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Use of Computer-Assisted Technologies (CAT) to Enhance Social, Communicative, and Language Development in Children with Autism Spectrum Disorders

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Use of Computer-Assisted Technologies (CAT) to Enhance Social, Communicative, and Language Development in Children with Autism Spectrum Disorders

Bertram O. Ploog · Alexa Scharf · DeShawn Nelson · Patricia J. Brooks

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Abstract Major advances in multimedia computer technology over the past decades have made sophisticated computer games readily available to the public. This, combined with the observation that most children, including those with autism spectrum disorders (ASD), show an affinity to computers, has led researchers to recognize the potential of computer technology as an effective and efficient tool in research and treatment. This paper reviews the use of computer-assisted technology (CAT), excluding strictly internet-based approaches, to enhance social, communicative, and language development in individuals with ASD by dividing the vast literature into four main areas: language, emotion recognition, theory of mind, and social skills. Although many studies illustrate the tremendous promise of CAT to enhance skills of individuals with ASD, most lack rigorous, scientific assessment of efficacy relative to non-CAT approaches.

Keywords Computer-assisted technology · Autism · Efficacy · Language · Social skills · Emotion recognition

Autism spectrum disorders (ASD) is an umbrella term for developmental disorders that affect foremost an individual’s social, communicative, and language skills (Lord and Volkmar 2002). According to the Diagnostic and Statistical Manual of Mental Disorders (4th ed., text revision, DSM-IV-TR; American Psychiatric Association 2000), these milestone characteristics are evident in the individual’s failure to develop peer relationships, lack of engagement in play with peers, lack of emotion recognition, difficulties in communicative interactions, and generally poor social skills. These children have difficulties related to pragmatics, and often misinterpret speech by relying on the literal rather than the contextual meanings of words (Grynszpan et al. 2008). Additionally, it has been suggested that inappropriate behaviors such as tantrums and self-injurious behaviors occur quite commonly as a consequence of the individual’s lack of social-communicative understanding (Bernard-Opitz et al. 2001; Ploog 2010b).

Even though all individuals with ASD are characterized by these core deficits in social and language skills, ASD might manifest itself quite differently in different individuals (Tager-Flusberg and Joseph 2003). For example, one individual may lack functional speech entirely (i.e., as is common in low-functioning autism) whereas another may have excellent language abilities (i.e., as is common in Asperger Syndrome). Both, however, would receive a diagnosis of ASD based on a deficit in social and communication skills. Any useful teaching technology, including computer-assisted technology (CAT), should be amenable to the diversity of individuals with ASD or at the very least be adjustable to the individual’s needs.

The utility of computers in research and treatment of autism was recognized early on (e.g., Colby 1973; see brief review in Schreibman et al. 1989). However, it has not been until fairly recently that computers have become widely and inexpensively available to private individuals and researchers (Ploog 2010a). Furthermore, in very recent years there have been quantum leaps in the development of computer-based audio-visual (multimedia) technology.
Approaches that were simply impossible a few years ago are now well within reach for the general public (e.g., applications—“apps”—on iPhone/iPod/iPad by Apple®, Computers Kinect by Microsoft®, Wii by Nintendo®). This technical and economic trend has further potentiated the utility of computers in the treatment of individuals with ASD. Importantly, CAT holds the promise of being effective where other treatment methods have failed (Williams et al. 2002). Note, however, that skills in engaging with modern technologies may have to be taught specifically to individuals with ASD (Kagohara 2011).

The increased popularity in computer applications in education and research in autism can be seen in the large number of blogs where families report anecdotally the benefits of computers in teaching individuals with autism. We conducted a more formal search, using PsycINFO® with keywords “autism” and “computer” to identify the number of publications in peer-reviewed journals for the time span of 1970–2011. As can be seen in Fig. 1, until about 1981, the number of publications per year was either 0 or 1. Then a discernible jump occurred (to about 5–7 publications per year). Note that in the early 1980s, personal computers (“PCs”—IBM® compatible or made by Apple®) became more readily available. The next clear increase in publications began in the mid to late 1990s, with a trend that has continued until today. Note that in the 1990s, the internet was popularized with the first publicly available web browsers. Our observations are also validated by the measure of accepted technology presentations at the International Meeting for Autism Research (IMFAR), from eight presentations in 2004 to 36 in 2008 (Bölte et al. 2010). Note also that in 2010 an entire special issue of the journal Autism was dedicated to innovative technologies and their applications to the treatment of individuals with ASD (Bölte et al. 2010). Similarly, in 2011, a special issue of the Journal of Behavioral Education was dedicated to evaluating assistive technologies (including CAT) in the education of persons with severe disabilities (including persons with ASD; Sigafoos 2011).

A crucial question is whether CAT actually has been demonstrated to be more effective than traditional teaching and training methods. Unfortunately, research studies to answer this question have been sparse (see also Bölte et al. 2010; Whalen et al. 2010 for a similar assessment). To address this shortcoming, Clark and Choi (2005) suggested five principles to guide the development of effective CAT, which included, e.g., operational definitions of the independent and dependent variables, and cost effectiveness; see also Higgins and Boone (1996). Unfortunately, the majority of published and available research is still not amenable to such a rigorous assessment of the efficacy of CAT relative to non-CAT approaches. For example, Pennington (2010) studied the effectiveness of CAT in teaching academic skills to individuals with ASD, and concluded that even though it appears that CAT is effective for teaching some academic skills, only a few studies have included a control group necessary for a rigorous assessment of efficacy. Another recent review by Ramdoss et al. (2011) evaluated the intervention literature employing CAT in teaching expressive and receptive language skills to individuals with ASD. These authors also concluded that even though CAT seemed promising, it should not yet be considered a research-based approach. Finally, Wainer and Ingersoll (2011) reviewed the intervention literature employing CAT for teaching social communication to individuals with ASD and similarly concluded that most of the publications are descriptive and exploratory, thus do not allow for a rigorous assessment of CAT’s efficacy.

To be fair, this state of affairs is not a reflection of methodologically poor research per se but rather a normal characteristic of a budding new science. Many of these studies should be considered exploratory work to be followed up with more rigorous investigations. That is, follow-up studies are needed that incorporate proper control conditions and randomized assignment of participants to conditions to allow for scientific, evidence-based assessment (e.g., involving a comparison of the effects of different treatment approaches, especially a comparison to traditional non-CAT methods; matching of individuals across conditions using to a variety of different criteria such as mental and chronological age, verbal skills, diagnostic subcategories, educational and cultural context; comparison with other diagnostic groups). But for now, the lack of such rigorous studies leaves open the possibility that CAT may in fact fare worse than traditional treatment.
approaches, despite great hopes and faith in advances due to CAT. (Indeed, numerous studies have already shown that playing violent video games may result in higher levels of aggressive behavior, cognition, and affect, in higher physiological arousal, and in lower levels of pro-social behavior; cf. Anderson et al. 2010 for a meta-analytic review. On the positive side, there are numerous controlled experiments utilizing video game training that show improvements in aspects of information processing, such as spatial imagery (e.g., mental rotation), motor skills (e.g., hand-eye coordination), and auditory and visual processing (e.g., object tracking, peripheral vision), after video game use (cf. Powers et al. 2011, for a meta-analytic review. Note, however, that neither of these meta-analytic reviews of video game research included studies conducted with individuals with ASD).

A few exceptional studies have specifically addressed whether CAT is superior to alternative or traditional approaches in educating children with ASD. For example, very early on, Plienis and Romanczyk (1985) studied seventeen 4- to 14-year-old children (six of whom had ASD) in a within-subject design in which the children participated in both person- and computer-instructed sessions involving two-choice discrimination tasks. They hypothesized that computer-instructed sessions would be superior because the attending adult in the person-instructed sessions would be more likely to reinforce inadvertently maladaptive behaviors by giving the child attention. Plienis and Romanczyk (1985) reported that while there was no overall difference in task performance between the conditions, indeed higher levels of maladaptive behaviors occurred when adults provided the instructions. With a more fine-grain analysis, however, it was clear that some children performed better in the computer-instructed sessions, whereas others performed better with a teacher. Given the variability in outcomes, they suggested that the goal should not be to simply supplant teachers with computers, but to look for ways to incorporate computers as the context dictates. In another early study, Chen and Bernard-Opitz (1993) compared computer- and teacher-implemented instructions in teaching four 4- to 7-year-old children with ASD to learn individually selected tasks such as counting and labeling. They used an enthusiasm scale to evaluate whether CAT was more enjoyable than traditional non-CAT instruction in addition to examining whether CAT resulted in superior task performance. Like Plienis and Romanczyk (1985), Chen and Bernard-Opitz (1993) also measured concomitant behavior problems. They found improved motivation in the children using CAT, with fewer behavior problems, but this, again, did not translate into improved learning. Only one of the four participants showed better learning in the CAT condition. Finally, Kodak et al. (2011) were successful in showing CAT’s superiority over one-on-one instructions with a labeling task, but this advantage was primarily in terms of an increase in independent responding, not in an increase in correct responding per se.

Whalen et al. (2010) conducted an exemplary large-scale, randomized (by classroom) control study specifically to assess the efficacy of TeachTown: Basics® educational software (CAT) versus a non-CAT approach in 47 children with ASD (ages 3–6 years). This study was conducted after an initial study demonstrated improved receptive language (e.g., object identification) and social skills (e.g., emotion understanding), coupled with decreased inappropriate behavior, in four children with ASD (ages 3–4 years) after 8 weeks of training with TeachTown software (Whalen et al. 2006). TeachTown: Basics introduces concepts through self-paced lessons utilizing 15–45 s animated reward games, which incorporate basic principles of Applied Behavior Analysis (ABA) such as variable-ratio reinforcement for correct responses; these lessons focus on four domains (receptive language, social understanding, life skills, academic/cognitive skills). For the 24 children in the preschool classrooms, use of TeachTown: Basics resulted in larger increases in receptive vocabulary size, as measured using the Peabody Picture Vocabulary Test, 3rd edition (Dunn and Dunn 1997), relative to the control condition. However, for the 23 children in Kindergarten-1st grade classrooms, improvements in receptive vocabulary size were equivalent across CAT and non-CAT conditions, and neither grade level showed evidence of CAT increasing expressive vocabulary size relative to the control condition. For the entire sample, the authors reported a significant correlation between the number of TeachTown: Basics lessons completed and improvements in general cognitive and social abilities, as measured using the Brigance Inventory of Early Development (Brigance 2004). Together with the positive effect on receptive vocabulary in the younger children, this provides evidence that CAT might be useful in remediating some of the language and social deficits associated with ASD.

Regardless of whether CAT is superior to traditional approaches in terms of efficacy, CAT may be preferred over traditional approaches simply because it may be easier with CAT to implement treatments with higher precision and less variability, thus ensuring higher treatment fidelity. It may also become possible to reach needy populations at a broader scale because of the savings due to automation, resulting in a reduced demand for highly trained, thus costly, service-providing professionals and allowing for broader dissemination of treatment, training, and education (i.e., the “democratization” of treatment and education; cf. Ploog 2010a; see also Goodwin 2008; Higgins and Boone 1996).

For the remainder of this article, we will specifically point out for each study we discuss in greater detail...
whether the design allowed for a meaningful comparison with alternative approaches, in terms of efficacy. If such a comparison was not possible, we tried to assess at least whether CAT was effective on its own. We conducted an exhaustive review of the literature with the following inclusion and exclusion criteria: The study had to employ some form of CAT, involve participants with ASD (there is a sizeable body of literature that evaluates CAT and mental retardation and other developmental disorders, but these studies were not included in our review; diagnosis of ASD was according to the criteria used in a given study), and the training/intervention was aimed at enhancement of social, communicative, or language development (i.e., studies that addressed improvement of life skills alone, for example, or studies limited to assessment without attempted intervention, were not included). We focused on the literature that was published in the past 20 years or so to capture the evolution of current approaches. We explicitly excluded training approaches available strictly through the internet—as perhaps offered by educational websites—because none were scientifically sound studies that would allow for assessment of efficacy. If an internet training program was scientifically sound, it was likely that the corresponding scientific literature was captured by our search of peer-reviewed journal articles that were compiled with our search criteria.

Areas of Application of Computer-Assisted Technologies

Our main goal was to categorize, summarize, and evaluate research that has been conducted in ASD with the employment of CAT. We organized our review of the literature into four categories: Remediation of deficits in language skills (including reading), enhancement of face processing and emotion recognition and comprehension, teaching Theory of Mind (ToM), and teaching social skills including non-verbal communication, play skills, and daily life skills—sometimes taught through virtual realities. Table 1 provides an overview of all of the research studies included in our review, grouped according to the four main topics of the current review.

Remediation of Deficits in Expressive and Receptive Language (Including Reading Skills)

By far the majority of the CAT literature focuses on remediation of language deficits. The earliest study in our review was conducted by Colby (1973) who used a computer- and keyboard-controlled audio-visual display to encourage children to speak. Colby reported that 13 of 17 “nonspeaking autistic children” increased their use of voluntary speech for social communication. Because no further characterization of the participants was provided, and no control group was included, an in-depth evaluation is not possible. However, this study clearly represents an example of pioneering work. Colby anticipated critical research by decades when stating: “… we believe there is something powerful but not well-understood about this [computer] method” (p. 259).

Indeed, CAT may offer new ways of teaching language skills to children under circumstances for which traditional teaching methods have not been effective or have been deemed inappropriate (C. Williams et al. 2002). These authors, for example, showed that the majority of eight children with ASD identified more words, spent more time reading, and showed less resistance to the reading material when instructions were given via computers rather than books. Because the authors considered this a pilot study (i.e., matching and other controls were limited), it is not possible to firmly assess the efficacy of CAT based on the presented data. (See also Yaw et al. 2011, using CAT to increase sight-word reading in a 12-year-old boy with ASD. These authors employed a multiple-baseline design, which provided evidence for the effectiveness of CAT itself, but a comparison to non-CAT approaches was not possible.)

Ploog et al. (2009) used CAT, in the form of a custom-made video game, to study abnormalities in attention to different aspects of spoken language, namely content (i.e., what is being said) and prosody (i.e., how it is being said). They found that children with ASD were able to play the video game successfully, and performed almost as well as their typical peers in perceiving differences in content and prosody. Nevertheless the children with ASD showed an atypical attention pattern as they did not prioritize the content information, which was conveyed through the use of specific words in the spoken sentences, to the same extent as their typical peers. Prioritization appears to be a critically important skill that typical children possess (e.g., attending to content when it is more important than prosody or vice versa). Note that this study focused on an assessment of attention patterns, and not on the remediation of any identified abnormalities per se. However, as described in Ploog (2010a), video games as a CAT approach have great potential to be developed into remediation tools (see also Powers et al. 2011).

Bernard-Opitz et al. (1999) compared computer-delivered instructions in the form of visual feedback (“Speech-Viewer”) with traditional play interaction in a study designed to promote vocal imitation in ten nonverbal 3- to 7-year-old children with ASD. Bernard-Opitz et al. (1999) found a significantly greater number of vocal imitations in the CAT condition in comparison to the control condition, although vocal imitations increased across sessions for both
Table 1: Studies that employed computer-assisted technology in teaching children with ASD, in alphabetical order and grouped according to the four main topics of the current review. Additional methodological information and participant characteristics are provided.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Participants</th>
<th>Age CA/MA</th>
<th>Participant assessment</th>
<th>Attempt to Match by</th>
<th>Type of CAT</th>
<th>Comparison of CAT with</th>
<th>Domain of training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bernard-Opitz et al. (1999)</td>
<td>10 ASD</td>
<td>6; 3</td>
<td>ABC, BIDS, or LIPS; nonverbal</td>
<td>None</td>
<td>Computerized visual feedback (SpeechViewer)</td>
<td>Personal instruction, play interaction</td>
<td>Language, vocal imitation</td>
</tr>
<tr>
<td>Bosseler and Massaro (2003)</td>
<td>8 ASD</td>
<td>10; 2</td>
<td>7/8 capable of speech; various tests of intellectual functioning</td>
<td>None but in Exp. II multiple-baseline design was used</td>
<td>Animated talking head</td>
<td>None but Exp. II included generalization tests</td>
<td>Vocabulary and grammar learning; association between pictures and spoken words</td>
</tr>
<tr>
<td>Colby (1973)</td>
<td>17 ASD</td>
<td>Not Specified</td>
<td>Nonspeaking</td>
<td>None</td>
<td>Keyboard-controlled audio-visual displays</td>
<td>None</td>
<td>Increase in voluntary speech for social communication</td>
</tr>
<tr>
<td>Coleman-Martin et al. (2005)</td>
<td>1 ASD</td>
<td>12; 0</td>
<td>2nd-grade</td>
<td>None</td>
<td>Index cards or cards on PowerPoint©; nonverbal reading approach (e.g., drill-reception-practice-feedback)</td>
<td>Compare CAT alone, teacher alone, and teacher + CAT</td>
<td>Reading and vocabulary skills; decoding and word identification</td>
</tr>
<tr>
<td>Coleman-Martin et al. (2005)</td>
<td>1 ASD</td>
<td>11; 0</td>
<td>2.9-grade</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coleman-Martin et al. (2005)</td>
<td>1 ASD</td>
<td>16; 0</td>
<td>1.0-grade reading; speech impaired</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colby (1973)</td>
<td>17 ASD</td>
<td>Not Specified</td>
<td>Nonspeaking</td>
<td>None</td>
<td>Keyboard-controlled audio-visual displays</td>
<td>None</td>
<td>Increase in voluntary speech for social communication</td>
</tr>
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<td>Colby (1973)</td>
<td>17 ASD</td>
<td>Not Specified</td>
<td>Nonspeaking</td>
<td>None</td>
<td>Keyboard-controlled audio-visual displays</td>
<td>None</td>
<td>Increase in voluntary speech for social communication</td>
</tr>
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<td>Colby (1973)</td>
<td>17 ASD</td>
<td>Not Specified</td>
<td>Nonspeaking</td>
<td>None</td>
<td>Keyboard-controlled audio-visual displays</td>
<td>None</td>
<td>Increase in voluntary speech for social communication</td>
</tr>
<tr>
<td>Hailpern (2008)</td>
<td>3 LFA</td>
<td>4; 10</td>
<td>Nonverbal</td>
<td>None</td>
<td>Visual feedback to spoken language by computer</td>
<td>None</td>
<td>Increase vocalization</td>
</tr>
<tr>
<td>Hailpern (2008)</td>
<td>3 LFA</td>
<td>4; 10</td>
<td>Nonverbal</td>
<td>None</td>
<td>Visual feedback to spoken language by computer</td>
<td>None</td>
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<td>3 LFA</td>
<td>4; 10</td>
<td>Nonverbal</td>
<td>None</td>
<td>Visual feedback to spoken language by computer</td>
<td>None</td>
<td>Increase vocalization</td>
</tr>
<tr>
<td>Heimann et al. (1993)</td>
<td>7 ASD</td>
<td>10; 4/6; 5</td>
<td>DSM-III, RAV</td>
<td>None</td>
<td>Creating sentences resulted in animations</td>
<td>Comparison to baseline (before implementation of CAT)</td>
<td>Reading and writing, communication skills</td>
</tr>
<tr>
<td>Heimann et al. (1995)</td>
<td>11 ASD</td>
<td>9; 4/6; 9</td>
<td>DSM-III, RAV, CARS, language test</td>
<td>Approximately comparable language skills</td>
<td>Creating sentences resulted in animations</td>
<td>Comparison to baseline (before implementation of CAT)</td>
<td>Reading and writing, communication skills</td>
</tr>
<tr>
<td>Heimann et al. (1995)</td>
<td>11 ASD</td>
<td>13; 1/5; 8</td>
<td>DSM-III, RAV, CARS, language test</td>
<td>Approximately comparable language skills</td>
<td>Creating sentences resulted in animations</td>
<td>Comparison to baseline (before implementation of CAT)</td>
<td>Reading and writing, communication skills</td>
</tr>
<tr>
<td>Hetzroni and Shalem (2005)</td>
<td>6 ASD</td>
<td>10; 10</td>
<td>DSM-IV</td>
<td>None</td>
<td>Computer-controlled fading of orthographic symbols (words)</td>
<td>Comparison to baseline (before implementation of CAT)</td>
<td>Identification of orthographic symbols (words)</td>
</tr>
<tr>
<td>Hetzroni and Tannous (2004)</td>
<td>5 ASD</td>
<td>9; 8</td>
<td>Echolalia</td>
<td>None</td>
<td>Computer-based audio-visual choice-paradigm</td>
<td>Comparison to baseline (before implementation of CAT)</td>
<td>Enhance communication regarding play, food, and hygiene</td>
</tr>
<tr>
<td>Massaro and Bosseler (2006)</td>
<td>5 ASD</td>
<td>10; 8</td>
<td>Delayed but capable of speech; various tests of intellectual functioning</td>
<td>None</td>
<td>Animated talking head</td>
<td>Face plus voice versus voice alone</td>
<td>Vocabulary and grammar learning; associating pictures and spoken words</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Participants</td>
<td>Age</td>
<td>Participant assessment</td>
<td>Attempt to Match by</td>
<td>Type of CAT</td>
<td>Comparison of CAT with</td>
<td>Domain of training</td>
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<tr>
<td>Moore and Calvert (2000)</td>
<td>14 ASD 3–6 years</td>
<td>Varying from some to complex verbal skills; all impaired.</td>
<td>None</td>
<td>Presentation of sounds and moving objects</td>
<td>CAT versus “behavioral program”</td>
<td>Vocabulary acquisition; attention and motivation</td>
<td></td>
</tr>
<tr>
<td>Ploog et al. (2009)</td>
<td>9 ASD 9 TYP 12; 9 8; 0</td>
<td>All but one had impaired verbal skills</td>
<td>Approximately by mental age</td>
<td>Computer game to present spoken language</td>
<td>None</td>
<td>Speech perception and attention to linguistic information</td>
<td></td>
</tr>
<tr>
<td>Tjus et al. (1998)</td>
<td>13 ASD 9; 8/7; 3</td>
<td>DSM-III-R, RAV, CARS, Language age of 5; 2</td>
<td>None</td>
<td>Multimedia computer program</td>
<td>Comparison to baseline (before implementation of CAT)</td>
<td>Language and reading skills</td>
<td></td>
</tr>
<tr>
<td>Tjus et al. (2001)</td>
<td>11 ASD 9 MH 9; 4/6; 9 13; 1/5; 8</td>
<td>CARS, RAV, Language age of 4; 9 (ASD) and 4; 1 (MH);</td>
<td>None</td>
<td>Multimedia computer programs</td>
<td>Comparison to baseline (before implementation of CAT); Child and Teacher.</td>
<td>Language and reading skills; help-seeking behavior</td>
<td></td>
</tr>
<tr>
<td>Whalen et al. (2006)</td>
<td>4 ASD 4 MH 3–4 years 4–5 years</td>
<td>CARS, DSM-IV-TR</td>
<td>Approximately by language age equivalent</td>
<td>Discrete trial visual and auditory stimulus presentation (incl. fading) based on applied behavior analysis</td>
<td>Comparison to baseline (before implementation of CAT)</td>
<td>Receptive language, social understanding, life skills, academic/social skills</td>
<td></td>
</tr>
<tr>
<td>Whalen et al. (2010)</td>
<td>47 ASD 3–6 years</td>
<td>PPVT-III, EVT, BIED, CARS</td>
<td>None</td>
<td>Discrete trial visual and auditory stimulus presentation (incl. fading) based on applied behavior analysis</td>
<td>Comparison of CAT versus non-CAT</td>
<td>Receptive language, social understanding, life skills, academic/social skills</td>
<td></td>
</tr>
<tr>
<td>Williams et al. (2002)</td>
<td>8 ASD 4; 7</td>
<td>ICD-10; Some speech</td>
<td>Age, severity of ASD, number of spoken words</td>
<td>Computer-instructed learning</td>
<td>Computer-instructed versus book-based learning</td>
<td>Reading skills, on-task behavior, resistance to learning</td>
<td></td>
</tr>
<tr>
<td>Williams et al. (2004)</td>
<td>15 ASD 9; 6/7; 2 15 TYP 8; 10/8; 7 5 ASD 10; 6/–</td>
<td>ADOS; ADI; BPVS; Some speech BPVS BPVS DSM</td>
<td>ASD and TYP according to approx. BPVS</td>
<td>Animated talking head</td>
<td>Unimodal versus bimodal (visual, auditory) presentation; comparison of TYP and ASD children; comparison to baseline after training</td>
<td>Vocabulary and grammar learning; association between pictures and spoken words; speech-reading ability; visual-auditory integration</td>
<td></td>
</tr>
<tr>
<td>Yamamoto and Miya (1999)</td>
<td>3 ASD 8; 7/3; 6</td>
<td>DSM-IV &amp; Binet; could label &amp; read some; no use of particles</td>
<td>None</td>
<td>Construct sentences on computer, pronounce them; use particles.</td>
<td>Pre- and post-test; no comparison to traditional techniques</td>
<td>Sentence construction, sequential responding, and use of particles</td>
<td></td>
</tr>
<tr>
<td>Author(s)</td>
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<tr>
<td><strong>Enhancement of face processing and emotion recognition</strong></td>
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</tr>
<tr>
<td>Golan and Baron-Cohen (2006)</td>
<td>54 HFA &amp; AS 24 TYP</td>
<td>Adults</td>
<td>High-functioning, DSM-IV, ICD, General population, WASI</td>
<td>Age, IQ, handedness, &amp; gender</td>
<td>Multimedia computer program for voice and photo (including faces) presentation</td>
<td>CAT versus no intervention at all</td>
<td>Emotion recognition in face and voice</td>
</tr>
<tr>
<td>Grynszpan et al. (2007, 2008)</td>
<td>10 HFA 10 TYP</td>
<td>12; 10, 9; 7</td>
<td>WISC (80.5), DSM-IV, Gender matched; no assessment</td>
<td>Estimated mental age and academic level</td>
<td>Virtual reality, game involving text, speech, and images</td>
<td>Simple to complex CAT</td>
<td>Emotional, facial expression; executive abilities; ability to detect sarcasm, irrelevant speech</td>
</tr>
<tr>
<td>LaCava et al. (2007)</td>
<td>8 AS 9; 9</td>
<td></td>
<td>Verbal; Asperger Syndrome</td>
<td>None</td>
<td>Multimedia computer program for voice and photo (including faces) presentation</td>
<td>Pre- and post-intervention test</td>
<td>Emotion recognition in face and voice</td>
</tr>
<tr>
<td>LaCava et al. (2010)</td>
<td>4 HFA 7; 6—no cognitive disability</td>
<td>Verbal; text- and computer-literate;</td>
<td>None</td>
<td>Multimedia computer program for voice and photo (including faces) presentation</td>
<td>Repeated-measures design</td>
<td>Emotion recognition in face and voice</td>
<td></td>
</tr>
<tr>
<td>Moore et al. (2005)</td>
<td>34 ASD 10; 11</td>
<td></td>
<td>Unspecified; recruited via autism listserves and schools</td>
<td>None</td>
<td>Virtual reality; presentations of emotional facial expressions</td>
<td>None</td>
<td>Emotional knowledge; recognition of emotion in facial expressions</td>
</tr>
<tr>
<td>Silver and Oakes (2001)</td>
<td>22 ASD/AS 10–18</td>
<td></td>
<td>DSM, ICD-10 BPVS</td>
<td>None</td>
<td>Photos, text, and response buttons to identify the correct emotion (no sound)</td>
<td>CAT versus no CAT</td>
<td>Emotion recognition in face, events, and mental states</td>
</tr>
<tr>
<td><strong>Teaching theory of mind</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charlop-Christy and Daneshvar (2003)</td>
<td>3 ASD 7; 3</td>
<td></td>
<td>Deficits in social behavior; language deficits</td>
<td>None</td>
<td>Video modeling (not bona fide CAT)</td>
<td>None but included training and generalization probes</td>
<td>Teach perspective taking (related to Theory of Mind)</td>
</tr>
<tr>
<td>Swettenham (1996)</td>
<td>8 ASD 8 DS, 8 TYP</td>
<td></td>
<td>DSM-III-R, BPVS, LIPS</td>
<td>Verbal mental age</td>
<td>Visual display on computer monitor of Sally-Anne Task</td>
<td>None</td>
<td>Teach Theory of Mind, false belief</td>
</tr>
<tr>
<td><strong>Teaching social skills: communication, play, and daily living skills, and related behaviors</strong></td>
<td></td>
<td></td>
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<tr>
<td>Bernard-Opitz et al. (2001)</td>
<td>8 ASD 8 TYP 7; 4, 1</td>
<td></td>
<td>ABC, K-BIT, BPVS; verbal</td>
<td>Cognitive functioning, language comprehension</td>
<td>Animated social situations</td>
<td>None but included training and probe sessions</td>
<td>Social skills and social problem solving</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Participants</td>
<td>Age</td>
<td>Participant assessment</td>
<td>Attempt to Match by</td>
<td>Type of CAT</td>
<td>Comparison of CAT with</td>
<td>Domain of training</td>
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<tr>
<td>Charlop-Christy et al. (2000)</td>
<td>5 ASD</td>
<td>7; 7/5; 2</td>
<td>LIPS, VABS, PPVT; language impaired</td>
<td>None</td>
<td>Video modeling (not bona fide CAT)</td>
<td>Video versus in vivo; assessed against baseline (“traditional procedures”)</td>
<td>Spontaneous, speech, labeling, cooperative and social play, daily living skills</td>
</tr>
<tr>
<td>D’Ateno et al. (2003)</td>
<td>1 ASD</td>
<td>3; 8</td>
<td>Stanford-Binet, PPVT, self stimulation, little play</td>
<td>None</td>
<td>Video modeling (not bona fide CAT)</td>
<td>Multiple-baseline design across behaviors</td>
<td>Complex play sequences; no extraneous reinforcers</td>
</tr>
<tr>
<td>Dauphin et al. (2004)</td>
<td>1 ASD &amp; ADHD</td>
<td>3; 1</td>
<td>For age; limited verbal abilities</td>
<td>None</td>
<td>Computer-based activity schedule</td>
<td>None</td>
<td>Social skills; sociodramatic play skills</td>
</tr>
<tr>
<td>Farr et al. (2010)</td>
<td>6 ASD</td>
<td>10; 7</td>
<td>Speaking and listening assessment; ASD was delayed</td>
<td>Age, plus two years, to compensate for developmental delay</td>
<td>Toys with Tangible User Interface</td>
<td>Non-CAT toys (LEGO™)</td>
<td>Social skills through group play</td>
</tr>
<tr>
<td>Kimball et al. (2004)</td>
<td>1 ASD</td>
<td>4; 0</td>
<td>Preschooler, case study</td>
<td>None</td>
<td>Video modeling</td>
<td>None</td>
<td>Teach social skills through video modeling</td>
</tr>
<tr>
<td>MacDonald et al. (2005)</td>
<td>2 ASD</td>
<td>5; 5</td>
<td>Verbal</td>
<td>None</td>
<td>Video Modeling</td>
<td>None</td>
<td>Teach pretend play through video modeling</td>
</tr>
<tr>
<td>MacDonald et al. (2009)</td>
<td>2 ASD &amp; 2 TYP</td>
<td>6; 0 &amp; 5; 0</td>
<td>Verbal (full sentences)</td>
<td>Approximated by mental age</td>
<td>Video Modeling</td>
<td>None</td>
<td>Teach pretend play through video modeling</td>
</tr>
<tr>
<td>Mineo et al. (2009)</td>
<td>42 ASD</td>
<td>6; 0 to 18; 8</td>
<td>Some receptive/expressive language deficits; some echolalia</td>
<td>None</td>
<td>Virtual reality</td>
<td>N/A</td>
<td>Social skills (engagement)</td>
</tr>
<tr>
<td>Nikopoulos and Keenan (2007)</td>
<td>4 ASD</td>
<td>6; 11</td>
<td>DSM-IV, CARS, some speech, echolalia</td>
<td>None</td>
<td>Video modeling (not bona fide CAT)</td>
<td>None but included training and generalization probes</td>
<td>Complex social sequences/behaviors</td>
</tr>
<tr>
<td>Parsons et al. (2004)</td>
<td>12 ASD</td>
<td>15; 4</td>
<td>DSM-IV, WASI</td>
<td>ASD matched by verbal IQ, performance IQ, age, and gender to SN and TYP</td>
<td>Virtual reality</td>
<td>None but included training and generalization probes</td>
<td>Executive functions; some social skills (being in a VR “café”)</td>
</tr>
<tr>
<td>Parsons et al. (2006)</td>
<td>2 ASD</td>
<td>14; 0 &amp; 17; 7</td>
<td>WASI; good verbal abilities</td>
<td>None</td>
<td>Virtual reality</td>
<td>Varying complexity of VR</td>
<td>Social skills in a café and on a bus</td>
</tr>
<tr>
<td>Rajendran and Mitchell (2006)</td>
<td>11 AS</td>
<td>21; 8</td>
<td>Verbal, DSM-IV, ICD-10, WASI</td>
<td>Match by gender, age, and education</td>
<td>“Text Chat” on computer/internet</td>
<td>Text chat (CAT) versus phone</td>
<td>Social use of language and communicative skills</td>
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</tbody>
</table>
Table 1 continued

<table>
<thead>
<tr>
<th>Author (s)</th>
<th>Participants</th>
<th>Age</th>
<th>Participant assessment</th>
<th>Attempt to Match by</th>
<th>Type of CAT</th>
<th>Comparison of CAT with</th>
<th>Domain of training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sansosti and Powell-Smith (2008)</td>
<td>3 HFA</td>
<td>8; 6</td>
<td>DSM-IV-TR</td>
<td>None</td>
<td>Video-modeling and computer-presented social stories</td>
<td>None</td>
<td>Social skills</td>
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<tr>
<td>Simpson et al. (2004)</td>
<td>4 ASD</td>
<td>5; 6</td>
<td>Mild to severe language impairments</td>
<td>None</td>
<td>Video modeling and computer-based instruction</td>
<td>None</td>
<td>Social skills</td>
</tr>
<tr>
<td>Whalen et al. (2010)</td>
<td>47 ASD</td>
<td>3–6 years</td>
<td>PPVT-III, EVT, BIED, CARS</td>
<td>None</td>
<td>Discrete trial visual and auditory stimulus presentation (incl. fading) based on applied behavior analysis</td>
<td>Comparison of CAT versus non-CAT</td>
<td>Receptive language, social understanding, life skills, academic/social skills</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chen and Bernard-Opitz (1993)</td>
<td>4 ASD</td>
<td>5; 5</td>
<td>ASI; verbal</td>
<td>None</td>
<td>Instructions for labeling and counting</td>
<td>Person- versus computer-presented instructions</td>
<td>Other: Motivation/enthusiasm, learning rate, and general behavior</td>
</tr>
<tr>
<td>Plienis and Romanczyk (1985)</td>
<td>6 ASD</td>
<td>7; 4</td>
<td>CA, VSQ, VAE, and PPVT-R</td>
<td>None</td>
<td>Instructions for labeling and counting</td>
<td>Person- versus computer-presented instructions</td>
<td>Other: Performance on visual discrimination task; assess collateral (disruptive) behaviors.</td>
</tr>
<tr>
<td></td>
<td>5 ED</td>
<td>5; 7</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>4 MR</td>
<td>11; 4</td>
<td></td>
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<tr>
<td></td>
<td>2 PSY</td>
<td>10; 0</td>
<td></td>
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</tbody>
</table>

a ADHD Attention Deficit/Hyperactivity Disorder, AS Asperger Syndrome, ASD Autism Spectrum Disorder, CP Cerebral Palsy, DS Down Syndrome, ED Emotionally Disturbed, HFA High-Functioning Autism, LFA Low-Functioning Autism, MH Mixed Handicaps, MR Mentally Retarded, PSY Psychotic, SN Children with Special Needs; low verbal IQ, TYP Typical Development  

b CA chronological age, MA mental age  
conditions. However, because these authors used a simultaneous treatment design (even though generally considered an appropriate, powerful, and efficient research design), it is possible that there were carry-over effects from one condition to the other, which warrant caution when evaluating the efficacy of CAT alone.

Similar to the approach of Bernard-Opitz et al. (1999), Hailpern (2008) explored how providing feedback through a computer interface could be used to encourage children with ASD to vocalize or speak. Three children with ASD and two children with both ASD and Down Syndrome, 3 to 8 years of age, all described as “low-functioning”, participated in the study. Hailpern’s work represents an excellent example of the use of current computer technology. His program was set up so that feedback could be presented visually or aurally, such that the program’s effect on children’s attention, affect, and phonetic production could be analyzed. In one implementation, for example, he introduced a graphic-matching task, in which the children were taught to match their vocal duration to the path of a visual display and their volume to the display’s width. Hailpern (2008) found that four of the five participants exhibited an increased frequency of spontaneous speech-like vocalizations with one form of feedback—two participants showed large increases in the frequency of spontaneous speech-like vocalizations with auditory feedback, one participant responded best to visual feedback, and another participant to the combination of visual and auditory feedback. Hailpern (2008) concluded that any type of feedback may be effective in enhancing spontaneous speech-like vocalizations in children with ASD, and that any application must be customized to match the abilities of individual children. He hypothesized that his program was successful because the children experienced CAT as a less anxiety-inducing situation and responded with less apprehension during play than in a typical human-to-human interaction. However, no situation and responded with less apprehension during play.

Hetzroni and Tannous (2004) employed CAT to enhance functional communication related to food, play, and hygiene in five children with ASD. For this, objects were displayed and prerecorded spoken sentences were presented, with choice buttons on the screen. To assess the effects of CAT, a multiple-baseline design across participants and behaviors was employed. This made it possible to demonstrate significant increases in functional communication such as a reduction in echolalia and an increase in communicated intentions and appropriate speech. Furthermore, successful generalization to natural classroom settings was evident. However, their design only provided a comparison to baseline levels (i.e., before treatment), but not a comparison of CAT with traditional teaching approaches.

In another study, Hetzroni and Shalem (2005) trained six children with ASD to identify words taken from commercial logos of food items. For this, a computer-controlled fading procedure was implemented. Again, a multiple-baseline design was used. Not only were the children enabled to identify the target words, but also, after training, they generalized their knowledge to classroom settings and maintained what they learned over time. Because neither a control group for the children with ASD nor a comparison group, taught by traditional teaching methods, was employed, it is impossible to assess the efficacy of their procedure in training children with ASD. The results, however, were encouraging. Note that the specific fading procedure used by Hetzroni and Shalem (2005) has been referred to as “transfer-along-a-continuum” and involves “attentional shaping”, which has been shown to be the most effective fading procedure available (cf. Ploog and Williams 1995, for a basic research study with pigeons comparing two fading procedures against a trial-and-error procedure). The implementation of such a fading procedure benefits greatly from computer technology as the fading steps, which involve gradual manipulation of visual stimuli, can be automatically generated, presented, and adjusted on-line depending on an individual’s performance.

In a particularly comprehensive study, Heimann et al. (1995) tested children with ASD, children with “mixed handicaps” (including Down Syndrome), and children with typical development. Even though these children varied greatly in terms of their individual characteristics (e.g., chronological and mental age, diagnosis, language skills), their mean mental age and language skills were comparable. A computer software ALPHA developed in the USA (Nelson and Prinz 1991) was adapted to the Swedish language. This software utilizes several modes of feedback (animation, video, and voice) to train basic vocabulary for reading and writing. It also allows the user to create simple sentences using the basic vocabulary. An example, given by the authors, of a sentence that the children could create is “The bear jumps over the horse.” Creation of this sentence was followed by the presentation of an animation that illustrated the sentence. All of the children in the three groups successfully acquired new words and sentences through this procedure. Most importantly for the purpose of the present review, the children with ASD showed significant gains in reading and phonological awareness, and were reported to exhibit increased enjoyment of learning as well. Unfortunately, however, the children did not show gains in a follow-up session. Furthermore, a comparison of CAT to traditional teaching methods was not possible given the lack of a non-CAT control group. A rigorous assessment of the efficacy of CAT itself was not possible.
either, even though a pre- and post-treatment comparison suggested that CAT did result in gains. (For an earlier study with comparable results, see Heimann et al. 1993, presented in Table 1).

Two other studies (Tjus et al. 1998), involving some of the same researchers as the two aforementioned studies (Heimann et al. 1993; Heimann et al. 1995), also utilized a multimedia software program—similar but more flexible than ALPHA—to enhance reading and language skills in children with ASD. The participating children could select textual components and, by doing so, create complete sentences. The children were then given graphic and spoken feedback for each sentence they had created. After the feedback, the children were asked to choose from several alternatives the sentence that best matched the meaning contained in the graphics accompanying the sentence. In Tjus et al. (1998), the children (all with ASD) made significant improvements in reading and phonological awareness. At follow-up, the gains were maintained for phonological awareness, but unfortunately not for reading. However, a “response time index” showed that reading had become more fluent following intervention. These authors employed a baseline-treatment (within-subjects design), which allowed them to attribute the gains to their implementation of CAT. However, no comparison with traditional teaching methods was possible due to the lack of an appropriate control group.

Tjus et al. (2001) expanded on the research conducted by Heimann et al. (1993, 1995), and Tjus et al. (1998) by including an assessment of the teachers’ behavior. For this study, they used the Swedish adaptation of ALPHA (Nelson and Prinz 1991) described above. Eleven children with ASD and nine children with mixed intellectual disabilities (including Down Syndrome) participated, as did nine teachers, which was a novel aspect of this line of research. Tjus et al. (2001) found that both groups of children improved in verbal expression. The children with ASD also showed greater enjoyment of the learning situation and willingness to ask their teachers for help when needed. With a more fine-grain analysis, by subdividing the children with ASD into high versus low language-age groups, it appeared that the low language-age children made improvements in verbal expression throughout the study whereas those with high language-age showed increased enjoyment. The teachers were reported to have reduced their instructions on how to use the computer over the course of training, but that this reduction was greater in the ASD group than in the comparison group (mixed intellectual disabilities). As in the other studies from this research group, no control group representing traditional teaching methods was included, thus the efficacy of CAT could not be compared to that of other methods.

Yamamoto and Miya (1999) employed computer-technology to train three children with ASD (mean age 8; 7, with mental age of 3; 6) to construct five-word sentences in Japanese (by clicking with a mouse on words presented on the monitor) and to pronounce these sentences. Specifically, the children were trained to sequentially respond to the different components of the sentence (subject, verb, object) and to use particles (i.e., Japanese grammatical markers). The children’s behavior was assessed in pre- and post-test sessions (with untrained stimuli) and during training. All students improved their skills in constructing sentences during the post-test, and appropriate vocal responses emerged. The use of particles also increased and generalized to untrained sentences in the post-test. Even though CAT resulted in an increase in appropriate language behavior, it was not possible—due to the lack of a control group without CAT—to assess whether CAT was superior over traditional training approaches.

A well-designed study by Coleman-Martin et al. (2005) is unusual in the sense that these authors compared CAT Alone, Teacher Alone, and Teacher + CAT conditions, thus providing a rare opportunity to assess the efficacy of CAT compared to traditional methods. However, only three children (one with ASD, one with cerebral palsy, and one with brain-injury from a stroke) participated in this study. Nevertheless, because a multiple-baseline design across participants was employed, a preliminary comparison of the three conditions was still possible. For all three conditions, the Nonverbal Reading Approach (NRA) was implemented. The NRA consists of teaching students “a metacognitive strategy using internal speech for decoding words” (Coleman-Martin et al. 2005; p. 81). The NRA involved teacher models and drill-repetition-practice-feedback sequences. The CAT Alone condition consisted of presenting words on slides (with visual and auditory components) via PowerPoint® (Microsoft). The participants were encouraged to pronounce each word along with a computer-voice, and then were encouraged to sound out the words silently while the computer-voice spoke aloud. After each word, a picture and a phrase were presented as reinforcement. The Teacher Alone condition consisted of the use of the guided practice component of the NRA. Each condition was in effect until a child reached an 80 %-performance criterion, and each condition was preceded by a baseline condition in which no training was performed (representing a complete ABACAD reversal design—the order of conditions, however, was not counterbalanced due to the small number of participants). In terms of efficacy, their overall results suggested that Teacher + CAT was slightly superior to CAT Alone; however, there was no evidence that CAT Alone was better than Teacher Alone. For the child with ASD specifically,
Teacher Alone and Teacher + CAT resulted in equivalent gains, whereas overall CAT alone resulted in slightly lower performance than the other two conditions. Still, the authors’ assertion that CAT might be useful in freeing up teacher time while allowing students to practice decoding and word identification is warranted, as the drop in CAT Alone was small, and the benefits of freeing up teacher time might be significant when the efficiency of an overall program is to be considered.

Moore and Calvert (2000) also compared CAT with a “behavioral program” (BP; non-CAT) in a between-participant design where each child only received one of the two conditions. Fourteen children with ASD, aged 3 to 6 years, participated. The BP condition consisted of teaching the names of simple objects by repeatedly presenting commands (e.g., “Give me _object_”). When the child responded correctly, he or she was given verbal praise or was allowed to play with the object. The CAT condition resembled the BP condition, except that reinforcing colors, animation, music, and sounds were presented when a correct response occurred. The children with ASD were more attentive, more motivated, and learned more vocabulary in the CAT than in the BP condition. Thus, this study provides convincing evidence of CAT’s high efficacy (i.e., CAT better than non-CAT) with beneficial side effects (e.g., greater motivation).

Bosseler, Massaro, and their colleagues conducted several studies that employed CAT (e.g., Bosseler and Massaro 2003; Massaro and Bosseler 2006; Williams et al. 2004) in the form of a virtual talking head, Baldi®. Baldi® encourages multimodal (visual and auditory) speech processing by teaching associations between pictures and words spoken by the talking head (cf. Massaro, 2006). Baldi® presents new words paired with images, and instructs the student to identify the corresponding object from an array, click on the printed word corresponding to the new vocabulary item, spell it, imitate pronunciation of the word, and independently name it. Throughout each lesson, Baldi® talks to the student and provides feedback regarding their responses, such as a happy face following a correct response. In brief, Bosseler and Massaro (2003) conducted two experiments with a total of eight children with ASD. All students increased significantly their vocabulary and improved their grammar. In their second experiment, employing a multiple-baseline design, it was possible to attribute the verbal improvements to the use of CAT and also to show that these improvements generalized to non-CAT environments. However, a comparison between the efficacy of CAT and traditional methods was not possible. In an attempt to assess the efficacy of Baldi®, using an appropriate within-subject alternating treatment design, Massaro and Bosseler (2006) studied whether providing a “face” was important when Baldi® was employed (as opposed to a voice alone). They found that the children (the same children who had participated in Bosseler and Massaro 2003) learned faster and remembered better what they had learned in the bimodal (voice + face) condition than in the unimodal (voice-only) condition. This represents some preliminary but important evidence that audio-visual CAT is superior to less complex, auditory-alone CAT for speech and language training. Williams et al. (2004) conducted a study primarily to test the ability for audio-visual integration during speech processing in children with ASD. They included a loosely matched group of typical children. Although some children with ASD exhibited deficits in recognizing speech-like stimuli in the unimodal conditions (voice or face only), the groups performed comparably in the bimodal (voice + face) condition after controlling for performance in the unimodal conditions. This result underscores the benefit of including visual information (i.e., oral-facial gestures) in speech training. Importantly, the use of visual cues to speech appears to be trainable using CAT: J. H. G. Williams et al. (2004) used Baldi® to train a group of five children with ASD in speech reading, and demonstrated significant improvements in their accuracy in utilizing facial cues in speech processing after training.

The aforementioned studies focused on speech, reading, and vocabulary development in children with ASD. In addition to several pilot studies, a few of the studies cited employed a multiple-baseline design (Yaw et al. 2011; Hetzroni and Tannous 2004; Hetzroni and Shalem 2005) to strengthen internal validity with respect to CAT’s efficacy. Some studies suggested improvement of language skills attributed to CAT (e.g., Whalen et al. 2010). Still, most studies did not employ a control condition to allow for a direct comparison of CAT with traditional teaching methods. Results from these studies suggest that CAT can play a strong role in helping ASD children to recognize more words and it may encourage children to spend more time reading. It is also suggested that CAT increases the enjoyment that the children experience while engaging in lingual activities (Tjus et al. 2001; Heimann et al. 1995). CAT also seems to induce less anxiety than other methods of instruction (Hailpern 2008). In the next section, we will address the use of CAT for the treatment of another landmark deficit in individuals with ASD: Recognition of emotions, often encoded in facial expressions.

Enhancement of Face Processing and Emotion Comprehension

The previously discussed work with Baldi® suggests that children with ASD attend to faces and that their speech perception and vocabulary acquisition are facilitated by exposure to facial cues (e.g., lip movements) correlated with speech sound production. Perhaps it is surprising then
that there is much research indicating that individuals with ASD have difficulties recognizing emotions through facial expressions (e.g., Bölte et al. 2006; Gross 2005; Lindner and Rosén 2006; Nijoki et al. 2001). Because of these findings, some researchers have tried to use CAT with individuals with ASD to improve their recognition of emotions in facial expressions.

Golan et al. have used CAT (“Mind Reading” software) to train individuals with high-functioning autism or Asperger Syndrome to recognize emotions in faces and voices (see also Golan et al. 2010, who, in a large-scale study, employed a computer-generated animation series for children with ASD to enhance recognition of emotions in faces. The training itself, however, was not based on CAT). Mind Reading is an interactive guide based on a taxonomic system of 412 emotions and mental states grouped into 24 emotional groups and six developmental levels. In Golan and Baron-Cohen (2006), 54 adults with high-functioning autism or Asperger Syndrome were trained with Mind Reading to recognize emotions and mental states in the faces of others. The participants were matched on the basis of age, verbal and performance IQ, handedness, and gender. A comparison between intervention with Mind Reading and no-intervention conditions was conducted. Participants in the Mind Reading intervention group improved significantly in their scores on the Cambridge Mindreading (CAM) Face-Voice Battery (Golan et al. 2006), in the number of emotional concepts recognized, on the Reading-the-Mind-in-the-Eyes task, and on the Reading-the-Mind-in-Voice task (cf. Golan et al. 2006, 2007). The participants, however, did not improve significantly in generalization tasks. Even though this study provides strong evidence of improved recognition of emotions with CAT itself, it does not allow for a comparison with traditional, non-CAT approaches.

LaCava et al. (2007) also used the Mind Reading software to train eight children with Asperger Syndrome to recognize basic and complex emotions in computer-presented voice and face stimuli. This study represents an extension of Golan and Baron-Cohen (2006) because the Mind Reading software was now shown to be effective in children, as well as in adults, and there were significant improvements from pre- to post-intervention in measures similar to those used by Golan and Baron-Cohen (2006). As a beneficial side effect, the participating children found the computer program to be fun, entertaining, and displayed good skills in operating the computer games. In a later study, again using the Mind Reading software, LaCava et al. (2010) found that this form of CAT indeed improved emotion recognition and social behavior in four boys with ASD, but the effects were not strong enough to conclude that CAT was superior over a non-CAT approach.

Research by Silver and Oakes (2001) also sought to evaluate and improve comprehension of emotions in children with autism and Asperger Syndrome through an “Emotion Trainer” computer program. One group of eleven children received CAT training, whereas eleven other children served as non-CAT controls. Training was organized into five sections: Section 1 asked children to identify the emotion (e.g., sad, angry, happy, or afraid) corresponding to a facial expression (e.g., an angry face). Section 2 displayed cartoons with captions describing a situation that would prompt an emotion (e.g., under a picture of a rabbit, the sentence “Carlos’s pet rabbit died” was displayed); children were asked whether the situation would make Carlos sad, angry, happy, or afraid. Section 3 displayed a picture of what a person wanted, along with a picture of what the person actually received. For example, along with pictures of a pizza and a hamburger, the sentence “Carol wants a pizza, but gets a hamburger” was displayed. Children were asked whether it made Carol sad or happy. Section 4 was similar to Section 2 but addressed mental states rather than physical events. For example, the sentence “Kathy thought the graveyard was haunted” was displayed and children were asked whether the situation would make Kathy sad, angry, happy, or afraid. Section 5 displayed an event that a person either liked or disliked, indicated whether the event did or did not occur, and asked the child whether the person was pleased or disappointed. Throughout the task, correct responses were rewarded by praise (“Well done!” displayed on the monitor) and a brief animation sequence (e.g., a bouncing ball). Children who received CAT improved on three measures: Identification of emotions in facial expressions, in cartoons depicting emotional content, and in stories, whereas children in the control group did not make such improvements, thus providing good evidence for the efficacy of CAT. Nevertheless, this outcome should be interpreted with caution, as it was not clear what type of training the control group actually received. It was only stated that the controls “had only their normal lessons.” It is not clear, for example, whether the normal lessons included explicit training on identifying emotions, and if so, how this was done without involving CAT. Thus, a direct comparison of CAT to non-CAT methods for training emotion recognition cannot be made.

Similar to Silver and Oakes (2001), Moore et al. (2005) used computerized visual representations of emotional facial expressions, however, they employed a humanoid “avatar”, i.e., a 3-D representation of a character simulating real life experiences. Their approach allowed for the presentation of faces and simple animated sequences conveying emotionally significant scenarios. Specifically, their avatar could display four different emotions: sad, angry, happy, or afraid. Moore et al. (2005) conducted their study in three stages: In Stage 1, the participants (34 children with ASD) were asked what emotion the avatar was feeling by
selecting the corresponding representation. In Stage 2, the participants were asked to predict the emotions in different scenarios. In Stage 3, participants were given an avatar representing a certain emotion and asked to choose the event or events that caused this emotion. Moore et al. (2005) analyzed the data by comparing the number of observed responses to the number of responses expected if they were selected by chance. Their results indicated that 90% of their participants were able to interpret, recognize, and predict the avatar’s emotions. Furthermore, they concluded that the collaborative virtual environment allowed the children to communicate more effectively with other people. They attributed this success to the fact that the children could practice repeatedly and express their own emotions through the use of the avatar. This study therefore qualifies as an example of using virtual reality in the treatment of individuals with ASD (to be discussed in more detail below). The authors themselves, however, readily pointed out that this was “an exploratory empirical study”, thus one should use caution when evaluating the efficacy of CAT (or specific aspects of CAT such as the use of an avatar), and there was no control group allowing for a comparison to a non-CAT condition. Yet, the overall interest and motivation that participants exhibited in this study confirms anecdotal evidence that computer technology itself represents a motivator for individuals with ASD. (For additional examples of training children with ASD in recognizing emotions in facial expressions, see Grynszpan et al. 2007, and Grynszpan et al. 2008, discussed in more detail below in the section Teaching Social Skills: Communication, Play, and Daily Living Skills, and Related Behaviors).

In summary, facial and emotion recognition skills are critical for social interactions with others. Individuals with ASD may be compromised in these skills as they commonly present marked impairment in nonverbal behaviors such as gaze monitoring and attention to facial expressions. Some of the studies employing CAT and targeting facial emotion recognition actually showed significant improvements but, again, the lack of explicitly defined non-CAT control conditions prevents one from concluding that CAT is superior to other approaches. Furthermore, the improvements in the participants with ASD do not seem to generalize well, which might suggest that individuals with ASD are simply learning to score high in a particular computer activity. Still, as studies in the previous section suggested, increases in motivation support CAT as a favorable mode of skills training for individuals with ASD.

Teaching Theory of Mind

The aforementioned studies by Moore et al. (2005) and Silver and Oakes (2001), for example, not only addressed identification of emotions per se but also identification of emotions in others, which represents one of several distinctly separate skills referred to collectively as Theory of Mind (ToM)—the ability to make inferences about others’ intentions, thinking, reasoning, emotions, and motivation. Some researchers consider a lack of ToM to be a hallmark deficit in ASD (for a review see Baron-Cohen 2001) even though this is not yet a symptom, as far as we know, that has been formally incorporated into any diagnosis of ASD. However, in the context of a presumed link between deficient ToM and ASD, it is not surprising that researchers have begun to apply CAT to enhance ToM in individuals with ASD, as will be described next.

Swettenham (1996) conducted an early, exemplary study utilizing a CAT program to teach ToM concepts to children with ASD; however, the training program proved to be unsuccessful. Swettenham based his CAT program on the Sally-Anne False-Belief Task developed by Baron-Cohen et al. (1995, cf. Wimmer and Perner 1983). Eight children with ASD, eight with Down Syndrome, and eight with typical development, matched by verbal mental age, participated. These children were presented with various false-belief scenarios, and were asked to choose correct responses (e.g., “Where does Sally think the ball is?” after the child witnessed that Anne had moved the ball, unbeknownst to Sally). If the child chose the correct answer, he or she was rewarded with a “Yes, well done!” message, flashing visuals, and music. There were several different types of tasks: The standard (Close Transfer) Sally-Anne False-Belief Task (e.g., Sally hides an object while Anne is watching; Anne moves the object without Sally watching; the child, who observed Anne changing the location of the object, is asked where Sally thinks the object is) and three Distant Transfer Tasks (e.g., “The Smarties Task”, requiring the child to state his or her own false belief, i.e., that they had thought candy would be in the Smarties box, after observing that the Smarties box unexpectedly contained a pencil; and as a further test, requiring the child to state what a friend unaware of the unexpected contents would think was inside of the Smarties box). Whereas all of the children passed the standard (Close Transfer) task, none of the children with ASD were successful in passing the Distant Transfer Tasks. Swettenham (1996) also assessed post-test and follow-up performance but observed no significant changes in the main findings. To our knowledge, no further CAT has been developed to improve performance on the False-Belief task in children with ASD, even though other aspects of ToM, such as the ability to identify emotions in others, have been successfully enhanced through CAT (e.g., Moore et al. 2005; Silver and Oakes 2001, as described above).

Through video modeling, Charlop-Christy and Daneshvar (2003) taught three children with ASD “perspective taking”—another skill considered to be an important component of ToM. Even though video modeling is not a
Even though the symptom cluster associated with ASD is and Daily Living Skills, and Related Behaviors. Teaching Social Skills: Communication, Play, perspective taking, but could not be compared with remediation; another study was successful in enhancing are rare. One study failed to demonstrate successful components of ToM to children with ASD. As this study was well designed, its implications are crucial for the development of effective CAT. However, despite this study’s methodological strength, it did not allow for a direct assessment of video modeling’s efficacy compared with traditional methods such as in vivo modeling. It remains therefore unclear whether their approach represents an improvement over traditional methods when attempting to teach components of ToM to children with ASD.

In summary, studies involving CAT that go beyond a mere assessment of deficits in ToM in children with ASD to investigate the remediation of putative deficits in ToM, are rare. One study failed to demonstrate successful remediation; another study was successful in enhancing perspective taking, but could not be compared with alternative approaches.

Teaching Social Skills: Communication, Play, and Daily Living Skills, and Related Behaviors

Even though the symptom cluster associated with ASD is extremely diverse (Tager-Flusberg and Joseph 2003), a common thread throughout the spectrum is a lack of social skills essential for communication, play, and daily living. Whereas language, discussed above, is certainly one aspect of social and communication skills, other aspects may be nonverbal. All individuals with ASD (including Asperger Syndrome) have some degree of difficulty with social skills and non-verbal communication, such as providing appropriate eye contact in social interactions (whether verbal or not), relating to others’ needs, and adhering to common social etiquette (e.g., with regard to sexuality). Deficits in social and communicative skills may well be a by-product of a deficit in ToM; nevertheless it makes sense to address deficits in specific social and communicative skills directly.

This last review section opens with a discussion of two technologies that have been employed to teach social skills: Video modeling and virtual reality. We organized the subsequent review into three subsections: Teaching communication skills, play skills, and daily living skills as related to social behavior. Several of the reviewed studies overlap and could have been listed under several subheadings. However, for sake of brevity, we discuss each study only under one subheading.

Video Modeling

Video modeling is not necessarily bona fide CAT (as often only a television screen is used to present the videos, without provisions for viewer interaction and control), but it is included in this review to illustrate it as an initial step towards developing an effective CAT. After all, to assess the efficacy of a CAT program incorporating video models, it makes sense to first evaluate the efficacy of procedures in which video models are presented on a computer screen. Once efficacy is established, computerized control over events during training, exerted by the viewer/player, can easily be implemented as part of the video-modeling session. Video modeling often has been applied to increase the frequency and diversity of social behaviors, and, ideally, a significant proportion of a young child’s social repertoire should consist of non-solitary, social play (i.e., play involving at least one person other than self). Given the limitations in verbal skills of children with ASD, it makes sense to employ technologies that lean towards visual-nonverbal modes of presentation of the relevant training materials, as is true in video modeling. The majority of these studies present evidence that video modeling can increase the acquisition of target social skills.

A study by Charlop-Christy, Le, and Freeman (2000) illustrates the video-modeling approach well in a study comparing the effects of video modeling with in vivo modeling in eight children with ASD (ages 7–11 years) using a within-participant design. Children were randomly assigned to start with either a video-modeling or live-modeling (in vivo) condition and subsequently participated in the alternative condition. Target behaviors for treatment were selected on an individual basis, depending on a child’s deficits, and included the following: expressive labeling of emotions, independent play, spontaneous greetings, spoken language comprehension, conversational speech, cooperative play, daily living skills, and social play. The use of a baseline condition in which the effects of “traditional procedures” were assessed made this a valuable study to assess the efficacy of video modeling as a preliminary step to employing CAT in comparison to traditional methods. The findings were that video modeling resulted in faster acquisition of the target behaviors than the in vivo condition, and that video modeling was also effective in promoting generalization of the target behaviors. The authors attributed the success of video modeling
to the fact that it encompasses qualities that enhance motivation and attention, which by extension, has important implications for CAT.

Pure video modeling was also used by Nikopoulos and Keenan (2007): In two experiments involving a multiple-baseline design, four children with ASD were taught complex social sequences encompassing social initiation, reciprocal play, imitative responses, and object engagement (i.e., solitary, toy-appropriate play). In their implementation of video modeling, videotapes were shown of a child with learning disabilities and average social skills acting as the model of each target behavior. Each child observed all the videotapes and was then placed in an outside area where social interaction and communication were allowed to occur. Nikopoulos and Keenan (2007) found in both experiments that video modeling in the form of short video clips successfully helped children with ASD to learn social behaviors and to initiate social interactions. Notably, they reported decreases in social isolation along with increases in reciprocal play following the intervention. The efficacy of CAT per se could not be assessed in this study but it provides further evidence that presenting information on a television screen is a viable training approach, with implications for CAT.

Simpson et al. (2004) combined video modeling and computer-based instructions (a form of bona fide CAT) to teach social skills to four children with ASD (ages 5–6 years). All of the children lacked social skills and had mild to severe speech and language impairments. The teacher designed a CAT program comprising video clips of typically developing students modeling examples and non-examples of the target behaviors: sharing, following a teacher’s directions, and social greetings. They employed a multiple-probe design across behaviors to evaluate the children’s improvement. They also scheduled in vivo generalization sessions where the children with ASD interacted with typically developing children. The effects of this training were clear: All children improved in the targeted social skills quickly. No component analysis, however, was done which would have allowed an assessment of which aspect of the treatment was responsible for the improvement, or whether the treatment was more effective than traditional, non-CAT methods.

Similar to Simpson et al. (2004), Sansosti and Powell-Smith (2008) also used video modeling and CAT to teach social skills (sharing, joining in, and greeting) to three boys with high-functioning ASD within an educational environment. CAT involved presenting “social stories” by computer; video models were employed to demonstrate the correct social behaviors. Sansosti and Powell-Smith (2008) found that video modeling combined with CAT increased the frequencies of the targeted social and communication behaviors. After the intervention, a 2-week follow-up was conducted and the results showed that all participants were able to maintain the learned social and communication skills.

Virtual Reality

The history and use of virtual reality in the training of individuals with ASD and other disorders is thoroughly documented in Strickland et al. (2007) along with discussions of several research projects that have utilized virtual reality. Virtual reality is a type of CAT that relies heavily on the efficient presentation of audio-visual information via television or computer (just as video modeling does). Virtual reality further depends on technology allowing for a high degree of user-control and interactivity between the user and the electronic media, which qualifies it as true CAT. Because of the high level of technical sophistication that is required for the management of audio-visual information in virtual reality, this type of CAT has emerged only very recently as an option for private entertainment, education, treatment, and as a research tool (e.g., Rutten et al. 2003; Trepagnier et al. 2005; Wallace et al. 2010). An early discussion of the pros and cons of virtual reality is provided by Strickland (1996).

Mineo et al. (2009) attempted to assess the workings of virtual reality in an impressive large-scale study. (Note, however, that this study was not explicitly designed to remediate any deficiencies in persons with ASD.) Forty-two children with ASD, with some language deficiencies, of ages 6–18 years, first viewed an animated video (baseline). Then they were randomly assigned to one of the three experimental groups: Self-Video (children viewed themselves engaged in some non-aversive activity), Other-Virtual-Reality (children viewed others engaged with a virtual reality system), and Self-Virtual-Reality (children viewed themselves engaged with the virtual reality system). “Engagement” was measured as the amount of time the child gazed at the screen and by the number of utterances produced while being immersed in the activities. Unfortunately, the results were not clearly interpretable: Measured by gaze, the children preferred Self-Video and Self-Virtual-Reality over Other-Virtual-Reality; measured by utterances, the children responded—from most to least—in Other-Virtual-Reality, Self-Virtual-Reality, and Self-Video conditions. The response levels in the Other-Virtual-Reality condition were clearly discrepant for the two dependent variables, gaze and utterance. Also, differences in responding during baseline and in the three experimental conditions did not differ consistently, which leaves unanswered the question of whether virtual reality is superior in any way to other forms of CAT or to simple video modeling. Nevertheless, the authors suggested reasonably that high levels of gazing is consistent with the idea that children enjoyed seeing themselves on the screen (thus looking at it longer) in the Self-Virtual-Reality and
Self-Video conditions, whereas the high number of utterances in the Other-Virtual-Reality condition was attributed to one subset of children becoming very "verbally effusive at the sight of a favored [other] person on the screen. (p. 183)"

Regardless, this study provides evidence that virtual reality is a promising tool by which to engage children with ASD in paying attention to audio-visually presented materials. It was not possible, however, to assess which of the three experimental conditions may have been the most effective or most engaging condition.

Grynszpan et al. (2008) provided another example of virtual reality. (Apparently, the same data were also reported in Grynszpan et al. 2007.) They assessed whether simple CAT (without facial expressions) or complex CAT (with facial expressions) involving text, speech, and images was more effective for training children with ASD to make correct decisions about emotional and other information. (The dependent variables were the number of correct choices, number of trials per scenario, and the duration spent on making correct choices.) Grynszpan et al. (2008) also assessed whether or not facial expressions were helpful in dialogues with complex pragmatics (e.g., involving sarcasm or metaphor). Two groups of children (ten in each group; with ASD and with typical development) were recruited, matched by gender and academic level. Training consisted of a game “What to Choose?” in which the children were presented with dialogues (e.g., Carole: “The French teacher is away today”; Nick: “Great! He was to give us an exam today”; Carole: “The exam has been cancelled”; Nick: “What a pity!”) This dialogue was accompanied by a picture of Nick (a human-like, virtual-reality character, smiling) with three statements to choose from by clicking on the statement (e.g., “Nick is disappointed that there is no exam today”, “Nick wishes the teacher was not away today”, and the correct choice, “Nick is quite happy that there is no exam today”). Feedback was given for the child’s choices. In another version of training, instead of the human-like character, a cartoon character was used. After the “What to Choose?” task, the children with ASD subsequently played another game, “Faces”, in which they had to identify the correct emotion in the virtual-reality, human-like face and in the cartoon character’s face. Across formats (virtual reality, cartoon), children with ASD showed above-chance recognition of facial expressions in the Faces test, which indicates an ability to recognize emotional expressions in synthetic stimuli (see also Moore et al. (2005), summarized in the section “Enhancement of Face Processing and Emotion Comprehension”, for evidence of the efficacy of CAT to improve emotion recognition).

To test for generalization of training, Grynszpan et al. (2008) asked the children to play an additional game, “Intruder” which added difficulty by including out-of-context or socially irrelevant statements in the dialogues (e.g., Passer-by: “Excuse me, I need a hand. […] where is Main Avenue?” Policeman: “I don’t want to give you any of my hands!”). This task was presented in two formats: multimedia with text, synthetic voice, and image versus text alone. Results showed that typically developing children improved in their ability to identify the contextually irrelevant statements in both versions of the “Intruder” game, whereas the children with ASD showed improvements only with the simpler, text-only version. Presumably, these children had greater difficulties locating the irrelevant statements when the task format was more complex; their apparent confusion with the multimedia displays provides further evidence of the atypical attention patterns reported numerous times in the literature on ASD (Ploog and Kim 2007; Ploog et al. 2009; Ploog 2010b).

A well-controlled study by Parsons et al. (2004) used virtual reality to assess the executive functions and social skills of individuals with autism (for technical details, see Rutten et al. 2003). There were three groups of participants: twelve children with ASD, twelve children recruited from a school for children with special needs, matched by verbal IQ to the children with ASD, and twelve typically developing children matched by performance IQ. In addition, the groups were matched by age and gender. During training, the children used a laptop to navigate through a virtual environment to perform different tasks (e.g., answering questions posed by the computer, interacting with the environment, such as making a choice from a menu and navigating to different areas in the environment). After training, the children were allowed to use the “Virtual Café”, which differed from the training environment in that it looked more realistic, there were other virtual-reality characters present, and there were textual and verbal prompts (e.g., when the virtual-reality users moved close to a table, they might hear a voice “Would you like to sit here?”) Parsons et al. (2004) found that children with ASD learned to use the computer-program quickly and efficiently, similar to the two control groups. However, the children with ASD had a greater tendency to “bump” into people or walk between them, that is, they showed an impaired sense of personal space and diminished competence in social situations—characteristics that are associated with ASD. (In this study, this is a deficit only if one assumes that virtual-reality characters are to be treated as if they were real.) Given the success of the children with ASD to use virtual reality competently, the authors concluded that virtual reality is a promising tool to improve social skills in people with ASD. Therefore, Parsons, Leonard, and Mitchell (2006) conducted two follow-up case studies to investigate if virtual reality indeed could be used to improve social skills and knowledge in individuals with ASD. Two boys with ASD, 14 and 17 years old, were...
presented with a laptop that had two types of virtual environments varying in difficulty and complexity: One was a café and one was a bus. Parsons et al. (2006) found that both boys enjoyed engaging with the virtual reality system and remembered the social skills that they had acquired during their training sessions. They concluded that virtual reality was an effective tool for teaching social skills to individuals with ASD.

Teaching Communication Skills

CAT has the potential of providing an efficient way to teach social skills and communication to children with ASD, as nicely illustrated by a study by Bernard-Opitz et al. (2001). These authors sought to evaluate social problem-solving skills in children with autism through CAT. They developed a computer program that represented eight different social settings and problems, with four easy problems (i.e., not requiring sharing and collaboration) and four difficult problems (e.g., not having enough money to purchase an item—therefore requiring collaboration and negotiation). The participants were asked to choose the correct answer from a number of different solutions. The computer program included audio clips that prompted participants to choose an answer (e.g., “What would you like to do?”). The computer program also included pictures and animations that reinforced correct responses. (Incorrect responses were simply ignored.) If a participant suggested a novel idea that had not been specifically shown in the computer game, his or her idea was reinforced as well. In this study, eight 5- to 8-year-old children with ASD and eight 4-year-old typically developing preschoolers (matched by general cognitive functioning) participated. The results showed that during the ten training sessions, the children with ASD generated fewer novel ideas than the typically developing preschoolers. However, over the course of six probe sessions (which, unlike training sessions, did not include thorough explanations of correct solutions to the presented social problems), the frequency of novel ideas generated by the children with ASD increased significantly. While the CAT approach was shown to be effective in increasing social competence in children with ASD, a comparison with an alternative approach to allow for an evaluation of CAT’s efficacy was not provided.

Teaching Play Skills

Farr et al. (2010) attempted to enhance social skills by using either “Topobo”, a so-called Tangible User Interface (TUI) toy, or LEGO® (a non-computer-based toy) in group play with typically developing children and children with ASD. This study is exceptional because its design allows for a comparison between a CAT versus a non-CAT approach, and for a comparison between children with typical development and with ASD. Both, Topobo and LEGO, are toys that can be played with in groups, thus both provide a good context for social play. Farr et al. (2010) found that for both groups of participants, more social forms of play occurred for Topobo, whereas more solitary play occurred for LEGO®.

D’Ateno et al. (2003) used video modeling to also teach complex play sequences to a 3-year-old girl with ASD. The behaviors that were modeled were having a tea party, shopping, and baking. The effect of video modeling was assessed with a multiple-baseline design across the three target behaviors. D’Ateno et al. (2003) found that video modeling increased the number of verbal and motor responses during play, and was effective in teaching complex play sequences in a relatively short amount of time, without the use of time-consuming chaining procedures. This study was noteworthy because video modeling was shown to be effective without the use of any extraneous reinforcers—simply being allowed to watch videos and engage in play activities was reinforcing enough to enhance the child’s play skills and verbal behavior. Further examples of attempts to increase pretend play through video modeling are provided by MacDonald et al. (2005; 2009). For more detail refer to Table 1.

A different approach for teaching communication and social skills to children and adults with Asperger Syndrome was taken by Rajendran and Mitchell (2006). Even though the social tasks in this study involved texting (verbal communication, typed on computer via internet) and speaking on the phone (spoken language), the goal was not to improve language per se (as individuals with Asperger Syndrome usually possess good language skills anyway); rather the goal was to compare text chat and telephone conversations to explore what types of communication individuals with Asperger Syndrome are more likely to use. Ten individuals with Asperger Syndrome (including some adults), one with high-functioning autism, and eleven typically developing participants, matched by age, gender, and educational level, participated. Using a within-participants design, each participant was asked to deduce two map routes (i.e., one for each task format) by asking a communication partner several closed-answer questions. Five individuals with ASD and five typical controls were given the text chat task first and then the telephone task, whereas task order was reversed for the others. The main finding was that the individuals with Asperger Syndrome took more time to work out a map route than the control group; however, despite their longer response times, they were able to ask appropriate questions that provided answers sufficient for them to ultimately complete the map routes. Rajendran and Mitchell (2006) failed to find evidence in support of their prediction that participants with Asperger Syndrome would communicate more effectively.
through text-chat than through telephone. In fact, both groups took longer to complete the task via text-chat than via telephone. Thus, in this study, CAT (texting) was not more effective than non-CAT (calling on the phone).

Teaching Daily Living Skills

Stromer et al. (2006) suggest that so-called “activity schedules” (a notebook—possibly computer-based—using pictures, symbols, and/or text to guide an individual through specific sequences of daily activities; e.g., Cihak 2011; Krantz and McClannahan 1998) can be combined with other CAT to promote social skills in individuals with ASD. Reviewing the literature, Stromer et al. (2006) suggest that such a combination may be effective in part because it allows for the easy pairing of visual and auditory stimuli, thus providing training in attention to multiple cues, which poses a problem for many people with ASD who often have difficulties attending to multiple cues (for a review of this literature, cf. Ploog 2010b).

Kimball et al. (2004) provide a description of a case study used to explore a combination of CAT with activity schedules to enhance social skills. These authors worked with a 4-year-old boy with ASD using a computer, video models, and computer-presented activity schedules. In this case, the approach proved to be effective in teaching the child age-appropriate social skills. The use of a computer was considered beneficial because of the efficient and consistent delivery of instructions and reinforcement contingencies, and because it promoted the combined use of audio and visual cues (see Stromer et al. 2006). Similar to Kimball et al. (2004), in another case study, Dauphin et al. (2004) combined activity schedules and video-based CAT to teach social skills and socio-dramatic play skills to a 3-year-old boy with ASD and attention deficit/hyperactivity disorder. The boy improved his social skills, and his improvements generalized somewhat to activities not specifically trained. Obviously, case studies are not amenable to a rigorous assessment of the efficacy of CAT, but nevertheless, these cases are good examples to show that video-based CAT is feasible and useful even with rather young children lacking age-appropriate social and verbal skills.

Conclusion

Properly designed CAT programs may be advantageous in helping children with ASD attain skills for increased adaptive functioning. A problem that often arises is that the majority of the available programs have not been developed specifically for this population. Among the few programs that have been developed for individuals with ASD, some have flaws and limitations. Some programs employ various sounds (“bells and whistles”) that might unintentionally set the occasion for undesirable behavior or distract from the relevant information to be conveyed. The abnormal attention patterns of children with ASD, who may have difficulties with the processing of complex multimodal or multi-dimensional information, may lie at the root of this issue. Also, poorly designed programs using CAT can socially isolate a child (i.e., only interacting with a machine and not with other people), as well as encouraging limited acts of behavior and ways of responding to various stimuli (because of the limited range of training situations incorporated in the CAT). In other words, the lack of generalization of treatment effects may become a problem. Still, assuming good design, CAT can be useful in providing opportunities for individuals with ASD to learn skills accurately, independently, and efficiently. A properly designed CAT program can encourage performance of a variety of new social and communication skills (including verbal and non-verbal skills). Furthermore, properly designed programs that utilize CAT can provide good training—possibly with higher precision than a teacher could. As a result, The Autism Technology Developers Association (ATDA) was created to educate researchers and developers about upcoming and existing technologies and to share their information and knowledge with one another (Kimball and Smith 2007).

There are some major scientific findings that if incorporated would likely result in more effective CAT designs. Many of the studies summarized were pilot studies aimed at testing the possible benefits of such new technologies. One important research direction would be to move from pilot to well-controlled, large-scale studies with increased sample sizes, and various subgroups (considering the diversity found in individuals with ASD). In addition to increasing sample size, it is crucial to include a comparison against more traditional (non-CAT) approaches. These research considerations are necessary to correctly assess the validity of the large variety of CAT programs. There are parents of children with ASD, teachers who work with them, adults with ASD, and practitioners who are eager to find practical solutions for enhancing the quality of the social life of individuals with ASD. It is ethically imperative that these constituents be served by sound scientific approaches rather than be misled by methods that are unproven and possibly ineffective at best or detrimental at worst, regardless of how well-intended and intuitive these methods may be.

In summary, much technological progress has been made to develop engaging CAT programs. However, at this date, most studies still lack scientific-methodological rigor to allow for a comparison between CAT and traditional, non-CAT, methods, to convincingly demonstrate the
efficacy of CAT. Thus, it is too early to rely fully on CAT alone—a conclusion supported by the aforementioned study by Coleman-Martin et al. (2005), who found that Teacher + CAT training was slightly superior to CAT alone. But even so, there is accumulating evidence that the use of computers in the treatment and education of individuals with ASD has advantages in terms of enhancing motivation and treatment fidelity. With continued rigorous scientific research, CAT will likely play a very prominent role in the treatment of individuals with ASD in the near future.

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