Abstract— As addiction is said to be a mental health condition which can be derived from Electroencephalogram, this study focuses on changes in EEG pattern due to smoking. A methodology is proposed here to identify smoker and nonsmoker by EEG domain analysis. In this research, three ANN were built for domain analysis to differentiate smoker from non-smoker. It was found that the neural network built with the attributes of time and frequency domain provided best quality with MSE of $6.238 \times 10^{-08}$ than the neural networks using either time or frequency domain features. On the other hand, frequency domain based ANN gives better performance than time domain properties based neural network. It is concluded in this paper that values of PSD and FFT is much higher in EEG of smokers than the nonsmokers.

Keywords— Electroencephalogram (EEG), Artificial Neural Network (ANN), Domain, Smoking

I. INTRODUCTION

As Electroencephalogram (EEG) varies from person to person and depends on one’s psychological condition, it is used in medical science popularly. Alcohol, tobacco, tar, nicotine will have an impact on EEG and psychological behavior. How much a person is addicted or what is patient’s mental condition is a great issue in various medical fields today.

Mood and behavior altering substances such as tobacco become a great concern today [1]. Tobacco makes effect on brain which consist of many neurons and working as a central processing unit of our body [2]. Effectiveness of public service announcement against tobacco is surveyed in a previous pilot study [3]. After horizontal rotation treatment improvement was seen in smokers to achieve a reduced addiction. It has been observed by EEG [4]. To achieve goals of Smoke Free Project a pilot study found the emotional impact due to biofeedback and neuro feedback training on smokers [5]. Nicotine affects the EEG during oddball task is also found by MRI analysis [6].

This paper represents a methodology to differentiate between smoker and non-smoker, domain analysis to find efficient features in different domains and determining smoking effect on EEG. BIOPAC system was used for data collection and Acknowledge-4.1 package [7] was used for extracting signals. MATLAB 2014a and artificial neural networks (ANN) were used for EEG signal analysis.

The following part of this article presents following: section II briefs the methodology, section III describes about EEG processing and analyzing, experimental data are discussed in section IV, classification discussed in section V and the article ends with a conclusion in last section.

II. PROPOSED METHODOLOGY

A. Developed Model

The developed model for differentiating smoker’s EEG from non-smoker and domain analysis is viewed in Fig. 1. At first the raw EEG is acquired by BIOPAC system with the help of MP 36, then pre-processed. Acqknowledge 4.1 package and MATLAB 2014a both were for feature extraction and classification. Features from each and both of time and frequency domain were utilized to train three ANN for classification. Comparing the mean square value, regression, accuracy the most effective domain was determined.

B. Signal Acquiring and Required Condition

The proposed work was executed in BME lab, KUET-9203, Bangladesh. Four male subjects, free of any psychological disorder were selected. Among them two were smoker and two were non-smoker. The subjects were instructed to be eye closed and they were said to solving some simple mathematical problems during experiment. The cognitive task was selected from the previous experience from pilot studies where the cognitive task has given clear EEG signals with less noise [8-10].
Total ten trials were taken. Eight trials were utilized for training the neural network classifier and the remaining were used for testing.

C. Environment Setup

1) Instrument description: The hardware utilized in the study was BIOPAC Systems, which was incorporated with M P36 device. The pictorial view during experiment is given in Fig. 2. The electrodes were placed on the frontal and temporal lobe as these regions are responsible for problem solving and cognitive function respectively.

2) Analytic software: BIOPAC student Lab Pro and Acqknowledge-4.1 package were utilized for the purpose of analysis. Acquired EEG properties were used to make artificial neural network in MATLAB environment.

B. Time-frequency domain overview

The features selected in time domain are standard deviation, max value, kurtosis, skewness; which was chosen according to the efficiency found in some previous studies [8-10]. On the other hand, Fast Fourier Transform (FFT) was done to convert the time domain features into frequency domain and to measure the Power Spectral Density (PSD). Equation (1) introduces the PSD measurement of a signal with a sampling time $T_p$.

$$\text{PSD}_{\text{EEG}}(f) = \frac{1}{T_p} \sum_{i=0}^{\text{output}} e^{-i2\pi fiTp} 2$$ (1)

IV. EXPERIMENTAL DATA

A. Comparison of Features in Different Domain for Individual

Total eight features were considered among four of them in time domain and four of them in frequency domain. Among the four subjects subject 1 and 2 were non-smoker, subject 3 and 4 were smoker. The features in time domain of subject 1 is given in Table I. Time domain feature of smoker subject 3 is shown in Fig. 3. Max. Value, S.D, skewness, kurtosis, PSD mean, PSD max, FFT mean, FFT max extracted for all subjects.

| Trial | Max. (Micro-Volt) | S.D (Micro-Volt) | Skewness (Micro-Volt) | Kurtosis (Micro-Volt) |
|-------|------------------|-----------------|----------------------|----------------------|
| 1     | 5.54748          | 1.599528        | 0.055565             | 3.020146             |
| 2     | 5.164284         | 1.588178        | 0.205031             | 3.124829             |
| 3     | 6.011841         | 1.855675        | 0.162281             | 3.666055             |
| 4     | 5.495193         | 1.697518        | 0.213440             | 3.181314             |
| 5     | 4.565170         | 1.700331        | 0.061398             | 2.924203             |
| 6     | 4.103498         | 1.470597        | 0.113646             | 2.813956             |
| 7     | 8.771454         | 2.566829        | 0.644382             | 4.666396             |
| 8     | 10.756666        | 3.013230        | 0.435639             | 4.265724             |
| 9     | 7.357595         | 2.043492        | 0.488964             | 3.299734             |
| 10    | 5.547480         | 1.599528        | 0.055565             | 3.020146             |
B. Comparison of features for smoker and non-smoker

By comparing all the data it was found that there are significant differences between the EEG signals of smoker and non-smoker. For example, smoker’s EEG PSD shows higher value than the others. Similarly it happens for FFT. Fig. 4 shows a comparison of FFT mean of all subjects. PSD mean value comparison which is shown in Fig. 5. It is a proof of all smoker subjects provide higher value of PSD and FFT. But smoker’s skewness value showed lower than non-smoker’s.

V. CLASSIFICATION RESULTS & DISCUSSION

This approach was necessary to differentiate between smokers and non-smokers and to determine the effective domain after extracting features. For this three neural network were built by using MATLAB nntool GUI. Used feed forward back propagation, TRAINLM training function, two layer, TANSIG transfer function, Levenberg Marquardt learning algorithm, LEARNNGDM learning function, ten neurons for each ANN. After designing these ANN the following situations were considered for analysis:

A. Consideration 1: Time Domain

The ANN designed with features of time domain (max. value, S.D, skewness, kurtosis) was able to differentiate between smoker and non-smoker successfully with a mean squared error (MSE) of 0.4579 at epoch 1.

B. Consideration 2: Frequency Domain

ANN built with PSD and FFT feature showed satisfactory accuracy for determination of smoker with MSE of 1.3565×10^{-07} after epoch 1.

C. Consideration 3: Time and Frequency Domain

By combining both time and frequency domain feature, a neural network was built. It was successful to detect smoker with mean squared error of 6.238×10^{-08} at epoch 5. Fig. 6 shows the performance of corresponding built neural network.

A comparison among the three built neural network is given in Table II. It shows that the time domain features based artificial neural network shows highest MSE of 0.4579 and lowest regression. The frequency domain shows better performance than previously built ANN with MSE of 1.3565×10^{-07}. The neural network built using both time and frequency domain showed MSE of 6.238×10^{-08}. It shows best performance with lowest MSE and highest overall regression.
VI. CONCLUSION

By observing all the findings it can be concluded that smoking has an effect on EEG; it increases the PSD and FFT value thus making a different EEG pattern which signifies their affected brain activity. This abnormal change in EEG pattern is detected by ANN depending upon the extracted features. The ANN based on both time and frequency domain shows best performance with MSE of $6.238 \times 10^{-08}$ and on the other hand attributes of time domain based ANN act worst with MSE of 0.457. So for domain selection not only a single domain but also both domain should be considered for analysis of EEG for differentiating smokers and non-smokers. The performance may increase with increasing number of channels. Future works should include the correlations between the psychological impacts and pattern changes in EEG for smoking.

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