Using AI to Improve/Manage the Behaviour of People With Attention Deficit Hyperactivity Disorder (ADHD)

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Abstract :

In today's world, almost 10 percent of people suffer from ADHD [1]. A variety of technology components enhanced ADHD treatment by raising motivation and encouraging adherence to therapies. Most of the approaches aim to treat ADHD by engaging graphical interfaces and games, and they have been shown to boost therapy efficacy. Those methods are expensive. Therefore, by extending them, we propose creating a cost-effective model that aims not treatment of ADHD but to improve individuals' behavior, increasing their engagement with the custom-made game, which employs a minimal cost BCI to assess participants' attention levels. These levels are used as the control mechanisms in the game. The participant's EEG signals will be recorded throughout each game step. In this approach, the EEG signals are subsequently captured by a Reinforcement Learning (RL) algorithm. The state of the individuals will be recorded and transferred to doctors via a cloud system.

1. OVERVIEW

1.1. Introduction

Being inattentive, hyperactive, and impulsive makes ADHD prominent among youths [1]. Multiple technological aspects have improved ADHD treatments by increasing motivation and encouraging adherence to therapies. In this report, we intend to use AI and propose a new model that will not treat but improve/manage the behavior of people with ADHD.Brain Computing Interface (BCI) is a device that uses recorded brain signals, such as EEG to control an external device [2]. BCIs have been utilized as a therapeutic approach, providing feedback to the user via recording EEG data. Gamers increasingly use neurofeedback software to induce meditative and relaxing states by measuring oscillatory rhythms [3].

1.2. Literature Review

There have been different approaches to using Virtual Reality (VR), combining 3D games with BCI technology-based therapy to treat people with ADHD [4]. A BCI-based 3D game was developed, realizing that both 3D games worked well with BCI for attention training. BCIs measure brainwaves: P300, steady-state visual evoked potentials, event-related potentials, and sensorimotor rhythms [5].this method was enhanced by an Augmented Reality (AR) based game to analyze the attention in ADHD patients enhanced [6]. A virtual telekinesis game was introduced, transforming virtual objects by regulating brainwave patterns. By gamifying the feedback, the therapy becomes more engaging and amusing. Two telekinetic control experiences were created: inflating a balloon and bending a spoon. AR Neurofeedback had a higher effectiveness and learning rate than the 2D interfaces [6]. later, a combined model comprising a VR environment and device detecting the P300 waves was proposed [7]. The games challenged individuals to discover relevant information provided in a short time, and points were awarded for the presence of both P300 and proper information collecting. The prototype was incorporated into a VR classroom, which acted as a stimulating setting where real-life distractions could be reproduced and managed [7].

1.3. Challenges/Opportunities

ADHD is a delicate subject. The affected patient's attention should only be monitored/analyzed and not proceed with anything close to treatment. Moreover, all the models are expensive to set up. Clinical trials can prove very costly if the game is tweaked based on the person affected with ADHD.
There is a lack of using AI to improve/manage the behavior of individuals with ADHD. With the development of novel BCI that is now wearable and minimally invasive, videogames that feature neurofeedback have gained popularity and commercialization [1]. Additionally, most consumers' low-cost BCI sensors are not equipped with hardware to process EEG signals [3].

1.4. Approach

Our proposed model is designed with Deep RL, VR, and a device to monitor P300 waves. The game's difficulty varies based on the risk/reward ratio of the user. The EEG signals of participants are captured at each level, and an RL algorithm is used to record their states. The game's control systems assess the abilities of the participants. The report prepared for each game player will be immediately transmitted to the medical professional by using cloud technology.

1.5. Benefit

Our model will benefit individuals with ADHD.

1.6. Constraints

We identify ethical issues as our constraints. We will take the ethics by design approach [8] and protect the following ethical principles: Respect for human agency, fairness, transparency, individual, social, and environmental well-being, accountability, oversight, privacy, and data protection [8].
Privacy And Data Protection - As we aim to develop a system/model that will help people with ADHD manage/improve their behavior, we will have to train the data models on people who are diagnosed with ADHD. We will collect and process their identity data (name, surname, age, gender), their diagnosis of ADHD, and EEG signals. Those data is special category information (Recital 35, 53, Art. 4(15) and 9 of GDPR) [9]. We will take the following steps:

- **DPIA** - we will conduct DPIA (recital 84, art. 35 of GDPR) [9], [10].
- **Informed consent –**We will only process data based on explicit informed consent from participants (Art. 4 (11), 7, and 9 of GDPR) [9]. A consent form will contain all the necessary information under GDPR (recital 32, 42, 43, art.7, 9) [9].
- **Data protection by default** – To guarantee the data minimization principle (Art. 5 and 25 of GDPR) [9], We will use pseudonymization technics.
- **Data Protection Policy –** We will create a data protection policy covering data protection measures during the whole lifecycle of the data.
- **Destroying the data** - Once the purpose of our project is achieved or after the retention period, we will securely destroy all the data in their entirety, including data on a cloud, all the backups [11].

1.7. Limitations

Our proposed model is beneficial to the therapy of ADHD, but it cannot cure ADHD.

2. <u>FUNCTIONAL DESCRIPTION</u>

We will create a specific 3D virtual reality videogame named "Catch Me" to teach attention self-regulation using a BCI system. A detailed explanation of the design approach is available in prior research work [12, 13]. The videogame "Catch Me Challenge" employs the MindWave BCI device to monitor players' attention levels using a dry electrode inserted in the frontal lobe. The attention levels are mapped from 0-100% for the game's user interface, making the physiological input visibly apparent. The player aims to catch the robot before reaching the mountain's pinnacle. The game will be both non-time and time-constrained. Three interaction stages will be created:

Stage-1:

In this stage, a player will be requested to sit on a chair, eyes closed, in a comfortable posture. We will utilize earbud headphones to block out the background noise while the player listens to calming music for 5 minutes. The MindWave device will be used to record the EEG signals. The time-series graphs will be collected using the user interface dashboard and remotely shared with the doctor.

Stage-2:

This stage is divided into three phases:

2.1 <u>Phase-1 (Involuntary Attention Capture Engine):</u>

A player will be instructed to move randomly to pique the user's interest. The robot will engage in a polite conversation to make the player feel at ease in the setting. After ten minutes, time will be captured for the movement with direction for subsequent study. This initial EEG signal data will be utilized to train the RL Algorithm since spikes may be detected owing to curiosity.

2.2 <u>Phase-2 (Voluntary Eye Blink Attention Engine):</u>

The primary goal of this phase is to identify the player's attention via eye blinks given by the robot. The RL method will determine whether there is a continuous signal in EEG indicating that the player is not putting forth any effort in capturing the robots. Once the RL algorithm detects no spikes or steady EEG signals due to the player's involuntary movement, it will send a message to the robot mocking the player to capture the robot by advancing towards the robot. A friendly signal would be given to the user, instructing them to move to catch the robot. At start, the game would be easy; we would collect the EEG signals and the time it took to catch the robot. The difficulty of the game would rise with each level. The time capture data will be provided to the RL system for training. This phase would not be time-limited since we want to examine how users interact with the game. The player will be able to end phase 2.

2.3. Phase-3 (Controlled Time Frame Readiness):

A player must maneuver within the time limit to catch the robot. Phase 3 will start only when the player is actively capable of catching the robot within the set time range. More moving spikes in the EEG signal data indicate an increase in difficulty. Whether the player cannot capture the robot within the time limit, the difficulty level will be adjusted to see if the player can deal with the task. The EEG signals will be captured again to monitor the player's performance.

Stage-3:

The player at this stage aims to capture the robot before it reaches the mountain's summit. Once the player has caught the robot before it reaches the mountain's summit, the difficulty level in terms of the robot's speed will be added to make the stage tougher. One challenge would be the inclusion of distractions (grass fields, sounds of waves, etc.) that would force the player to move further to catch the robot. The benefit of this stage is that it increases the player's focus and confidence. The RL algorithm will determine the difficulty level of the stage with the time-capture and, most crucially, the EEG signals that will be captured concurrently.

Pros:

- The gaming environment may be configured at the user's location, it can be utilised in an uncontrolled setting.
- The records are maintained in a cloud-based location and doctors may easily follow patients who present at odd hours.
- The graphical display enables doctors to remotely alter settings based on the patient's performance.

Cons:

- At some time, the game may get tedious.
- The system does not support those with ADHD and physical disabilities such as hearing/blindness.

3. SYSTEM ARCHITECTURE

The architecture of the system is divided into three parts:

EEG Transducer - This is the architecture's primary component, and it is responsible for monitoring the EEG signals during all readings of various stages. EEG Transducer will record the EEG variations in brain's electrical activity.

After that, the following will be combined: 1) an EEG electrode headset and an integration unit; 2) a pair of game controllers, and 3) an external processing unit that interfaces the two with the application.

AI Integration – this part consists of 2 different sub-components:

Transmitter - After analyzing the EEG signal, the response and associated command are sent to the application through the transmitter. Transmitter will send the EEG signals to the application, which will then transfer signal readings to the processing unit, the RL algorithm.

Processing Unit - All readings of the EEG signals at various stages will be captured through the transmitter. The trained algorithm will transmit information to the processing unit regarding the robot's action during application play. It will interface with cloud-based technologies responsible for visualizing the player's performance. Data from the screen time capture will be analyzed along with the signals.

Feedback Mechanism - This is where the AI will monitor the player's and robot's feedback activity, which will be given to the AI RL. This component is in charge of adjusting the difficulty level throughout the game.

CLOUD-based Integration Panel - This component will display most of the visuals to the doctor. It can be active (online) or static (offline). The player's performance dashboard will be hosted on cloud, allowing the doctor to remotely monitor the player's data and performance.

4. EVALUATION

The RL algorithm we suggest using is Deep Q-Networks (DQN), which uses deep neural networks to train a Q-network to predict the total reward, in this case, different game levels as shown in the figure below (a denotes user action and s denotes state of the model) Our algorithm will try to beat the player as they keep focusing more and take appropriate actions to move ahead in the game.

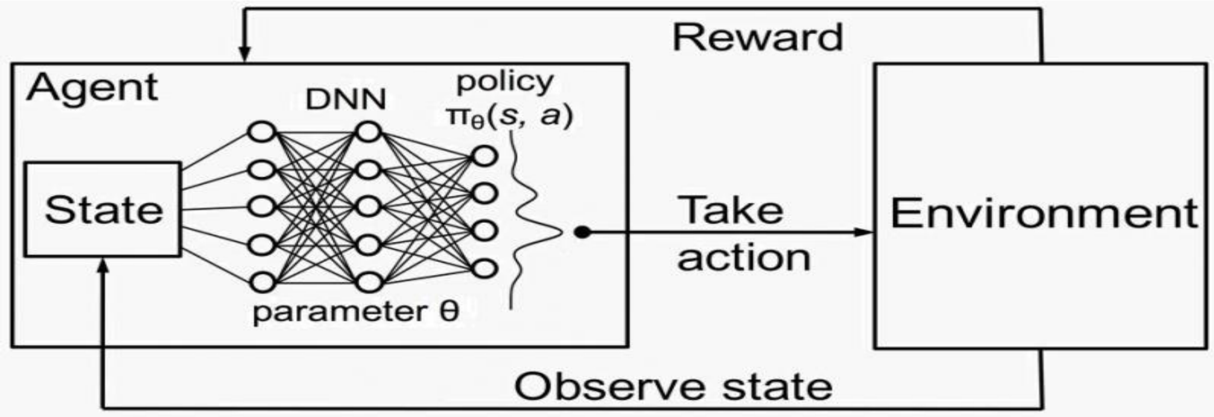

Figure 1. DQN back-propagation method [14]

The model will be evaluated using time-frequency distribution (TFD). TFD evaluates a model's efficiency using noiseless signals such as EEG. The EEG signal will be divided into k segments. Each segment will give the value of E_k (energy), F_k (Frequency), and L_k (length of the principal track) and construct a 3D feature vector of each segment. The following equation represents the energy segment:

$$E_k = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \vartheta_k(t, f)\, dt\, df, \quad [15]$$

Where $\vartheta_k(t, f)$ represents time-frequency trade-off for a segment. Similarly, the segments for frequency and length of principal track will be calculated. They will be fed into the DQN model as a back-propagation method to fine-tune the model's parameters. Based on the time-frequency variation of the player's response to the system, a graph representing the modeling of brain energy (player) and the frequency of the correct outcomes in the game will be analyzed to measure the player's performance in the game. The graph will also define the extent to which our model was able to predict the rewards offered to the player.

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