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BMI 510 Final Paper: Fall 2010

Robots in Autism Therapy

Robotics is increasingly being incorporated into healthcare environments. OHSU is a leader in implementing surgical robots [1] while headlines from Japan talk about the use of robots for elder care [2]. But one of the applications that seems to be drawing the most attention from both researchers and the media recently is the use of robots in autism therapy.

Autism is a neurodevelopmental disability which according to the DSM IV-R [3] is characterized by the presence of markedly abnormal development in social interaction and communication and a restricted repertoire of activity and interests. Specific diagnostic criteria include delay in or lack of spoken language as well as impairments in the use of nonverbal behaviors such as eye-to-eye gaze, facial expression and gestures. By definition, the onset of autism is prior to the age of 3 years, although its milder version, Aspergers, which does not have cognitive development or language delays, is generally diagnosed in older children. According to the latest CDC figures, an average of 1 in 110 children in the US have an autism spectrum disorder (ASD)[4]. The main form of treatment is behavioral therapy, such as Applied Behavioral Analysis (ABA) or Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH), which is recommended to start as young as possible while the child's brain is presumably most receptive to growth. Robots were first used for autism therapy in 1976 by pediatrician Sylvia Weir and psychotherapist Ricky Emanuel with a mobile turtle-like robot LOGO at MIT[5]. However, it was not until the late 1990s and early

2000s, as autism rates continued to escalate, that multiple labs adopted this topic for research.

In this paper, I summarize a variety of different robotic systems being developed and/or tested for autism therapy found through searching ACM Digital Library and PubMed and getting additional references from the initial set of papers and web sites. In some labs, this is a long term project so it was possible to see progress over time in multiple papers, of which I only selected a few to summarize. These papers are multidisciplinary, motivated by both the novelty of technology interactions and assessing the efficacy of use in autism therapy.

Summary of Robots in Autism Studies

One of the earliest projects is the AURORA project, started in 1998 at the University of Hertfordshire in the UK. Their 1999 paper [6] discusses their initial philosophy based on the TEACCH method where the teacher guides the child's behavior to teach communication and "proper behavior". Their first trials involved a small Labo-1 robot which they describe as "resembling a sturdy flat-topped buggy". Their 2001 paper [7] talks about the trials in greater detail, describing three pairs of children and how they reacted to the robot with observations of instruction, cooperation and possibly learning by imitation. Dautenhaum's 2003 paper [8] focused on the different roles robots can play; in their autism research, the robot's roles are: therapeutic playmate, social mediator and model social agent. For a 2005 paper [9], they had moved on to a 45 cm humanoid robot called Robota, which they did a longitudinal study on with four children over several months at a school. They defined four behavioral criteria to evaluate based on the video data: eye gaze, touch, imitation and nearness to robot. There were three phases over the

four months—familiarization, learning, with the teacher showing how the robot could imitate his movements (in reality a 'puppet' mode where the investigator controlled the robot via laptop) and free interaction. They used both qualitative and quantitative analysis, showing graphs showing changes in the child's behavior over time. They emphasized the highly individual nature of autism and different ages and levels of children when giving the results to try to caution that this only gives a general view of what is possible. A 2004 paper [10] extended this study, comparing children's response to different appearances of robot—one with a "pretty-girl" appearance and one with a featureless, masked face. They found that initially the children preferred the plain robot though over the course of the longitudinal study they became used to both robots. This backed up their hypothesis which was based on an assumption that children with autism preferred a predictable environment and simple designs. These studies led to the design of another robot, KASPAR [11], which was minimally expressive with a face influenced by comics design and Japanese Noh theatre. Rather than go into details about trials, they showed several illustrative uses including how a therapist would incorporate them. In their table comparing KASPAR with the earlier robots, Labo-1 and Robota, there were more intended therapeutic uses including turn-taking, joint attention, collaborative activities, imitation of hand gestures, proactive behaviour, initiative taking, mediation between child and other persons via the robot, and body awareness.

Probably the most famous autism-related robot (due to its dancing abilities as shown on You Tube[12]) is Keepon, developed by teams at NIICT in Japan and Carnegie Mellon University. Keepon is described as having a "yellow snowman-like body" and is only 120 mm tall. Its eyes are color CCD cameras with wide-angle lens and

its nose is a microphone. Its body is made of silicone rubber and it has four degrees of freedom: nodding, turning, rocking, and bobbing. It can directs its gaze to enable eye contact and joint attention (attentive action) and its rocking/bobbing while keeping its attention focused on a target gives the impression of expressing its internal state (emotive action). In [13] they describe the longitudinal field observations of both typically-developing preschool children and children with developmental disorders. Over the course of the four years covered by their study they conducted and recorded approximately 400 hours of interaction between Keepon and hundreds of children. For the autism-related observations, they had 100 sessions or 700 child-sessions in total observing over 30 children (age 2-4) at a day-care center. They describe three cases which represent the emergence of dyadic interaction (Keepon and child), triadic interaction (Keepon, child and therapist or mother), and empathic interaction. The video feed from the robot's cameras were provided to the therapists and parents in the form of a story narrated from the first person perspective of the robot in order for the caregivers to have data to better understand the child and tailor therapeutic activities. They also made a point of mentioning ways in which their findings contradicted common assumptions about autism, claiming that "1-simple robots with minimal and comprehensible expressiveness can facilitate a spontaneous exchange of mental states in autistic children, 2- autistic children therefore possess the motivation for this mental exchange and 3) the major social difficulties that autistic children generally suffer from stem not so much from a lack of this motivation but rather from the difficulty in sifting out socially meaningful information (e.g. attention and emotion) from the vast incoming perceptual information".

Another research team that particularly stood out was from the University of Southern California, led by Maja Matarić. Their original approach [14] was rooted in DIR/Floortime therapy (DIR: Developmental, Individual-Difference, Relationship-Based), an individualized approach which involves a therapist playing with the child on the floor, and using the child's existing social skills to form new social behaviors. They proposed to use a robot to augment DIR/Floortime therapy and designed the Behavior-Based Behavior Intervention Architecture (B3IA) to be an autonomous system in a therapeutic setting. In B3IA, a robot observes the behavior of the child through multiple sensors that may be on-board, in the environment, and/or worn by the child. Their hypothesis was that a child interacting with a contingent robot (one that responds to the child's behavior) would exhibit more social behavior than when interacting with a robot that responds randomly. For their pilot study, they recruited four participants for their study (3 ASD, 1 typically developing, with age range of 20 months-12 years). They used an ANOVA for direct scenario comparisons. While the data supported the hypothesis, they admit that a larger population would be needed to achieve desired statistical power. Based on the pilot, they redesigned the robot to use automatically recognized proxemic information and operator-recognized vocalization information to augment robotic sensing capabilities so it could react to the child's behavior. The second experiment described in [15] involved the humanoid robot Bandit and five children aged five to nine. They originally wanted to compare Bandit to an immobile toy, but when 2 of the first five children were scared by it, they introduced the non-biomimetic robot. They also compared two robotic behavior strategies: random, where the robot moves around without regard for the child's position and behavior, blowing bubbles and making

random sounds at random intervals and contingent where the robot behaved more as a social partner to the child designed to encourage social actions. They coded video data based on frequency and duration of child's looking at the robot or toy, verbal behavior about the robot/toy, verbal behavior directed toward the parent, fraction of time child spent within arm's distance to robot/toy and how often child said something with anthromorphic content while looking at robot/toy. They summarized this in a table where it is possible to compare the different participants. They concluded with an extensive discussion about their findings including guidelines for observing expressive behavior with multiple cameras and how to program the robot's behavior.

Yale's team is led by Brian Scassellati, whose MIT thesis on developing a theory of mind for robotics prepared him for the questions emerging from using robots in autism therapy. His initial work [16]used a simple commercial robot named ESRA which had several facial expressions. Two conditions were used, with a non-contingent condition where ESRA performed a short script with set of action and audio file and was non-responsive to the child and a contingent condition where the robot's behaviors were triggered by an experimenter behind a one-way mirror. Of the 13 subjects (mean age= 3.4 years), 7 were on the spectrum and 6 were "typically developing". It was found that much of the behavior was the same with the children on the spectrum smiling at the robot, making eye contact and vocalizing to the robot. The main difference was that for the non-contingent condition the "neurotypical" children lost interest quickly while the children with ASD spent most of the session with the robot even if it didn't respond to them. Scassaletti goes on to talk about how autism diagnosis could be approved by quantitative, objective measurements of social response based on passive sensors which

show gaze direction and focus of attention, position tracking (proxemics related to social cues), and vocal prosody. The Yale team's more recent papers work with Pleo, a 2 foot commercial dinosaur robot. In their study [17] they take 11 children with high-functioning ASD (2 autism, 5 Aspergers, and 4 PDD-NOS) and 9 neurotypical children. Their statistically significant results were that children with ASD were more likely to orient toward the examiner face to face and express interest in response to the examiner's story, suggesting that the social interaction with the robot promoted social behaviors.

One remarkably written paper [18] from the University of Washington (drawn from an undergraduate research project!) had a quantitative design with eleven children on the autism spectrum (age 5-8) comparing their interaction with the robotic dog toy AIBO vs a simple mechanical toy dog. They coded the behavioral data using four different categories: 1-amount of time spent interacting with each dog, 2-amount of speech each child produced in talking to each, 3- number of behavioral social interactions typical of children without autism and 4-behavioral interactions typical of children with autism pulled from the Gilliam Autism rating scale (ex. rocking back and forth, repeating words, high-pitched noise, withdraws, etc). Their results showed that in comparison to the toy dog, the children spoke more to AIBO, and more frequently engaged in three behaviors typical of children without autism (verbal engagement, reciprocal interaction and authentic interaction) while showing less stereotypically "autistic behaviors". Their table displays means, medians, and Z and p-values from a Wilcoxan Signed-Rank Test. Most of the values were statistically significant or approached statistical significance. They admit that the small sample size mean there was little power in their statistical tests.

Not surprisingly, they conclude with the need for more quantitative studies which show generalizable results.

Rosalind Picard's lab at MIT has primarily worked on wearable computing sensors to facilitate social interaction for individuals on the autism spectrum[19]. Of particular note is their participatory design work where young adults on the spectrum as well as parents and autism specialists were involved in early stages of the design and prototyping process[20]. They also collaborated with social robotics pioneer Cynthia Brezeal on Shybot [21], a personal mobile robot that they designed to embody and elicit reflection on shyness behaviors. Shybot is a robotic toy car controlled by Bluetooth with proximity sensors, a motor and a wireless camera. The paper was presented as a work-in-progress, to describe motivations and research questions with plans to do controlled studies with observations in the future.

A good overview paper which reviews much of the above research is provided by Brigham Young researchers Ricks et al [22]. They categorize the purpose of the autism research projects as 1-diagnosis 2-self-initiated interactions 3-turn-taking activities, 4-imitation, 5- emotion recognition, 6-joint attention and 7-triadic interaction. They also categorize the various types of robots on a continuum from humanoid to non-humanoid: android, mascot (ex Keepon), mechanical, animal, and non-humanoid mobile robots. Feil-Seifer et al[14] also categorize socially assistive-robotics research approaches as feasibility studies to design systems and show that they work, user studies to evaluate interface design and failure points, behavior studies to show how a user's behavior changes when a robot is present, and ethnographies which are long-term involving entire user populations rather than individual users.

Discussion

Given that most of these papers were published or presented in technology venues, it is not surprising that they focus more on the technology and human-robot interaction components. It is quite common in technology papers evaluating systems to have very small scale studies, which explains why most papers seemed to have a small number of participants that precluded a rigorous statistical analysis.

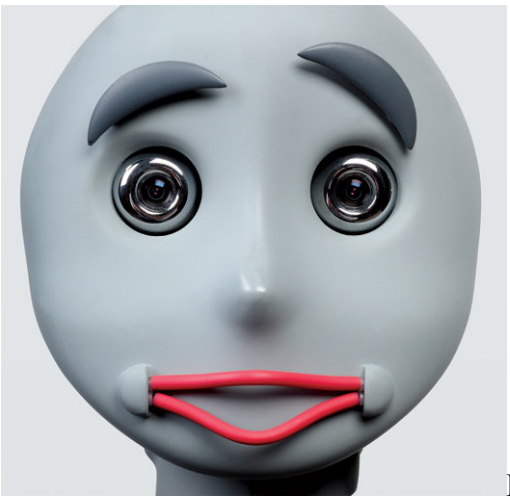
From a technology viewpoint, there are many challenges that must be worked on in implementation of robots, particularly the ability to respond to a child's behavior. Feil-Seifer et al made a point of mentioning the children's expectations that the robot would respond to what they were saying and obey commands. He mentions the difficulty in real-time natural spoken language processing of children as well as the trade-off between potentially contradictory goals of autonomous robot behavior and a well-controlled experiment. [15] Many of the systems are still in a "Wizard of Oz" design stage [23] , where there is someone doing a lot of the control behind the scenes. Most studies are still in a lab environment, though Kozima et al made a point of doing their observations in a day-care center [13] and Mozaric expressed the desire to implement technology cheaply enough to build an affordable consumer version (under $1000) within the next ten years[24].

I think there is also a need to question the goals of the robot interaction, especially in light of headlines that proclaim the robots as "fighting"[25] autism. Some teams, which I ended up editing out due to lack of space, seemed to have a very superficial understanding of autism while some are more clearly informed. As more off-the-shelf robots such as Nao [26][27] and Popchilla [28]become available, it appears that research

teams lead by people in psychology departments and autism research centers are becoming more common which will probably change the nature of the studies. It would also be interesting to bring in more literature from related areas of autism research such as animal-assisted therapy [29] and assistive technology [30]. Finally, there are still plenty of opportunities for collaboration by individuals on the autism spectrum, where we again see leadership from OHSU with respect to involving people on the autism spectrum as part of participatory research with its AASPIRE program [31].


Keepon from

[13] 


Bandit [24] on left and KASPAR[11] on right


Nao from

http://www.theautismnews.com/2010/08/16/emotional-humanoid-robot-nao-used-to-treat-autistic-children/

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