The Use of Technology in the Study, Diagnosis and Treatment of Autism

Final term paper for CSC350: Autism and Associated Developmental Disorders

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Introduction

Man is a technological creature. Technology constitutes the very foundations our survival relies on and is all-pervasive in modern-day human life. The invention, use, and continual improvement of tools and utilities sets man apart from other species. In its most basic definition, technology is nothing more than the practical application of knowledge to a particular area, a core human ability.

We use technology to augment our physical capabilities, developing methods to accomplish tasks, such as flight and prolonged submersion in water, that would have taken millions of years to result through evolution. In a similar manner, man has used technology to extend his communicative abilities (writing, telephones, computers), to regulate his environment (heat, electricity, buildings) and to improve the process of gathering food (farming, agriculture), among many others.

Perhaps most interesting, however, is our use of technology in order to treat ailments, illness and disability. We constantly seek and explore new ways of improving the health of sick individuals and try to enable those with disabilities to lead as close to a normal life as possible. From the use of wooden sticks to support and mend broken bones to the analysis of the human genome, technology is at the very core of every aspect of medicine.

Of all medical conditions, pervasive developmental disorders and autism spectrum disorder present one of the most challenging application domains of technology in the diagnosis, study and treatment of disease. As is the case with other psychological illnesses, the condition of autism is particularly intangible and multifaceted, providing no obvious, straightforward way of employing technology or conducting technological research to improve the condition of a patient with autism. Furthermore, the deeply social aspect of the disease does not lend itself to simple treatment using physical apparatus or trivial clinical methods. Still, considerable effort has gone into the exploration of technology to aid in the diagnosis and treatment of the disease, resulting in remarkable tools and methods that not only have the potential of improving the everyday life of an autistic person, but may also answer some of the open questions about the nature of the disease.

The aim of this paper is to provide an overview of some of the uses of technology in the study of autism. It focuses particularly on devices and methods that directly interface with patients and the technological approaches for evaluating different theories of autistic development. Emphasis is also placed on current developments, with previous approaches serving as examples of more or less successful strategies for coping with autism through technology.

Video

As a behavioral syndrome, autism requires a certain number of key types of behavior to be present in a patient in order for a positive diagnosis to be established. The DSM-IV (American Psychiatric Association, 1994) requires them to come from the following broader definitions:

1. Abnormal social relationships and social development
2. Failure to develop normal communication
3. Restricted, repetitive, stereotyped patterns of behavior

The onset of these symptoms also has to occur before the age of 3.

Part of the assessment for autism takes place at a clinic, during a standardized context in which a child's behavior is observed. This process includes intelligence and language testing, as well as neurological and medical examinations. The direct interaction of medical personnel with the potential patient is crucial for establishing a diagnosis. However, the observation of a child in his or her familiar environment (e.g. at home or at school) can support a clinic diagnosis by demonstrating the patient's behavior in situations where natural communication and social interaction should occur.

Observing a patient in such familiar situations has been greatly facilitated by the availability of inexpensive video equipment. It is now easy for parents to film their children at home or for a camera to be present in the classroom at school. The filmed materials can then be evaluated by experts and support or weaken a clinically-established diagnosis, as described in (Maestro, Casella, Milone, Muratori, & Palacio-Espasa, 1999) and (Adrien et al., 1991).

Even more interesting is the potential of video in early diagnosis of autism. Using conventional clinical methods described above, experts are often reluctant to declare a patient autistic before the age that he or she would have typically developed the social and communicative abilities that autistic patients lack. (Baranek, Grace T., 1999) uses retrospective video analysis to investigate the possibility of establishing a diagnosis of autism during the first 9–12 months of life. Home videos shot by parents during that time were analyzed. In addition to the social behaviors, Baranek investigated the use of sensory-motor behaviors as early indicators of autism. The author concludes that, although home videos need to be considered carefully due to their inherent bias towards pleasant events, they can provide an early indication of the onset of autism. Sensory-motor behavior exhibited by infants also serves as a fairly reliable indicator of possible onset.

Video has also been employed in treatment methods for autism. (Charlop & Milstein, 1989) use video modelling to teach autistic children conversational skills by showing them videotaped conversations and later asking them to generalize the conversation topics with different partners and in different settings. A signifcant learning effect was exhibited, together with retention of the learned skills over a period of 15 months. (LeBlanc et al., 2003) use video modelling and reinforcement to teach perspective-taking skills to autistic children. Their results indicate poor generalization to new situations, but show promise of a video-based approach as a treatment method. (Steinborn & Knapp, 1982) provide an interesting therapeutic application of video in autism, teaching a child pedestrian skills using both a model of the streets and intersections in question, as well as video recordings of the traffic at the intersections in question. The child later successfully generalized the skills to the real-world environment. (Charlop-Christy, Le, & Freeman, 2000) illustrate the advantages and disadvantages of video modelling versus in-vivo modelling in a teaching environment.

Biological and Genetic Methods

In the quest for earlier indicators of the onset of autism, many turn to biology. The hope is that the human body exhibits some biological feature very early on in development (perhaps prenatally or at birth) that predicts autism. An earlier diagnosis allows earlier intervention, which is crucial in developmental disorders.

Szatmari & Jones, in (Volkmar, 1998), argue that autism is a strongly genetic disorder. There are many efforts currently under way to map autism genes through methods like heritage analysis, linkage analysis and sib-pair analysis. The gene analysis technology made available over the last few years (Human Genome Program, U.S. Department of Energy, 2003) has enormously facilitated this task. Having (almost) the entirety of the human genome available publicly makes genetic searches much more straightforward and enormously speeds up the rate at which experiments can be carried out. Still, the fact that a large number of genes may be involved in autism, together with the need for homogeneous subgroups of people as suppliers of genetic material and the mystery of autism's exact mode of transmission makes genetic research in autism a challenging endeavor.

Other current research takes a different approach. Instead of trying to identify the genetic expression indicative of autism, researchers have found that certain peptides are elevated in children with autism from birth (Philipkoski, 2002). Mass spectrometry in proteins is used to detect certain characteristics in samples and compare them to find differences specific to autism. The aim is to find a biomarker for autism. The technology being employed is in the early stages of development, but might be quick and accurate enough for biomarkers to hold some promise as a method for early autism diagnosis.

Imaging

Neuroimaging techniques such as magnetic resonance imaging (MRI) or positron emission tomography (PET) are one of the most prominent examples of recently developed technology that allows some analysis of the structure and functioning of what is perhaps the most difficult to analyze part of the human body: the brain. MRI and PET studies have been carried out in a variety of contexts, including post-stroke damage assessment and recovery or the study of brain activity during linguistic, numerical or social task learning, among many others.

Structural MRI has been used in the study of autism to determine the physical properties of the brains of patients. In particular, (Courchesne et al., 2001) found early abnormal brain overgrowth in children with autism, followed by abnormally slow growth. Young autistic children (age 2 to 4) were found to have larger brain volumes (often bordering on macroencephaly), despite having normal brain sizes at birth. In autistic children, the increased amount (hyperplasia) of white matter in both the cerebrum and the cerebellum as well as of grey matter in the cerebral cortex is offset by a smaller than normal amount of grey matter in the cerebellum. Older autistic children (age 8 onwards) do not exhibit these excesses in brain volume. Courchesne et al. even report diminished brain volume for autistic children of age 5–16 when compared to neurotypicals. (Sparks et al., in press) supports the findings of increased brain volume, as do (Piven et al., 1992; Piven, Ardnt, Bailey, & Andreasen, 1996). Generally, though, the evidence resulting from structural MRI studies is somewhat inconclusive. For instance, (Howard et al., 2000) shows an increased volume of the amygdala (believed to be crucial in social and emotive processing) in autistic patients, while (Aylward et al., 1999) shows decreased amygdaloidal volume. Similarly inconclusive findings are reported for the hippocampus and the brain stem (Cody, Pelphrey, & Piven, 2002). However, new image processing methods currently being developed provide dramatically more information about the morphological characteristics of brain structures than previously available (Csernansky, J., et al., 1998).

Various studies have also been performed that relate autism with functional activation in the brain while the patient performs certain cognitive processes. This noninvasive, in-vivo method allows changes in the organization of these processes to be documented. Functional MRI provides a way of investigating the neuropsychological basis of the deficits in social cognition (e.g. the processing of emotional cues or facial expressions) and executive functioning (e.g. flexibility in generating situation-appropriate actions, rather than exhibiting stereotyped behavior) that constitute the prime characteristic of autism. (Baron-Cohen et al., 1999) used fMRI (see Figure 1 for example images) to measure brain activity during a task related to the Theory of Mind (ToM), requiring participants to infer the mental state of another individual from the expression of that individual's eyes. The autistic patients activated frontal brain components less extensively than the controls and, more importantly, showed no amygdala activity. Instead, the frontal-temporal region was activated during the ToM tasks. This supports a popular hypothesis that amygdala dysfunction may be responsible for the patient's decreased ability to perform emotional and mental state processing. (Schultz et al., 2000) used fMRI to show that autistic persons exhibit greater activity in the inferior temporal gyri and less activity in the fusiform gyrus during face processing (picture discrimination). The converse was true for the controls. The authors conclude that autistic persons use feature-based strategies in face processing that are more typical of non-face perception. The findings of (Critchley et al., 2000) support this hypothesis, showing decreased activity in the fusiform gyrus and amygdala, while showing increased activity in the superior temporal gyrus, during processing of emotional expressions from face pictures. (Pierce, Muller, Ambrose, Allen, & Courchesne, 2001) also report similar results. (Ring et al., 1999) focus on the executive functioning of autistic patients during visuospatial

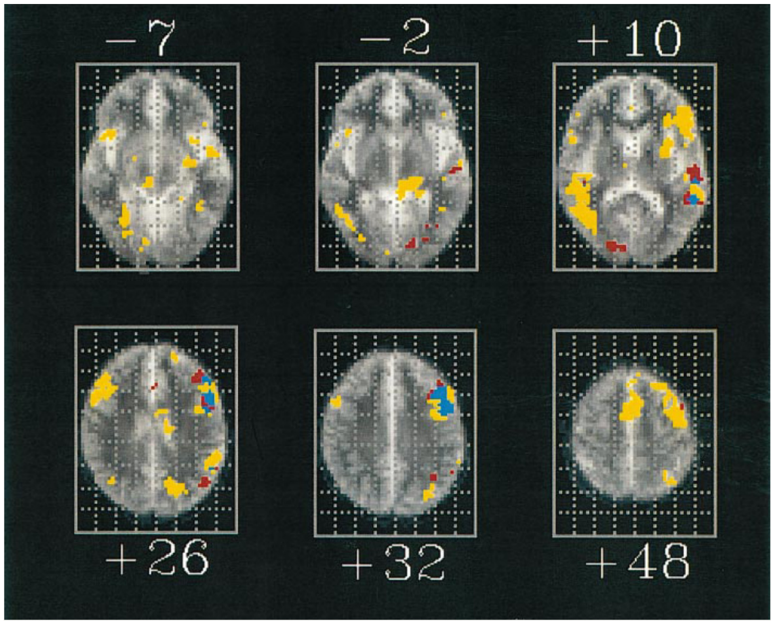

Figure 1: fMRI images of brain activity during a ToM task. Numbers indicate z-coordinates of the slice relative to the intercommisural line in the standard space. Activity occurring in the control group only is yellow, activity occurring in the autistic group only is red. Activity occurring in both groups is blue. Taken from (Baron-Cohen et al., 1999).

processing tasks (the embedded figures task, in particular), showing different activation regions for persons with autism when compared to healthy individuals. The authors claim that their results provide support for the theory of weak central coherence (Frith, 1989) as a determining factor of the disease.

Although comparatively little literature on imaging studies and autism exists to date, imaging technology has made some significant contributions towards a better understanding of both the brain phenotype and the neural basis of the autism disorder. It can be expected that further significant understanding will be gained with the availability of more advanced technology. The use of in-vivo imaging techniques may also prove to be crucial in providing early diagnostic evidence of the onset of autism.

Assistive Technology

An assistive technology is defined as "any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of individuals with disabilities" (according to the Technology-related Assistance for Individuals with Disabilities Act of 1998). Assistive technologies run a wide gamut, from trivially simple pen and paper solutions to cutting edge computer-based technology. It is thus instructional to conceptually categorize them as 'low', 'mid' and 'high' technology. Many companies today produce assistive solutions to aid disabled persons, including those with autism. To exhaustively list all available products is impossible. Rather, the following sections are meant to give an overview of the different approaches that have been taken towards building useful assistive technology that can be used in coping with autism.

Low Technology

Children with autism tend to process visual information easier than auditory information. Especially pictorial information has been shown to be highly effective (Pierce & Schreibman, 1994). Hence, most low-tech approaches have a simple paper or cardboard-based form.

Many autistic children insist on heavily regimented daily routines, often becoming severely confused and perturbed if their routine is broken. Scheduling is thus essential. Visual schedules (Figure 2a) can be used to give the autistic child information on what is currently happening, what is coming up, and what has already happened. Thus, the child is provided with a trustworthy guide it can refer back to. Visual calendars (Figure 2c) work similarly, but on a larger timescale. Activity schedules (McClannahan & Krantz, 1999) (Figure 2b) can be used to cue the child to engage in a certain independent activity. They often take the form of photographs of someone else performing the activity. Visual directions are also often very effective in giving the child information of what is expected of him or her. Complex processes the child might not be able to comprehend fully by himself can thus be broken down into manageable sequential steps, represented visually, that the

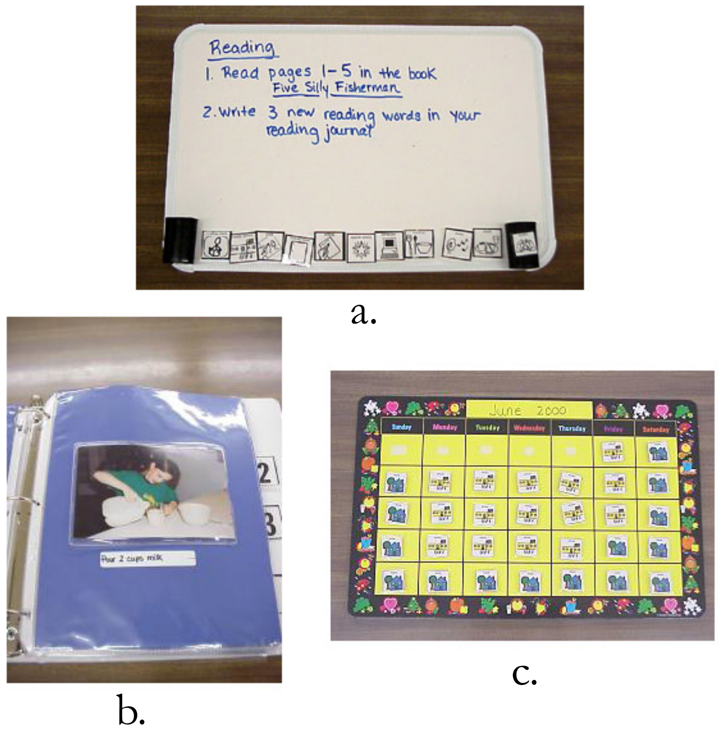

Figure 2: Low tech methods of aiding comprehension skills: visual schedules (a), activity schedules (b), and calendars (c).

child can refer back to (see Figure 3). Visual representations of rules and alternative behaviors help the child in understanding what behavior is expected of him or her in particular situations (e.g. no screaming in school) and provides the child with appropriate choices when it has engaged in inappropriate behavior.

Other low-tech approaches focus on expanding a child's expressive communication skills, especially crucial for nonverbal patients (Lancioni, 1983). For instance, the child can point to certain visual representations, such as photographs, to communicate a message. One of the more famous and successful approaches is the Picture Exchange Communication System (PECS), described in (Bondy & Frost, 2001) and shown in Figure 4). The child can communicate the desire to obtain particular objects by giving the partner a card depicting that object. PECS encourages the child to initiate the communicative exchange. Break cards (to communicate the desire for a break in the activity), choice

Figure 3: Visual directions for a bathroom task.

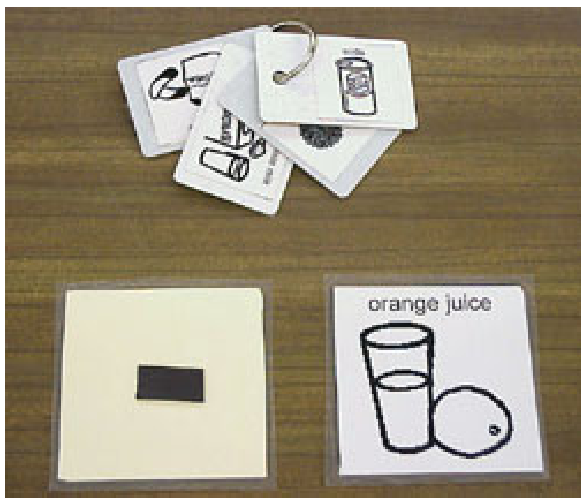

Figure 4: The Picture Exchange Communication System. Pictures of desired items are exchanged for the actual items.

cards ("I'd like to do it this way"), and cards that help in relating past events pictorially are also often used.

Yet other low-tech measures focus on social skills, aiding to teach children appropriate behavior in social settings and generalizing the behavior. (Gray, 1993) describes the use of social stories, where a parent or caretaker writes and illustrates a short first-person story describing how to conquer difficult social situations. The child reads those repeatedly and can refer back to them. Short comic strips describing social interactions have also proven to be effective in teaching social skills (Gray, 1994). Turn-taking cards (which can be used explicitly during conversation) and help cards (to ask for help) are also widespread.

Mid technology

Included here are self-contained, inexpensive electronic devices that can be used in autism treatment. Mostly, this concerns Voice Output Communication Aids (VOCAs). These devices produce synthetic or digitized speech when a symbol is selected from the VOCAs display and have been found to be easily adopted by autistic children. They exhibit great potential for generalization across settings and encourage the use of gestures, words and vocalizations by the child (Schepis, 1998). A selection of VOCA-style devices is shown in Figure 5. VOCAs are useful in allowing children to produce alternative communicative behaviors that serve the same purpose as their problem behaviors (screaming, etc.) (Durand, 1999). Their main benefit, however, lies in their ability to facilitate natural interpersonal interactions and socialization due to the speech output they generate. (Schepis, Reid, Behrmann, & Sutton, 1998) showed that children quickly learn to use VOCAs to request items, respond to questions and provide comments, encouraging spontaneous and contextually appropriate interactions. It was also shown that the use of VOCAs increases the interactions initiated by teachers and caretakers. VOCAS also constitute a crucial component in aiding language development in autism through a method called the System for Augmented Language (SAL) (Romski & Sevcik, 1992, 1996). In SAL, communication partners of children with autism are taught to use symbols and the learning child's VOCA to augment their speech during naturally occurring communication interactions. Learners are also encouraged to use their VOCAs. It has been shown that SAL is very successful, resulting in patients consistently using the referential symbols (e.g. physical objects) on the VOCA as well as the social-regulative symbols (e.g. please, thank you). Some patients meaningfully combined symbols to form more complex ones. Some exhibited an increase in intelligibly articulated words throughout the study.

Figure 5: Different styles of Voice Output Communication Aids.

High Technology

An increasing number of studies show that computer technology used in teaching and therapy is well accepted by individuals with autism spectrum disorder (Moore, McGrath, & Thorpe, 2000). (Jordan, 1995) reports that the use of computers with autistic children in a teaching environment led to increases in focused attention, attention span, in-seat behavior, fine motor skills, generalization skills, etc. (Hileman, 1996) posits that computers are appealing to children with autism due to their predictability and consistency, their controllability by the child and their lack of confusing social messages. (Pleinis & Romanczyk, 1985) provide supporting evidence that, although computer-based instruction does not necessarily increase the learning performance, it significantly reduces disruptive behaviors and increases compliance with instructions. This section surveys some of the more traditional uses of computer technology (see also (Panyan, 1984)) related to autism, especially with regard to instruction.

Mind Reading (Baron-Cohen & Tead, 2003) helps children learn about emotions and their expression, especially in human faces. It provides an interactive guide and a library of videos of people expressing emotions, together with quizzes and games to check the child's progress (see Figure 6).

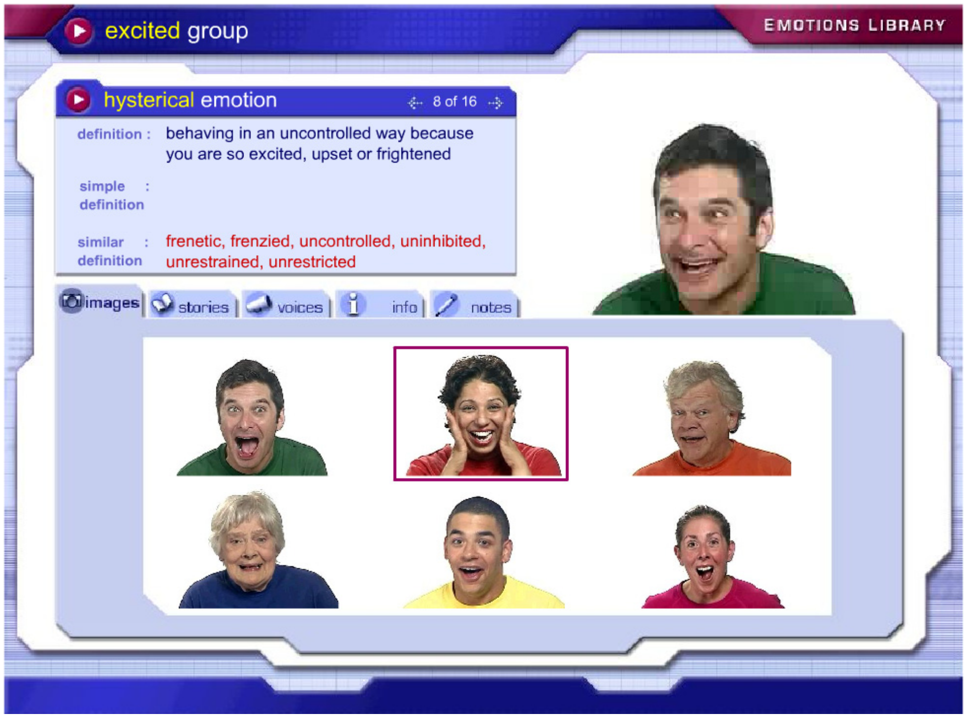

Figure 6: Screen capture from the Mind Reading software by Baron-Cohen.

KidTalk (Cheng, Kimberly, & Orlich, 2003) confronts children with common social situations through an online chat system, moderated by a therapist. Much traditional software exists for teaching behavior in social situations to children with autism (Hagiwara & Myles, 1999), in a similar way that paper-based stories and illustrations do. The interactivity added by computers provides instantaneous feedback and thus more appropriately reflects situations that would be encountered in real life. Talking word processing software (MacArthur, 2000) has also been developed to support spelling and general communication in disabled children. Such software, together with similarly functioning speech generating devices (Blischak & Schlosser, 2003) have been shown to be helpful in supporting the learning of spelling by providing children with instantaneous text and speech feedback. Various software has been developed to increase reading and general communication skills in children with autism (Heiman, Nelson, Tjus, & Gillberg, 1995). Yet other software focuses on classification and abstraction activities and time concept/event sequencing activities (see (Lehman, 1997)), often based on essentially the same concepts as those used in low-technology activity schedules and other paper-based tools.

Most of these computer-based solutions aim at a teaching environment. They make use of some of the benefits afforded by computer technology, but are often based on exactly the same concepts as tried-and-true, lower-tech solutions. One could argue that the rather traditional approach of these technologies fails to exploit some of the most novel and interesting properties of computer-based high technology. Are there ways of extending the use of high technology beyond a teaching scenario to more directly address the interpersonal communication scenarios autistic children find so difficult to cope with?

Current Developments & The Cutting Edge

This section explores some of the most recent and novel applications of technology to the study of autism spectrum disorder. It should be stated that caution is required when considering the claims made by the most recent research developments. It is easy to become fascinated by the intricacies and apparent promise of a cutting-edge technology in the study of autism. However, most research findings have not been subjected to extensive patient testing. Their true promise can only be shown over time, as thorough, controlled clinical trials are carried out. Gadgetry does not matter. Everyday usefulness to an autistic patient does.

Mind Reading Devices

Sparked in part by Baron-Cohen's work on Theory of Mind (Baron-Cohen, 1995), considerable research effort has gone into the development of novel technologies that could support the process of 'mindreading'. Most of this work clusters around the idea that emotions expressed in a person's face can serve as a guide to his or her mental state.

(El Kaliouby & Robinson, 2004, forthcoming) are developing a portable assistive device, called the 'emotional hearing aid', to assist people with Asperger's syndrome in the process of mindreading

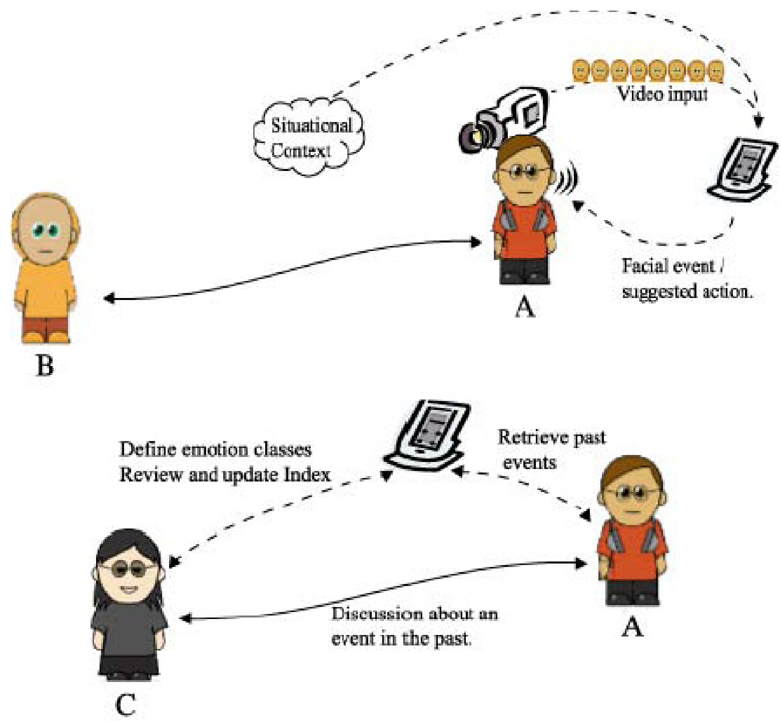

Figure 7: Overview of emotional hearing aid function. Video of person B's facial expressions and situational cues are sent to the PDA for analysis, resulting in suggested reactions, either as audio or on the PDA screen (upper image). Later, the PDA can be queried about past events and tuned by a caretaker, person C (lower image). Taken from (El Kaliouby & Robinson, 2004, forthcoming).

in real life situations. It consists of a camcorder, a PDA and an earpiece. Figure 7 illustrates the operation diagrammatically. A facial affect analyzer is employed to identify facial events and annotate them with an emotional label. This task is rather challenging to accomplish and is closely related to the large field of automated facial expression analysis. (Michel & El Kaliouby, 2003) describes one possible approach, (Pantic & Rothkrantz, 2000) gives a good overview. The device uses contextual cues (e.g. situation descriptions like "at home" or "at school") to assist emotion interpretation. Facial events are archived for later review by the child together with a caretaker. This archiving also provides the child with the ability to reference a current facial event with past events and reactions (e.g. "the expression now is the same as the one your mother had when you broke the glass"). Reactions to be performed by the child are computed from predefined templates (e.g. "smile back if person happy") and are extensible.

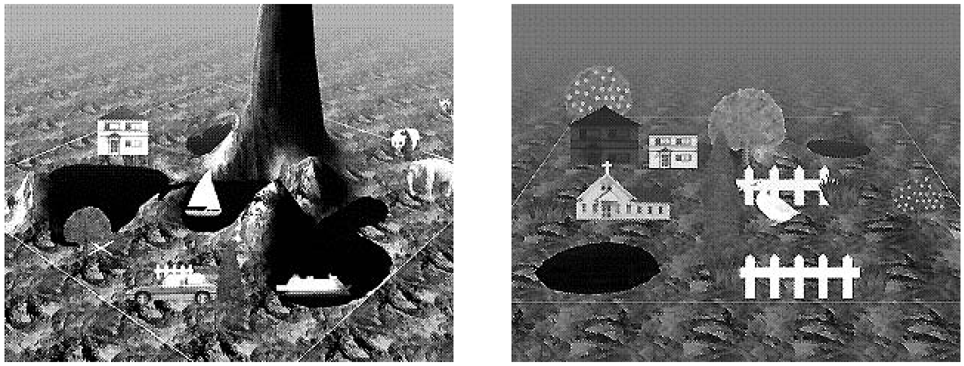

Figure 8: Landscapes created during patient trials of the virtual sandbox system. Taken from (Hirose et al., 1997).

The emotional hearing aid is a work in progress, but hints at what can be accomplished by using portable computing technology directly during human-human social interaction.

Multimedia Toys

(Blocher, 1999) describes the affective social quotient project uses short digital videos that display one of several basic emotions and a set of physical “dolls” linked by infrared to the system. The system knows which dolls correspond to which clips, so that the child can explore emotional situations by picking up dolls with certain emotions, or the system can prompt the child to pick up dolls that go with certain clips.

Virtual Reality

The sandbox technique (Lowenfeld, 1939) is a psychotherapy technique employed for neurosis but also for autism. Patients are asked to play with a small sandbox, making ground shape with sand and placing various available figures (people, animals, buildings, stones, monsters, etc.) into the created landscapes. These are subsequently analyzed by therapists. (Hirose, Kijima, Shirakawa, & Nihei, 1997) have created a virtual sandbox to support this technique. It employs a 3D input device (an electronic wand), and a large display and is designed for ease of use. Two of the images created by patients in trials are shown in Figure 8. This system has not been subjected to thorough trials, and the real use of the sandbox technique in analyzing and treating persons with autism spectrum disorder is not established. Furthermore, the study showed that, somewhat predictably, children with autism found it difficult to operate the computer controls. (Strickland, 1997) has used virtual reality as a learning and instructional aid. The author cites controllable input stimuli, easy modification for generalization and the fact that VR is a primarily visual/auditory world as advantages of a VR learning system. VR is also able to closely model the real world without the inherent dangers. The system built by Strickland has been used to teach autistic children to track and find specific objects in virtual space. Trials were successful, although it took some training to have the autistic children accept the required headgear. The hope is that eventually such a system could be used to teach a child to e.g. cross streets. A number of related uses of virtual reality in the study of autism exist, e.g. (Parsons et al., 2000).

Eye Tracking

(Klin, Jones, Schultz, Volkmar, & Cohen, 2002a, 2002b) have used eye tracking equipment to investigate the social dysfunction at the core of autism spectrum disorder.

Klin and colleagues showed videos containing naturalistic, highly social scenes ("Who is afraid of Virginia Woolf?") to 15 autistic patients and 15 controls. Head mounted eye tracking equipment was used to gather eye fixation data throughout the duration of the movie. Fixations as well as their duration were coded on regions such as eyes, mouth, body and objects. Figure 9 shows a typical still frame used for coding. Trials performed revealed significantly different fixation patterns for autistic patients when compared with the control group. In general, autistic children focused much less on the eye region, often preferring the mouth region instead. Still, focus on the mouth correlated with improved social adjustment and less strongly developed social impairment. Focus on bodies and objects correlated strongly with autistic development in the viewer. Klin et al. were thus able to show that fixation on mouths and objects but not on eyes are strong predictors of degree of social competence.

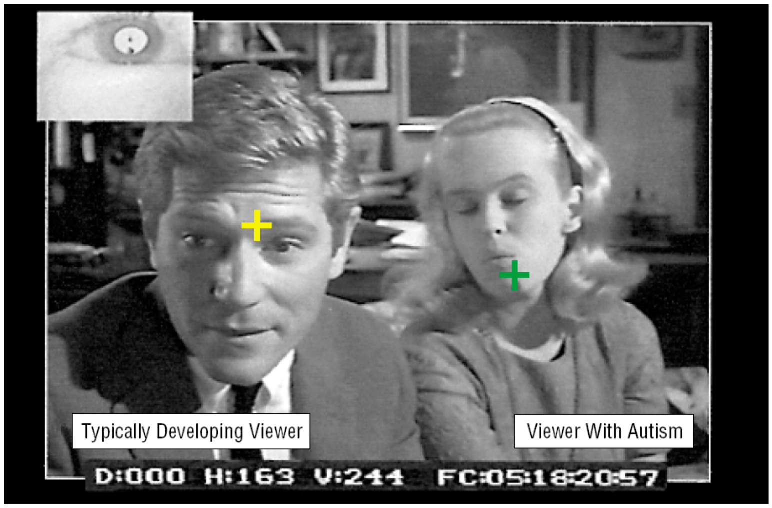

Figure 9: Typical still frame used during coding of visual fixation patterns. Points of regard for an autistic viewer as well as a control are superimposed on the image, as is coordinate data of a control. Taken from (Klin et al., 2002b).

The innovative use of eye tracking technology, which has mostly found applications in the military domain, for example in visually guided targeting systems, enabled the researchers to give a quantitative meaning to the degree of social competence an autistic person exhibits. The measurement of social competence in naturalistic conditions carried out by Klin et al. provides a unique insight into how autistic people perceive social situations and try to make sense of them and demonstrates one of the most impressive uses of cutting edge technology in the investigation of the core defining characteristics of the autistic condition.

Robotics

Perhaps the most exciting and surprising use of cutting-edge technology in the study of autism, various researchers have increasingly studied the application of robotic systems to education and autism therapy (Dautenhahn, 1999; Michaud, Clavet, Lachiver, & Lucas, 2000; Plaisant et al., 2000).

The Aurora Project (Dautenhahn, 1999)[1] investigates the therapeutic and educational potential

[1] http://www.aurora-project.com

Figure 10: Examples of the humanoid doll and mobile robots used in the Aurora project.

of robots for children with autism. Dautenhahn argues that robots allow simplified but crucially embodied interaction involving touch, manipulation, etc. This is seen to be an important difference from computer-based methods. Interaction with a robot lies between the complexity of interacting with a software agent and that of interacting with a real person. Robots also foster interaction dynamics that closely reflect the real time nature of human-human interaction and naturally support multi-modal interaction. In essence, it is hoped that robots provide highly configurable and controllable interaction partners that naturally elicit social responses from children with autism. Robots allow experiments to be performed that address core social interactive behavior such as eye gaze, turn taking, joint reference or imitation. Results from the Aurora project have shown that both simple mobile robots and humanoid robotic dolls (Robins, Dautenhahn, Boekhorst, & Billard, 2004, forthcoming) prove to be useful interaction partners as well as mediators of human-human interaction for autistic children. Figure 10 shows examples of the robots used. Patients were reported to use the robot as a mediator during interaction with teachers, for instance. Furthermore, after prolonged

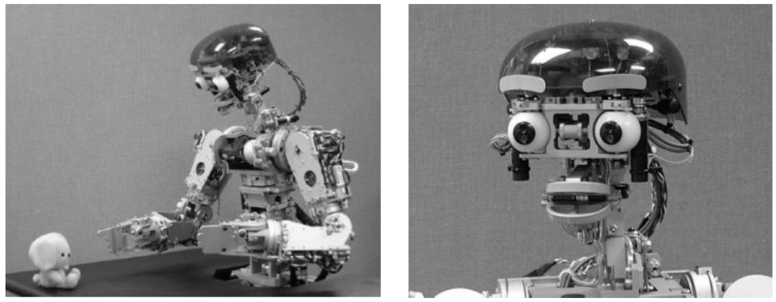

Figure 11: Infanoid, an upper-torso infant robot. Taken from (Kozima & Yano, 2001).

exposure to the robot, the children actively adopted the robot and sought to share their experience of the world with it. Longer term studies of any concrete therapeutic effects are under way.

More complicated robots have also been constructed with the use in autism studies in mind. (Kozima & Yano, 2001) have designed a 'babybot' called Infanoid, as a possible naturalistic embodiment for human-robot interaction (shown in Figure 11). Infanoid possesses a complex mechanical design and a humanoid (albeit somewhat bare) physical appearance. The researchers have begun using the design in contingency-detection games (e.g. eye contact and joint attention), where the robot engages in social interaction with autistic children, reacting to any social cues, as well as trying to elicit these from the children by producing social cues itself. It is hoped that the robot can elicit empathic identification from the children, allowing further study of that process in persons with autism. Infanoid is very much a work in progress, but provides a powerful platform for studying human-robot interaction scenarios in autistic children.

Last, but not least, Scassellati and others (author included) at Yale are currently developing Nico, a novel humanoid robot that interacts with people using natural social cues. One of the aims of the project is to construct a powerful and flexible platform on which theories of human social development can be implemented and evaluated. Significant emphasis is placed on the use of results from the study of human cognition in the construction of the robot. Autism research is a core application area of this research. This includes plans for extensive future studies of interaction between the robot and children with autism. The work also ties in with the eye tracking work described above. There are plans to have the robot imitate the autistic viewing patterns while watching movies. The parameters of the robot's attention system can subsequently be used to quantitatively define the autistic viewing behavior and may reveal further insight into the social phenotype of the disease.

Conclusion

This paper presented an overview of some of the past and present uses of technology in the diagnosis, treatment and general study of autism spectrum disorder and associated conditions, as well as hinting at possible future research directions.

It is worth pointing out that, while a vast amount of different technologies have been developed and shown to be more or less effective and relevant for the treatment of autism, many crucially lack thorough clinical evaluation. As good as a technology may sound on paper or look in the early stages, only prolonged exposure to patients with autism can reveal its true degree of usefulness. Many practical problems arise when trying out a piece of novel technology on children with autism, as the author has experienced first hand during clinical sessions.

It should also be self-explanatory that the autism disorder, first and foremost, revolves around one thing: people. The patients must remain the center of research attention and all research should be carried out with their benefit as the prime motivation.

That being said, we live in exciting times for the use of technology in autism. Past experience has shown us that technology can and does make an enormous difference in diagnosis and treatment. And never has more varied and promising research been carried out that focuses on applying novel technologies to autism.

As we continue to illuminate some of the central characteristics of autism, both familiar and cutting-edge technologies will play a increasingly important role in research and treatment, thus further allowing patients with autism spectrum disorder to lead satisfying and fulfilled lives.

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