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Understanding Psychophysiological Response to a Virtual Reality-based Social Communication System for Children with ASD

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Abstract— **Deficits in social communication skills are thought to be one of the core deficits in children with autism spectrum disorders. Specifically, these children are characterized by communicative impairments, particularly regarding expression of affective states. However, they often experience states of emotional or cognitive stress measured as Autonomic Nervous System activation without proper external expression placing limits on traditional conversational and observational methodologies. In recent years, several assistive technologies, particularly Virtual Reality (VR), have been investigated to promote social interactions in this population. Here we present the development of a VR-based social communication system that is made affect-sensitive by using a physiology based approach.**

Keywords- ASD; virtual-reality; physiology; affective states

I. INTRODUCTION

Impairments in skills related to social communication are thought to be core deficits in children with Autism Spectrum Disorders (ASD) [1]. Researchers are employing technology to develop accessible, quantifiable, intensive and individualized interventions for core deficit areas related to ASD [2]. Among the different alternative interactive technologies, we chose Virtual Reality (VR) because a VR-based system provides controllability, reduced sensory stimuli, individualized approach, safety, and a reduction of human interaction during initial skill training [3].

Despite potential advantages, current VR environments as applied to ASD intervention are often designed to chain learning via aspects of performance alone (i.e., correct, incorrect) that limits individualization of application [4] [5]. Given the importance of affective information in ASD intervention practice and concerns about low-learning effects and efficacy of interventions delivered without individualization [6], a more intensive individualized system that can go beyond only predicting performance to capture the intricacies of one's affective states may be a step towards building an adaptive intelligent system.

However, children with ASD often have communicative impairments, particularly regarding expressions of affective states. They often experience states of emotional stress measured as Autonomic Nervous System (ANS) activation without external expression [7]. In our present work we chose the implicit measure by using the physiological signals. These signals are continuously available and are not necessarily directly impacted by the communicative impairments [8].

Given the evidence of dynamic shifts in indicators of ANS activity being accompanied with transition in affective states [9], and the ability of VR-based systems to promote social communication skills in children with ASD [4], the development of a system that can combine physiological signal measurement with VR-based social communication tasks in a time-synchronized manner can be critical. The scope of this paper is limited to the development of the VR-based social communication system integrated with the physiological signal acquisition in a time-stamped manner. In addition, we carry out a small usability study with four pairs of children with ASD and typically developing (TD) children to assess the potential usefulness of such a technology-based system.

II. SYSTEM DESIGN

The VR-based system has three main sub-systems:

A. *VR-based Task Presentation*

Vizard (www.worldviz.com), a commercially available VR design package, is employed to develop the environments. The avatars within the system can make different eye contact and stand at varying distances from the participant in the virtual environment (Fig. 1).

The social parameters of interest, eye gaze ("straight," "averted," "normal," and "flip of normal," which correspond to the avatar staring straight ahead 100%, 0%, 30%, and 70% of the time) and social proximity ("invasive" and "decorum," with the avatar standing approximately 1.5 ft and 4.5 ft from the main view of the scene), are examined in a 4x2 experimental design.

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Figure 1. Avatar displays direct gaze at invasive distance (left); and averted gaze at decorum distance (right).

B. *Physiological Signal Acquisition and Processing Module*

The physiological signals were acquired using the Biopac MP150 physiological data acquisition system (www.biopac.com). We investigated various physiological signals, broadly classified as Cardiovascular (CV); Electrodermal activity (EDA); Electromyographic (EMG) activities from corrugator supercilii, zygomaticus major, and upper trapezius muscles; and peripheral Skin Temperature (SKT). These signals were mapped with the underlying affective states of anxiety, enjoyment, and engagement of participants.

C. *Integrated System*

We developed a handshake module to transmit task-related (e.g., trial start/stop) event markers from the Vizard environment being executed on the VR Task Computer to a Physiological Data Acquisition module via a parallel port. These signals along with task-related event markers were sent over an Ethernet link to a Physiological Data Logger Computer to enable acquiring and logging of the signals in a time-synchronized manner with VR-based social task. The signal from the VR Task Computer was routed to a separate monitor for the observers to view how the VR-based task progressed.

III. RESULTS

A small usability study was carried out with four pairs of ASD (A1-A4) and TD (T1-T4) participants (ages 13-18 years) to evaluate the system that combines ratings reported from a clinical observer with physiological responses indicative of affective states of the participants, both being collected when the participants engage in VR-based social tasks.

A. *Variation in the Participants' Affective States*

The clinical observer's rating on the affective states (Table I) indicates that VR-based social communication is capable of creating variations in these states among both the ASD and TD participants.

TABLE I. AFFECTIVE INTENSITY (FULL RANGE [1-9]) REPORTED BY CLINICAL OBSERVER.

	Anxiety			Enjoyment			Engagement		
Group	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
ASD (N=4)	5.1	1.7	7	4.4	1.6	6	4.5	1.6	7
TD (N=4)	4.3	1.4	6	4.6	1.3	5	5.2	1.4	6

B. *Analysis of the Affective States with the Physiological Features*

We investigated the correlation of the affective states (as rated by the clinical observer) with the physiological features and found ASD participants responding in similar and also different ways from their TD counterparts.

As can be seen from Table II, each participant showed significant correlations ($p<0.05$) in their variation of a number of physiological signals with anxiety, enjoyment, and engagement.

TABLE II. NO. OF PHYSIOLOGICAL FEATURES WITH STATISTICALLY SIGNIFICANT CORRELATION WITH AFFECTIVE STATES

	Anxiety				Enjoyment				Engagement			
	F1	**F2**	**F3**	**F4**	**F1**	**F2**	**F3**	**F4**	**F1**	**F2**	**F3**	**F4**
A1	4	2	5	-	2	1	6	-	2	1	5	-
A2	5	2	4	-	6	2	4	1	7	2	5	1
A3	1	-	-	1	3	2	-	1	2	1	4	-
A4	-	-	1	-	-	-	3	-	1	-	-	1
T1	1	-	-	-	2	-	-	-	-	1	-	-
T2	8	-	1	2	2	-	1	1	4	-	3	1
T3	-	-	1	-	2	-	-	1	7	-	-	-
T4	-	-	1	-	1	-	3	-	2	-	-	-

F1 : Cardiovascular (CV) features; F2 : Electrodermal (EDA) features; F3 : Electromyographic (EMG) features; F4 : Skin Temperature (SKT) features.

IV. CONCLUSION

In the present work we developed a VR-based social communication task that can systematically manipulate eye gaze and social distance of the avatars. We then integrated it with the physiological signal acquisition module. Results of our analysis reveal that the VR-based social communication task has the ability to generate varying affective states among the participants. Also, results indicate a number of physiological features are significantly correlated with one's affective states in similar and also different ways between the participants with ASD and their TD counterparts. Thus this system paves the way for developing a valuable tool that can predict one's affective states from objective measures, such as physiological signals, and in turn adapt itself in an individualized manner to promote social skill training among children with ASD.

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