The Application of Modeling and Simulation to the Behavioral Deficit of Autism

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Abstract. This abstract describes a research effort to apply technological advances in virtual reality simulation and computer-based games to create behavioral modification programs for individuals with Autism Spectrum Disorder (ASD). The research investigates virtual social skills training within a 3D game environment to diminish the impact of ASD social impairments and to increase learning capacity for optimal intellectual capability. Individuals with autism will encounter prototypical social contexts via computer interface and will interact with 3D avatars with predefined roles within a game-like environment. Incremental learning objectives will combine to form a collaborative social environment. A secondary goal of the effort is to begin the research and development of virtual reality exercises aimed at triggering the release of neurotransmitters to promote critical aspects of synaptic maturation at an early age to change the course of the disease.

1.0 INTRODUCTION

Autism is one of a group of disorders known as autism spectrum disorders (ASD's). It is characterized by developmental disabilities that cause substantial impairments in social interaction and communication and the presence of unusual behaviors and interests. It begins before age three and lasts throughout a person's life. Autism occurs in all racial, ethnic, and socio-economic groups. It is also on the rise. New research indicates a possible mitigation strategy for autism. Deletions of genes or regions potentially involved in regulation of gene expression, suggests that defects in activity-dependent gene expression may be a cause of cognitive deficits in patients with autism. Therefore, disruption of activity-related synaptic development may be one mechanism common to at least a subset of seemingly heterogeneous autism-associated mutations. If the above hypothesis is true, then controlled environmental experiences coupled with calculated experiential exposure might be able to allow treatment through behavioral modification to facilitate learning in normal environments. But given the characteristics of autistic individuals, controlled environmental experiences are difficult to conduct. Reports from teachers, therapists, researchers and parents indicate that many children with ASD show an affinity for computers. Current research indicates that computer-based tasks can motivate people with autism and encourage learning. Efforts to incorporate the ability to interact with and control virtual characters (avatars) within a computer generated environment are increasing. While there is good evidence that virtual environments are well accepted by individuals with ASD and of potential benefit to them, the use of the technology remains relatively unexplored. There is great potential to re-purpose technology and simulation content developed for the U.S. military that combines 3D video game technology with the constructivist principles of coaching, scaffolding and deliberate practice to help teach cultural awareness and non-verbal communications skills.

This paper describes a research effort designed to leverage this military technology, re-purpose game assets and adapt learning strategies to support virtual social skills training within a computer game environment in an effort to diminish the impact of social impairments on the lives of people diagnosed with ASD. If successful, the potential return on investment is enormous, both in actual cost savings, and in reduction of family suffering. Researching this area is an ethical imperative.

2.0 AUTISM

Autism is one of a group of disorders known as Autism Spectrum Disorders (ASDs). They include Autistic Disorder, Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS, including atypical autism), and Asperger Syndrome. These conditions all have some of the same symptoms, but they differ in terms of when the symptoms start, the severity of the symptoms, and the exact nature of the symptoms. The three conditions, along with Rett Syndrome and childhood disintegrative disorder, make up the broad diagnosis category of pervasive developmental disorders. ASD begins before the age of 3 and lasts throughout a person's life. It occurs in all racial, ethnic, and socioeconomic groups and is four times more likely to occur in boys than girls. [1]

3.0 THE COST

Dr. Michael Ganz, MS, PhD, Assistant Professor of Society, Human development and Health at the Harvard School of Public Health, and respected expert on the societal costs associated with autism and its related disorders claims that Autism is a very expensive disorder costing upwards of $35 billion in direct (both medical and nonmedical) and indirect costs to care for all individuals diagnosed each year over their lifetimes. [2]

In a paper published in the Archives of Pediatric Adolescent Medicine, Dr. Ganz details the substantial costs resulting from lifetime care and lost productivity of individuals with autism, their caretakers and society in general. [3] Direct costs measure the value of goods and services used and indirect costs measure the value of lost productivity due to autism. Physician and other professional services, hospital and emergency department services, drugs, equipment and other supplies, and medically related travel and time costs are typical components of direct medical costs. Special education, transportation, childcare and babysitting, respite care, out-of-home placement, home and vehicle modifications and supported employment services are typical components of direct nonmedical costs. Indirect costs are the value of lost or impaired work time (income), benefits, and household services of individuals with autism and their care givers because of missed time at work, reduced work hours, switching to a lower-paying but more flexible job, or leaving the workforce. Behavioral therapies, which are the largest component of direct medical costs, make up 6.5% of total discounted lifetime costs. Those costs, combined with very limited to non-existent income for their adult children with autism combined with potentially lower levels of savings because of decreased income and benefits while employed, may create a large financial burden affecting not only those families but potentially society in general.

4.0 AUTISM IS INCREASING

The U.S. Center for Disease Control and Prevention (CDC) states that it is clear that more children than ever before are being classified as having ASDs, however, it is unclear how much of this increase is due to changes in how we identify and classify ASDs in people, and how much is due to a true increase in prevalence. By current standards, ASDs are the second most common serious developmental disability after mental retardation/intellectual impairment. The impact of having a developmental disability is great for families affected and for the community services that

provide intervention and support for these families. It is important that we treat common developmental disabilities, and especially ASDs, as conditions of urgent public health concern, do all we can to identify children's learning needs, and start intervention as early as possible to give all children the chance to reach their full potential. The CDC also states that ASDs can often be detected as early as 18 months and children in high-risk groups - children with a parent or sibling with an ASD - should be watched particularly closely. Studies have shown that among identical twins, if one child has autism, then the other will be affected about 75% of the time. In non-identical twins, if one child has autism, then the other has it about 3% of the time. Also, parents who have a child with an ASD have a 2% - 8% chance of having a second child who is also affected. [4], [5]

5.0 RESEARCH DIRECTIONS

New research conducted by Eric M. Morrow et al., of the Division of Genetics at Children's Hospital Boston and Harvard Medical School, states that the regulation of expression of some autism candidate genes by neuronal membrane depolarization, suggests the hypotheses that neural activity-dependent regulation of synapse development may be a mechanism common to several autism mutations. Early brain development is driven largely by intrinsic patterns of gene expression that do not depend on experience-driven synaptic activity. Postnatal brain development requires input from the environment that triggers the release of neurotransmitters and promotes critical aspects of synaptic maturation. During this process, neural activity alters the expression of hundreds of genes, each with a defined temporal course that may be particularly vulnerable to gene dosage changes. The connection between experience-dependent neural activity and gene expression in the postnatal period forms the basis of learning and memory, and autism symptoms typically emerge during these later stages of development. This finding that deletions of genes regulated by neuronal activity or regions potentially involved in regulation of gene expression in autism suggests that defects in activity-dependent gene expression may be a cause of cognitive deficits in patients with autism. Therefore, disruption of activity-related synaptic development may be one mechanism common to at least a subset of seemingly heterogeneous autism-associated mutations. [6]

If the above hypothesis is true, then controlled environmental experiences coupled with calculated experiential exposure might be able to allow treatment, behavioral modification, and learning to occur in normal environments.

6.0 THE USE OF COMPUTERS AND VIRTUAL REALITY

Reports from teachers, therapists, researchers and parents indicate that many children with ASD show an affinity for computers. Previous research has shown that computer-based tasks can motivate people with autism and encourage learning [7]. The social and communication deficits of ASD make it difficult to engage in social interaction, and therefore, access to learning opportunities in these social settings is limited. Computer-based experiences in constructed social environments mitigate this deficiency. New research efforts incorporate the ability to interact with and/or control virtual characters (avatars) within a virtual environment. The Authorable Virtual Peers (AVP) program at Northwestern University uses language-based avatars to enable children diagnosed with ASD to learn about language and social interactions

through collaborative storytelling [8]. The use of avatars has also been found to increase facial recognition, emotion recognition and social interaction skills for children with ASD through repeated practice of multiple different interactions [9]. This affirms the commonly used approach of repeated practice in a natural setting to successfully teach skills to those with ASD.

- Virtual reality uses sight and sound more that touch: auditory and visual stimuli have been found to be most effective in teaching abstract concepts to people with autism.
- In the virtual environment, input stimuli can be modified to a tolerable level.
- The environment can be altered gradually to teach generalization and cross-recognition.
- Virtual reality offers a safe learning environment in which the individual may make mistakes that might be physically or socially hazardous in the real world.

A research study on autistic children conducted at the University of Haifa, focused on the transfer of skills mastered within a virtual environment to the real world and found that the intelligence level or severity of the autism does not affect the ability to understand the system and therefore is an important way to improve their cognitive and social abilities [11]. Six autistic children, ages 7-12 spent one month learning how to cross virtual streets, to wait for the virtual light at the crosswalk to change, and to look left and right for virtual cars using a simulation programmed by Yuval Naveh. The children in the study showed substantial improvement throughout the learning process. At the beginning of the study, the average child was able to use the 2nd level of the software, while by the end; they mastered the 9th level, which is characterized by more vehicles traveling at a higher speed. A local practice area with a street and crosswalk, complete with traffic signals, was used for validation. The children's ability to cross the street safely was tested in this area, evaluating for example, whether they stopped to wait on the sidewalk or waited for a green light before crossing. The children were brought to the practice area before and after their virtual learning. Here too, the children exhibited an improvement in their skills, following the training on the virtual street, with three of the children showing considerable improvement. One of the study participants, a 16 year old, had participated in the past in a road safety program in the school, but he was not able to learn how to cross the street safely. Following learning the skill in a virtual environment, he learned how to stop on the sidewalk before stepping into the street, to look at the color of the traffic light, to cross only when the light was green and to cross without waiting too long.

7.0 LEVERAGING CURRENT MODELING AND SIMULATION TECHNOLOGY

While there is good evidence that virtual environments are well accepted by individuals with ASD and of potential benefit to them, the use of this technology remains relatively unexplored. New computer-based game technologies increasingly integrate a social as well as a cognitive component. There is potential to leverage this technology in an innovative new direction to provide a context that can scaffold social interactions and communications skills for children with ASD.

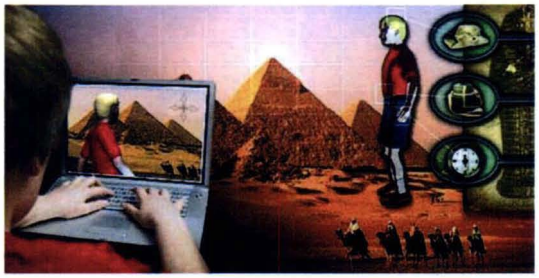
The ability to simulate, test and assess cognitive and social skills within a virtual environment provides professionals with rigorous practice and guidance to increase their chances of success in situations that may not be safe or cost effective to perform in a live training environment.

Simulations and games can supplement traditional training methods by providing challenges and experiences that closely approximate a complex situation in the real world where students must think in real-time and the course of events will be determined by their decisions. Students with ASD may be able to develop a deeper understanding of the knowledge presented and retain that information better when it is learned through the process of repeatedly solving problems in realistic situations. This approach places the learner in a "real-world" environment, which allows the student to learn in context and apply what they have learned. It is this contextual experience of knowledge acquisition in an authentic environment that facilitates the learner to create their own constructs that can be applied to new and unfamiliar situations. There is also an opportunity to provide practical, hands-on

experience in situations that cannot easily be practiced using real scenarios.

There is also great potential to re-purpose technology and simulation content developed for the U.S. military that combines 3D video game technology with the constructivist principles of coaching, scaffolding and deliberate practice to help teach cultural awareness and non-verbal communications skills. The emerging importance of cultural identity and its inherent frictions make it imperative for soldiers and leaders to understand societal and cultural norms of the populaces in which they operate and function. Much of this communication occurs through nonverbal channels, especially when language skills are minimal or absent. It is totally feasible to leverage this military technology, re-purpose game assets, and adapt learning strategies to support virtual social skills training within a 3D video game in an effort to diminish the impact of social impairments on the lives of people diagnosed with ASD.

8.0 SPECIFIC APPLICATION STRATEGIES



The symptoms and characteristics of autism can present themselves in a wide variety of combinations. The uniqueness of each individual with autism and the context of their lives provide interesting design challenges for the successful creation and adoption of technologies for this domain. The first goal is to enable children with ASD to not only interact with a virtual environment, but also to build social skills. A socially relevant scenario can be designed which encourages human interaction with artificially intelligent avatars. Inside the virtual world, which includes settings commonly encountered in everyday life such as restaurants, shops, offices, parks and other social places, autistic individuals will be able to interact with other real people's avatars as practice. The user interface and scripts will be extremely clear and simple, and since previous ASD research has shown benefits of storytelling, each game scenario may consist of a short vignette design to elicit response from the student. Vignettes used for the project may include:

- Teaching the student how to interact through social stories, modeling, role-playing and other activity-based learning.
- Conflict resolution and managing disagreement with compromise and recognizing the opinions of others. Learning not to respond with aggression or immature mechanisms.
- Turn taking and other socially acceptable mannerisms such as verbal interactions, changing conversational topics, introductions to new people and others.

Individuals with autism will encounter prototypical social contexts via a computer interface and will have to interact with 3D avatars within the game that have predefined roles, tasks, and visible body language. Within the context of the game's scenario, the student will trigger events, which equate to learning objectives that they must successfully interact with to advance further into the game. Incremental learning objectives will eventually combine to form a fully collaborative social environment. The initial sequence of tasks will most likely follow a linear model progressing from simple tasks to more complex ones. The effects of the student's actions, will impact the behaviors of the other avatars within the scenario in a realistic fashion. Further, as the scenario reacts to the student's input, it will track performance and provide feedback concerning the consequences of particular actions and or omissions. In terms of people with ASD learning social behaviors, errors do need to be made to support learning. Therefore, a balance must be made between allowing the user to make errors and clearly showing what options are available at any given time within the game.

A secondary goal is to begin the research and development of VR exercises aimed at triggering the release of neurotransmitters to promote critical aspects of synaptic maturation at an early age, to change the course of the disease. Rigorous scientific

evaluation is necessary to estimate the likely benefits of this approach and its application to the individual. Research should also attempt to evaluate the contribution of this technology to any observed gains through comparison with traditional teaching approaches.

Web-based instruction and testing via "intelligent" computer simulations of typical social environments will prove an efficacious means for people with ASD to acquire social skills. Computer-based media allows people with autism continuous access to the curriculum, while concurrently allowing researchers to track the frequency of exposure and/or duration of exposure to a given skill (e.g. time logged onto vignettes and testing). It is expected that participants may engage in virtual skills training for longer durations when compared to traditional lecture-based curriculum.

For the parents, teachers and families of autistic children, understanding and active participation can be critical to their development and eventual independence. Adolescents often play games. These games, whether played in isolation or in a group setting, may be an effective reinforcement for skills that can be practiced in the home with family members and peers. Combining skill instruction with the gaming experience offers the gamer a chance to repeatedly practice skills. Although the skills learned may be constrained to the capabilities of each individual, such strategies may prove to be the gateway to increased socialization and acceptance by peers.

The vision is to use online, PC-based games and immersive 3D environments that leverage existing DOD research and development in modeling, simulation, serious gaming, performance assessment, and after action review technologies. The goal is to establish a seamless management and delivery capability to provide a distributed virtual environment where skills can be practiced and honed as a student interacts within each prescribed scenario. Virtual reality and gaming applications for social skills may prove to be less resource intensive than traditional in-vivo and "Video Self Modeling" training models. Further, this technology may provide a more engaging, and socially controlled environment in which autistic individuals can practice social skills without excessive distractions. Attention must be paid to new collaborative technologies such as massive multi-player environments that allow interactive experiences for groups as well as individuals. Automated support tools should be investigated to help teachers perform in depth assessments of student performance and to identify and mitigate critical behaviors by providing essential feedback. In this way, distributed and collaborative virtual environments can be incorporated into the continuum of ASD treatment to work in tandem with the full spectrum of other case management interventions [11].

Based on positive outcomes from this effort, additional studies could also begin to look at which social skills acquired and practiced via virtual models will generalize to school, home, and community environments. Scenario authoring capabilities should also be investigated to provide the ability to modify and insert new resources into the virtual environment as required by the various ASD treatment interventions. The ability to tailor virtual scenarios to specific student needs is intended to help the student contextualize social situations and events. The application of this augmented virtual reality technology contained within the science of modeling and simulation could produce tremendous synergy in mitigating the treatment and educational interventions to reduce the rising cost in resources, as well as in pain and suffering. Researching this area is an ethical imperative.

9.0 END NOTES

[1] U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, hhtp://www.cdc.gov/ncbddd/autism/overview.htm, accessed October 21, 2008

[2] Ganz ML. The Costs of Autism. In: Moldin SO, Rubenstein JLR, eds. *Understanding Autism: From Basic Neuroscience to Treatment.* Boca Raton, Fla: Taylor and Francis Group; 2006.

[3] Ganz ML. The Lifetime Distribution of the Incremental Societal Costs of Autism. *Archives of Pediatric Adolescent Medicine, Apr. 2007; 161.* Downloaded from www.archpediatrics.com on July 29, 2008

[4] Boyle C, Van Naarden Braun K, Yeargin-Allsopp M. The Prevalence and the Genetic Epidemiology of Developmental Disabilities. In: Genetics of Developmental Disabilities. Merlin butler and John Meany eds. 2004 (Table 3, p. 716-717).

[5] Muhle R, Trentacoste V, Rapin I. The Genetics of Autism. Pediatrics 2004; 113; 472-486

[6] Morrow, Eric M., et al. Identifying Autism Loci and Genes by Tracing Recent Shared Ancestry. *Science* 321, 218 (2008); DOI: 10.1126/science.1157657

[7] M. Hart, 'Autism/excel study' *ASSETS 2005: Seventh International ACM SIGACCESS Conference on Computers and Accessibility, (2005).*

[8] Tartaro, A., & Cassell, J. (2006). Authorable Virtual Peers for Autism Spectrum Disorders. Paper presented at the *Combined Workshop on Language-Enabled Educational Technology and Development and Evaluation for Robust Spoken Dialogue Systems at the 17th European conference on Artificial Intelligence (ECA106),* Riva del Garda, Italy.

[9] Hopkins I.M. (2007). Demonstration and Evaluation of Avatar Assistant: Encouraging Social Development in Children with Autism Spectrum Disorders. *Dissertation Abstracts International,* 68, 5-B.

[10] University of Haifa (2008, January 29). Virtual Reality Teaches Autistic Children Street Crossing, Study Suggests. *ScienceDaily.*

[11] Smith, B. (2007). Virtual Self and Peer Modeling to Build Social Competence in Children who have Autism, (*Unpublished Report by Engineering & Computer Simulations (ECS)).*