Stress Effects on Exam Performance using EEG

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***Abstract*—Mental stress can be one of the most prominent factors of failure or poor performance in students. The traditional method of examination involves evaluating performance of students in limited time that may increase their stress level and may deteriorate their performance. Electroencephalogram (EEG) is one of the most commonly used methods to measure stress using brain waves. In this study, we investigate the influence of time limitation in exam on the performance of students and use EEG to explore the contribution of stress towards the change in performance. For this purpose, students performed mental arithmetic task (MAT) based on Montreal Imaging Stress Task of same difficulty level twice; once with time limitation accompanied by feedback for every question to induce stress and once without any time limitation and feedback. We observe vast difference in performance of the students for the two MAT tests and significant change in the power spectral density of theta, alpha, and beta frequency bands associated with increase in stress level for three chosen electrodes in EEG results. Our results show that stress may be one of the major factors for bad performance of the students in the exam resulting in failure.**

Keywords: EEG, Stress, Power Spectral Density, Exam performance.

I. Introduction

Stress is the physical, mental, and emotional human response to a particular stimulus or stressor [1]. In present era, various stressors influence mental health of people leading to continuous state of anxiety, depression, and other psychological and physical abnormalities. Long term stress can be a reason for not achieving the maximum output from a task and may even lead to failure. For student population as well stress may be a major cause of bad grades or failure in exams. This stress may be intensified due to existing examination system for higher education, [2] in which the students are graded on their performance during a few hours only. Consequently, the results may not be a true reflection of their intelligence and knowledge but of their ability to combat exam induced stress.

There are different known methods to evaluate the stress in a person in which most common is a clinical psychological assessment. In such assessment, behavioral or physical responses against a mental task are observed and decisions are made according to a known scale. Some of the famous tests are perceived stress scale [3] and the college student stress scale [4]. These methods mostly evaluate the stress due to long term psychological illness.

Besides these traditional clinical methods there are other methods which use human bio-signals for the quantification of stress. Mental stress detection by analyzing the heart beat fluctuations using variability and morphologic variability of ECG Signals is another known method [5]. Galvanic Skin Response (GSR) along with speech signals [6] are also used to quantify stress level. Analyzing the stress using data collected with electroencephalogram (EEG) has become a popular tool due to it's non-invasive procedure [7]. In [8] the authors induced stress by MAT based on montreal imaging stress test (MIST). To increase the stress level, authors simply increased the difficulty level of mathematical questions and reported only mean alpha power as a strong feature to distinguish the stress and relaxed states. In [9] Cohens perceived stress scale (PSS) as stress questionnaires was used to measure human stress, and right after that the stress was calculated using alpha and beta powers. Root mean square voltages of alpha, beta and theta was used to quantify stress in [10]. Due to maximum efficiency and low noise effect we used EEG in the current study [11].

Electroencephalogram is being used to detect the electrical signals caused by any activity in autonomic nervous system (ANS) which is a source of creation of ionic current within the neurons. There are 5 different type of brain waves, distinguished according to their frequencies ranging from 4 to 48 Hz. Three out of these five waves, namely theta (5-7 Hz), alpha (8-15 Hz), and beta (16-32 Hz) have modified amplitudes during stress. According to the previous study in [9] lower beta and alpha waves are most commonly used to analyze the stress in an object.

In this study, we investigate the influence of time limitation in exam on the performance of students and use EEG to explore the contribution of stress towards the change in performance. For this purpose, students performed mental arithmetic task MAT, based on MIST, of same difficulty level twice; once with time limitation accompanied by feedback for every question to induce stress (timed) and once without any time limitation or feedback (untimed). Power spectral density (PSD) of alpha, beta, and theta bands is used to measure the difference between stress levels of the students during timed and untimed tests.

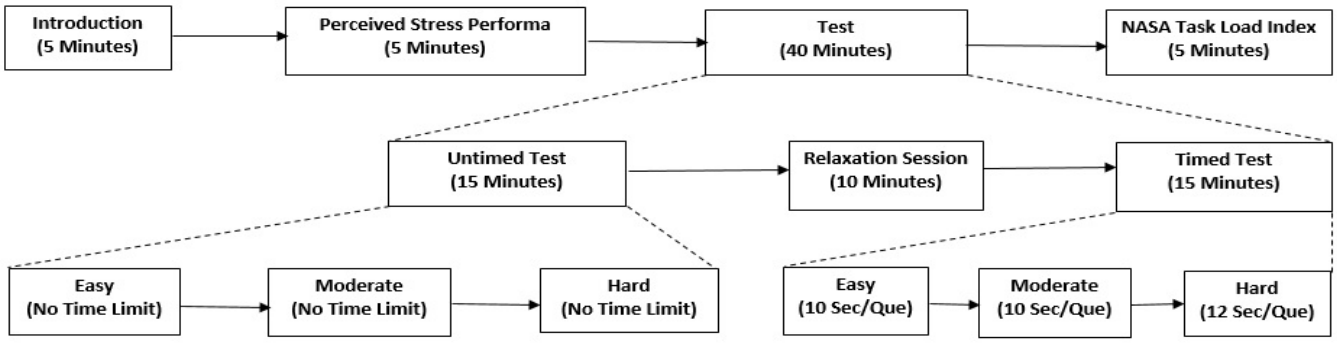

Fig. 1. Block Diagram of experiment

The rest of paper is arranged as follow. Section 2 describes the basic adopted methodology. It contains the information about the subjects, the pattern of the test, and preprocessing techniques. In section 3, results are reported on basis of PSD. Section 4 concludes this paper.

II. Methodology

A. Subjects

14 healthy (11 males and 3 females) undergraduate students of first semester in Electrical Engineering department at Institute of Space Technology, Islamabad, Pakistan participated in this study. The first semester students were chosen since they have highest rate of failures out of all semesters. We hypothesize that these students may already be under stress due to factors like competitive environment, teaching style different from schools, and fast paced teaching. As a result, limited time exam may add to their stress and deteriorate their performance. Ages of these students range from 18 to 20 years. None of these subjects had any psychological or neurological illness and all of them were nonsmokers. A declaration of participation as volunteer which was approved by the ethics committee of Institute of Space Technology, Islamabad, Pakistan was signed by each individual.

B. Data Acquisition

The EEG device used in this experiment was OpenBCI Cyton board. It is an open source, eight channel EEG device (extendable to 16) with wireless transmission and a raw data storage at the device level. The sampling frequency of the device is 256 samples per second. Software used to interface device with the laptop was OpenBCI GUI. Output of this device was in micro volt. Power of each band was converted into dBs by using the following formula:

$$P(dB\mu) = 10log(\mu W). \quad (1)$$

Data was recorded a week before the midterm exam of the students. The motive behind this time slot was to take the real exam stress into account. Subjects were previously briefed about the whole procedure and were directed to avoid any unnecessary movements during the data collection like shaking of head so that the artifacts could be minimized.

It was one hour long session for each individual participant which was divided into 4 parts. First of all, the subjects were briefed in details about the test procedure and all necessary precautions. Afterwards, the subjects were asked to fill a perceived stress scale performa [3], which was later used to identify the pre-test stress according to its known scale. Afterwards, the subjects performed the MAT and EEG data was collected during that time by placing the electrodes on frontal lope of the scalp according to international 10/20 system of electrodes. This step consisted of collecting the data during MAT tests and relaxed sessions as given below.

- Untimed test (15 minutes session)
- Relaxation session (10 minutes session)
- Timed test (15 minutes session)

It is to mention here that difficulty level of both the timed and untimed MAT tests was exactly the same. We created untimed test and timed test by either shuffling its questions and answers or by minor changes in the numbers provide in the questions. For example, a 3-2 in untimed test may have been changed to 13-12 in timed. Furthermore, subjects were informed about the importance of the experiment and were instructed to perform to the best of their ability so the scenario could be close to actual exam scenario.
In untimed test there were 85 questions which were further divided into 3 parts, first 30 questions were easy (simple addition and subtraction of one or two digit numbers). Second 30 questions were a bit difficult as compared to first part (addition, subtraction, multiplication or division of two digit numbers). The last 25 were considered as difficult (combined basic mathematical operations). In the first session, which was untimed, there was no time constraint on individual questions. However, a maximum time to solve this test was previously calculated by rough experiments and was 15 minutes. In second part, which was of relaxation, the subjects were directed to sit still and minimize the body movement for about ten minutes. The purpose of this session was to create a baseline or reference to which the stress was calculated in timed and untimed sessions. In the last part, every individual question had a time limit. For first 60

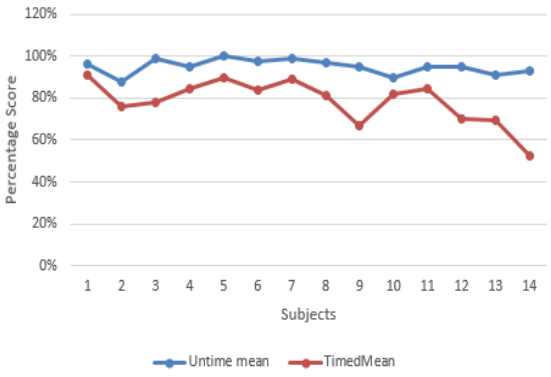

Fig. 2. Test Results for Untimed and Timed Test

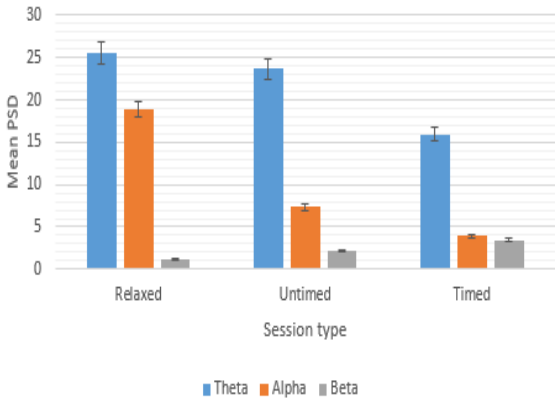

Fig. 3. Mean and Standard Deviation in Power of Theta, Alpha and Beta

questions (easy and moderate sessions) the time limit was 10 seconds each and for the difficult section, limit was kept as 12 seconds for each question. Additionally, feedback was provided after submission of each answer. Conditions of time limit and instant feedback were created to induce stress in the subjects and were expected to influence their performance. Test scores of all the subjects for all sections of tests were recorded along with the collection of EEG data. Fig. 1. shows a block diagram of the whole experiment sequence. In the last session, NASA load Performa was used to confirm the task difficulty.

C. Preprocessing of Data

Data collected through the EEG device was in raw form. At the gadget level no filtration was done. This raw data was preprocessed in EEGLAB which is a Matlab based tool specifically designed to process EEG data. First of all, the DC factor was detached by applying a high pass filter at 2 Hz frequency which allowed signals above 2 Hz to pass. The power line effect which is at 50 Hz interfered with the original data significantly. It was removed by applying a 50 Hz notch filter. Artifacts like eye blinking were eliminated by rejecting continuous data from eye in EEGLAB. For the removal of artifacts like cross channel interference and ECG, independent component analysis was used. Filtered data was then additionally separated into three groups of frequencies. Three bands of interest and their frequencies are shown in Table I.

TABLE I
EEG BANDS AND THEIR FREQUENCY RANGES

Sr. No	Frequency Band	Frequency Range
1	Theta	4-8
2	Alpha	8-16
3	Beta	16-31

III. RESULTS

Main objective of this study was to determine the effect of stress on the performance of the students under limited timed system of examination. The limitation of time induced more

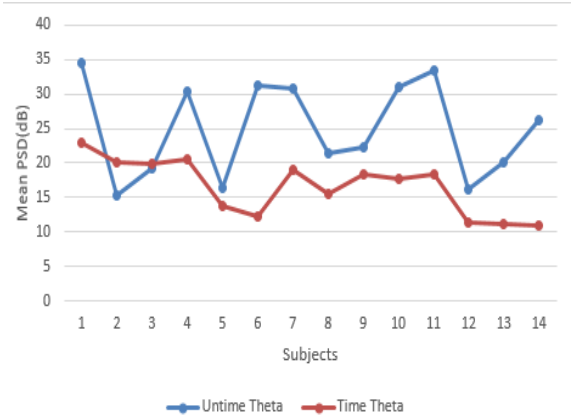

Fig. 4. Comparison between mean theta power of untimed and timed test.

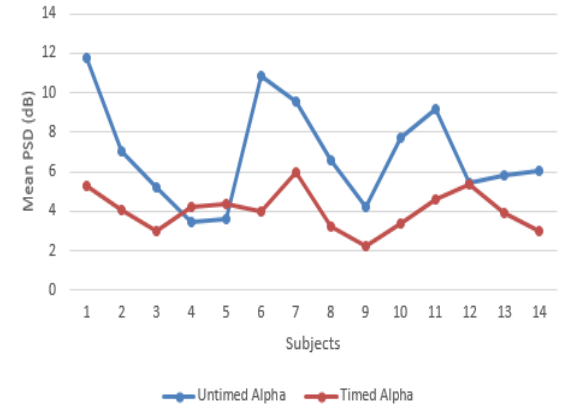

Fig. 5. Comparison between mean alpha power of untimed and timed test.

stress into the students and regardless of their same age and knowledge level they performed differently under stress. Fig. 2. Shows the mean scores (for all levels of MAT tests) of all the 14 subjects. It can be observed from the figure that the mean score for untimed test was higher than for timed test for all the subjects..

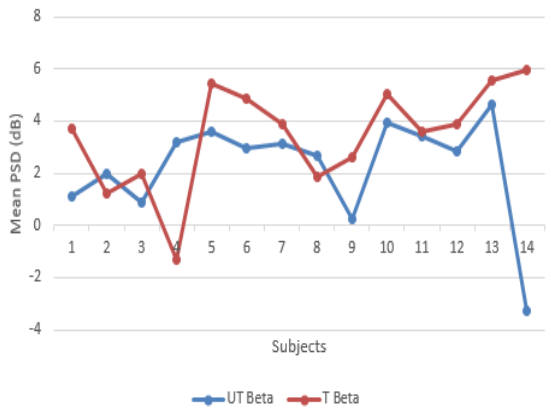

Fig. 6. Comparison between mean beta power of untimed and timed test.

Fig. 3. shows the mean PSDs of three electrodes (Fp1, Fp2, and Fpz) of alpha, beta, and theta frequency bands of EEG collected data. Mean power of the relaxed session was observed as highest, followed by untimed as moderate, and was observed as lowest in case of timed test. The same trend was observed in the alpha band in which the mean power of relax state was highest, moderate in case of untimed and lowest in case of timed test (red line). The trend of beta was observed as reverse as the mean power of the beta band was highest in timed, moderate in untimed and observed as lowest in relaxed session. These patterns show the effectiveness of the stimuli which was used to persuade stress in the subjects. Compared to relaxed sessions, the subjects were observed to be under stress in untimed and timed sessions.

In second part of study, we compare the performance of each individual subject with the induced stress. Fig. 4. shows PSDs of theta band for all the subjects in case of timed and untimed tests. A reasonable drop was observed in case of timed test for most of the subjects which indicate that the induced stress lower down the performance of subjects. Fig. 5. shows the same trend in case of alpha band, whereas Fig. 6. is showing the reverse trend of beta waves, in which power of each individual band has the rising trend with increase in task difficulty and stress level which indicated that higher induced stress has lower down the performance of students. Till now

TABLE II
CHANNEL ACCURACY TO FIND STRESS

	Fp1	Fpz	Fp2
θ	78%	93%	86%
α	86%	86%	93%
β	72%	86%	79%

we reported the mean PSDs of three frequency bands for Fp1, Fp2, and Fpz electrodes. In Table II, we are reporting the percentage of students found to be under stress for individual electrodes. For example, 79% for Fp1 in theta band indicates that power of 79% of the students in this band was reduced in timed test compared to untimed test.

IV. CONCLUSION

The main aim of this study was to identify relationship between the stress level and students performance in limited time tests. We focus on this specific scenario since all over the world the students are graded by their performance in limited duration exams. We hypothesize that these exams may not be the effective means of grading the knowledge or skill levels of a student since performance degradation may be influenced by the stress. A MAT test was designed and the data was collected a week before the exams. A perceived test performa results show that all the students were already in above average stress before the start of the experiment. We found a clear degradation in the performance of all the students during timed test compared to untimed test despite the fact that the difficulty level of the two tests were exactly the same. The factor of stress was inspected by measuring the PSDs of three frequency bands which are reported to change during stress in previous studies. We found that on average for three selected electrodes, more than 85% of the students had increased stress levels during the timed test. Furthermore, from individual electrodes data PSDs, we observe that more than 71% of the students were more stressed during timed test. The experiment showed that the limitation of time might be a key influence of dropped performance of the students in real exams scenario.

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