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Comparing the Gaze Responses of Children with Autism and Typically Developed Individuals in Human-Robot Interaction

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Abstract— **Robots are becoming a part of humans' social life as assistants, companionbots, therapists, and entertainers. One promising application of the socially assistive robots is in autism therapy, where robots are employed to enhance verbal and non-verbal skills (e.g. eye-gaze attention, facial expression mimicry) of individuals with Autism Spectrum Disorder (ASD). One important question is "How the gaze responses of individuals with ASD differ from that of Typically Developing (TD) peers when interacting with a robot?" We present the results of our recent studies for modeling and analyzing the gaze pattern of children with ASD when they interact with a robot called NAO. This paper reports the differences of gaze responses of TD and ASD group in two conversational contexts: *Speaking* versus *Listening*. We used Variable-order Markov Model (VMM) to discover the temporal gaze directional patterns of ASD and TD groups. The results reveal that the gaze responses of the TD individuals in speaking and listening contexts, can be best modeled by VMM with order zero and three, respectively. As we expected, the result show that the temporal gaze patterns of typically developed children are varying when the role in the conversational context is changed. However for the ASD individuals for both conversational contexts the VMM with order one could best fit the data. Overall, the results conclude that VMM is a powerful technique to model different gaze responses of TD and ASD individuals in speaking and listening contexts.**

I. INTRODUCTION

Socially Assistive Robotics (SAR) [9] is an emerging research field that aims to enhance the humans' social responses and improve the engagement level of individuals in the community. In other words SAR uses robots, either solely or in conjunction with caregivers, to improve the social skills and wellbeing of individuals who have difficulties in their social behaviors. The social disabilities may be related to depression, stroke, or autism. Socially assistive robots hold great promise to positively impact therapies for many of these maladies, although the focus of this paper is on the use of robots in the field of autism.

Autism Spectrum Disorders (ASD) refers to a spectrum of complex developmental brain disorders causing qualitative impairments in social interaction and the presence of repetitive and stereotyped behaviors [5]. Individuals with ASD experience deficits in appropriate verbal and nonverbal communication skills including motor control, emotional facial expressions, and eye gaze attention. One critical deficit that is common among the ASD population is difficulty in detecting other's eye gaze and maintaining their own eye gaze attention appropriately. These deficits often pose problems in individuals' ability to establish and maintain social relationship that may lead to anxiety, depression, and avoidance of social interactions [24].

Currently, the majority of clinical and therapeutic treatments employ human-based behavioral and educational programs to teach individuals with ASD appropriate social and behavioral skills. However, recent studies show that individuals with ASD are more comfortable using technologies (e.g. computers, iPad, robots) than interacting with humans, because they find robots to be more predictable and less complicated than human responses [25]. This evidence has encouraged several researchers to incorporate computers and robots in interventions for individuals with ASD and to investigate how ASD (and TD) individuals are performing in different social situations.

For over a decade, different robotic groups have investigated the responses of individuals with ASD to robots [21], [22], [8] and the use of robot-based interactions have shown several practical advantages for assisting individuals with ASD [14]. For instance, compared to animal assistants (e.g., service dogs), robots need less expensive training procedures. In addition, robots can provide an interface as an embodied agent, which does not exist in computer programs, iPads, or other electronic devices. In cases when a human-based therapeutic interaction is not accessible or feasible, robot interactions could be a valuable solution. However very few studies investigated the parameters and conditions that can make the robot interactions beneficial, especially for therapeutic applications.

Generally speaking, recent research suggests that children with ASD exhibit certain positive social behaviors when interacting with robots compared to their peers who do not interact with robots [18], [5], [20], [10], [25], [11]. These positive behaviors include showing emotional facial expressions (e.g., smiling), gesture imitation, and eye gaze attention. These investigations suggest that interaction with robots may be a promising intervention approach for children with ASD. For example, a social robot can be used to teach children with autism to regulate their eye gaze attention or recognize basic facial expressions.

There have also been a few studies that illustrated the effectiveness of machine-based therapy sessions compared to the conventional sessions using human therapists [18], [20]. For instance, Moore and Calvert [18] demonstrated that a computer-based program can be more effective than the human-based therapy sessions for teaching new vocabular-

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