THE EFFECT OF THE ENVIRONMENT ON BRAIN ACTIVITY DURING PROBLEM SOLVING

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Abstract**—**In all functions of the brain, electrical signals called volumetric conduction occur in nerve cells in the brain. The process of measuring and recording these electrical signals by means of sensors placed in certain areas on the scalp is called electroencephalography (EEG). EEG signals occur in body movements, sleep and wakefulness, and in all kinds of processes in the brain, including cognitive processes. In this study, we investigate the effect of city noise and popular music environments while solving questions with different levels of difficulty (simple and hard) employing the EEG signals in Cognitive Tasks Database in Different Environments. Features are extracted from the EEG data, collected from 17 undergraduate and postgraduate students while solving simple and hard questions, by means of Continuous Wavelet Transform. EEG signals recorded while solving simple and hard questions, in city noise and popular music environments are classified with average accuracies of 90.10% and 93.92%, respectively using Bayesian Networks. Results show that, EEG data collected in two different environments, noise and favorite music, while solving problems can be classified with high accuracy and distinction can be made with higher success for difficult questions.

Keywords**—***EEG, Cognitive Tasks, Classification, City noise and Popular music environments*

1. INTRODUCTION

THE process of recording electrical signals produced in the brain is called EEG. The frequency range of the EEG signals varies between 0.5-100 Hz, and the amplitude is about 1-100µV. EEG signals are used in the diagnosis and treatment of various diseases in addition to providing information about all kinds of processes that occur in the brain by means of EEG signals [1,2,3,4,5].

Music is an educational activity. The lifestyle and view of life of individuals can change with the help of music [6]. Using music in education enables the creation of a positive emotional environment in learning due to the relationship between music and emotions. It is also known that listening to some music contributes to the individual's concentration skills [7]. The level of electrical energy in the brain nerve cells affects the individual's concentration and fatigue impact scale. It has been stated that, concentration decreases and fatigue occurs as the energy of the individual decreases. Therefore, high frequency music between 5000 and 8000 Hz should be given as stimulus to the individual in order to increase the energy in brain cells [8].

It is accepted that noise has psychological and physiological negative effects on people. There are many sources of noise in cities. One of the most important of these sources is the traffic noise in the city centers. Many studies have shown that traffic sound can be accepted as noise pollution [9, 10, 11]. There are three main factors affecting road traffic noise. These are the noise caused by vehicles, the noise caused by the interaction of vehicles with the road and the environment, and the noise caused by the driver. Traffic noise on the road is composed of components such as motor noise, brake sounds and the sounds of the wheels on the road. Noise originated by the driver is mostly caused by improper use of vehicles. The most important factors in driver-induced noise are the sounds generated by the use of horns and removal of parts that provide sound insulation in vehicles [12].

In this study, we conducted a study on whether individuals were affected by their environment during a cognitive task. EEG signals recorded while subjects are solving the questions consisting of numerical and visual logic questions were compared each other on traffic noise and favorite music environments.

2. MATERIAL AND METHOD

The main steps used in the study is summarized in Figure 1.

Fig.1. The basic steps of the experimental study

2.1. EEG Recordings

EEG signals in Cognitive Tasks Database in Different Environments are used in this study. EEG data in this dataset are collected from a total of 17 healthy and all-male participants who are studying undergraduate and postgraduate on a voluntary basis in this study. The participants are asked a total of 10 questions consisting of numerical, visual and verbal questions with different degrees of difficulty in their favorite music and traffic noise environments. These questions are approved by the International Cognitive Ability Resource (ICAR) project [13], jointly conducted by Germany, the United States and the United Kingdom. ICAR is a project that researchers are allowed to access on the internet. This project provides a wider assessment of cognitive abilities in psychology and other social sciences and aims to facilitate neuropsychological assessment in medical research. In this study, problems were translated to Turkish, by permission,

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since all the subjects are native Turkish speakers. Samples for each problem type used in the experimental setup during EEG recording are shown in Figure 2-4.

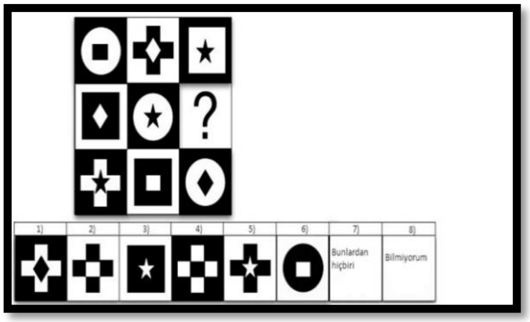

Fig. 2. A visual question

Fig. 3. A numerical question

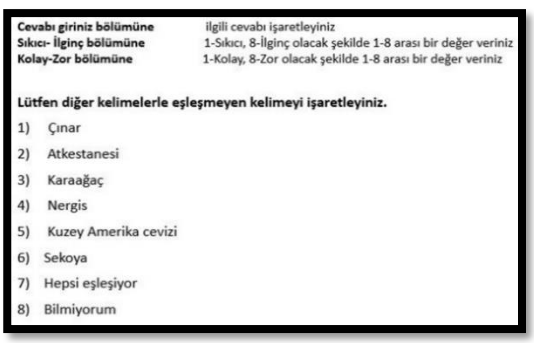

Fig. 4. A verbal question

EEG data is collected with 14-channel, wireless, high quality Emotive EPOC+ which can automatically remove network noise. EEG device are demonstrated in Figure 5.

Fig. 5. Emotiv EPOC+ device

The EEG device has 14 electrodes consisting of AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4. The sampling frequency is 128 Hz.The electrodes are placed on the scalp in accordance with the internationally recognized 10-20 system. An example image collected from volunteers during EEG recording is shown in Figure 6. Details of the database can be found in [14].

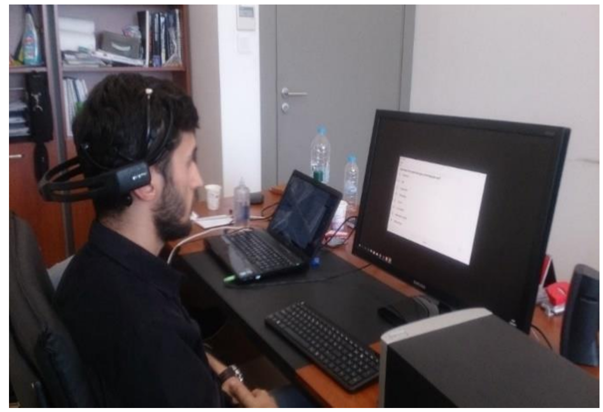

Fig. 6. The position of the device on the scalp and test environment

TABLE I
EXPERIMENTAL SETUP

Rest (10 sec)	Stimulus (Duration changes with the difficulty of the question)	Marking (20 sec)	Rest Duration (10 sec)	………	Stimulus (Duration changes with the difficulty of the question)	Marking (20 sec)	Rest (10 sec)

2.2. Pre-Processing

50 Hz network noise is automatically cleaned by the device during recording EEG signal. After the recordings, signals are bandpass-filtered between 0.2 and 45 Hz.

2.3. Feature Extraction

Continuous Wavelet Transform (CWT) is calculated as the convolution of the signal by an analysis function, similar to Fourier Transform (FT).However, the trigonometric basic sine analysis functions in FD have been replaced by the wavelet function, called mother wavelet, in CWT. The mother wavelet is a function with different frequency contents as opposed to the sine (or complex exponential) function with constant frequency content. Time information is obtained by shifting the mother wavelet along the signal. Frequency information is captured by means of opening and contraction of wavelet. The CWT is defined as follows [15].

$$CWT_X^{\psi} = W_X(\tau, s) = \frac{1}{\sqrt{|s|}} \int_{-\infty}^{+\infty} X(t).\psi * \left(\frac{t-\tau}{s}\right) \qquad (1)$$

CWT_X^{ψ} depends on τ and scale parameter s. $\psi(t)$ is a transformation function and it is called fundamental wavelet. Other window functions used for transformation are derived from this wavelet. The energy of the signal is normalized at each scale by dividing the wavelet coefficients by $1/\sqrt{s}$. Thus, the same energy is obtained at each scale.CWT is used for feature extraction in this experimental study. By this method, energy values are obtained for each channel in the time-frequency domain. The total energies in the theta (3-7 Hz), alpha (8-12 Hz), beta (13-29 Hz) and gamma (30-45 Hz) bands and the ratio of these energies to total energy are used as features. Features are extracted from 1 second segments with 50% overlapping.

2.4. Classification

Bayesian Network serves to classify EEG data in this study. This method works based on Bayesian Theorem. Bayesian network is an algorithm which is used for analysis of high-dimensional data. The algorithm is efficiently and reliably formed by the development of existing methods to solve hard questions [13].

3. RESULTS

Table 1 shows the effect of the environments (city noise and popular music) on EEG signals recorded while solving simple questions for each participant.

TABLE II
THE CLASSIFICATION RESULTS OF EEG SIGNALS RECORDED WHILE SOLVING SIMPLE QUESTIONS IN CITY NOISE AND POPULAR MUSIC ENVIRONMENTS FOR ALL PARTICIPANTS

No of Participant	Accuracy	Precision
1	90.17	90.24
2	88.03	88.59
3	77.35	78.26
4	81.62	81.63
5	88.89	89.18
6	99.15	99.15
7	81.62	82.68
8	88.89	88.93
9	96.15	96.16
10	92.74	93.12
11	85.47	85.56
12	86.75	86.82
13	97.44	97.45
14	79.49	79.63
15	99.57	99.58
16	98.29	98.35
17	100	100
Average	**90.10**	**90.31**

Examining Table 1,17th participant has the highest classification success, with accuracy rate of 100%. On the other side, 3rd participant has the poorest accuracy, 77%. During the solution of simple questions, it is seen that city noise and popular music sounds make differences on the recorded EEG signals of the participants. Table 2 shows the results on EEG signals acquired when solving hard questions in above-mentioned environments.

As is seen from Table 2, environments can be distinguished from each other by an average accuracy of 93.92% when Bayesian Network algorithm is performed to EEG features extracted by continuous wavelet transform. Moreover, participant 7 has the worst classification result, with accuracy rate of 81.99% although participant 6 and participant 16 have the highest classification result with accuracy rate of 100%.

TABLE III
THE CLASSIFICATION RESULTS OF EEG SIGNALS RECORDED WHILE SOLVING HARD QUESTIONS IN CITY NOISE AND POPULAR MUSIC ENVIRONMENTS FOR ALL PARTICIPANTS

No of Participant	Accuracy	Precision
1	94.95	94.95
2	95.96	95.96
3	95.12	95.27
4	93.60	93.89
5	95.62	95.63
6	100	100
7	81.99	82.02
8	89.23	89.34
9	98.15	98.15
10	82.83	82.98
11	91.08	91.16
12	98.99	99.00
13	97.98	98.06
14	89.73	89.97
15	99.83	99.83
16	100	100
17	91.58	91.86
Average	**93.92**	**94.00**

The city noise and popular music environments are classified with success rate of 90% and above for 8 participants while performing simple cognitive tasks in spite of fact that the environments are classified with success rate of 90% and above for 13 participants while carrying out hard cognitive tasks.

4. CONCLUSIONS

In this study, we investigate the effects of city noise and popular music environments on EEG signals recorded during the solution of simple and hard questions. Results show that, the noise and favorite music environments during problem solving can be distinguished from each other, using the corresponding EEG signals, with high accuracy rates. Results also show that, accuracy rate is higher in classifying environments while solving hard problems. Considering this result, we may conclude that, people are more affected by the environment while solving hard problems than solving simple ones. This might be due to the engagement level the subject needs, which is expected to rise as the difficulty level of the problem increases. This specific topic will be investigated as a feature work.

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