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ORIGINAL PAPER

Technology-Aided Interventions and Instruction for Adolescents with Autism Spectrum Disorder

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Abstract The use of technology in intervention and instruction for adolescents with autism spectrum disorder (ASD) is increasing at a striking rate. The purpose of this paper is to examine the research literature underlying the use of technology in interventions and instruction for high school students with ASD. In this paper, authors propose a theoretical and conceptual framework for examining the use of technology by and for adolescents with ASD in school, home, and community settings. This framework is then used to describe the research literature on efficacy of intervention and instruction that utilizes technology. A review of the literature from 1990 to the end of 2013 identified 30 studies that documented efficacy of different forms of technology and their impact on academics, adaptive behavior, challenging behavior, communication, independence, social competence, and vocational skills.

Keywords Technology · Autism spectrum disorder · Adolescents · Natural settings

Few individuals in the world are untouched by some form of technology; they wear it on their wrists, carry it in their pockets or purses, go to sleep and wake up to it, and may even depend on it to keep their heart beating at the right pace. The rapid "uptake" of technology in interventions and teaching strategies that affect the daily lives of individuals with autism spectrum disorder (ASD) is a prime example of this

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phenomenon and is reflected in the large number of studies that have emerged in recent years (Boser et al. 2014; Grynszpan et al. 2014; Keintz et al. 2013; Knight et al. 2013; Mechling 2011; Pennington 2010; Ploog et al. 2013; Ramdoss et al. 2011a, b, 2012; Wainer and Ingersoll 2011). The unique appeal of electronic technology for children and youth with ASD (Kuo et al. 2014; Mazurek et al. 2012; Mineo et al. 2009; Shane and Albert 2008) has engendered much excitement about its use in educational, clinical, and community settings. This enthusiasm has led to a somewhat unbridled adoption of applications and equipment with little regard for, or knowledge about, the efficacy of such approaches, or their potential collateral effects. Discussing communication needs of individuals with ASD, Shane et al. (2012) noted, "caution must continue to be exercised to ensure that the dazzle of this impressive technology does not replace a methodical, clinical process that matches a person … with optimal communication technology available (p. 1229)." This statement holds true for other forms of technology that have yet to be demonstrated effective via high quality research studies.

The purpose of this paper is to examine the current research on the use of technology in educational settings the community, and in homes for adolescents with ASD and their families. The rationale for focusing on adolescents is that in the autism intervention literature, researchers and scholars have paid less attention to this age group, with research studies primarily including preschool- and elementary-age children as participants (Wong et al. 2014). However, given the dismal post-school outcomes for young adults with ASD (Shattuck et al. 2012) and the fact that they are approaching the end of the traditional years of public education where they might access support for technology use, adolescents with ASD are a population for which technology-assisted interventions is very important. In this paper, the authors begin with a working definition of technology, propose a conceptual framework for matching the user, the technology, and the activity (i.e., goals), and use this conceptual framework for organizing research findings. A review of research published between 1990 and 2013 follows with a discussion of findings about the users involved in the research, activity addressed, types of technology, and contexts. The paper concludes with a discussion of the implications for current practice and future directions.

Definition, Theoretical Foundation, and Conceptual Framework

The development and use of technology to assist individuals with ASD is a decidedly interdisciplinary work. Professionals contributing to this development are from the fields of human computer interaction within the broader field of computer science, design, assistive technology, occupational sciences and therapy, rehabilitation engineering, speech-language pathology, learning sciences/psychology, and special education (Porayska-Pomsta et al. 2012). Because disciplines often use different terminologies, a discussion about technology should begin with a common working definition. To establish such a definition for this paper, members of the Technology Work Group from the Center on Secondary Education for Students with ASD (CSESA) drew from the United States (US) federal definition of assistive technology (PL 108-364, http://www.gpo.gov/fdsys/pkg/PLAW-108publ364/html/PLAW-108publ364.htm) and the definition established by the Canadian Association for Occupational Therapy (2012). For the purposes of this paper, technology refers to an electronic item/equipment, application, or virtual network that is used to intentionally increase, maintain, and/or improve daily living, work/productivity, and recreation/leisure capabilities of adolescents with autism spectrum disorders (CSESA Technology Group 2013). "Low tech" or soft technologies, while often effective, are different in instructional features (e.g., two dimensional, non-electronic), and the authors did not include them in this review.

Theoretical Foundation

Persuasion Theory underlies work in the field of human–computer interaction (Fogg et al. 2002). Although its roots stretch back to Aristotle, contemporary interests in Persuasion Theory lie in social psychology, rhetoric, and business. Persuasion Theory focuses on factors within the individual (i.e., capabilities, interests, attitudes), the characteristics of messages or information conveyed, and features of specific contexts, all with the intent of understanding their influences on behavior and attitude change (Reardon 1981). For example, persuasion (e.g., a teacher trying to promote the social communication of a nonverbal adolescent with ASD) may occur through both the content of the message (e.g., a specific greeting to a peer), the cues in the information context that are attractive (e.g., an iPad with voice activation), and motivation provided by the context (e.g., an interest in the peer responding, interest in assistance with a task, engaging in a fun game; Petty and Brinol 2008). Employing this theoretical model to the development of technology, Fogg et al. (2002) proposed that Persuasive Technology is "any type of computing system, device, or application that was designed to change a person's attitudes or behavior in a predetermined way (n.p.)."

Persuasive Technology consists of two key concepts. The first is credibility (Fogg and Tseng 1999), which refers to the trustworthiness (i.e., inherent goodness or morality) and expertise (i.e., functionality) of technology. An example of credibility is a visual schedule application (more commonly termed "app") on a smartphone with tactile cuing that reliably signals an upcoming transition to an adolescent with ASD and visually displays the next activity. The second key concept, *Kairos*, is the delivery of a message at the right time and/or place (Fogg and Eckles 2007). An example of Kairos would be an adolescent with ASD using the smartphone visual schedule app, just described, during the times of the day and locations in which transitions are the most troublesome. Although not without critics, Persuasive Technology has the value of focusing technology design on functionality, perceived value, and its use in context (Mintz and Aagaard 2012). For example, the developers of a project entitled *Helping Autism-diagnosed Teenagers Navigating and Developing Socially* (HANDS, http://hands-project.eu/index.php?page=proj) directly employed principles of Persuasive Technology in their design of a mobile smartphone application for adolescents with ASD (Mintz 2013; Mintz et al. 2012).

Conceptual Framework

The CSESA Technology Group (2013) has proposed a framework for conceptualizing variables affecting the use of technology for adolescents with ASD that is consistent with the principles of Persuasive Technology. It also draws from the Human Activity Assistive Technology Model (HAAT) established by Cook and Hussey (2008). As can be seen in Fig. 1, this model consists of characteristics of the user (e.g., adolescents with ASD), the activity that is to be supported by the technology, and the technology itself. The overlap of these factors represents the ideal user-activity-technology match. These factors are situated within the broader ecological context of school, home, and/or community (Bronfenbrenner 1979).

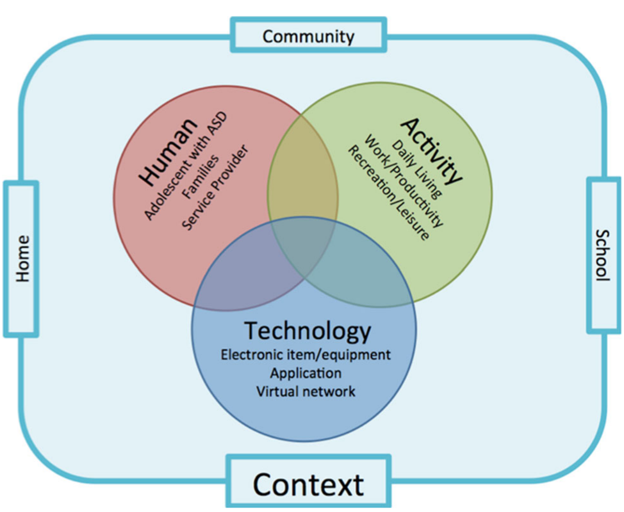

Fig. 1 Conceptual framework for technology-use for adolescents with ASD

Users

The current generation of adolescents is the first to have computer and online technology as a part of their lives since early childhood, and its use is pervasive. In a recent national survey, investigators with the Pew Foundation reported that 78 % of respondents between 12 and 17 years had a smartphone and 95 % were online through some form of technology (Madden et al. 2013). Although the survey did not report information about respondents with ASD, it is reasonable to assume that this demographic description applies to many adolescents with ASD (i.e., they are teenagers as well as being individuals with ASD) and it certainly reflects a peer group context that is technologically active.

For many youth with ASD, technology appears to be particularly engaging (Keintz et al. 2013). Visual presentation of information is a preferred form of learning and support for many adolescents with ASD (Shane and Albert 2008). There is evidence that animated or video presentations are more effective in conveying information than static visual presentations (Van Laarhoven et al. 2010), large screen displays may be more effective than smaller screen displays (Mechling and Ayres 2012), certain types of visual screen media (e.g., seeing self on screen, virtual reality) may be preferred over others (Mineo et al. 2009) and learning tasks presented via a computer and visual medium may result in more efficient performances than the same tasks presented in a tangible format (Mechling et al. 2006). In addition, when given a choice, adolescents with ASD prefer to access and use technology relative to other social and leisure activities. In their study of discretionary time use by children (8–18) with ASD, Mazurek et al. (2012) found that participants spent on average 4.5 h per day using screen-based media (i.e., video games and television) compared to 2.8 h per day in non-screen activities (including playing with friends, engaging in sports and reading). Focusing specifically on adolescents' media use and using 2009 data, Kuo et al. (2014) found that 98 % of the 92 participants with ASD surveyed used computers approximately 5 h per day to watch cartoons and play games. These studies confirm earlier findings from a nationwide survey of transition age youth with disabilities (using 2001 data) that revealed heavy screen-based media use of high school students with ASD (Mazurek et al. 2012).

Activity

The key linkage for using technology to support the daily activities for individuals with ASD is the match between the individualized goal(s) for youth with ASD and the daily activities in which these goals will be addressed. Because of the broad spectrum of characteristics for youth with ASD (e.g., having vs. not having an intellectual disability), the variety of goals is large. The learning needs, and thus the individual learning goals may include communication (Loucas et al. 2008), social competence (Walton and Ingersoll 2013), personal independence (Hume et al. 2009), challenging behavior (Matson et al. 2010), academics (Estes et al. 2011), and/or transition to work and community (Lee and Carter 2012). High school students work on these goals in a variety of contexts like school classes, transitions within or between classes, school activities (e.g., lunch, clubs), the workplace in the community, and/or in the home.

Technology

The technological device or application is the third factor in this conceptual framework. The forms of technology are as broad as the goals themselves, and some of these forms are more available and acceptable with the rapid spread of technology. In their review of technology designed for individuals with ASD, Keintz et al. (2013) identified eight interactive technology platforms: personal computers, use of the web, mobile devices, shared active surfaces, virtual reality, sensor and wearable technologies, robotics, and natural user interfaces.

A variety of examples of these platforms have appeared in the intervention literature. For students who are nonverbal or need augmentative assistance for communication, specialized speech generating devices have been developed (Ganz et al. 2012). More recently the advances in tablet technology include speech generating device applications that operate on commercially available equipment (Kagohara et al. 2013). Service providers and researchers initially used personal digital assistants (PDAs) to support independent performance of individuals with ASD (Gentry et al. 2011), but now smartphones, iPod touches, and MP3 players can accomplish similar functions (Mechling 2011). In the early studies of video modeling, traditional videocassette recorder (VCR) and monitor technology provided video demonstrations (Gelbar et al. 2012). Service providers and researchers now use more portable devices such as tablets and smartphones to collect and design video examples for video modeling interventions as well as to deliver the intervention (Plavnick 2012). Computer-assisted instruction was an early application to support learning of individuals with ASD and other disabilities (Hofmeister and Friedman 1986), and it continues to support a variety of learner outcomes such as academic skills (Ramdoss et al. 2011b) and social competence (Reed et al. 2011). In addition, researchers have explored virtual reality systems in which youth with ASD may participate in social or other activities with an avatar (Hopkins et al. 2011), as well as the use of robotics to simulate facial expressions and interactive engagement (Kim et al. 2013). Bluetooth® and other audio telemetry may allow the traditionally clinic and lab-based covert auditory coaching or "bug in the ear" practice to be extended to the school and community (Allen et al. 2012). Further, the availability of telecommunication systems, such as Skype, FaceTime, and telemedicine, is allowing service providers to deliver interventions to clients in remote locations (Vismara et al. 2009). As Keintz et al. (2013) observed, these platforms exist and the number is growing, but not all have evidence of efficacy.

Contexts

As noted, the selection and use of technology occurs in multiple contexts. Advocates of Persuasive Technology propose that technology use should extend beyond the school and into the home (Mintz et al. 2012), in which case family members are also potential users and supporters of technology in the home and community. Similarly, adolescents with ASD often participate in job training, community living skills training, and/or recreation in the community. Features of these contexts influence the activity or goal and type of technology selected, as well as the critical situations in which the technology may be most helpful (i.e., the Kairos).

The Overlap

The conceptual model proposed here suggests that three factors affect the successful use of technology by adolescents with ASD. These factors are characteristics of the individual (e.g., ASD proclivity for visual display, typical technology interest and use by most adolescents), the activity or purpose for which the adolescent uses the technology (e.g., support for making transitions between classes in a school), and the device itself (e.g., ease and reliability of using a smartphone to provide prompts during class transitions). The overlap of these variables in the Venn diagram in Fig. 1 represents the intersection of information that a teacher, parent, or student should use to make the decision about technology use. Leaving out any of these sources of information may lead to an ill-informed decision.

The CSESA conceptual framework for technology is also useful for organizing information from the empirical intervention literature about technology-assisted interventions.

In the review of the literature in the subsequent section, the authors provide information about the three primary CSESA framework variables as well as the broader ecological contexts in which research occurred.

Review of the Literature

Descriptions of the potential use of technology for individuals with disabilities have appeared in the professional literature in recent years (DiGennaro Reed et al. 2011; Grynszpan et al. 2014; Keintz et al. 2013; Knight et al. 2013; Mechling 2011; Pennington 2010; Ploog et al. 2013; Ramdoss et al. 2011a, b, 2012; Wainer and Ingersoll 2011). However, as Bennett et al. (2013) noted, a question may exist about whether potential applications meet the current standards for evidence-based practice proposed for the field (Gersten et al. 2005; Horner et al. 2005). Recalling the point by Shane et al. (2012), it is essential that the efficacy of interventions incorporating technology be systematically evaluated, so that empirical support as well as enthusiasm guides selection of intervention and instructional practices. To date, a comprehensive review of intervention practices involving technology use specifically for adolescents with ASD has not appeared in the literature. The purpose of this review is to summarize this research base, focusing on the users of technology, the activity/goals addressed, the type of technology employed, and the contexts in which intervention practices are employed for adolescents with ASD.

Previous Literature Search and Selection Procedures

Recently, Wong et al. (2014) conducted a comprehensive review of the intervention literature for children and youth with ASD published between 1990 and 2011. An initial computer search yielded 29,501 articles, which the review team reduced to 1,090 through a stepwise screening process. The review team trained a pool of 154 external evaluators to use a quality indicator rubric for group and single case design to evaluate the methodological acceptability of each article. The methodological criteria were based on the quality indicators established by the Council for Exceptional Children Division for Research (Gersten et al. 2005; Horner et al. 2005). For example, indicators examined the match between research question and dependent variable, comparability of groups for group design, appropriateness of the statistical analysis (for group design), and adequate demonstrations of experimental control (for single case design). Inter-rater agreement was calculated and acceptable (i.e., 92 % for single case design, 84 % for group designs). For the current paper, a subset of the articles that Wong et al. categorized as "technology assisted intervention and instruction" or "video modeling" were selected for inclusion in the current review. To be included, participants in a study had to be between the ages of 13 and 22 years or supporting youth of that age, and the majority of the participants had to be identified as having an ASD (e.g., autism disorder, Asperger syndrome).

The Wong et al. (2014) review covered literature up to 2011. The authors of the current review conducted an additional computer and hand search of the literature for studies published between 2011 and the end of 2013. For this latter computer search, the systematic library search tools included AMC Digital Library, Academic Search Complete, CINAHL, ERIC, IEEE Xplore, PsychINFO, Social Work Abstracts, Medline, and Sociological Abstracts. It incorporated a variety of keyword terms: *autism, Asperger, Pervasive Developmental Disorder, intervention, treatment, practice, strategy, therapy, program, procedure, approach, iPad, iPod, technology, computer, computer-assisted instruction, device, personal digital assistant, computer-based instruction, application, app, virtual,* and *electronic*. In addition, authors examined recent reviews of the literature on selected technology interventions to obtain articles that the searches may have missed (Gardner and Wolfe 2013; Grynszpan et al. 2014; Irish 2013; Knight et al. 2013; Keintz et al. 2013; Mason et al. 2012; Ploog et al. 2013; Ramdoss et al. 2011a, b, 2012; Stephenson and Limbrick 2013; Wainer and Ingersoll 2011). The authors used the same inclusion criteria rubric to evaluate each of the articles generated by this supplemental review.

General Description of Studies

A total of 30 articles (7 group design and 23 SCD studies) met the inclusion criteria as technology interventions for adolescents and young adults with ASD. Table 1 contains summarized information from the studies. Using the conceptual framework presented earlier, information and findings will be reported for user characteristics, activity, and type of technology.

User Characteristics

A total of 238 individuals with ASD and three individuals supporting teens with ASD participated in the reviewed SCD (n = 58) and group design (n = 183) studies, respectively. Eighty-four percent of the participants in SCD and 88 % in the group design studies were male. One group design study (n = 22) did not note gender. In the general ASD population approximately 75–80 % are male (Baio 2014), which suggests that girls are somewhat under-represented in these studies. Seventeen studies included participants with co-occurring conditions. The most frequently

Table 1 Summary of technology articles

Name of tech study	Activity	User characteristics	Technology	Intervention	Context	Design	Outcomes
Allen et al. (2012)	Vocational	N = 3 Male = 2 CLD = 0 CoC = ID (N = 3); seizure disorder (N = 1)	Laptop and audio cueing device (head set paired with cell phone)	VM and CAC	Community	S	Video modeling resulted in little to no change in behaviors, skills increased to criterion for all participants following audio cueing
Allen et al. (2010)	Vocational	N = 3 Male = 3 CLD NR CoC = ID (N = 1)	Videotape model of skill in vocational task	VM	Community	S	Met criterion for engaging in multiple behaviors in vocational task (advertisement character for store)
Bennett et al. (2013)	Vocational	N = 3 Male = 2 CLD = 1 AA CoC NR	Covert audio-coaching device (two way radio with head set)	CAC	Community	S	Increased frequency and accuracy of shirt folding task in community worksite
Bereznak et al. (2012)	Independence	N = 3 Male = 3 CLD = 2 AA, AsA CoC NR	Video prompting on iPhone	VP	School	S	Increased independent completion of steps in using a washing machine, making noodles, and using the copy machine
Burton et al. (2013)	Academic	N = 3 (with ASD; total participants N = 4) Male = 3 CLD NR CoC NR	Video self-modeling on iPad of completion of mathematics story problem	VM	School	S	Increased independent completion of mathematics story problems and maintained across 6 novel problem types
Cannella-Malone et al. (2011)	Independence	N = 2 Male = 1 CLD NR CoC = ID and Hearing Loss N = 1	Video prompting compared to video modeling for teaching daily living skills	VP	School	S	Video prompting was more effective than video modeling for washing clothes and dishes tasks
Faja et al. (2008)	Social	N = 10 Male = 10 CLD NR CoC NR	Specific face training software developed using black and white photos, Adobe Photoshop and Microsoft PowerPoint	ST	Community	G	Showed greater sensitivity to facial details but did not differ on holistic facial processing from control group.
Golan and Baron-Cohen (2006)	Social	N = 41 and 27 Male = 31 and 23 (Two studies) CLD NR CoC NR	Interactive multimedia presentation of social competence training	ST	Home and Community	G	Increased recognition of complex emotions

Table 1 continued

Name of tech study	Activity	User characteristics	Technology	Intervention	Context	Design	Outcomes
Haring et al. (1995)	Independence	N = 6 Male = 5 CLD NR CoC = ID	Videotape model of purchasing skills paired with in vivo training	VM	Community	S	Video-modeling and in vivo instruction together produced acquisition of purchasing skills
Hart and Whalon (2012)	Academic	N = 1 Male = 1 CLD NR CoC = Moderate ID	Video self-model on iPad	VM	School	S	Increased correct unprompted responses during small group science instruction
Hopkins et al. (2011)	Social	N = 49 Male = 44 CLD = 14 AA = 13 Other = 1 CoC = ID N = 25	Computer-based interactive software using avatar assistants	ST	School	G	Improvements in facial and emotional recognition, social interactions
Johnson et al. (2013)	Independence	N = 1 (with ASD; total participants N = 2) Male = 1 CLD NR CoC = ID	Video prompting on iPod to teach food preparation skills	VP	School	S	Increased independent completion of steps in food preparation across three meals
Kagohara et al. (2010)	Communication	N = 1 Male = 1 CLD NR CoC = OCD, ADHD	iPod used as speech generating device	SGD	School	S	Increased communication
Kellems and Morningstar (2012)	Vocational	N = 4 Male = 4 CLD NR CoC NR	Video model on iPod	VM	Community	S	Increase steps of vocational tasks (e.g., cleaning, taking inventory) completed independently
Mechling and Ayres (2012)	Vocational	N = 4 Male = 4 CLD NR CoC = Mild and moderate ID	Video model on personal digital assistant versus laptop	VM	School	S	Increased completion of fine motor tasks in both conditions; however, much higher level of correct completion with model provided via laptop
Mechling et al. (2013)	Independence	N = 3 (with ASD; total participants N = 4) Male = 3 CLD NR CoC = ID (N = 3); Williams Syndrome (N = 1)	Comparison of commercial video prompting versus custom-made video prompting; both delivered on laptop	VP	School	S	Both modes of video prompting resulted in increased independent completion of food preparation, however custom-made video prompting resulted in higher level of accuracy for all participants

Table 1 continued

Name of tech study	Activity	User characteristics	Technology	Intervention	Context	Design	Outcomes
Mechling et al. (2006)	Academic	N = 2 Male = 2 CLD NR CoC = Mild and moderate ID	Video recording of choice selection	VP	School	S	Reduced task completion time
Mechling et al. (2009)	Independence	N = 3 Male = 1 CLD NR CoC = Moderate ID	Video and picture prompts on Cyrano Communicator PDA	VP	School	S	Students able to adjust prompt levels used on the PDA and use to independently complete cooking recipes
Mechling and Savidge (2011)	Independence	N = 3 Male = 2 CLD NR CoC = Moderate ID	Picture prompts on Cyrano Communicator PDA	VP	School	S	Increased completion of novel tasks and independent transitioning within and between tasks
Myles et al. (2007)	Independence	N = 1 Male = 1 CLD NR CoC NR	PDA with programming to prompt homework recording	VP	School	S	Increased homework completion
Nepo (2011)	Independence	N = 3 (staff working with adolescents with ASD) Male = 3 CLD NR CoC NR	Bluetooth technology used to record number of prompts given to student with ASD and to give in vivo feedback to staff	CAC	Community	S	Reduction in number of prompts provided to students with ASD
Ozonoff and Miller (1995)	Social	N = 9 Male = 9 CLD NR CoC NR	Videotaped performance feedback during social skills group	PF	School and Clinic	G	Increased performance on Theory of Mind Tasks and ratings of social behavior
Richter and Test (2011)	Transition	N = 3 Male = 2 CLD NR CoC = Moderate to Severe ID	Multimedia presentation	VP	School	S	Increased knowledge of adult outcomes and opportunities
Silver and Oakes (2001)	Social	N = 22 Male NR CLD NR CoC NR	Emotion Trainer software	ST	School	G	Improved understanding of emotions and emotional expression
Soares et al. (2009)	Academic and Behavior	N = 1 Male = 1 CLD NR CoC = Self injury	Desktop computer used to manage self-monitoring	SM	School	S	Increased task completion and decrease in tantrums
Strickland et al. (2013)	Vocational	N = 22 Male = 22 CLD NR CoC NR	JobTIPS online program and VenuGen4 virtual reality interview space with avatars	ST	Community	G	Significant positive effects on interview content skills. Nonsignificant improvement on interview delivery skills

Table 1 continued

Name of tech study	Activity	User characteristics	Technology	Intervention	Context	Design	Outcomes
Stromer et al. (1996)	Academic	N = 1 Male = 1 CLD = NR CoC = ID and Hearing Loss	Desktop computer and software supporting spelling program	ST	School	S	Increased spelling performance
Taylor et al. (2004)	Independence	N = 3 Male = 1 CLD NR CoC NR	Vibrating pager	ST	School and Community	S	Increased ability to produce card to seek assistance in response to pager vibration
Van Laarhoven et al. (2010)	Independence	N = 2 Male = 2 CLD NR CoC = ID	Video display on laptop computer	VP	School	S	Increase in independent performance of self-care tasks
Van Laarhoven et al. (2012)	Vocational	N = 3 (with ASD; total participants N = 6) Male = 3 CLD NR CoC = ID and Down Syndrome	DVD of video model	VM	Home and Community	G	Increase steps of vocational tasks (e.g., food prep, loading dishwasher) completed independently
Yakubova and Taber-Doughty (2013)	Independence	N = 2 (with ASD; total participants N = 3) Male = 2 CLD NR CoC NR	Video modeling and electronic self-monitoring checklist on electronic interactive whiteboard	VM and SM	School	S	Increased independent completion of cleaning tasks

CLD culturally and/or linguistically diverse, *NR* not reported, *AA* African American, *AsA* Asian American, *CoC* co-occurring condition, *ID* intellectual disability, *CAC* covert audio coaching, *PF* performance feedback, *ST* specific training, *SGD* speech generating device, *SM* self management, *VM* video modeling, *VP* video prompting, *VR* video as reinforcer, *G* group design, *S* single case design

co-occurring condition was intellectual disability (i.e., listed in 15 studies), with a variety of other conditions mentioned in individual studies. Only three articles included racially diverse participants and none reported linguistically diverse participants.

Activity and Goals

As noted previously, the authors defined participant activity by the goals and outcomes of the intervention for individual participants. The activities or goals that researchers reported most frequently were independence (12 studies) followed by vocational (seven studies), academics (four studies), social (five studies) and behavior (two studies). Communication was the goal in one study. The total number of studies exceeds the number in the review because one study (Soares et al. 2009) had two outcomes.

Technology and Its Use in Interventions

As can be seen from Table 1, researchers employed a variety of different forms of technology. In some studies, traditional technology was the focus of the study. Examples of traditional technology included standard desktop computers with specialized software, videotaping performances of participants using VCR technology, and multimedia displays (e.g., PowerPoint presentations). Other studies employed more recent innovations in technology such as smartphones, personal digital assistants, electronic tablets, Bluetooth® technology, and virtual reality applications.

In addition to the form of technology, the authors identified seven types of interventions or instruction in which the researcher used technology. *Video modeling* (VM) depends on the presentation of a video image that provides a demonstration of the behavior in which the participant is to engage. Seven studies employed different types of technology to provide the video model: laptop (Allen et al. 2012), videotape (Allen et al. 2010), iPad (Burton et al. 2013; Hart and Whalon 2012), iPod (Kellems and Morningstar 2012), PDA (Mechling and Ayres 2012), DVD (Van Laarhoven et al. 2012), and electronic interactive whiteboard (Yakubova and Taber-Doughty 2013). Researchers in other studies used technology to *visually prompt* (VP) the participants with ASD to engage in the activity or behavior. In these studies, researchers used iPhones (Bereznak et al. 2012), iPods (Johnson et al. 2013), laptops (Mechling et al. 2013; Van Laarhoven et al. 2010), and PDAs (Mechling et al. 2009; Mechling and Savidge 2011). In several studies, researchers delivered *specific training* (ST) on social skills or academic content through specialized software on standard desktop computers (e.g., Faja et al. 2008; Golan and Baron-Cohen 2006; Hopkins et al. 2011; Silver and Oakes 2001; Stromer et al. 1996). Three interventions utilized *covert audio coaching* (CAC) to reinforce students' on-task performance (Bennett et al. 2013), prompt employees to exhibit specific behaviors (Allen et al. 2012), or remind service providers to reduce the number of prompts they were giving to students (Nepo 2011). In other single studies, researchers used technology for *speech generating devices* (SGD; Kagohara et al. 2010), *performance feedback* (PF; Ozonoff and Miller 1995), reinforcement (Mechling et al. 2006), and *self-management* (SM; Soares et al. 2009).

Contexts

The majority of studies (20) took place in school settings, while 11 studies occurred in the community or in community work sites. A smaller number of studies (2) occurred in the home and both were in combination with intervention in the community. One study occurred in a combined school and clinic context.

Discussion

The current study contributes to the literature in five important ways. First, it focused the review on TAII for adolescents with ASD. In the autism intervention literature, adolescents with ASD are an under-represented group. Highlighting the high quality studies that have been conducted and their implications would be important. Second, this review was comprehensive in that it provided information across outcomes, types of interventions, and technology platforms. Other previous reviews of TAII have focused on individual outcome areas such as social communication (Irish 2013; Ploog et al. 2013; Ramdoss et al. 2011a; Wainer and Ingersoll 2011), social skills (DiGennaro Reed et al. 2011; Ramdoss et al. 2012) or academic skills (Knight et al. 2013; Pennington 2010; Ramdoss et al. 2011b). Third, the current review included both single case design and group design studies, whereas other comprehensive reviews have at times left out single case design as an acceptable methodology (Keintz et al. 2013). Fourth, in the current review the authors used a systematic evaluation process to evaluate and include only studies of high methodological quality, whereas some previous reviews did not follow a systematic evaluation of methodology. Last, the authors proposed a conceptual framework for organizing information from the research literature that was consistent with current thinking in the fields of assistive technology and human computer interaction.

In this review, authors used the CSESA technology conceptual framework for summarizing current knowledge about the uses of technology in interventions for students with ASD. One factor in this framework focused on users, and the literature appears to be addressing participants with ASD across the spectrum, involving students with and without intellectual disability as well as those having other co-occurring conditions. However, boys were even more over-represented in these studies than naturally occurs in the ASD population, and a future focus on including girls in intervention studies would be warranted. Also, few researchers included children from ethnically, linguistically, or racially diverse backgrounds and in fact few reported these variables at all. This finding is consistent with the broader literature on representation and report of ethnicity in autism research (Pierce et al. 2014). Examining factors related to technology use and racial/ethnic/linguistic diversity would be an important direction for research in the future.

The second factor in the CSESA framework was activity, which was also reflected in the goals for participants and outcomes. The selection of activity/goals that are relevant for students' lives reflects a key Persuasive Technology concept of trustworthiness (i.e., the activity having relevance for participants' lives). Examples include shirt folding at a community work site (Bennett et al. 2013), increased independent and academic performance at school (Burton et al. 2013; Mechling and Savidge 2011), and increased food preparation and clothes washing at home (Van Laarhoven et al. 2012). Also, the studies in this review addressed the range of activity/goals that would be a concern for adolescents with ASD in high school programs: independence, vocational skills, academics, and social competence. However, only one study (Kagohara et al. 2010) focused specifically on communication, and used commonly available technology (iPods) for the purpose of generating speech for nonverbal students. This was surprising given the communication needs of nonverbal adolescents with ASD and the advances researchers are making in that area (Achmadi et al. 2012). It may well be that such innovative practices are not being frequently used in this age range or that studies did not meet methodological criteria, which is discussed further in a subsequent paragraph. Regardless, more research is needed in this area.

The third factor in the CSESA framework is technology. The variety of technology that researchers employed in these studies was broad and reflects the increasing sophistication of the technology itself and its utilization in practice. As would be expected, studies from the 1990s employed standard videotape technology (Haring et al. 1995; Ozonoff and Miller 1995) and desktop computer software (Stromer et al. 1996). The utility of the current technology allows for creation of potentially effective applications to important problems in contexts. For example, the ability to provide video models and video prompts on smartphones and electronic tablets (Bereznak et al. 2012; Hart and Whalon 2012) overcomes the past problems of only having an unwieldy video monitor through which to provide a video image, usually in limited locations. Similarly, the CAC practice was previously limited to clinical contexts, but with the advent of Bluetooth® and other audio-telemetry technology (Bennett et al. 2013; Nepo 2011), researchers may incorporate it into interventions that promote students' performances or address other perennial problems in the field (e.g., how to reduce staff over-prompting). These utilizations of technology exemplify the expertise principle from Persuasive Technology noted previously. That is, the research is solidifying the reliability and to some extent, standardization of technology that students or staff may use with confidence in their daily activity.

The three factors in the CSESA technology framework are situated in the broader ecological contexts. Importantly, studies in this review primarily took place in school, community, and to some extent home contexts. They are not subject to the criticism sometimes applied to intervention research only happening in a laboratory or clinical settings (Kasari and Smith 2013). The contexts in which students use the interventions in these studies build upon the Persuasive Technology concept of Kairos. For the most part, the technology-based interventions in this review occurred in the contexts, times, and situations where they could be useful for students.

Although 30 studies met the methodological and content selection criteria for inclusion in this review, some relevant studies did not meet the criteria and were omitted. The field has moved forward in establishing methodological standards for efficacy research in recent years, especially for single case design (Gersten et al. 2005; Horner et al. 2005; Kratochwill et al. 2013). In this review, the authors used a standard article evaluation rubric. For example, current standards required three demonstrations of a functional relationship between the independent (i.e., the intervention) and dependent (i.e., the outcomes) variables. A number of studies, which were quite well designed otherwise, did not meet the three demonstration criteria (e.g., multiple baseline designs across two participants).

The intervention literature has documented important positive outcomes of technology use for adolescents with ASD, however little is known about the collateral, and possible negative, effects that could occur (e.g., over-use of technology to the exclusion of engagement in other activities, cyber-bullying, social stigmatization even when using popular devices). To date, only a few researchers have examined the use of technology by adolescents in schools, home (e.g., Kuo et al. 2014; Orsmond and Kuo 2011), or communities. The exception is the National Longitudinal Transition Study-2 (Newman et al. 2011), which provided general information about high school experiences for students with ASD and other disabilities. From the NLTS-2 dataset, Newman (2007) reported that computers were rarely used in academic instruction for students with ASD, with no report of other technology use. However, NLTS-2 data were collected before the current wave of technology and apps. Obtaining an understanding that goes deeper than the popular media coverage and testimonials would be important. It could provide valuable insights into the possibility of the positive and collateral effects of intervention, the actual usage of technology in typical high school and community contexts, and the potential barriers to and facilitators of technology use. A national study such as this does not exist and should be a direction for future research.

One limitation of this review may be that it did not tie the tripartite conceptual organization of the information from studies to the relative efficacy of the TAII interventions. That is, if there were a close match between participant, goal, and outcome, for TAII interventions, then one could expect that the effect sizes of the intervention might be larger than in studies where this match did not occur. Because the current study was a review rather than a meta-analysis, effect sizes were not calculated. In fact there is not complete agreement on how one calculates effect size for single case design studies nor whether effect sizes from single case and group designs should be mixed (Kratochwill et al. 2013). Also, because of the selective nature of the review process, only high quality studies were included in the review and the outcomes for the interventions were almost always positive, which reduces the variance that would be needed for comparison among studies.

Conclusion

The research literature reported in this review supports the use of technology in interventions and instruction for adolescent students with ASD, which is consistent with other recently published reviews of the broader age-range for individuals with ASD (Fletcher-Watson 2014). Technology has been used to provide models or prompts to engage in the behaviors being learned, to provide performance feedback or self-monitoring, to systematically teach skills or concepts through software presented on traditional desktop computers, and in one case to generate speech on iPod technology. Researchers have conducted these studies with students across the autism spectrum in naturalistic locations such as schools and community settings. The research is also accelerating, with the majority of the acceptable studies published since 2006. Certainly, the next step in this program of research will be to translate this research into practices that are feasible in a variety of contexts and design professional development that may move the research-based practices into common use for adolescents with ASD who may be in need of the interventions.

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* Indicates intervention studies included in the review of the literature

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