Autism, Augmentative Communication, and Assistive Technology:
What Do We Really Know?

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This article provides a review of the empirical literature on a number of topics related to augmentative and alternative communication (AAC) and assistive technology as they have been used to support communication and learning in individuals with autism/PDD-NOS. The review is presented in six main topic areas: Assessment, Staff/Family Training, Supports for Augmented Input, Supports for Augmented Input + Output, Supports for Augmented Output, and Assistive Technology for Communication and Learning. Finally, recommendations for future research are provided.

This article provides a review of the published, empirical literature through 1999 on a number of topics related to augmentative and alternative communication (AAC) and assistive technology as they have been used to support communication and learning in individuals with autism/PDD-NOS. First, a brief description of the criteria used to select the papers reviewed in this article and the search strategies used to locate them will be provided. Then, the review will be presented in six main topic areas: Assessment, Staff/Family Training, Supports for Augmented Input, Supports for Augmented Input + Output, Supports for Augmented Output, and Assistive Technology for Communication and Learning. Finally, recommendations for future research will be provided.

Selection of Sources

Several criteria were established for selecting the sources reviewed in this paper. Papers had to meet all of the criteria in order to be included.

1. Only studies that used aided AAC symbols were included in the review. *Aided symbols* require some type of device or aid that is external to the user's body, while ***unaided symbols*** require nothing other than the user's body parts to convey a message (Fuller, Lloyd, & Stratton, 1997). Examples of aided symbols include real objects, photographs, and black-and-white line drawings, and examples of unaided symbols include facial expressions, manual signs, and natural speech and vocalizations.

2. Studies were selected only if they included at least one individual with autism or pervasive developmental disorder–not otherwise specified (PDD–NOS). Thus, studies that focused on AAC or computer technology for individuals with other disorders on the autism spectrum were excluded (e.g., Rett syndrome; Van Acker & Grant, 1995). If individuals with other disabilities also participated in a study, only the results for those with autism or PDD-NOS were examined.

3. Only sources that provided at least minimal evidence related to outcomes were evaluated. Case studies (A-B) were included if they provided rich detail or informal data about an intervention and its impact. Discussion papers, literature reviews, tutorials, and other nonempirical works were not included, even if they focused on autism (e.g., Mirenda & Schuler, 1989).

4. Only published reports that appeared in refereed journals or peer-reviewed book chapters were included. Unpublished dissertations or theses, manuscripts, conference presentations, as well as manuscripts submitted but not yet accepted for publication were excluded.

5. Studies had to focus, at least minimally, on the functional, interactive use of aided AAC for communication or on the learning outcomes associated with assistive technology for instruction. Thus, studies that explored theoretical issues related to AAC (e.g., Kozleski, 1991) or that were designed to teach skills considered by the authors to be "prerequisites" to interactive communication (e.g., Berkowitz, 1990; LaVigna, 1977) were excluded. Studies that explored the use of automated but non-computerized instruction were also excluded (e.g., Russo, Koegel, & Lovaas, 1978; Strickland, Marcus, Mesibov, & Hogan, 1996).

6. Sources written in languages other than English were excluded (e.g., Heimann, Nelson, Gillberg, & Kärnevik, 1993; Nakamura, 1997).

Search Strategy

Several search methods were used to locate the sources reviewed in this article. First, the on-line PsycINFO and ERIC data bases were searched using terms that included *augmentative communication, computer-assisted instruction, autism, autistic, technology, picture, symbol, voice output communication aid,* and *communication.* Second, hand searches of all issues (through 1999) of the *Journal of Autism and Developmental Disorders, Focus on Autism and Other Developmental Disabilities, Augmentative and Alternative Communication,* and the *Journal of Special Education Technology* were conducted. Third, the reference sections of all located sources were reviewed for additional sources that did not appear in the on-line searches. Finally, the author personally contacted several individuals in the AAC field who have previously published books or articles related to one of the topics assigned to this paper to solicit information about additional "in press" manuscripts that might be appropriate to include.

Assessment

In the broadest sense, the goal of AAC interventions is to assist individuals with severe communication disorders to become communicatively competent today in order to meet their current communication needs and to prepare them to be communicatively competent tomorrow in order to meet their future communication needs (Beukelman & Mirenda, 1998). AAC assessment involves the processes by which information is gathered and analyzed so that users of AAC systems and those who assist them can make informed decisions about the adequacy of current communication, communication needs, AAC systems and equipment, instruction, and outcomes.

An excellent example of AAC assessment and subsequent intervention planning was provided in a recent case study describing the process used by a school team to support a 6-year-old boy with autism (Light, Roberts, Dimarco, & Greiner, 1998). The authors used no special procedures for the assessment just because the child happened to have autism; indeed, no "autism-specific" AAC assessment procedures have been documented or reported in the literature to date. However, they did use the general structure of the Participation Model (Beukelman & Mirenda, 1998), a widely-used process for AAC assessment and intervention, to address three primary assessment goals: (1) to gather information about the student's current and anticipated future communication needs and identify priority needs that were unmet; (2) to determine the student's abilities with regard to the sensory, receptive language, expressive communication, symbol representation, lexical organization, and motor skills needed for communication; and (3) to investigate the interaction strategies used by frequent communication partners and identify barriers that limited the student's opportunities to communicate.

The authors used a combination of interviews (e.g., with parents, teachers, etc.), a communication needs survey (Beukelman & Mirenda, 1998), ecological inventories (Reichle, York, & Sigafoos, 1991), systematic observations, and both formal and informal (i.e., criterion-referenced) assessment approaches to gather this information. On the basis of the assessment results, they designed a comprehensive AAC intervention to support the student's development of both language forms and language functions. His multimodal communication system consisted of natural speech, pointing and other conventional gestures, a communication book and dictionary, and a Macintosh Powerbook with a high-quality speech synthesizer and Write Out:Loud software (see Note 1).This case study example is unique in that it illustrates the application of state-of-the-art AAC assessment procedures to a child with autism.

Staff/Family Training

The empirical literature specifically focused on staff and family training in AAC and assistive technology with individuals with autism is virtually nonexistent. In fact, only one such study was located in the published literature to date (Stiebel, 1999). In this study, the parents of three children with autism (ages 4–6) were taught a problem-solving intervention to promote the children's spontaneous use of AAC symbols during daily routines at home. The symbols consisted of three-dimensional objects (e.g., candies glued to an index card); associated objects (e.g., an empty videocassette container, an empty juice bottle); and colored photograph picture cards to represent objects, verbs, people, places, and activities. The symbols were displayed in a variety of formats, including folders or boards with velcro, picture albums, and small baskets. The parents were first taught to use the natural teaching paradigm (NLP; Koegel, O'Dell, & Koegel, 1987; Laski, Charlop, & Schreibman, 1988) to teach use of the symbols in specific natural contexts. Then, they were taught to use an 8-step problem-solving intervention to facilitate generalization of the children's symbol use to novel routines in which this did not occur spontaneously. The eight steps included: (1) identifying the problematic routine in which the child did not use the symbols; (2) identifying possible reasons for the problem; (3) brainstorming solutions to increase symbol use; (4) discussing the pros and cons of each solution; (5) selecting the solution that best fits with the routine; (6) planning and implementing a strategy; (7) evaluating the strategy in light of its long-term "fit" with the family's lifestyle; and (8) planning a follow-up meeting to review progress. The results indicated that the children learned to use their symbols spontaneously and that the problem-solving intervention was successful at increasing parent-provided opportunities for communication in daily routines. The authors noted the importance of teaching parents to facilitate communication using strategies that can be embedded into relevant daily routines in home and community settings.

Supports for Augmented Input

AAC interventions include a wide range of strategies and procedures whose common goal is to facilitate an individual's ability either to (a) *communicate* more effectively *with* others (i.e., expressive communication strategies) or (b) *understand* communication *from* others (i.e., augmented input strategies: Wood, Lasker, Siegel-Causey, Beukelman, & Ball, 1998). Although the latter set of strategies has received relatively little attention until recently, there is increasing evidence that many individuals with autism benefit greatly when language input is augmented, particularly through the visual modality (Hodgdon, 1995, 1996; Quill, 1997).

One of the earliest published reports of the use of pictorial symbols (in this case, line drawings) to support comprehension was provided by Lancioni (1983). Three children, two of whom had been diagnosed as having autism (ages 10-4 and 12-8), were involved in a multi-step "training program" that was conducted 6 days a week for 5 hours a day, for a total of over 100 days. They were taught to follow pictorial directions on cards, beginning with simple object discriminations (e.g., touching a pictured object) and terminating with activities that were performed with a peer partner (e.g., carrying an object from the beginning to the end of a row of blocks and dropping the object into a container held by a typical peer). According to the report, both children with autism learned to follow "thousands" of pictorial directions correctly over the course of the study and demonstrated generalized learning with new pictures. This report is among the first to provide support (albeit weak) for the use of visual supports for comprehension.

Schedules

One of the most common augmented input strategies involves the use of pictorial or written schedules to assist individuals to understand and follow predictable activity sequences in school and home settings (Quill, 1997; Wood et al., 1998). In a few published reports investigating this approach, children with autism or their caregivers were taught to use *within-task* pictorial schedules to assist with completion of specific activities in school and home settings. For example, Pierce and Schreibman (1994) taught Robby, a 6-year-old boy with autism, to use a 10-photograph sequence for "getting dressed." Hall, McClannahan, and Krantz (1995) taught a classroom aide to support Larry, an 8-year-old boy with autism, with a pictorial schedule depicting the steps of an independent writing task in his Grade 2 classroom. Finally, Mirenda, MacGregor, and Kelly-Keough (in press) taught the mother of a 6-year-old girl with PDD-NOS and profound deafness to use a within-task schedule for hair-washing to decrease her tantrum behavior.

In other studies, participants used *between-task* schedules to access information about what would happen next as they moved from one activity to the next. For example, Flannery and Horner (1994) used a written schedule to support Aviv, an adolescent with autism who engaged in aggression, self-injury, and property destruction. Aviv was known to exhibit problem behaviors when the sequence and duration of activities at school were unpredictable. Because he was able to read, Aviv was provided with a printed, sequential list of upcoming activities and their durations at the beginning of each school period, and was prompted to consult the list regularly to predict "What activity is next?" When the schedule was not available, he engaged in moderately high rates of problem behavior, compared to no such behaviors when the schedule was provided. Similar results were found in a study with young children (ages 6–8; Krantz, MacDuff, & McClannahan, 1993) as well as in one with older children (ages 9–14; MacDuff, Krantz, & McClannahan, 1993). Such results suggest that individuals with autism can learn to use pictorial or written schedules for independent self-management, and that, at least in some cases, their problem behaviors may be reduced or eliminated when these supports are provided.

Based on the extant research, a number of user-friendly books or manuals are available to assist caregivers in designing pictorial or written schedules that can be used as visual prompts to teach appropriate behaviors and expectations in specific situations (e.g., Hodgdon, 1996; McClannahan & Krantz, 1999; Quill, 1997). Such schedules are similar to social stories used with pictorial symbols (Gray, 1995). Only four published studies (one, a series of uncontrolled case studies) have investigated the efficacy of social stories using pictorial symbols, with children with autism between the ages of 7 and 12 (Hagiwara & Smith Myles, 1999; Kuttler, Smith Myles, & Carlson, 1998; Norris & Dattilo, 1999; Swaggert et al., 1995). All four provided suggestive evidence in support of this approach for teaching appropriate social skills and/or reducing problem behaviors; however, all four studies had various methodological weaknesses, and additional research is needed in this area.

Visual Symbols for Choicemaking

A few published reports have documented the successful use of visual symbols as augmented input related to choicemaking by individuals with autism (e.g., Peterson, Bondy, Vincent, & Finnegan, 1995; Vaughn & Horner, 1995). For example, Vaughn and Horner provided food choices during mealtimes at home to Karl, a young man with autism. Sometimes the choices were presented verbally (e.g., "Do you want *X* or *Y*?") and sometimes they were presented verbally *and* with their corresponding photographs (e.g., "Do you want *X* [show photo] or *Y* [show photo]?"). With verbal choices only, Karl accepted around two-thirds of the foods he chose, and exhibited frequent disruptive and aggressive behaviors. When verbal + photograph choices were provided, Karl's acceptance rate for the foods he chose rose to around 85%, and there were many days on which he rejected no meals and exhibited no challenging behaviors at mealtime. This study suggests that the use of visual symbols to support choicemaking may be of benefit to individuals who require augmented input for language comprehension.

Supports for Augmented Input + Output

The supports in this category differ from those discussed previously in that they are specifically designed to support *both* comprehension (i.e., receptive language) and production (i.e., expressive language). Thus, they include strategies for augmenting both the input to and the output from an AAC user. For example, a recent study explored the effects of various spoken and/or written interaction strategies for input and output on the conversational abilities of 5 literate men with autism (Forsey, Raining-Bird, & Bedrosian, 1996). Each participant with autism engaged in four conversations with the same adult communication partner over a 3-day period. In Condition A, both members of the dyad spoke. In Condition B, the participant with autism spoke and the partner typed all of her messages on an IBM laptop computer, while in Condition C, the opposite occurred. Finally, in Condition D, both members of the dyad typed all of their messages. The results indicated that in the conditions in which one or both individuals typed (i.e., B, C, and D), the participants with autism produced significantly longer utterances than in Condition A, when only spoken language was used. The results provide some support for the use of the written mode as a possible augmentative tool for both input and output in interactions with literate, speaking persons with autism.

Aided Language Stimulation (ALS)

Aided language stimulation (Elder & Goosens', 1994; Goosens', Crain, & Elder, 1995) is another AAC "input + output" approach, the goal of which is to teach individuals to understand and use visual–graphic symbols for communication. In ALS, a communication partner "highlights symbols on the user's communication display as he or she interacts and communicates verbally with the user" (Goosens' et al., 1995, p. 101). For example, the partner might say, "It's time to put the cookie mix in the bowl," while pointing to the symbols "PUT," "COOKIE," "IN," and "BOWL" on a communication display. Augmented input is achieved when the facilitator points to or highlights symbols while he or she is talking. Augmented output is elicited from the user through the use of a rather elaborate hierarchy of nonverbal and verbal instructional strategies. To date, only two unpublished doctoral dissertations have investigated the effectiveness of ALS with individuals with autism (Cafiero, 1995; Dexter, 1998); there are no published studies in this area.

System for Augmenting Language (SAL)

A third type of intervention in this area is the System for Augmenting Language (SAL), which is quite similar to ALS, with two notable exceptions: (a) the use of an electronic voice-output communication aid (VOCA) is considered a critical component (Romski & Sevcik, 1992, 1996), and (2) the elaborate procedures for augmented input and elicitation used in ALS are greatly simplified. In SAL, communication displays using visual–graphic symbols with a printed word gloss are constructed for each learner's VOCA, and communication partners are taught to use the symbols + VOCA to augment their speech input during naturally-occurring communication interactions. Learners are encouraged, though not required, to use the device throughout the day. Like ALS, the SAL relies heavily on partners' cooperation and use of the technique on an ongoing basis in natural settings.

Romski and Sevcik (1996) conducted a 2-year longitudinal study of SAL and its outcomes with 13 students (ages 6–20) with moderate or severe intellectual disabilities and severe expressive communication impairments. Two of the students had autism; one was 7-3 and the other was 16-7 at the start of the study. All of the students were in primary or secondary school classrooms, had no more than 10-word spoken vocabularies, and were ambulatory. They were each provided with portable VOCAs with abstract lexigrams to represent single-word messages. Communication partners were taught to operate the VOCAs and to use them in accordance with the basic components of SAL, as described previously.

The results of the SAL project are quite impressive. All of the participants, including the two with autism, learned to use both referential symbols (i.e., those for which there were real object referents) and social-regulative symbols (e.g., *please, thank you, more, yes, no, finished*) to communicate (Adamson, Romski, Deffebach, & Sevcik, 1992). They used the SAL in an average of 37% of their communications, primarily to make requests, label objects, and answer questions (Romski et al., 1994). Seven of the 13 participants (including the 2 with autism) showed evidence of advanced achievement with regard to symbol use, including: (a) production of messages consisting of two or more symbols in combination (e.g., WANT MORE, HELP PLEASE); (b) production of an increased proportion of spoken words that were rated intelligible over the course of the study (Romski & Sevcik, 1996), and (c) recognition of many of the printed words paired with both referential and social–regulative symbols. At the end of 2 years, individual participant achievements ranged from 20–70 symbols (Romski & Sevcik, 1996); 5 years later, all 13 participants were still using their VOCAs during daily communicative interactions and had a mean of 70 symbols (range = 41–104) (Romski, Sevcik, & Adamson, 1999). The SAL project demonstrated that a naturalistic, "total immersion" approach can be effective in facilitating both receptive and expressive communication skills in individuals with intellectual disabilities, including those with autism.

AAC Supports for Output

Visual-Spatial Symbols

Schuler and Baldwin, in a seminal paper on "nonspeech communication and childhood autism" published in 1981, were among the first to suggest that the relatively strong visual-spatial strengths of individuals with autism were a natural "match" for the use of visual-spatial symbols such as photographs and line drawings for expressive communication. Subsequently, reports of the successful use of such visual–graphic symbols with persons with autism began to appear in the literature, and by the late 1980s, they were widely used in AAC interventions, at least in North America (Mirenda & Mathy-Laikko, 1989; Mirenda & Schuler, 1989; Mirenda & Erickson, in press).

Many of the published studies of the use of visual–spatial symbols for expressive communication with individuals with autism have incorporated Picture Communication Symbols (PCSs; Mayer Johnson Co., 1994) to represent messages (e.g., Hamilton & Snell, 1993; Mirenda & Santogrossi, 1985; Rotholz, Berkowitz, & Burberry, 1989). Others have reported the use of photographs (Stiebel, 1999), rebuses + Pictograms (Reichle & Brown, 1986), or non-specific graphic symbols (e.g., Garrison-Harrell, Kamps, & Kravits, 1997; Sigafoos, 1998). The studies have explored various aspects of instruction related to AAC instruction; in most cases, the fact that the participant(s) were on the autism spectrum was incidental to the purpose of the study. One exception was a case study by Mirenda and Santogrossi, who successfully used a "prompt-free" instructional strategy that was specifically designed to teach communication symbol use to an 8-year-old girl with autistic-like characteristics who was overly reliant on instructional cues. The second study was an investigation of the effects of a peer network strategy on the duration of social interaction and social–communicative skills (Garrison-Harrell et al., 1997). In this study, typical peers were successfully taught to engage in social-communicative interactions with three 6- to 7-year-old students with autism via "low-tech" (i.e., non-electronic) visual symbol displays. The results showed increased interaction time for all 3 students with autism and increased expressive language for 2 of them.

The remaining studies, all of which involved individuals with autism or PDD-NOS, have documented the following:

(a) the successful use of milieu techniques to teach communication book use to an adolescent (Hamilton & Snell, 1993);
(b) two adolescents' successful use of communication books but not manual signs in community settings (Rotholz et al., 1989);
(c) the instructional procedures used to teach an adult to use a multipage communication book (Reichle & Brown, 1986);
(d) strategies used to teach conditional use of a "WANT" symbol to a 6-year-old boy (Sigafoos, 1998); and
(e) the use of a problem-solving intervention to increase both communication opportunities provided by parents and the spontaneous use of photograph cards by young children in home settings (Stiebel, 1999).

The papers reviewed so far in this section were designed to investigate a wide range of visual-spatial symbols as techniques for expressive communication. In addition, several papers are related to two specific techniques for communicative output, the Picture Exchange Communication System (PECS) and functional communication training (FCT). These will be summarized and reviewed in the sections that follow.

Picture Exchange Communication System

The Picture Exchange Communication System (PECS) is a structured behavioral intervention program designed to teach the use of visual–graphic symbols for communication (Frost & Bondy, 1994). It is used widely in North America with children and adults with autism, although it is also applicable to other individuals with severe communication impairments. PECS utilizes visual-graphic symbols (usually PCSs, although photographs and other types of symbols can be used as well). It is unique in that the initial goal is to teach individuals to make requests by handing (i.e., exchanging) symbols for desired items (e.g., foods, drinks, toys) to a communicative partner. Once an individual can initiate this exchange under a variety of conditions and with a wide range of people, the system is gradually expanded to teach additional communicative functions such as labeling and information gathering.

Most of the published data on PECS are anecdotal in nature and are based on the cumulative experiences of the PECS authors at the Delaware Autistic Program (Bondy & Frost, 1994). Bondy and Frost (1998) reported on the use of PECS with a group of preschoolers from this program who had no functional speech or previous AAC systems. Of 19 children who used PECS for less than 1 year, 2 acquired independent speech and 5 developed some functional speech while using PECS. The remaining 12 children used PECS as their sole communication modality. Among 66 children who used PECS for more than 1 year, 39 developed independent speech (59%), 20 others used speech + PECS (30%), and the remaining 7 used only PECS (11%) (Bondy & Frost, 1998). Thus, a total of 89% of the children in the latter group developed at least some functional speech after 1 to 5 years of PECS instruction.

There is also one published study on the use of PECS with participants outside of the Delaware program (Schwartz, Garfinkle, & Bauer, 1998). The study involved 31 children who attended an integrated, university-affiliated preschool; 16 of the children (52%) had autism or PDD-NOS. The study was conducted over a 4-year period, during which the 31 children were exposed to PECS instruction. Over an average of 14 months, all of the children learned to use PECS with both adults and peers in the preschool. They required, on average, 11 months to learn to spontaneously discriminate and exchange "I want + symbol" sentence strips with adults, and an additional 3 months to learn to do this with peers. In a subsample of 18 of these children (11 of whom had autism), 8 (44%) developed robust verbal skills after learning PECS; 6 of these "talkers" had autism. The remaining 10 children (56%) acquired very little speech but continued to use PECS as their primary communicative mode at school; 5 of this group (50%) had autism. From these data, which are generally congruent with those provided by Bondy and Frost (1994, 1998), it appears that PECS can be used successfully to teach at least beginning communication symbol use, and that its use may facilitate speech development when used with children on the autism spectrum under the age of 6. Data regarding the co-development of speech in older children are not currently available (Bondy & Frost, 1998).

Functional Communication Training

The term *functional communication training* (FCT) has been used over the past decade to refer to a set of procedures designed to reduce problem behavior by teaching functionally equivalent communication skills. FCT requires a thorough assessment to identify the function of the behavior of concern, and systematic instruction related to teaching functionally-related alternative communicative behaviors. The growing body of empirical literature demonstrating the efficacy and mechanisms of this procedure has included a number of examples in which AAC techniques were used during intervention with individuals with autism (Mirenda, 1997). In fact, one of the first empirical demonstrations of the potential of FCT involved an 11-year-old boy with autism who had extremely limited expressive language and displayed frequent grabbing and yelling behaviors during the school day (Horner & Budd, 1985). After informal assessment of the conditions in which the behaviors occurred, a decision was made to teach him five manual signs for items that appeared to be related to the grabbing/yelling. In other words, he was taught to request the items for which he usually grabbed/yelled. The data indicated quite clearly that once he had learned to use the signs in the natural environment of the classroom, his sign use increased and his grabbing and yelling behaviors decreased dramatically.

In a review of FCT studies published between 1985 and 1996 in which one or more AAC techniques were used (Mirenda, 1997), 8 of the 52 participants (15%) had autism (Bird, Dores, Moniz, & Robinson, 1989; Campbell & Lutzker, 1993; Day, Horner, & O'Neill, 1994; Horner & Budd, 1985; Horner & Day, 1991; Sigafoos & Meikle, 1996; Wacker et al., 1990). They ranged in age from 7 to 36 (four were 8 years old or younger) and engaged in one or more problem behaviors, including self-injurious behavior, aggression, crying, screaming, property destruction, tantrums, non-compliance, and self-stimulatory behavior, as well as the aforementioned grabbing and yelling. The "messages" or functions of their behaviors included "Pay attention to me" (attention), "I want *x*" (tangibles), and "I don't want to do this" (escape), with the majority (63%) in the latter group. A variety of AAC techniques were taught as alternatives to the challenging behaviors, including tangible symbols (1 participant), manual signs and/or gestures (6 participants), a card with printed words (e.g., "I want a BREAK") (1 participant), and line drawing symbols (1 participant). There was an immediate and substantial reduction in the frequency of problem behavior for all 8 participants after the FCT interventions were initiated, and this reduction was maintained for as long as 1 year (follow-up data were not provided for all participants). Since the Mirenda (1997) review was published, additional documentation of the successful use of FCT/AAC as one component of multielement interventions for young children with autism has also appeared in the literature (e.g., Dunlap & Fox, 1999; Thompson, Fisher, Piazza, & Kuhn, 1998). In addition, a recent study provided convincing evidence for the use of VOCAs in the context of FCT/AAC interventions with 5 children, 2 of whom had autism but were over the age of 8 (Durand, 1999). FCT/AAC interventions have the clear advantage of "killing two birds with one stone," in that they teach individuals to communicate one or more functional messages while at the same time providing positive alternatives to their problem behavior(s).

Assistive Technology for Communication and Learning

Numerous assistive technology options are currently available to support the learning and communication of students with a wide variety of disabilities. These include voice output communication aids (VOCAs) as well as computer hardware and software applications that provide writing and/or spelling assistance, support various aspects of learning, and/or facilitate classroom participation in general. In this section, the research specifically related to the use of such technologies with individuals on the autism spectrum will be reviewed.

VOCAs

VOCAs are portable, computerized devices that produce synthetic or digitized speech output when activated. A variety of visual–graphic symbols are used to represent messages, which are activated when an individual uses a finger, hand, optical pointer, headstick, switch, or some other means to select a symbol from the VOCA's display.

Only one published research study has investigated the relative effectiveness of VOCA versus non-VOCA output in persons with autism. In this study, a 10-year-old boy was taught to spell words under three feedback conditions (Schlosser, Blischak, Belfiore, Bartley, & Barnett, 1998). In the auditory–visual condition, the participant received both synthetic speech (via the VOCA) and orthographic feedback. In the visual condition, he received only orthographic feedback; and in the auditory condition, he received only synthetic speech feedback. The participant reached criterion and maintained performance in all three conditions, but his performance was slightly more efficient in the auditory and auditory–visual conditions. It is important to note that this study did not include a condition in which natural speech (as opposed to synthetic speech) feedback was provided. Thus, although it appears that the provision of some type of auditory (i.e., spoken) feedback enhanced learning efficiency with regard to spelling, it is not clear whether *synthetic* speech feedback via a VOCA was essential in this regard.

An additional advantage of VOCAs is that because they provide speech output, they have the potential to be easily integrated into everyday environments with unfamiliar people. This was demonstrated in the aforementioned FCT/AAC study by Durand (1999), in which 5 children (2 with autism) learned to use VOCAs to produce alternative communicative behaviors that served the same functions as their problem behaviors (e.g., "I need help," "I want more"). The study included empirical evidence that following initial instruction, all of the participants were able to use their VOCAs without prompting in novel community settings with untrained community members.

Finally, a third potential advantage of VOCAs is their ability to facilitate natural interpersonal interactions and socialization by virtue of the speech output they provide. Schepis, Reid, Behrmann, and Sutton (1998) investigated this issue in a study of 4 young children with autism (3–5 years old) who had little or no functional speech and attended a self-contained classroom with 4 other children with autism. The participants were taught to use individual VOCAs with line drawing symbols to represent messages such as "I want a snack, please," "more," and " I need help." Each of the messages was activated by touching a single symbol on the display. Naturalistic teaching procedures, including child-preferred stimuli, natural cues such as expectant delay and questioning looks to elicit communication, and non-intrusive prompting techniques were used to teach the children to interact with classroom staff through their VOCAs. Over a 1- to 3-month period, all 4 children learned to use their VOCAs to request items, respond to questions, and make social comments (e.g., "thank you") during natural play and/or snack routines in the classroom. By the end of formal training, the majority of interactions by the children were spontaneous (i.e., unprompted) and contextually appropriate. In addition, classroom staff engaged in a higher frequency of communicative interactions with the children following naturalistic teaching with the VOCA; however, no such effects were seen with regard to child–child interactions (see Note 2). This study provides the first empirical demonstration of the potential of VOCA use for supporting the communicative interactions of children with autism.

Computer-Assisted Instruction

In the 1970s and 1980s, several "concept papers" that presented various rationales for the use of computers with individuals with autism began to appear in the literature. Most were accompanied by anecdotal reports of positive outcomes with regard to, for example, increased peer interactions, motivation, and communication (e.g., Colby, 1973; Frost, 1984, Hedbring, 1985; Panyan, 1984). The first study to compare human instruction and CAI in this population involved 17 children, 6 of whom had autism (4 were 8 years old or younger) (Pleinis & Romanczyk, 1985). Results indicated that although there was no overall difference in participants' learning performance between conditions on a progressively more difficult 2-choice discrimination task, the participants as a group exhibited fewer disruptive behaviors and higher rates of compliance to instruction in the CAI condition. Separate analyses were not conducted for the participants with autism vs. the other participants in this study. However, Romanczyk, Weiner, Lockshin, and Ekdahl (1999) described three unpublished follow-up studies that investigated various aspects of CAI effectiveness specifically with students with autism (ages unknown). Although these three studies did not meet the criteria for inclusion in this article, they seem to provide additional evidence that relationships between behavior and performance during CAI are quite child-specific and interact with the modality, method of instruction, and type of reinforcement or corrective feedback available. In a related study that involved 4 young children with autism in Singapore (Chen & Bernard-Opitz, 1993), 3 showed evidence of more motivation and fewer problem behaviors with CAI, although this did not affect their overall learning rates. In fact, one child's rate of learning was considerably better with human instruction, and one child's was better with CAI. This study supports the conclusions of Romanczyk and his colleagues with regard to the child-specific nature of the effects of CAI.

Two more recent studies provided some evidence of the efficacy of CAI with regard to learning, although neither assessed the comparative effects of CAI versus human instruction. The first study, conducted by a Swedish research team (Heimann, Nelson, Tjus, & Gillberg, 1995), investigated the use of a Swedish version of Alpha (Nelson & Prinz, 1991), an interactive multimedia software program that has been used successfully to teach reading and language skills to children with severe hearing impairments. The study compared the use of Alpha with 11 children with autism (ages 6–14, mean = 9-4 years), 9 children with mental retardation and at least one motor or sensory impairment, and 10 typical preschoolers. Results indicated that children in all three groups made significant gains in reading, phonological awareness, verbal behavior, and motivation over the course of the study (approximately 5 months). In the second study, an adult with mental retardation, a profound hearing impairment, and autism was exposed to a software program designed to teach basic spelling skills (Stromer, Mackay, Howell, McVay, & Flusser, 1996). The participant's spelling skills for 12 target words (3 letters each) improved both on the computer and during a written generalization task.

A related issue of interest is the use of computers with synthesized speech to facilitate speech development or production. Only one study has investigated this application of CAI to date; it involved six verbal children with autism, ages 4-8 to 6-8 (Parsons & La Sorte, 1993). The children were exposed to a computer with simple software programs for learning in two conditions: synthesized speech ON and synthesized speech OFF. The children's spontaneous verbal utterances were counted during teaching sessions under both conditions. The results indicated marked increases in their spontaneous utterances in all of the ON conditions, compared to both baseline (no computer) and OFF conditions. These results suggest that CAI with synthesized speech may have a facilitative effect on speech production for children with autism, although additional research is clearly needed in this area.

Recommendations for Future Research

Several recommendations for future research, some quite general and some more specific, can be made on the basis of this review and summary. Those related to aided AAC will be presented first, followed by those related to assistive technology.

AAC Recommendations

Few papers were located in the areas of AAC assessment and staff/family training, perhaps because there is no perceived need in these areas for "autism-specific" techniques that differ significantly from those used with other AAC populations. On the other hand, clinical experience suggests that parents and AAC practitioners frequently struggle to provide AAC supports, including assessment and training, to individuals with autism. For example, Nebraska speech–language pathologists (SLPs) with experience in AAC scored themselves as only 23% competent (out of a possible 100%) with regard to their ability to provide AAC services to school-aged students with autism; and SLPs without AAC experience rated themselves as only 13% competent (Simpson, Beukelman, & Bird, 1998). This suggests that a research focus on empirically validated assessment and staff/family training processes is long overdue and should be encouraged.

In terms of specific aided AAC applications, the extant empirical literature varies widely. For example, a substantial number of well-controlled single-subject studies have documented the efficacy of the use of pictorial or written schedules for communicative input with this population, to the extent that at least one user-friendly manual based on the literature is now available (McClannahan & Krantz, 1999). Similarly, substantial bodies of empirical work exist with regard to the efficacy of the SAL, the use of visual–spatial symbols for expressive communication, and FCT/AAC interventions. On the other hand, many applications that are in common use in North America have only weak empirical support, including visual symbols for choice-making input, aided language stimulation, and PECS. Focused research in these three areas in particular is necessary in order to establish the efficacy of these approaches empirically.

In addition, it is clear from the research to date that there is no "one way" and probably no "best way" to provide aided AAC supports to individuals with autism. As is the case for AAC with other populations, many strategies and techniques appear to be effective with individual children and adults, depending on their needs and capabilities as well as those of their communicative partners. However, the research to date has been dominated by single-subject or quasi-experimental studies that provide almost no information about the relative effectiveness of AAC interventions that are based on different theoretical paradigms. For example, PECS, FCT/AAC, and most of the AAC applications for expressive communication using visual–spatial symbols are based on the principles of applied behavior analysis. This is in contrast to aided language stimulation and the SAL, which are derived primarily from a social-pragmatic/developmental paradigm (Prizant & Wetherby, 1998). Future research that compares aided AAC interventions across paradigms (e.g., PECS vs. the SAL) might be helpful to identify the relative strengths and weaknesses of the various theoretical orientations.

Finally, it is clear that much needs to be done to strengthen the quality of the research conducted in this area, regardless of the type of research design used. Few of the papers reviewed provided information about participants' ethnicity or social class, the nature of the criteria used to diagnose participants' autism/PDD-NOS, or the inclusion/exclusion criteria that were used for the study. None provided information either about the number of potential participants who were excluded from the study or about the financial cost of any benefits obtained. Data on generalization were mostly anecdotal, and few studies included assessment of the social validity of the interventions. A significant number of the single-subject studies utilized simple A-B designs that provided only minimal experimental control over the dependent variables, and several others were case study reports that utilized no experimental designs at all. Half of the single-subject studies had fewer than 3 participants. It is clear from this review that there is an urgent need for rigorous, well-controlled studies that incorporate outcome measures beyond those that document short-term behavior change.

Assistive Technology Recommendations

Because computers are now used widely in schools and homes with individuals with autism, and because they are still quite expensive relative to their "low tech" equivalents such as books and pencils, it is important to investigate the extent to which they actually enhance learning in children with autism—particularly since the limited research outcomes to date have not provided positive results in this regard. The same concern applies to VOCAs, except that the question here is not whether they "work," but whether they "work better than" low-tech (and less expensive) alternatives. Overall, it is clear that the research in this area is even less well-developed than that in AAC, and similar concerns were identified with regard to a need for (a) additional single-subject research investigating the efficacy of VOCAs and CAI with individuals with autism; (b) comparative studies in this regard (e.g., human instruction vs. CAI, low-tech vs. VOCA output, etc.); and (c) more rigorous subject descriptions, research methodologies, and outcome measures, in general.

Summary

This paper has summarized and analyzed the extant research literature on aided AAC and assistive technology for individuals with autism across a variety of dimensions. It is interesting to note that most of this research has been published in speech–language pathology/communication, education, and applied behavior analysis journals. This probably reflects the fact that all three fields have made major theoretical contributions in the specific topic areas covered, as well as the fact that single-subject designs have been the primary methodologies used to date. Collaborative efforts across these three disciplines should be encouraged in future research, as each brings its own unique strengths to the endeavor.

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NOTES

1. *This software is available from Don Johnston, Inc., 1000 N. Rand, Bldg. 115, PO Box 639, Wauconda, IL 60084-0639.*
2. *The authors noted, however, that communicatively competent peers were not available in the target classroom, which was a self-contained setting for children with autism.*

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