Responses during Facial Emotional Expression Recognition Tasks Using Virtual Reality and Static IAPS Pictures for Adults with Schizophrenia

Esubalew Bekele[1,*], Dayi Bian[1], Zhi Zheng[1], Joel Peterman[2], Sohee Park[2], and Nilanjan Sarkar[1,3*], IEEE

[1] Electrical Engineering and Computer Science Department
[2] Psychology Department
[3] Mechanical Engineering Department, Vanderbilt University, Nashville, TN, USA
(esubalew.bekele,nilanjan.sarkar)@vanderbilt.edu

Abstract. Technology-assisted intervention has the potential to adaptively individualize and improve outcomes of traditional schizophrenia (SZ) intervention. Virtual reality (VR) technology, in particular, has the potential to simulate real world social and communication interactions and hence could be useful as a therapeutic platform for SZ. Emotional face recognition is considered among the core building blocks of social communication. Studies have shown that emotional face processing and understanding is impaired in patients with SZ. The current study develops a novel VR-based system that presents avatars that can change their facial emotion dynamically for emotion recognition tasks. Additionally, this system allows real-time measurement of physiological signals and eye gaze during the emotion recognition tasks, which can be used to gain insight about the emotion recognition process in SZ population. This study further compares VR-based facial emotion recognition with that of the more traditional emotion recognition from static faces using a small usability study. Results from the usability study suggest that VR could be a viable platform for SZ intervention and implicit signals such as physiological signals and eye gaze can be utilized to better understand the underlying pattern that is not available from user reports and performance alone.

Keywords: facial expression, emotion recognition, virtual reality, IAPS, adaptive interaction, eye tracking, physiological processing, schizophrenia intervention.

1 Introduction

Schizophrenia (SZ) is a debilitating psychotic disorder that affects about 1% of the population, costing more than $100 billion annually in the USA. It causes emotional and cognitive impairments [1] and is defined as a splitting of thoughts from feelings [2]. Some of the psychotic symptoms such as hallucinations and delusions are partly

* Corresponding author.

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ameliorated by antipsychotic drugs, but the route to recovery is hampered by social impairments [3]. Currently available social interventions can be helpful but low compliance rates and lack of access to such programs for most patients can be problematic.

Deficits in social cognition, including emotion processing, social cue perception, empathy, mental state attributions, and theory of mind lead to poor functional outcome in SZ even after improvement in psychotic symptoms [3,4]. Thus, there is a need for efficacious cost-effective, low-burden and high-compliance interventions for social deficits in SZ, which would likely increase positive outcome. Improvement in emotion processing, a core deficit, and social understanding would be crucial for improved social outcomes. SZ patients appear to have impairments in recognizing faces and emotional expressions and disturbances in emotional functioning are major disability in SZ [5,6]. Traditional static emotional pictures, more specifically the International Affective Picture System (IAPS), were used to elicit emotional experience in SZ [1]. The apparent disconnect between outward display of emotion by SZ patients and the actual internal feeling could be studied by understanding the involuntary peripheral physiological responses of the sympathetic central nervous system (CNS).

In the context of technology-based SZ intervention, Virtual Reality (VR) systems have been investigated with SZ for symptom assessment [7], training of medication management skills [8], hallucinations training [9], social perception [10], role play [11], and improving the diagnosis of SZ [12]. However there are limited applications of VR in emotion processing and identification for SZ. Moreover, these VR systems solely rely on user reporting and outward measures of performance. To mitigate these limitations, one should combine dynamic presentation of emotional expressions together with implicit physiological response and eye gaze processing. Implicit cues can be useful to understand the underlying psychological states that are not possible using performance-based systems or simple user reporting.

In this work, we present a novel VR-based system that incorporates implicit cues from peripheral physiological signals [13,14] and eye tracking [15] for the understanding of facial emotional expression. We compare how a SZ group and a matched group of healthy non-psychiatric adults performed emotion recognition tasks when presented in the form of static IAPS slides and when presented in a VR environment with the avatars expressing emotions dynamically.

The remainder of the paper is organized as follows. Section 2 describes the details of the two systems (i.e., the static IAPS pictures presentation system and the VR system). Section 3 details the methods and procedures followed in the usability study. Section 4 presents the results and highlights their implications. Finally, Section 5 discusses the conclusions and future extensions of this preliminary work.

2 Systems Overview

Both the IAPS presentation system and the VR system were composed of three major components: the presentation environment, the eye tracking component, and the peripheral physiology monitoring component. The presentation environments were based on Unity3D game engine by Unity Technologies (http://unity3d.com).

A remote desktop eye tracker by Tobii Technologies (www.tobii.com) called Tobii X120 was employed for gaze tracking. A wireless physiological signals acquisition device called BioNomadix by Biopac Inc. (www.biopac.com) with 8 channels was used to record the physiological signals. Each component ran separately while communicating via a network interface.

2.1 The Static IAPS Presentation

We developed a picture presentation system using Unity3D that displayed the full screen images on a 24” flat screen monitor at 1024x768 resolution. The pictures were preselected from the pool of about 600 IAPS pictures [16]. They were categorized into 6 major groups, namely, social positive (pictures of erotica), social negative (violence pictures), social neutral (people in normal scenery), non-social positive (pictures of food), non-social negative (pictures of dirty and unpleasant scenery), and non-social neutral (normal pictures of objects). The emotional pictures were broadly divided into social and non-social and within each broad category, they were further categorized into positive, negative and neutral. All the 6 categories consisted of 4 pictures each. The erotica pictures were selected appropriately for men and women subjects. After a 10 second presentation of the picture, the subjects were presented with choices to rate their emotional experience on how aroused the pictures in the preceding category made them feel (in a pictorial scale of 1-9, see Fig. 1), the valence of the emotion they felt (in a pictorial scale of 1-9) and the actual emotion they felt (out of 5 emotions and neutral). The subjects were seated around 70-80 cm from the computer screen during the whole IAPS pictures presentation session.

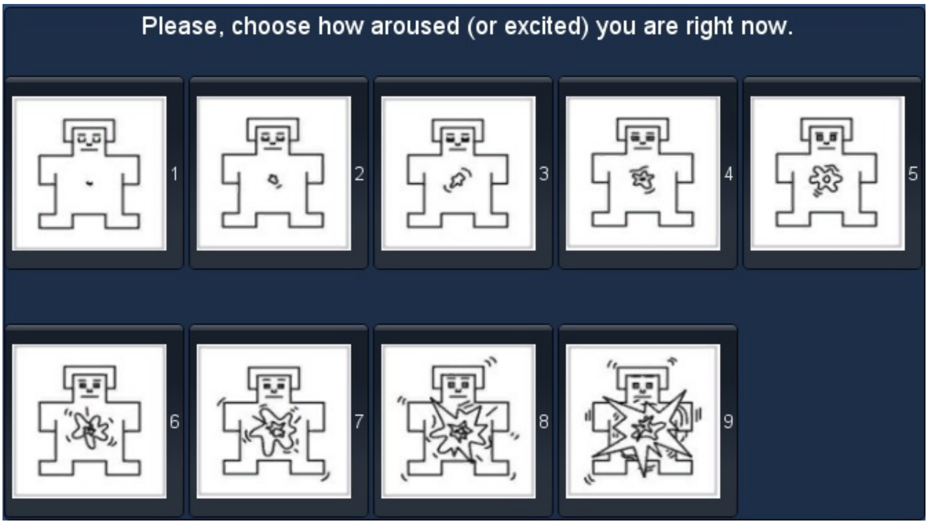

Fig. 1. IAPS pictures presentation system with the arousal rating

2.2 VR Emotion Presentation

The VR environment was originally developed for emotion recognition for adolescents with autism spectrum disorders (ASD) [17]. Due to the similarity of emotion recognition impairment in ASD and SZ, we customized the system to suit the new target group with 5 emotions (joy, surprise, fear, anger, and sadness). The avatars were customized and rigged using an online animation service, mixamo (www.mixamo.com) together with Autodesk Maya. All the facial expressions and lip-syncing for contextual stories narrated by the avatars were animated in Maya. A total of seven avatars including 4 boys and 3 girls were selected. Close to 20 facial bone rigs were controlled by set driven key controllers for realistic facial expressions and phonetic visemes for lip-sync. Each facial expression had four arousal levels (i.e., low, medium, high, and extreme, see Fig. 2). A total of 315 (16 lip-synced stories + 28 emotion expression plus neutral for each character) animations were developed and imported to Unity3D game engine for task presentation.

Fig. 2. Example surprise emotion with its four degrees of arousal

The logged data was analyzed offline to illustrate differences in physiological and gaze responses between the patient and the control groups.

2.3 Eye Tracking and Physiological Monitoring Components

The eye tracker recorded at 120 Hz frame rate allowing a free head movement of 30 x 22 x 30 cm (width x height x depth) at an approximately 70 cm distance. We used two applications connected to the eye tracker: one for diagnostic visualization as the experiment progressed and another one to record, pre-process and log the eye tracking data. The main eye tracker application computed eye physiological indices (PI) such as pupil diameter (PD) and blink rate (BR) and behavioral indices (BI) [18] such as fixation duration (FD) from the raw gaze data.

The wireless Bionomadix physiological monitoring system with a total of 8 channels of physiological signals was running at 1000 Hz. The physiological signals monitored were: pulse plethesymogram (PPG), skin temperature (SKT), galvanic skin response (GSR), 3 electromyograms (EMG), and respiration (RSP). Due to the apparent disconnect between what patients with SZ feel and their outward expressions, they are not usually expressive of their internal affective states and these states often are not visible externally [2]. Physiological signals are, however, relatively less affected by these impairments and can be useful in understanding the internal psychological states and pattern [1]. Among the signals we monitored, GSR and PPG are directly related to the sympathetic response of the autonomic nervous system (ANS) [19].

2.4 Physiological and Gaze Data Analysis

The collected physiological data were processed to extract useful features and decipher any differences between two subject groups for conditions of selected emotional expressions presentation and neutral baseline condition. We specifically chose features from PPG, GSR, RSP and SKT for this analysis. These features were chosen because of their correlation with engagement and emotion recognition process as noted in psychophysiology literature [14,19,20,1]. The PPG were used to extract heart rate (HR), which is a cardiac index used to measure stress and certain emotions [21]. The GSR is decomposed into two major components, i.e., phasic and tonic components, and from them features such as skin conductance response rate (SCRrate) and mean skin conductance level (SCL) were extracted. The RSP signal was used to extract the breathing rate (BR). The mean skin temperature (SKT) was obtained from the SKT signal. For the eye tracking data, we extracted the following features: pupil diameter (PD), fixation duration (FD), sum of fixation counts (SFC), saccade path length (SPL), and blink rate (BR). Statistical two sample unequal variance t-test was used to quantify the significance of the differences.

3 Methods and Procedure

3.1 Experimental Setup

The presentation engine ran on Unity while eye tracking and peripheral physiological monitoring were performed in parallel using separate applications on separate machines that communicated with the Unity-based presentation engine via a network interface. The VR task was presented using a 24'' flat LCD panel monitor (at resolution 1980 x 1080) while the IAPS picture was presented on the same monitor with a resolution of 1024 x 768 in order to preserve the original resolution of the images. The experiment was performed in a laboratory with two rooms separated by one-way glass windows for observation. The researchers sat in the outside room. In the inner room, the subject sat in front of the task computer. The task computer display was also routed to the outer room for observation by the researchers. The session was video recorded for the whole duration of the participation. The study was approved by the Institutional Review Board of Vanderbilt University.

3.2 Subjects

A total of 6 patients with SZ (Male: n=3, Female: n=3) of ages (M=45.67, SD=9.09) and an age and IQ matched 6 healthy non-psychiatric subjects (Male: n=5, Female: n=1) controls of ages (M=42.5, SD=8.21) were recruited and participated in the usability study. All patient subjects were recruited through existing clinical research programs and had established clinical diagnosis (Table 1).

Table 1. Profile of subjects in the patient group and the control group

Demographic Information	Groups	
	Healthy Controls (1F, 5M)	Schizophrenia (3F, 3M)
Age	42.5 (8.21)	45.67 (9.09)
IQ[a]	109.5 (8.86)	106.5 (4.09)
Years of Education	16.5 (2.34)	13.33 (1.97)
Age of Illness Onset		20.83 (4.07)
Medication Dose[b]		386.89 (194.65)
Current Symptoms[c]		
BPRS		10.83 (2.56)
SAPS		13 (5.66)
SANS		21.83 (9.06)

[a]Premorbid intelligence was assessed using the North American Adult Reading Test [22]. [b]Chlorpromazine equivalent (mg/day; [23]). [c]Semi-structured clinical interviews assessing symptoms over the past month. Brief Psychiatric Rating Scale (BPRS; [24]); Scale for the Assessment of Positive Symptoms (SAPS; [15]); and the Scale for the Assessment of Negative Symptoms (SANS; [3]).

The control group was recruited from the local community. The IQ measures were used to potentially screen for intellectual competency to complete the tasks.

3.3 Tasks

The VR-based system presented a total of 20 trials corresponding to the 5 emotional expressions with each expression having 4 levels. Each trial was 12-15 s long. In each trial, first, the character narrated a context story that was linked to the emotional expression that followed for the next 5 seconds. The avatar exhibited a neutral emotional face during story telling. The IAPS picture was presented in such a way that each category was presented as a block and rating was performed after each category resulting in a total of 6 trials of 10 s for each picture in the category whereas ratings in the VR systems was after each trial of emotion expressions. Therefore, each IAPS trial consisted of four pictures from the same category. It has to be noted that all the four pictures in a category were selected carefully for equivalence as far as eliciting equivalent emotional responses were concerned. A typical laboratory visit was approximately one hour and 30 minutes long. During the first 15 minutes, a trained therapist prepared the subject for the experiment by placing the physiological sensors on the participant. Before the task began, the eye tracker was calibrated. The calibration was a fast 9 points calibration that took about 10-15 s. At the start of each task, a welcome screen greeted the subject and described what was about to happen and how the subject was to interact with the system. Immediately after the welcome screen, the trials started. At the end of each trial, questionnaires popped up asking the subject what emotion he/she thought the avatar displayed and how confident he/she was in his/her choice in the VR system. The questionnaires for the IAPS pictures asked the level of arousal and valence of the emotion they felt together with the emotion they felt by watching the pictures. The emotional expression presentations were randomized for each subject across trials to avoid ordering effects. To avoid other confounding factors arising from the context stories, the stories were recorded with a monotonous tone and there was no specific facial expression displayed by the avatars during that context period.

4 Results and Discussions

We have compared similarities and differences of physiological and eye behavioral responses using physiological and eye behavioral and physiological features. The physiological and eye tracking data were processed to extract five features each to compare elicited responses during the facial emotional recognition tasks in the dynamic virtual environment as compared to the static IAPS presentation system. Results indicate that there are differences in both physiological and eye tracking indices between the patient and the control group. We categorized the trials into three groups: negative, positive, and neutral in the IAPS study and into two groups: positive and negative in the VR study for both physiological and eye tracking data. In the IAPS pictures presentation, the 6 trials were categorized into three groups by combining the social and non-social stimuli together whereas in the VR presentation, the prominent positive (joy and surprise) and negative emotions (anger and disgust) were combined with high and extreme levels of arousal. We also extracted baseline features for the physiological data to compare the responses in these categories to note whether they were above or below the baseline values.

4.1 Physiological Features Comparison

Table 2. IAPS Pictures Session Physiological Features

	Positive Category				Negative Category			
	Patients		Controls		Patients		Controls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HR (bpm)	85.24	9.27	82.92	10.76	84.30	15.75	86.15	11.33
SKT (F)	85.44	11.72	93.09	3.05	85.70	11.84	93.11	3.14
BR (bpm)	16.60	6.11	16.62	3.13	18.28	9.01	15.31	4.56
SCL (μS)*	5.21	3.33	8.84	4.21	5.19	3.17	8.79	4.30
SCRrate	2.61	1.38	2.12	0.96	2.13	1.29	2.38	1.14

*$p<0.05$

As shown in Table 2, the patient group had higher emotional response indicators including higher heart and skin conductance response rates and comparable breathing rate when presented with positive emotional pictures than negative emotional pictures. However, only the tonic skin conductance rate was statistically significantly different in both the positive and negative emotional categories.

Table 3. VR Session Physiological Features

	Positive Category				Negative Category			
	Patients		Controls		Patients		Controls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HR (bpm)	85.53	13.23	80.80	15.04	83.27	10.39	83.10	14.36
SKT (^{0}F)*	86.84	11.28	94.29	2.35	86.78	11.15	94.22	2.43
BR (bpm)	17.25	12.77	17.65	7.04	23.18	15.95	21.35	15.07
SCL (μS)*	4.76	2.84	7.94	4.05	4.81	2.91	7.75	4.02
SCRrate	2.65	2.89	3.18	2.73	2.72	2.73	2.68	2.70

**p<0.05*

Table 3 shows that the patient group showed similar differences from the control group as in the case of the IAPS static pictures presentation. However, in the VR case, both SKT and SCL were statistically significantly different in both the positive and negative emotion categories.

The baseline conditions were: 1) for the patient group: mean (SD), HR: 82.24 (10.76) bpm, SKT: 86.59 (10.93) ^{0}F, BR: 28.87 (16.66) bpm, SCL: 4.23 (2.41) μS, and SCRrate: 2 (0.61); and 2) for the control group: HR: 79.18 (11.72) bpm, SKT: 94.64 (1.55) ^{0}F, BR: 16.56 (3.53) bpm, SCL: 7.79 (3.55) μS, and SCRrate: 2.1 (0.65). Note that BR for the patient group decreased from the baseline case in almost all conditions whereas it increased for the control group. Another observation is that the patient group had more responses in the positive category than the negative ones, which agrees with the existing literature that people with schizophrenia report increased response to positive emotional facial pictures than negative emotional facial pictures as compared to control non-psychotic people.

4.2 Eye Tracking Indices Comparison

Most of the eye gaze indices showed statistically significant differences between the two groups (Table 4). The patient group showed more saccadic eye movement as indicated by higher SFC, lower FD and shorter SPL. These indices are known to correlate with one's engagement. Therefore, the patients were less engaged than the control group.

Table 4. IAPS Pictures Session Eye Features

	Positive Category				Negative Category			
	Patients		Controls		Patients		Controls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PD (mm)	2.66	0.37	2.91	0.24	2.68	0.36	2.91	0.19
FD (ms)*	203.91	177.04	453.72	176.03	170.91	103.27	371.00	146.84
SFC*	150.67	56.56	92.00	35.41	172.58	69.86	101.67	41.99
SPL (pix)*	67.24	24.56	139.00	46.73	92.16	32.35	147.63	54.69
BR (bpm)	11.25	3.51	10.83	5.00	10.58	4.70	10.08	4.94

**p<0.05*

Similar pattern of less engagement was observed in the patient group than the control group during the VR presentation (Table 5). Only exception in this case was pupil diameter, which was statistically significantly different with the patient group having lower PD. Pupil constriction was associated with engagement. The blink rate was statistically different for the negative category of emotions.

Table 5. VR Pictures Session Eye Features

	Positive Category				Negative Category			
	Patients		Controls		Patients		Controls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PD (mm)*	2.61	0.39	2.91	0.20	2.62	0.40	2.95	0.18
FD (ms)*	123.38	125.71	439.67	345.32	134.00	118.98	450.78	333.50
SFC*	56.65	28.08	35.75	28.36	57.35	24.98	37.20	30.04
SPL (pix)*	48.43	30.12	101.04	43.29	52.48	35.14	88.74	38.93
BR (bpm)	2.10	1.09	3.10	1.55	2.70	1.65	2.70	1.45

*$p<0.05$

5 Conclusion and Future Works

Both the IAPS and the VR systems were able to present the facial emotional expression trials successfully. Eye tracking and various physiological signals were collected and analyzed offline. The results from gaze and physiological feature level analysis show that they are viable indicators of internal emotional states of patients with SZ although their self-reporting can be biased by their emotion processing and understanding impairments. The patient group overall responded slightly stronger in the positive emotion presentations than both the negative and neutral (baseline, in the case of VR) emotion conditions for almost all the features. This preliminary study could inform future adaptive VR applications for SZ therapy that could harness the inherent processing pattern of patients with SZ as captured from their gaze and body physiological signals. Such implicit mode of interaction is advantageous over performance-only interactions for objective, extensive, and natural interaction with the virtual social avatars. Despite several limitations related to the design of the emotional expressions in the VR system and limited interactivity in the current system, this initial study demonstrates the value of future adaptive VR-based SZ intervention systems. For example, the ability to subtly adjusting emotional expressions of the avatars, integrating this platform into more relevant social paradigms, and embedding online physiological and gaze data to guide interactions to understand psychological states of patients with SZ could be quite useful tools. We believe such capabilities will enable more adaptive, individualized and autonomic therapeutic systems in the long run.

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