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Emotion-Driven Training: Innovating Virtual Reality Environment for Autism Spectrum Disorder Patients

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Abstract: Autism Spectrum Disorder (ASD) presents neurodevelopmental challenges in social interaction, communication, and restricted or repetitive patterns of behaviour. Common conditions of ASD may include difficulties in understanding social cues and engaging in conversations. With the spread of virtual and augmented reality technologies, there has been growing interest to develop game-based learning approaches for helping patients and reducing the impact of ASD. Thus, a virtual environment has been developed to be used in a system dedicated for the emotional training of patients with ASD to improve social interaction and develop appropriate emotional responses to real-life scenarios.

Keywords: Autism spectrum disorder, virtual reality, serious game, emotion, VR-based training.

1 Introduction

Autism spectrum disorders (ASD) is a complex neurodevelopmental disorder characterized by challenges impacting social communication, interaction, and behaviour [1]. One out of 100 children are diagnosed with ASD worldwide [2]. ASD involves a spectrum of symptoms varying in severity and manifestation among individuals. Difficulties in social communication and interaction are the main diagnostic indicators for ASD, as outlined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [3]. These difficulties often include reduced social responsiveness, impaired gestural communication skills, and struggles in initiating and maintaining interactive social exchanges. Additionally, individuals with ASD can encounter difficulties in understanding gestures and recognizing emotions and their expressions may not be consistence with their intentions [4].

Behavioural treatment plays a crucial role in mitigating the impacts of ASD, particularly in the early stages [5]. This form of treatment aims to assist patients with ASD in better understanding social situations, enhancing their responses and correcting undesirable behaviour patterns. The behavioural treatment can be provided through the use of games specially developed for this purpose. Games offer a friendly and safe environment, particularly for children, while also reducing the workload for clinicians guiding the treatment process. Several games have been proposed to boost skills in patients affected by ASD. For example, a virtual reality (VR) game was developed to train children with ASD on how to cross the road safely [6]. Another game was designed to simulate the experience of being a dolphin trainer, with the goal of enhancing social interaction [4]. However, such games often lack the ability to measure the appropriateness of user responses to various situations.

This work is part of a research project aiming to develop a training concept to improve social interactions in individuals affected by ASD. The project is based on developing a system that offers a gaming environment to train the users interacting and communicating with others in various daily encounters. Additionally, the system collects and processes user data such as facial images and physiological signals to assess user feedbacks and generate comprehensive reports for the clinicians. The focus of this work is the development of a virtual environment for predefined real-world scenarios.

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2 Emotional training system

2.1 System overview

The main components of the proposed system for emotional training of patients with ASD include a VR game and an emotion recognition model, as shown in Figure 1. The VR game employs one or multiple avatars that follow certain scenarios to engage the subject with diverse situations and interact with the subject throughout the gameplay. On the other hand, recognising emotions of the subject is another core component in the system to evaluate the responses from the interaction with avatars. To achieve this, data are collected and processed during the gameplay. The data includes face images and physiological signals which are cardiovascular and electrodermal activity (EDA) [7], [8].

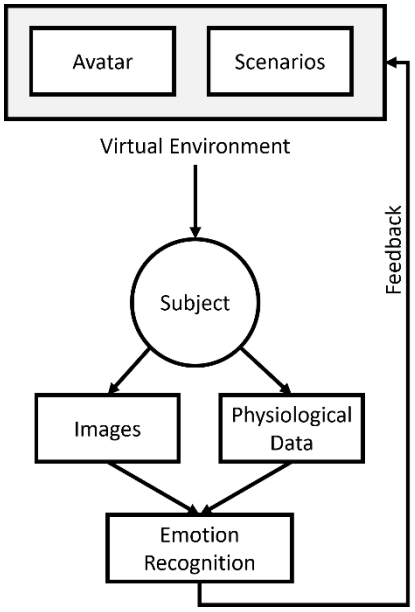

Fig. 1: Overview of the training system.

Analysing face images enable the recognition of the subject's emotions, while analysing physiological signals enable the detection of e.g., reaction intensity, arousal, stress, or other responses to the interactive scenario being played. Based on the analysis of subject data, a feedback can be delivered to the subject in the form of a reward or a winning score to motivate them to maintain engagement in the scenario and interaction with the situation. Moreover, by considering the subject's responses and physiological reactions, the presented scenarios can be adapted to meet the individual needs of the subject. Scenario adaptation involves adjusting intensity of the avatar emotion to stimulate the appropriate reaction in the subject. Additionally, reports can be generated using subject information and analysed data.

2.2 System requirements

As the aim of the system is to train patients with ASD to develop emotions, emotion-related interactive scenarios are required [9]. Moreover, avatars should effectively express diverse emotions such as happiness and fear [10]. A 3D avatar capable of accurately representing emotions through facial expression is required. Additionally, the system requires the capability to control the intensity of emotion expression, allowing for adjustment based on individual status and needs.

Detecting subject reaction and providing appropriate feedback requires acquiring and analysing the data in real-time. The recognition of emotional response is crucial in the proposed system. Since the facial expression of the subject are the key cues for emotion recognition, facial images are required to be collected via a camera integrated on VR glasses. A convolutional neural network (CNN) model integrated with an attention module and a guided training strategy were developed for emotion recognition using solely face images [11].

Understanding the subject's reactions and engagement in the VR game requires analyzing their physiological data. A wearable device can be used for acquiring physiological signals such as ECG and EDA. Emotion detection using these signals has been investigated through a machine learning approach [12]. Additionally, a CNN model (ResNet50) has been applied on the same type of data for estimating the emotion intensity.

To implement the complete system (shown in Figure 1), various components need to be developed. The pipeline for implementing the training system involves several key steps, as demonstrated in Figure 2. The initial step involves defining the required scenarios and creation of avatars. This step was conducted by clinical and industrial partners of the project. The next step is the development of the virtual environment that incorporates emotion-related scenarios. Once the virtual environment is realized in a VR game form, experiments need to be conducted to evaluate different components of the developed game. On the other hand, approaches for recognising emotions and physiological reactions need to be developed by obtaining relevant data and developing appropriate methodologies and models. Following the completion of evaluation experiments and examining the robustness of the proposed solutions, the training system can be tested on patients with ASD. These tests are required to evaluate improvements in their interaction performance,

particularly in developing appropriate emotions and maintaining their attention.

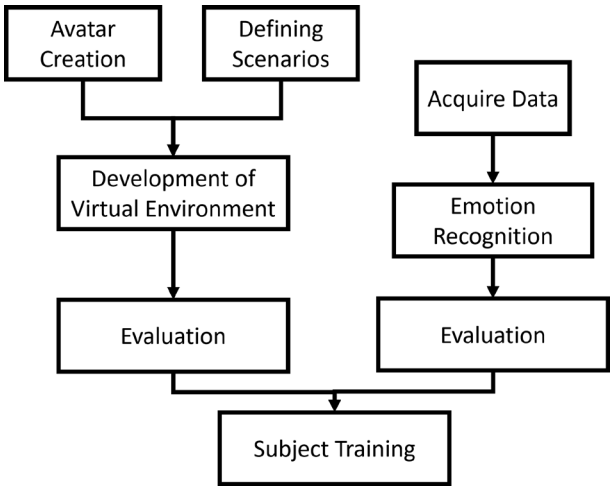

Fig. 2: System implementation pipeline.

3 Virtual training environment

The game environment was developed using Unity software (version 2022.3.13f1 provided by Unity Technologies), chosen for its high capabilities in game development. Three elements are required for the creation of a VR game, the characters, scenarios and a virtual world. Each element plays a crucial role in shaping the game and motivate the subject for interaction. Characters bring interaction to the virtual world as defined in the scenarios that provide context and objectives for the subject to engage with.

The virtual world was created according to the defined scenarios. In addition to the avatars, various components were required for creating the virtual environment. A building with a number of rooms and halls was necessary to apply the defined scenarios. Additionally, furniture such as tables, chairs, monitors were also required. Some components were designed and provided by our partners and other components were imported from the unity asset store e.g., polygon office building.

One of the implemented scenarios involves engaging in a conversation with one or more colleagues. Another scenario requires the user to complain about a product in a shop. These scenarios were implemented with varying difficulty levels (see [9] for more details). The game starts in a transition room designed to facilitate the selection of the scenario and the level. Upon selecting the desired scenario and level, a new scene starts. In the work environment conversation scenario, one or multiple colleagues approach the subject. Then, colleagues initiate conversations with the subject, expressing facial emotions corresponding to the scenario and level. In the product complaint scenario, the subject enters a shop and starts explaining his complaint to the salesperson. The politeness of the salesperson varies at different levels, expressed through facial expressions and replies. The VR game enables basic interaction with the avatars through selectable buttons displayed at defined timing, typically following certain events or prompt within the conversation. Figure 3 shows example of the VR environment's appearance.

(a)

(b)

Fig. 3: VR environment: (a) A transition room for level selection, and (b) An office room with an avatar representing the subject.

4 Conclusion and outlook

This work presents a virtual reality environment developed using predefined scenarios that mimic real-life situations. The created VR environment serves as a crucial component in establishing a system for aiding patients with ASD in social interactions and emotional development. In future work, the VR environment will be examined by professional clinicians,

followed by conducting experiments on a number of subjects to assess its efficacy. The complete system, including the feedback loop, will be implemented upon the evaluation of the robustness and efficiency of both the VR environment and emotion recognition approaches.

Author Statement

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