thus teaching social contingencies in controlled formats. For example, researchers have used emerging virtual reality technology to train appropriate responding within the context of these controlled formats (Self, Scudder, Weheba, & Crumrine, 2007).

Higgins and Boone (1996) suggested that computer-based teaching interactions allow learners with ASD to bypass the complexity of social contexts that may confound instructional objectives. D. Moore et al. (2000) addressed concerns that CAI may contribute to the further isolation of students with ASD. They argued that CAI was an acceptable alternative to human interaction during "domain specific" learning activities when communication difficulty resulted in decreased progress. They suggested that a balance could be maintained by incorporating the use of CAI during group activities and by imposing clear limits on time engaged in computer-based activities.

CAI also may be effective for addressing impairments in communication during instruction. Janzen (1996) suggested that differences in cognitive processing might often render spoken language transient for many individuals with ASD. The controlled multimedia presentation of stimuli during CAI affords the learner a visual prosthesis during instruction. These visual prostheses may benefit students during instruction by increasing the salience of instructional stimuli. Additionally, difficulties with retrieval may be decreased by the frequent requirement during CAI for learners to select correct responses from an array of receptive choices. D. Moore et al. (2000) also suggested that deficits in creativity and spontaneity might be mitigated by allowing learners with ASD to participate in the development of multimedia technology.

Individuals with ASD also may benefit from the use of computer-generated speech during CAI. Schlosser and Blischak (2001) suggested that the characteristics of computer-generated speech (e.g., monotone, limited-affect) might be preferable to individuals with ASD because of their decreased ability to detect changes in prosody and an increased desire for "sameness." In addition, the recorded audio features of computer-based technologies might provide learners with the opportunity to replay missed directions and auditory cues.

Researchers have suggested that individuals with ASD may find the multisensory interactions of CAI to be reinforcing. D. Moore et al. (2000) suggested that individuals with ASD might benefit from the incorporation of preferred stimuli into multimedia programming. Individuals with ASD have been shown to exhibit fewer inappropriate behaviors during CAI than during traditional one-on-one instruction (Chen & Bernard-Opitz, 1993; M. Moore & Calvert, 2000). Additionally, these students have expressed enjoyment and exhibited increased appropriate behaviors during CAI (Bosseler & Massaro, 2003; Heimann, Nelson, Tjus, & Gillberg, 1995).

Research literature in the area of CAI and autism first appeared in the 1970s, consisting primarily of concept papers and anecdotal accounts (Mirenda, 2001). In one of the earliest research studies involving CAI for students with autism, Colby (1973) demonstrated the effectiveness of a computer program on increasing voluntary speech. Colby used software that presented auditory and visual feedback in response to pressing a letter on a keyboard. He reported that 13 of 17 children with limited communication increased their use of voluntary speech and demonstrated motivational gains. Plienis and Romanczyk (1985) compared the effects of CAI to teacher instruction for 6 students with autism. They found no differences in learning between the groups, but they demonstrated that students exhibited increased compliance and decreased disruptive behavior during the CAI condition. Chen and Bernard-Opitz (1993) also sought to compare CAI to teacher-delivered instruction. They taught a variety of basic academic skills (i.e., addition, labeling, concept learning) to 4 children with ASD using personal instruction (teacher-to-student) or CAI. Results indicated that neither CAI nor personal instruction was more effective across participants but that students were more motivated and exhibited fewer problem behaviors during CAI.

Heimann et al. (1995) used a multisensory program (i.e., voice, animation, video) to facilitate language learning in 11 children with ASD. Students completed 112 computer-based lessons and subsequently demonstrated gains on measures of reading, phonological awareness, and vocabulary. In addition, it was noted that the students engaged in increased verbal interactions with the instructor during CAI. In another study, Stromer, Mackay, Howell, and McVay (1996) used computer software to teach spelling to an adult with autism. The participant learned to write the name of objects depicted in pictures by touching letters on a computer screen. The researchers found that the acquired spelling skills generalized to handwriting tasks.

In the contexts of evolving computer technology, an increasing prevalence of ASD, and a shift toward teaching core content to all students with disabilities, researchers have stressed the need for further investigation into the utility of CAI (Stromer et al., 1996). The purpose of the current review is to summarize the empirical research that has been conducted in the past 10 years on the use of CAI to teach academic skills (e.g., literacy, math, science) to students with ASD.

Method

The researcher conducted an electronic search of the Educational Research Information Center (ERIC), PsychINFO, and the Psychology and Behavioral Sciences Collection databases for the years from 1998 to 2008. The researcher used the keywords *autism, Asperger syndrome, computer, assistive technology, computer-assisted, computer-based, and technology.*

In addition, the researcher conducted hand searches of the following journals for the years from 1997 to 2007: *Alternative and Augmentative Communication; Assistive Technology Outcomes and Benefits; Exceptional Children; Education and Training in Mental Retardation; Education and Treatment of Children; Focus on Autism and Other Developmental Disabilities; Journal of Autism and Developmental Disorders; Journal of Special Education Technology; Journal of Applied Behavior Analysis; Journal of Behavioral Education; Research and Practice for Persons with Severe Disabilities; Journal of Speech, Hearing, and Language Research;* and *Language, Speech and Hearing Services in Schools.*

The articles in this review met specific inclusion criteria. First, they were published in a peer-reviewed journal between the years 1998 and 2008. Second, the studies described in each article had to be based on experimental or quasi-experimental research (i.e., the researchers introduced an independent variable and analyzed its effects on a dependent measure). Third, the articles described the manipulation of independent variables that incorporated the use of CAI. Fourth, the researchers described the collection of data on the acquisition of an academic skill (e.g., literacy, writing, math). Finally, at least one of the participants had to be identified as having an autism spectrum disorder (e.g., autism, Asperger syndrome, Rett/Rett's).

Results

The search of research literature produced 15 articles that met the criteria to be included in the current review (see Table 1).

Participants and Settings

Twelve females and 40 males participated in the reviewed studies (N = 52). Eleven of the studies involved three or fewer participants. The remaining studies involved between four and fourteen participants. The participants' ages ranged from 3 to 17 years and the majority of participants (n = 47) were younger than 13 years of age. Forty-five of the participants were diagnosed with autism, three with Rett's disorder, three with Asperger syndrome, and one with pervasive developmental disorder–not otherwise specified.

Researchers conducted the majority of the studies in school settings (n = 12). Six of the studies were conducted in self-contained settings (i.e., special class, special school). The remaining research teams did not report the type of school setting in their descriptions. Researchers conducted two of the studies in university settings and one study in a combination of a home and university setting.

Targeted Skills

All of the investigations involved instruction on skills related to literacy. Eight of the investigations directly involved reading instruction. Seven of the studies involved the acquisition of target vocabulary through match-to-sample activities. The instructional targets in these studies included identifying common nouns, letters, numbers, and food words. One study addressed the acquisition of decoding skills (Coleman-Martin, Heller, Cihak, & Irvine, 2005).

The remaining seven studies investigated written expression. Researchers in three studies evaluated the effects of CAI during spelling instruction. Researchers in two studies involved teaching sentence construction (Basil & Reyes, 2003; Yamamoto & Miya, 1999); one set of researchers explored Japanese character construction (Sugasawara & Yamamoto, 2007); and one researcher addressed the use of CAI to teach self-regulated strategy development (SRSD) to improve essay writing skills (Delano, 2007).

Technology

Researchers used a variety of technology devices. Eight research teams described the use of specific operating systems for implementing CAI. In four of the articles, authors described independent variables that included computers using Apple (Macintosh) operating systems; four described using various other operating systems (i.e., Microsoft, IBM). Two of the studies involved the use of a LightWRITER-SL35, which is a portable text-to-speech word processor, and one team used the Delta Messages software program. Most of the researchers (n = 9) used computer software that was specifically designed for the purposes of their investigations, but five research teams used commercially available technology in their interventions. Two of the research teams used Microsoft's PowerPoint to develop interventions.

The participants used different methods for responding during CAI. In five studies, the participants manipulated a

Table 1. Summary of Studies

Study	Participants	Target Skill/Design	Technology/Student Response	Generalization/ Maintenance	Treatment Fidelity/IOA	Social Validity
Basil & Reyes (2003)	1 female/1 male 8 & 14 years old autism	Sentence construction/ Pretest-posttest	Multimedia software (Delta Messages)/ Mouse click	+/+	–/–	–
Bosseler & Massaro (2003)	1 female/8 male 7–12 years old autism	Vocabulary/ Multiple baseline, pretest-posttest	Computerized talking head/ Mouse click or touch screen	+/+	–/–	–
Clark & Green (2004)	2 male 9–11 years old autism	Matching word to sample/ Alternating treatment design	Matching software/ Touch screen	–/+	–/–	–
Coleman-Martin, Heller, Cihak, & Irvine (2005)	1 female 12 years old autism	Decoding and metacognitive strategies/ Multiple condition with drop down baselines	Microsoft PowerPoint/ Gesture	–/–	+/+	+
Delano (2007)	3 male 13–17 years old Asperger syndrome	Essay writing and SRSD/ Multiple baseline	Computer-based video modeling/ Handwriting	+/+	–/+	–
Hetzroni, Rubin, & Konkol (2002)	3 female 8–10 years old Rett's disorder	Matching word to sample/ Multiple probe	Matching software/ Eye gaze	–/+	–/+	–
Hetzroni & Shalem (2005)	3 female/3 male 10–13 years old autism	Matching word to sample/ Multiple probe	Matching software and computerized fading/	+/+	+/+	+
Kelly, Green, & Sidman (1998)	1 male 5 years old autism	Matching animal/letters to sample/ Training-test	Matching software/ Touch screen	+/–	–/+	–
Kinney, Vedora, & Stromer (2003)	1 female 8 years old autism	Spelling/ Test-teach with timed-lagged replication	Microsoft PowerPoint and embedded video/ Writing	+/+	–/+	–
Mechling, Gast, & Langone (2002)	1 male 9 years old autism	Sight word reading/ Multiple probe, pretest-posttest	Hyper studio, computer-based video/ Touch screen	+/–	+/+	+
M. Moore & Calvert (2000)	2 female/12 male 3–6 years old autism	Matching word to sample/ Pretest-posttest	Matching software/ Mouse click	–/–	–/–	–
Schlosser & Blischak (2004)	4 male 8–12 years old autism	Spelling/ Adapted alternating treatments design	Text to speech writer/ Keyboard	+/+	+/+	+
Schlosser, Blischak, Belfiore, Bartley, & Barnett (1998)	1 male 10 years old autism	Spelling/ Adapted alternating treatments design	Text to speech writer (LightWRITER-SL35)/ Keyboard	–/+	+/+	+
Sugasawara & Yamamoto (2007)	1 male 4 years old PDD-NOS	Constructing and reading Japanese characters/ Pretest-posttest	Matching software/ Mouse click	+/–	–/+	–
Yamamoto & Miya (1999)	3 male 6-10 years old autism	Sentence construction/ Pretest-posttest	Sentence construction software/ Mouse click	+/–	–/+	–

IOA = Interobserver agreement SRSD = self-regulated strategy development. PDD-NOS = Pervasive Developmental Disorders–Not Otherwise Specified.

mouse and used the click function, whereas in four of the studies, the participants used a touch screen. One study involved the participants using eye gaze to make selections, while the teacher recorded the responses and facilitated the participant's interaction with the technology. During two of the studies, the participants responded by pressing keys on a keyboard. The remaining three studies involved the observation of stimuli on the computer by participants, but a response was by using topographies independent of computer technology. For example, Coleman-Martin et al. (2005) used software that highlighted parts of words and provided auditory cues for participants to sound out words using internal speech.

Instruction

Authors of eight of the articles included a description of pretraining sessions that occurred on the use of technology prior to intervention. Pretraining conditions varied in format and duration across the investigations. Researchers used demos, the presentation of computer tasks that gradually increased in complexity, familiarization sessions, and behavioral instruction during pretraining sessions. Researchers addressed a variety of skills during the pretraining sessions. Bosseler and Massaro (2003) spent several months teaching participants to interact with a computerized talking head named Baldi. During training, Baldi presented instructional targets previously acquired by the participants. The researchers then reinforced participants for interacting with Baldi. Several researchers taught basic attending skills (e.g., tracking the cursor, sitting). One research team allowed students 3 days of access to the software so that they could become familiarized with its functions (Basil & Reyes, 2003). Pretraining sessions lasted from one day to several months.

Several studies (n = 6) included software packages designed for independent interaction between the software and learner. In three studies, computers delivered vocal task demands. Bosseler and Massaro (2003) used a computerized talking head to deliver vocabulary instruction. The participants received feedback in the form of electronic "smiley" faces for correct responses and "sad" faces for errors. Hetzroni, Rubin, and Konkol (2002) used technology that provided auditory task demands during instruction and feedback in the form of electronic smiling and frowning cartoon faces. In an attempt to mitigate staffing concerns associated with the delivery of discrete trial instruction, M. Moore and Calvert (2000) developed a behavioral teaching program. The software presented auditory task demands and delivered sounds and images to differentially reinforce correct responses. Two sets of researchers described the computer presentation of only visual stimuli as discriminative stimuli. Hetzroni and Shalem (2005) used software that independently presented visual match-to-sample tasks and provided feedback in the form of computerized smiling face tokens for correct responses. Incorrect responses elicited the repeated presentation of the instructional trial. Yamamoto and Miya (1999) used a software program that independently presented instructional trials and delivered electronic feedback. Correct responses elicited an auditory "fanfare" whereas incorrect responses elicited a beep tone and a 5-s presentation of the correct response. Finally, Delano (2007) developed computer-based video models that were viewed independently by participants prior to writing activities.

More than half (n = 8) of the studies involved various levels of teacher facilitation during the participants' use of software. Four of the authors described procedures in which the teacher delivered instruction while the student responded using technology. Schlosser, Blischak, Belfiore, Bartley, and Barnett (1998) and Schlosser and Blischak (2004) used a copy-and-cover method to deliver instruction while requiring the learner to respond using the LightWRITER-SL35. Kinney, Vedora, and Stromer (2003) and Coleman-Martin et al. (2005) used guided practice while participants viewed PowerPoint slides with embedded video. In another study, the teacher controlled the software presentation of stimuli during computer-assisted instructional trials (Kelly, Green, & Sidman, 1998). Finally, Mechling, Gast, and Langone (2002) vocally directed participants to identify grocery words presented on a computer screen.

Eight authors described the use of additional teacher-mediated feedback (i.e., error correction, reinforcement) during intervention. Two investigations included the use of edible reinforcers for correct responding (Clark & Green, 2004; Kelly et al., 1998). Yamamoto and Miya (1999) used noncontingent reinforcement during instruction by delivering a pat on the shoulder and a small prize following every ninth trial.

Experimental Design

Five of the research teams used only pretest and posttest comparisons to evaluate the effects of intervention on dependent measures. Two research teams used pretest-posttest procedures in combination with single-subject designs. Mechling et al. (2002) used pretest and posttest measures to demonstrate participants' acquisition of grocery words. Bosseler and Massaro (2003) used pretest and posttest measures to demonstrate overall group improvement in word identification skills.

Ten of the research teams used single subject designs during their investigations. Two research teams used multiple baseline designs (i.e., Bosseler & Massaro, 2003; Delano, 2007) and three used multiple probe designs (i.e., Hetzroni et al., 2002; Hetzroni & Shalem, 2005; Mechling et al., 2002). One team, Kinney et al. (2003), employed a test-teach design across three stimulus sets in a time-lagged fashion. Two teams used adapted alternating treatments designs (i.e., Schlosser & Blischak, 2004; Schlosser et al., 1998) and one team used an alternating treatments design (i.e., Clark & Green, 2004). Finally, Coleman-Martin et al. (2005) used a multiple conditions design with drop-down baselines.

Efficacy

Generally, the data in the 15 studies led researchers to conclude that the participants acquired targeted academic skills. Five of the authors described comparison studies. Clark and Green (2004) evaluated the acquisition of dictated-word/symbol relations across two procedures. During a delayed cue procedure, the computer presented a set of stimuli and then faded distracters following a gradually increasing delay. In an exclusion procedure, the computer presented a set of stimuli in which at least one of the distracters was familiar to the participant. The researchers determined that the delayed cue procedure was more efficient in terms of number of trials to criterion. M. Moore and Calvert (2000) found that students were more attentive and learned more words during CAI than during teacher-led instruction conditions. In addition, more students elected to stay in treatment during the CAI condition. Coleman-Martin et al. (2005) found that CAI and teacher instruction was more efficient in terms of sessions to criterion than CAI or teacher instruction alone.

Two teams of researchers compared the effects of using the cover-and-copy method and different types of electronic feedback during spelling instruction. Schlosser et al. (1998) found that in terms of numbers of sessions to criterion, auditory feedback was more efficient than visual feedback. In a replication of the previous study, Schlosser and Blischak (2004) found differentiated results across participants. Two of the participants met criterion first in a print (visual) feedback only condition, and two of the participants in a speech (auditory) and print feedback condition.

Generalization and Maintenance

Nine authors described the generalization of intervention effects. Basil and Reyes (2003) reported gains in literacy skills that were not explicitly taught during intervention. Though their intervention was designed to teach sentence construction, one student demonstrated gains on measures of phonological awareness, word spelling, and spontaneous writing. Similarly, Sugasawara and Yamamoto's (2007) participant acquired reading responses following training on a Japanese character construction task. Following training conditions, Bosseler and Massaro (2003) conducted probe sessions in which a human instructor presented novel exemplars of instructional stimuli. They reported that the participants generalized learning to novel conditions. Kelly et al. (1998) demonstrated the generalization of treatment effects to novel stimuli. During generalization conditions, the participants responded to different line drawings and photographs representing the same objects presented during training. Hetzroni and Shalem (2005) presented generalization tasks following computer-based match-to-sample activities that included the matching of trained stimuli to cards and objects. Four of the six participants demonstrated high levels of generalization (i.e., greater than 80%) and two demonstrated minimal levels of generalization (i.e., between 25% and 40%). After teaching students to use SRSD strategies to improve performance in writing persuasive essays, Delano (2007) demonstrated generalized effects to expository writing.

Two authors found that spelling skills taught with CAI generalized to the spelling of untrained words. After teaching a student to spell words by using a computer-based video model, Kinney et al. (2003) systematically taught a student to spell novel words based on elements of trained words. In addition, they cited anecdotal increases in the oral reading of trained words. Schlosser and Blischak (2004) demonstrated the generalization of spelling skills for two of four participants to untrained words.

Yamamoto and Miya (1999) described the generalization of newly acquired sentence construction skills to novel response topographies. Following CAI, the participants demonstrated increases in vocal and written sentence construction.

Authors for the majority of the studies ($n = 10$) described procedures for assessing the maintenance of acquired skills. Follow-up data probes were conducted from 1 week to 6 months following intervention. All of these investigations resulted in high levels of skill maintenance. Five of the authors reported that the participants maintained skills for more than 3 months. Two of the research teams reported the maintenance of skills after 6 months (i.e., Basil & Reyes, 2003; Hetzroni et al., 2002).

Reliability

Eleven of the research teams reported dependent variable reliability. Agreements were consistently high, ranging from 84% to 100%. Fewer of the research teams ($n = 5$) reported independent variable reliability. The researchers reported accuracy measures ranging from 97.6% to 99%.

Social Validity

Few research teams addressed measures of social validity. Two research teams used teacher questionnaires to determine the appropriateness of the research procedures for participants (i.e., Schlosser & Blischak, 2004; Schlosser et al., 1998) One team selected instructional stimuli based on teacher and parent reports (i.e., Hetzroni & Shalem, 2005). The remaining two research teams gathered social validity data following intervention. Coleman-Martin et al. (2005) used a questionnaire to determine that the teachers perceived the intervention to be acceptable and effective. Mechling et al. (2002) used interviews to determine that parents perceived their children demonstrated improved performance in community settings.

Quality of Studies

Despite reports of student improvement across all of the studies, the majority of research teams did not demonstrate a functional relation between the use of CAI and increases in target responses. Of the 10 articles describing the use of single subject designs, one of the studies used an AB-type design (Coleman-Martin et al., 2005). This design did not allow for the adequate replication of treatment effects to demonstrate experimental control. In two other studies, the demonstration of experimental control was reduced by students' increasing trends in baseline conditions (Bosseler & Massaro, 2003; Mechling et al., 2002). Of the three research teams that used comparison designs, only two directly compared treatment to baseline conditions (Schlosser & Blischak, 2004; Schlosser et al., 1998). None of the three research teams replicated treatment effects within participants or across participants in a time-lagged fashion. The four remaining research teams employed multiple probe or baseline-type designs and were able to demonstrate clear functional relations between operationalized interventions and targeted responses (Delano, 2007; Hetzroni et al., 2002; Hetzroni & Shalem, 2005; Kinney et al., 2003).

Of the authors that described the use of pretest-posttest procedures, only one team (M. Moore & Calvert, 2000) used any randomization of their participants, and no research teams compared treatment effects to a control group. Generally, the studies used small numbers of participants and, therefore, were unable to conduct meaningful statistical analyses. Only three teams reported the use any statistical analysis procedures. M. Moore and Calvert (2000) used a one-way ANOVA to compare the effects of teacher-based instruction and CAI. Basil and Reyes (2003) and Bosseler and Massaro (2003) used *t* tests to compare pretest and posttest measures. The remaining authors reported effects as percentage of increases from pretest to posttest measures. Finally, none of the research teams in the current review reported the use of parametric (i.e., effect size) or nonparametric (i.e., percentage of overlapping data points, improvement rate difference) procedures to determine effect sizes.

Discussion

Despite a limited body of research, analysis of the current review of literature suggests that CAI may have promise as an effective intervention component for students with autism. Horner et al. (2005) proposed that a practice might be deemed as evidence-based if it (a) is clearly operationalized, (b) has been demonstrated to be effective in a minimum of five single-subject studies (c) conducted by at least three different research teams (d) across three different geographical locations, and (e) if those studies included a minimum of 20 participants. Similarly, Gersten et al. (2005) set forth criteria for defining an evidenced-based practice using group experimental or quasi-experimental research. They suggested that a practice should be supported by at least four studies of acceptable quality or two high-quality studies and that weighted effect sizes are calculated to be significantly above zero. The reviewed studies clearly did not meet either sets of criteria for determining CAI as an evidenced-based practice, but they do add to the limited body of research on teaching academic skills to students with ASD. Fifteen different teams of researchers across different geographical areas evaluated the effects of CAI on the acquisition of academic skills. All of the 52 participants acquired targeted academic skills when CAI was used during instruction. Researchers also demonstrated that interventions that included CAI were more efficient than teacher-only instruction and resulted in more appropriate behavior during teaching sessions. Additionally, the majority of the authors described generalization and maintenance of newly acquired skills by the participants. This is particularly significant in that difficulties in generalization are pervasive in students with ASD (Koegel & Koegel, 1995). Interestingly, Yamamoto and Miya (1999) reported that skills learned during CAI generalized to different response topographies (i.e., handwriting, vocal behavior). These findings are especially encouraging in documenting that technology evoked vocal behavior, a response that is absent in a large number of individuals with ASD.

The majority of the studies (n = 11) included measures of interobserver agreement. Unfortunately, only one third of the research teams reported collecting independent variable reliability data. This finding is consistent with the observations of other researchers. McIntyre, Gresham, DiGennaro, and Reed (2007) reviewed reports of treatment fidelity in the *Journal of Applied Behavior Analysis* during the years 1991 to 2004. They found that only 30% of the articles reviewed contained independent variable reliability data. The delivery of CAI is complex and involves many instructional variables (e.g., training, reinforcement, error correction). It is imperative that researchers evaluate the efficacy of CAI in the context of rigorous implementation to increase the likelihood of successful replication and generalization to applied settings.

Another interesting finding is that despite the wide availability of educational software, researchers have investigated the use of CAI only on literacy skills. This finding is not surprising in light of the increased focus on reading research during the past decade (National Reading Panel, 2000). Researchers may have selected literacy skills because they are typically affected by the communication deficits associated with ASD. The presence of communication deficits may also have determined the types of skills that were addressed. Most of the studies involved the acquisition of basic literacy skills (i.e., picture matching, word identification, spelling). Only two researchers focused on the acquisition of more complex skills (i.e., decoding, essay writing). Researchers investigated the effects of several types of technologies on skill acquisition. All of the independent variables included the presentation of visual stimuli during instruction. Many of the interventions involved computer-based match-to-sample activities in which participants responded by selecting from a visual array. Researchers also incorporated the use of computer-based video models to teach students new skills. The effectiveness of the computer-based technologies that incorporate visual media is not surprising in that the use of visual supports during instruction has been recommended by interventionists in the area of autism (Hodgdon, 1995; Quill, 2000).

Five teams of researchers investigated technology that is commercially available. It is encouraging that the widely available Microsoft PowerPoint was used to develop instructional materials. It is important to continue to develop affordable and accessible technology in the context of fluctuating special education resources. It is disheartening that the current review included only one commercially available multimedia software program, despite the numerous educational software programs that are used in school settings. It is imperative that these programs, which typically come with a large price tag, be evaluated for use with children with ASD. These products should be evaluated within the context of experimental designs.

Several research teams ($n = 6$) demonstrated that students were able to acquire skills through independent interactions with computer technology. Researchers demonstrated that software programs effectively delivered task requests, reinforcement, and error correction. Software programs that can effectively deliver instruction may be invaluable to educators for delivering increased amounts of direct instruction during the school day. Additionally, this software may provide a way for parents who are not trained in instructional methodology to deliver instruction in the home setting.

Future researchers should involve the use of CAI in other academic areas. Students with autism may benefit from CAI in mathematics, science content, and social studies content. The articles included in this review also provided limited information about the environments in which CAI was evaluated. In light of recent trends toward inclusion, researchers need to evaluate the effectiveness of CAI in general education settings and in the contexts of varying instructional arrangements. If CAI can be effective in one-to-one arrangements, researchers need to evaluate the effectiveness of CAI during group arrangements. Innovations in Internet and virtual reality technologies may afford opportunities for individuals with ASD to interact with instructors and other students from separate locations.

Researchers also need to conduct further analyses of educational software packages to determine the most effective components (e.g., task presentation, feedback) for students with autism. Higgins and Boone (1996) developed guidelines for developing educational software for students with autism based on available research (e.g., varied presentation, portability, naturalistic stimuli, real-world counterparts to computer-based lessons). They stressed the importance of considering the wide variability across individuals with autism, but they made several recommendations that, a decade later, remain to be empirically validated.

In conclusion, researchers have demonstrated the effectiveness of various forms of CAI for teaching academic skills to students with autism, although the absence of experimental control in most of the studies makes these conclusions tenuous. It is important to interpret these results with caution because of the limited quality and number of studies included in this review. It also is important to note that an effect size was not calculated for the studies, and therefore CAI may not be compared to other teaching methodologies. Overall, the current review provided data suggesting that CAI has noteworthy potential for improving the lives of individuals with ASD and exposed several unexplored areas in the research literature that relate to instructional arrangements, technology components, and the evaluation of commercially available software. Clearly, recent innovations hint at the endless possibilities for the application of computer-based technologies in programming for students with ASD.

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