

# Control of Serious Games Designed for Alzheimer's and Dementia Patients by EEG Signals

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**Abstract** — Alzheimer's Disease and Dementia are increasing diseases with the aging population. These diseases cause memory loss, impaired attention, impaired problem-solving abilities. Serious games are designed to prevent or slow the progression of these diseases and to reduce the effects of diseases. In this study, a 2-dimensional maze game is designed as a serious game. The purpose of this study is to play the game by using EEG signals recording from the user.

**Keywords:** Brain-Computer Interface, Serious Game, EEG

## I. INTRODUCTION

Dementia and Alzheimer's disease (AD) are increasing day by day with the aging population [1]. These diseases affect memory, attention, problem-solving abilities and speaking ability [1],[2]. Unfortunately, there is no certain way to treat these diseases [2]. However, there are scientific studies that show with early diagnosis of the diseases drug and the mental exercises reduce or stop the progression of AD. According to the Cognitive-Enrichment hypothesis [2], non-pharmacological approaches as cognitive stimulations, physical activities, and social engagement positive affect and reduce psychological distress. This hypothesis suggests an idea of the usage of video games as Enriched Environments [3]. Also, video games affect cognitive functions and neuroplasticity [4]. The cognitive decline of AD patients causes new questions about the usage of video games designed for healthy users. As a result of that, designing specific video games for these kinds of patients called serious games [5], [6]. Serious games often have educational purposes or health-related purposes rather than entertainment. In general, such games can be classified as games for e-learning and medical applications [5],[6], [7].

Recently, Brain-Computer interface technology has become more popular in the markets and serious game design and development has become more popular. Brain-Computer Interface (BCI) is a system that recognizes and reacts to the user's brainwaves [8]. BCI measures and analyzes brain signals and then converts them into commands to control external devices i.e. wheelchair, computer game, TV, light system, etc. BCI designs are differentiated according to their signal acquisition technique. Also, they can be invasive or noninvasive.

In this study, a 2D maze game designed as a serious game. The purpose of this game is controlling the game by using the user's Electroencephalography (EEG) signals. It is aimed to move the ball out of the maze by moving the up, down, right and left of the ball in a maze. By this way, the user needs to be concentrated to move the ball, to find a way out of the maze user should use the memory and problem-solving abilities.

## II. MATERIALS AND METHOD

### A. Game Design

A maze game was chosen as a serious game because for playing the game, the player should use own memory and should be concentrated. The game was made by using Unity real-time development platform. Unity is a platform that you can design 2D or 3D real-time games [9]. This platform allows using two programming languages, Java and C#. It is communicating with Microsoft Visual Studio. There are various versions of Unity for users, in this study the free personal edition of Unity is used.

Firstly, a maze picture was drawn on Adobe Photoshop and then added this picture to Unity as a background as shown in figure 1, initially it goes "Assets>Scenes". Then, it was dragged to "SampleScene" section and named as "Labirent". In the program, every piece of the character of the game goes here including the camera. After that, "2D Box Colliders" were built on each wall, so the maze gains physical properties because of the box colliders. Then the center position of the maze was set in the 3D space at (0, 0, 0).

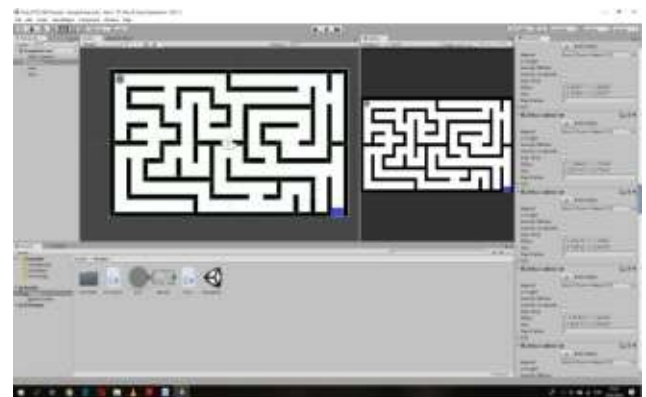


Figure 1. Unity Game Design Platform

Secondly, a ball picture was drawn which is going to move in the maze by using Adobe Photoshop. It was added to “Assets>Scenes” then dragged to “SampleScane”. “2D Circle Collider” added on the ball picture which’s radius is 1.03 unit. In addition, “2D Rigidbody” added to the ball and it was made dynamic. Center position of the ball was set in the 3D space at (-5.978, 3,092, -1). “x” and “y” positions are for the location of the upper left and “z” position for the seeing the ball on the maze. After doing that, gravity scale was arranged as zero otherwise ball goes “-y” direction. Then, the code was written in C# language for the movement of the ball in x and y directions by using Microsoft Visual Studio. For +y direction “w”, for -y direction “s”, for +x direction “d” and for -x direction “a” were assigned. This code was added to “Assets>Scenes” as script than dragged into the ball in the “SampleScane”. After the signal processing, writing threshold values of EEG frequency bands in the directions of the code was planned.

Lastly, a “2D Box Collider” was added for the exit of the maze and named it “exit”. Again, it goes “Assets>Scenes” as script than dragged into the “exit” in the “SampleScane”. The code was written for the finishing the game in C# language and the script was added into the exit box.

### B. Experimental Setup

Firstly, a section of the maze picture was prepared which is seen in figure 2. Then, an instruction paper was prepared for the subjects, and the EEG recording instructions were explained to each subject separately and recordings were taken as shown in Figure 2. When the rest was instructed, the subject was asked not to think about anything, and when a direction (right, left, up or down) was specified, the subject was asked to think that the ball was moving in that direction. There are 8 subjects in the experiment. 4 women (ages: 20, 22, 22, 23) and 4 men (ages: 20, 23, 24, 24). These subjects have no known mental disorder in their past.

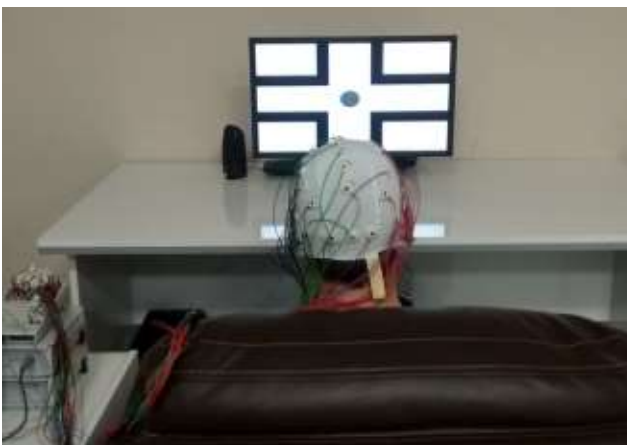


Figure 2. EEG recording process of a subject

32 channel EEG device is connected to subjects, EEG signals are recorded by using “BrainVision” software. BrainVision Analyzer is a software that is used in this study for recording EEG signals. The user interface is shown in figure 3. All channels seem red when no connection. When there is a connection, according to connection quality, the color of circles goes green from red. Red means very low quality or no connection, yellow means enough quality, green means good quality. This software allows us to save EEG files in different formats. In this study, to view data “.vhdr” extension files were used.

First, EEG recording was started and the subject was asked to rest with his eyes closed for 20 seconds. The subject was then asked to look to the right and waited again for 20 seconds. The subject was then asked to rest with his eyes closed, and waited for 20 seconds. This method was applied for every direction (right, left, up and down) for 20 seconds. Then the record was terminated. Files were saved in .vhdr extension.

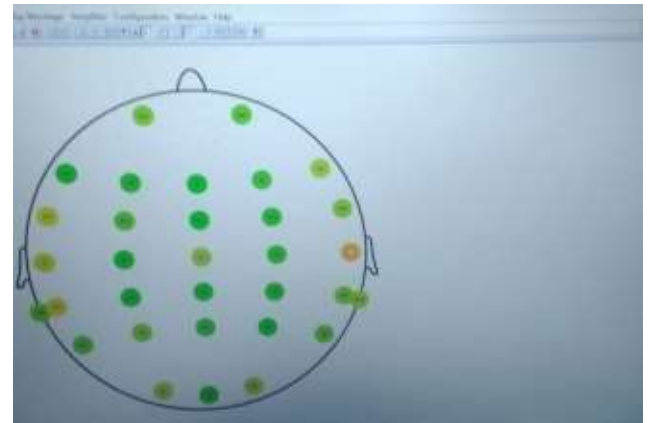


Figure 3. BrainVision Analyzer user interface

### C. Signal Processing

In this study, Matlab was used for signal processing. EEG recordings were saved as “.vhdr” extensions. To open these files in Matlab, “EEGLAB” toolbox was used. EEGLAB is an interactive Matlab toolbox for processing continuous and event-related EEG, Magnetoencephalography (MEG) and other electrophysiological data. In this study, it is used for opening “.vhdr” files in MATLAB.

EEG recording process took 160 seconds which means there are 160000 samples for each subject because EEG device takes 1000 sample per second. First 20000 samples of these data are the subjects’ resting state. Between 20000 - 40000 samples of data are the subjects’ right thinking state, 40000 – 60000 samples of data are resting state, 60000 - 80000 samples of data are left thinking state, 100000 - 120000 samples of data are up thinking state and 140000 - 160000 samples of data are down thinking state.

However, We had warned subjects for every 20 seconds by saying the direction or rest, so in order to prevent the noisy or unnecessary data, We cropped first and last 2 seconds of each state.

Thus, there are 16000 samples for right, left, up and down states as shown in figure 4 for one channel of EEG. In the study 32 channels are used, therefore all channels' data are taken. After that, in every channel Power Spectral Density (PSD) distribution on delta, theta, alpha, beta and gamma bands are calculated separately using Welch method for right direction. The same calculation is applied to left, up and down states of the subject.

Lastly, the mean of these PSD values in 32 channels for right, left, up and down states are calculated. Results of three subjects are shown in table 1 as an example. These results are going to give the input for the game.

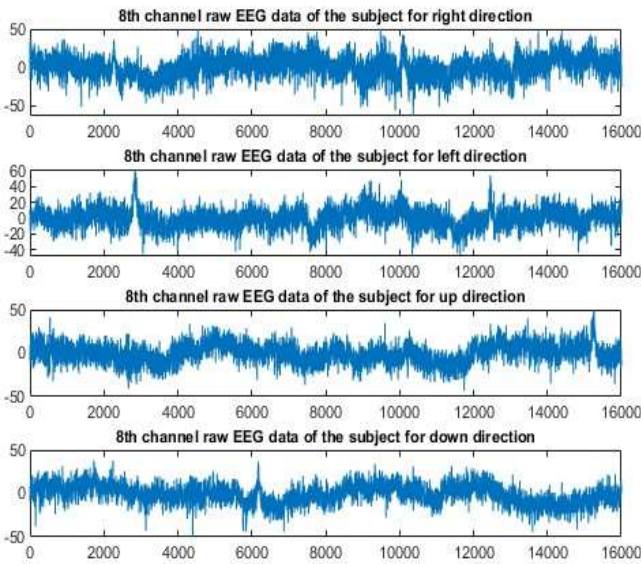


Figure 4. 8<sup>th</sup> channel raw EEG data of subject #1 for four directions

### III. RESULTS AND DISCUSSION

The maze game worked properly by using attached buttons. However, the lack of interface between Microsoft Visual Studio or Unity and 32 Channel EEG Device causes an obstacle to communication between them.

Results of PSD distribution on delta, theta, alpha, beta and gamma bands of eight subjects are shown in table 2. It shows the sum of every channel's PSD distribution on frequency bands. There is no significant similarity among the subjects so, it may show each subject react differently to the said directions. Also, every subject's casual mental condition could affect the results.

Interestingly, when comparison of Gamma values of 8 subjects, Gamma values of right state are higher than other Gamma values. However, that is not sufficient to make a difference. Therefore, it is not possible to set a general platform for all users. Nevertheless, each subject's data has quite significant differences for classification of directions frequency values. To classify the data, individually classification may show good results.

These results show that setting a general BCI for all users is not possible. However, to set individual BCI may be a good option. In this work, every subject's data have a significant difference. Coming from this point, it is possible to create proper BCI for the game.

For obtaining user's data, applying all the signal process which is applied in this work right before the game to the user is necessary. After that, to classify the data a logic method is shown in down.

Recorded data before the game for directions:

*Subject's PSD values for right:*

$$\Delta=\delta_1, \Theta=\theta_1, \text{Alpha}=\alpha_1, \text{Beta}=\beta_1, \text{Gamma}=\gamma_1$$

*Subject's PSD values for left:*

$$\Delta=\delta_2, \Theta=\theta_2, \text{Alpha}=\alpha_2, \text{Beta}=\beta_2, \text{Gamma}=\gamma_2$$

*Subject's PSD values for up:*

$$\Delta=\delta_3, \Theta=\theta_3, \text{Alpha}=\alpha_3, \text{Beta}=\beta_3, \text{Gamma}=\gamma_3$$

*Subject's PSD values for down:*

$$\Delta=\delta_4, \Theta=\theta_4, \text{Alpha}=\alpha_4, \text{Beta}=\beta_4, \text{Gamma}=\gamma_4$$

*Real time data for:*

$$\Delta=\delta, \Theta=\theta, \text{Alpha}=\alpha, \text{Beta}=\beta, \text{Gamma}=\gamma$$

Logical expression of the code (std $\alpha$ : standard deviation of alpha frequency bands of a subject for all directions):

*For the right direction:*

$$\text{if } [(\delta_1 - \text{std}\delta) < \delta < (\delta_1 + \text{std}\delta) \text{ and } (\theta_1 - \text{std}\theta) < \theta < (\theta_1 + \text{std}\theta) \\ \text{and } (\alpha_1 - \text{std}\alpha) < \alpha < (\alpha_1 + \text{std}\alpha) \text{ and } (\beta_1 - \text{std}\beta) < \beta < (\beta_1 + \text{std}\beta) \\ \text{and } (\gamma_1 - \text{std}\gamma) < \gamma < (\gamma_1 + \text{std}\gamma) \Rightarrow \text{"right" is activated}]$$

*For the left direction:*

$$\text{if } [(\delta_2 - \text{std}\delta) < \delta < (\delta_2 + \text{std}\delta) \text{ and } (\theta_2 - \text{std}\theta) < \theta < (\theta_2 + \text{std}\theta) \\ \text{and } (\alpha_2 - \text{std}\alpha) < \alpha < (\alpha_2 + \text{std}\alpha) \text{ and } (\beta_2 - \text{std}\beta) < \beta < (\beta_2 + \text{std}\beta) \\ \text{and } (\gamma_2 - \text{std}\gamma) < \gamma < (\gamma_2 + \text{std}\gamma) \Rightarrow \text{"left" is activated}]$$

*For the up direction:*

$$\text{if } [(\delta_3 - \text{std}\delta) < \delta < (\delta_3 + \text{std}\delta) \text{ and } (\theta_3 - \text{std}\theta) < \theta < (\theta_3 + \text{std}\theta) \\ \text{and } (\alpha_3 - \text{std}\alpha) < \alpha < (\alpha_3 + \text{std}\alpha) \text{ and } (\beta_3 - \text{std}\beta) < \beta < (\beta_3 + \text{std}\beta) \\ \text{and } (\gamma_3 - \text{std}\gamma) < \gamma < (\gamma_3 + \text{std}\gamma) \Rightarrow \text{"up" is activated}]$$

For the down direction:

if  $[(\delta 4 - std\delta) < \delta < (\delta 4 + std\delta)]$  and  $(\theta 4 - std\theta) < \theta < (\theta 4 + std\theta)$   
and  $(\alpha 4 - std\alpha) < \alpha < (\alpha 4 + std\alpha)$  and  $(\beta 4 - std\beta) < \beta < (\beta 4 + std\beta)$   
and  $(\gamma 4 - std\gamma) < \gamma < (\gamma 4 + std\gamma) \Rightarrow$  "down" is activated]

**Table 1.** PSD values in Delta, Theta, Alpha, Beta and Gamma bands for three subjects.

Directions	Frequency Values of Bands				
	Delta	Theta	Alpha	Beta	Gamma
<b>Subject 1</b>					
<b>Right</b>	327.08	34.27	16.88	32.284	77.45
<b>Left</b>	373.16	30.91	26.66	35.99	66.28
<b>Up</b>	145.71	19.60	15.28	35.89	60.37
<b>Down</b>	214.2	24.66	22.23	46.87	61.29
<b>Subject 2</b>					
<b>Right</b>	172.83	16.25	16.37	64.97	137.03
<b>Left</b>	134.65	17.42	20.91	61.13	106.92
<b>Up</b>	153.02	16.86	24.29	57.09	99.37
<b>Down</b>	184.25	16.53	17.00	55.74	78.74
<b>Subject 3</b>					
<b>Right</b>	1434.53	47.41	19.25	37.65	66.85
<b>Left</b>	265.34	26.44	19.28	37.26	48.36
<b>Up</b>	2041.76	68.67	27.31	40.94	43.63
<b>Down</b>	984.91	29.64	23.33	37.03	55.58

After the EEG record process, subject's PSD values of Delta, Theta, Alpha, Beta, and Gamma are saved in the code for right, left, up and down. Each of them divided by 64 because in the recording process 16000 samples were taken and in the real-time process 250 samples to be taken. Taken number of samples can be changed according to the used EEG device's sample rate.

Then, for all frequency bands, the standard deviation is calculated for the classification of data. By adding and subtracting standard deviation of frequency bands a range is determined for the directions. When the game is started, PSD of real-time data is calculated for 250 samples, then if it enters a direction's range, this direction is going to be activated.

For 8 subjects who are used in this study, the given method is proper for the movement of the ball. By applying this method a useful BCI for the game can be created.

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