Mental Fatigue Measurement using EEG While Performing General Mechanical Assembly Task

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Abstract— In recent years, interest in fatigue detection technologies has been increased so that fatigue related accidents can be prevented. There are number of mental fatigue measurement methods, which can be performance, perceptual or electrophysiological based. Among them, Electroencephalogram (EEG) might be the most predictive and reliable indicator of mental fatigue. The aim of this paper is to evaluate mental fatigue while performing the general mechanical assembly task as till date most of the EEG studies have been done where workers are made to perform jobs involving mental work. Methodology of the study was to put four operators on exhaustive and actual two sessions per person, with each session of four hours. While performing mechanical assembly task EEG raw data was acquired on BIOPAC MP150 system and later on analysis on BIOPAC acknowledge 4.3 software was carried out. The results indicate that the subjects alertness level declines greatly and the excitement level of brain decreases after the completion of task. In this study, with the help of ratio indices $(\alpha+\theta)/\beta$ and β/α, we were able to find out whether the mental fatigue has occurred or not.

Key words: EEG, Mental Fatigue Measurement

I. INTRODUCTION

Fatigue is a common phenomenon. In modern society, the number of accidents has been increased due to decrease in alertness level of operator. It has become serious problem in case of traffic accidents too. Due to driver fatigue, about 60% of very harsh truck accidents takes place. It is now considered as the main cause of heavy truck crashes [1]. Many accidents are associated with mental fatigue due to sustained performance of worker in industry too. It is very necessary to manage and cope with mental fatigue so that harm to the worker health can be avoided. Therefore, on the basis of vocational risk protection and productivity, there should be a proper management of mental fatigue.

There are number of methods to detect mental fatigue changes. These methods are based on subjective measures, behavioral measures and physiological measures. However subjective and behavioral measures have some limitations, for example, they cannot give moment-to-moment fluctuations of mental fatigue. Moreover the results may be varied by the subject's cognitive ability, mood and anxiety levels [2,3]. Recently, physiological measures of mental fatigue has created a lot of interests. Physiological measures based study is focused on measuring physiological changes of subjects, such as the electrooculogram (EOG), respiratory signals, heart beat rate, skin electrode potential and EEG activities as a means of detecting the mental fatigue states. Although many physical indicators are available to explain the mental fatigue of person, the EEG has been considered as the most reliable and predictive because it is directly related to neuronal activity in the cerebral cortex [4, 5, 6]. The EEG is widely considered as the physiological 'gold standard' for the evaluation of mental fatigue. There were many EEG studies associated with mental fatigue in the past. Some studies observed EEG spectral changes as alertness declines. For example, low frequency EEG waves such as theta and alpha rhythms increases while high frequency waves such as beta rhythms decreases [7, 8, 9, 10]. Other studies showed the relation between fatigue and changes in event related components (ERP) components. P300 amplitude decreases while latency increases with mental fatigue [11, 12].

This paper is concerned with measuring mental fatigue in human individuals from their EEG recordings. The approach taken in this work is to first identify important features in the EEG signals that correlate with mental fatigue in an individual from a collected mental fatigue EEG dataset. Then these key features are used to find out ratio indices, with the help of which we will find out occurrence of mental fatigue.

II. METHODOLOGY

A. Subjects

Four right handed adults of different age groups were allowed to perform the task. Subjects were recruited from the local institute for experiment. To qualify for the study, subjects had to have no medical contraindications such as severe concomitant disease, alcoholism, drug abuse, and psychological or intellectual problems likely to limit compliance. Table showed the subjects characteristics

ID	AGE	GENDER	HEIGHT (cm)	WEIGHT (kg)
1	23	male	165	60
2	27	male	172	76
3	40	Male	167	80
4	60	male	164	81

Table 1: Characteristics of subjects studied

B. Experiment protocol

There were four pair of iron plates of same size. In the plates eleven holes were drilled. Two holes were of diameter 2 inch and 3 inch , three holes were of diameter 4 inch, two holes were of diameter 5 inch, two holes were of diameter 6 inch and two holes were of diameter 8 inch. Subjects were allowed to assemble the pair of plates with the help of screws, nuts and bolts by holding them in the vice at the same time.

Subjects were allowed to assemble the pair of plates for two sessions i.e. morning session and evening session. Morning session consist of four hour work with 10 minutes break after two hour of working hours. Then there was a lunch break of 40 minutes. After lunch break, evening session starts. Evening session also consist of four hour working with rest is given for 10 minutes after two working

hours. Means the study consist of exhaustive eight working hours.

Fig. 1: Experiment Set Up; Subject Performing Task

C. Data Acquisition

EEG data were recorded at the same time. 6-channel EEG was recorded according to the international 10-20 system. EEG data was first recorded before the subject performed the task. Then after one hour each, EEG data was recorded i.e. there are total nine recordings for each subject. Fp1, Fp2, C3, C4, 01, 02, F3, F4, Cz, P3, P4 leads were used with Ag/AgCl electrodes.

D. Data Analysis

To judge the mental fatigue while performing the task, comparison of ratio indices (α+θ)/β and β/α is done for various channels for morning session and evening session. The difference between ratio index for various readings was analyzed. All the analyses were conducted with Biopac system software.

III. RESULTS

In this study, the EEG components of four frequency bands obtained were: delta (0-3 Hz), theta (4-7 Hz), alpha (8-12 Hz), and beta (13-30 Hz). With the help of BIOPAC system software, we calculated the mean value of alpha, beta and theta for each reading of EEG. After that, we calculated the ratio index (α+θ)/β and ratio index β/α. These ratio indices of EEG were reported to relate with sleepiness [13].

After artifact detection and ocular correction, five minute EEG data of each trail for each subject in the morning and evening session were selected to be analyzed. Then the ratio indices (α+θ)/β and β/α for all data segments were calculated.

A. Morning session

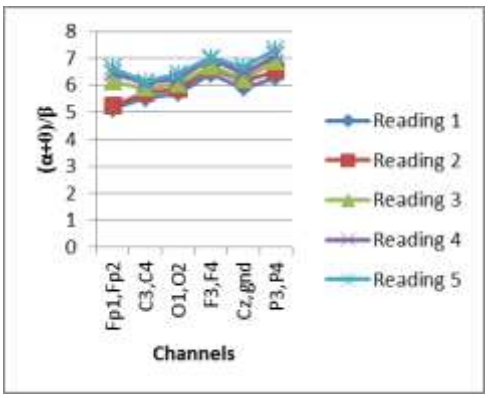

Fig. 2: comparison of (α+θ)/β between various readings

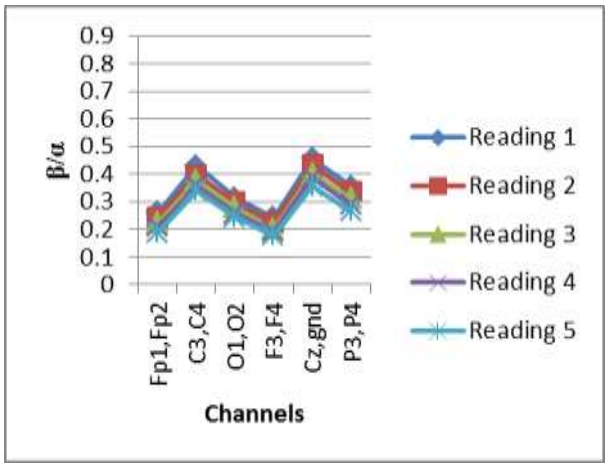

Fig. 3: comparison of β/α between various reading

B. Evening session

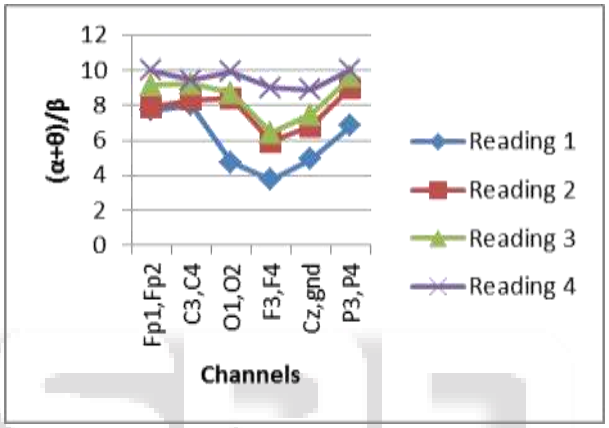

Fig. 4: comparison of (α+θ)/β between various readings

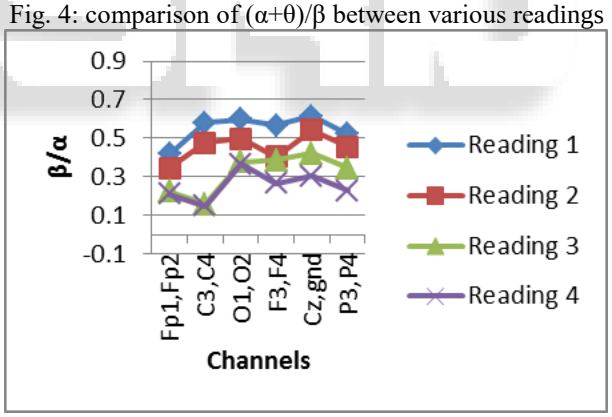

Fig. 5: comparison of β/α between various readings

The results of comparison of ratio indices (α+θ)/β and β/α for obtained frequency bands between various readings for each session is shown in above figures.

For morning session, compared with previous reading, the mean value of (α+θ)/β significantly increased for all electrodes and the mean value of β/α significantly decreased for all electrodes after the completion of task. Same is the trend for evening session.

IV. CONCLUSION

The results indicate that subject alertness level decreased and mental fatigue increased after the completion of task. Beta rhythm are generally considered as fast waves. Beta rhythms changes are closely related with mental fatigue.

Ratio indices, index (α+θ)/β and index β/α are very important in this experiment. Theta waves are considered as

slow waves. Theta waves are related to low levels of alertness during drowsiness and sleep and as such have been associated with decreased information processing [14]. In our experiment, the mean value of $(\alpha+\theta)/\beta$ increased considerably for all electrodes while the mean value of β/α decreased for all electrodes. The ratio index $(\alpha+\theta)/\beta$ and β/α are sensitive to the change of mental fatigue.

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