The Effect of Mental States on Blood Pressure and Electrocardiogram

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***Abstract*- This paper describes the effect of mental states on blood pressure and electrocardiogram (ECG). Blood pressure and ECG were recorded before and during four types of mental task. The mental task involved the four tasks that encompassed Motor Action (MA), Thoughts (TH), Memory Related (MR) and Emotions (EM). Blood pressure and ECG were recorded using BIOPAC system. These variables were analyzed using BIOPAC Acknowledge software. In MA and TH tasks, significant changes were observed in blood pressure, although during MR and EM tasks there were no significant changes in it. The present study demonstrated the changes in ECG during MR and EM tasks. But there were no significant changes in ECG during MA and TH tasks.**

***Keywords*- Mental states, blood pressure, electrocardiogram, BIOPAC system, Fast Fourier Transform (FFT).**

I. INTRODUCTION

The objective of this work is to study changes in physiological variables viz blood pressure and ECG during the problem solving process. Blood pressure (BP) and Electrocardiogram (ECG) were recorded during four types of mental tasks. The mental states are classified into four pre-specified states based on Card's Information Processing Model: Motor Action (MA), Thoughts (TH), Memory Related (MR) and Emotions (EM). Others (OT) is defined as the state without any specific cognitive activities and/or the state that can not be categorized into any of the above [2]. It is quite rare that only one of these states exists at the specific moment. It is natural to assume that several of these states can exist simultaneously taking human's parallel processing capability into account [2]. Fig. 1 gives the classification of cognitive states based on Card's Information Processing Model. Fig. 2 illustrates the whole process of physiological variables measurement and analysis. We provided the subjects with some questions which can induce a variety of cognitive states and measured the blood pressure and ECG signals using BIOPAC. FFT of the measured signals was taken using Hamming Window. After FFT, smoothing of the signals was done with a smoothing factor of 40.

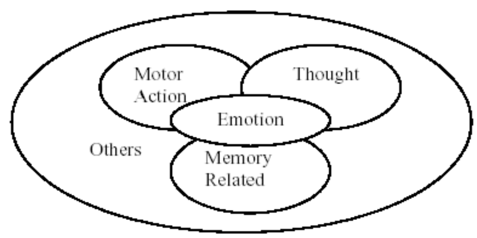

Fig. 1 Classification of mental states [2]

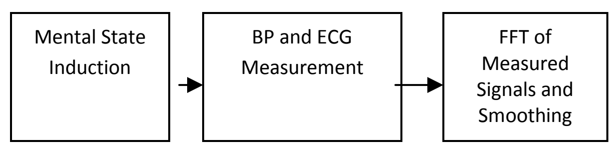

Fig. 2 Induction of mental states, measurement and analysis of BP and ECG [4]

II. MATERIALS AND METHODS

A. Subjects

The whole experiment was processed in Biomedical Laboratory, Department of ICE, NIT Jalandhar (India). The subjects consist of 11 undergraduate and postgraduate students majority in Instrumentation Engineering. The subjects consist of 8 males and 3 females and all were in healthy state.

B. Tasks

It is quite difficult, however, to keep a subject in one specific cognitive state when subject is interfacing with the interface voluntarily. In the present system, the laboratory experiments explicitly controlling the subject's cognitive states by properly prescribed tasks were conducted to collect the data. Four kinds of tasks shown

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below were prepared for the experiments, in which the subject was forced to undergo following sequence of the cognitive states:

1. Simple moving task for motor action state
2. Thinking task
3. Long term memory and short term memory handling tasks for memory related state
4. Simple calculation task for emotional state

A record of 15 minutes for physiological variables of the subject was prepared and the subject was instructed to go through above cognitive states. A particular cognitive state is generated at a particular instance of time of the 15 minutes record. For example, moving task is performed at an instance of 200 seconds. Before this instance the subject is assumed to be at rest state. After an interval of 100 seconds i.e. at 300 seconds, second state is ignited and so on.

Simple moving task is taken as an example to show how cognitive state shifts during the task. The subject was instructed to virtually move his hand/leg and his/her physiological variables were measured through MP100 BIOPAC System.

During thoughts state the subject was asked to think about a particular topic e.g. he/she is asked to think about his future planning after completion of his/her studies.

The short term memory handling task begins with displaying a set of seven numbers on the multimedia projector screen. The subject was instructed to memorize these numbers. Twenty seconds after the set disappeared from the screen, one number was displayed on the screen and the subject was asked to judge whether it was in the set or not. The point is that memory related (RM) cognitive state may be dominant among other cognitive states during the time interval between the disappearance of the number set and the appearance of the target. The physiological data measured during this interval is taken as the sample data for the cognitive state 'Memory related'.

Since EM is defined as the state when emotional aspects are dominating in the mental activities. Also, surprise, confusion and embarrassment are supposed to be major factors evoking the state of EM [1]. Therefore, the subject was asked to solve an aptitude problem for this task.

C. Measurements

Continuous blood pressure was measured using NIBP100A Measurement System. The NIBP100A is a noninvasive blood pressure monitor that uses a pressure sensor placed on the wrist over the radial artery. This device uses a "sweep technique" which applies a varying force on the radial artery. The counter-pressure in the artery produces a signal which is digitized and used to calculate blood pressure parameters. With just a few easy calibration steps, the NIBP100A and AcqKnowledge work together to provide automated, continuous, non-invasive blood pressure measurements. Following settings of DA100C are used for blood pressure monitoring: Amplifier Gain: 100, Low Pass Filter: 10 Hz, High Pass Filter: DC [5].

Lead II ECG was recorded using electrocardiogram amplifier module (ECG 100C) in BIOPAC. Three Ag-AgCl electrodes are used to record Lead II ECG signal. Two active electrodes are affixed on right arm (RA) and left leg (LL). Reference electrode is applied on right leg (RL) of the subject. The electrodes are connected to the ECG amplifier (ECG 100C) using three leads. The following settings of the ECG 100C are used to record ECG II of the subject: Amplifier Gain: 1000, Output selection: Normal, Low pass filter: 35Hz, High pass filter: 0.5 Hz [5].

D. Procedures

On arrival at the laboratory, recording sites of subjects were all attached with respective electrodes/probes for monitoring ECG and Blood Pressure before subjects were comprehensively briefed on performing the task. Subjects were then laid on a bed until a persistently restful condition was sufficiently obtained. Multimedia projector was used to provide questions related to different mental tasks. The order of task was arranged in such a fashion that the accommodative effect of the order was completely cancelled out.

III. ANALYSIS OF MEASURED VARIABLES

Analysis of the measured signals was done using BIOPAC Acknowledge software. Time interval for a particular cognitive state is taken as 20 seconds. Time intervals for different cognitive states are shown in table I. Reference for comparison purpose was taken from the rest state. The subject was assumed to be at rest state during the interval 150 – 170 seconds.

Table I TIME INTERVALS FOR DIFFERENT COGNITIVE STATES

Mental State	Time Interval (seconds)
Reference	150-170
Motor Action	210-230
Thoughts	310-330
Memory Related	510-530
Emotions	610-630

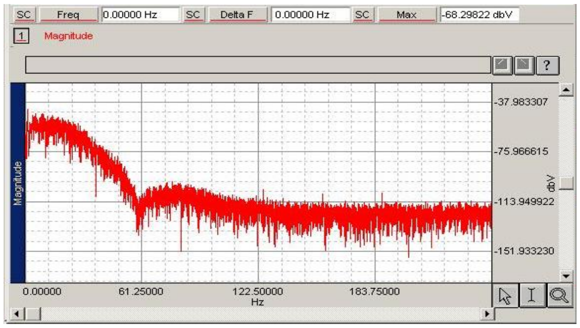

Fig. 3 FFT of the selected (reference) portion of the ECG waveform

A. Fast Fourier Transform (FFT)

The Fast Fourier Transform (FFT) is an algorithm that produces a description of time series data in terms of its frequency components [5]. This is related to the frequency spectrum. The output of an FFT appears in a graph window with magnitude (vertical axis) plotted against various frequencies (horizontal axis) as shown in fig. 3. A large component for a given frequency appears as a positive (upward pointing) peak. The range of frequencies plotted is from 0 Hz to ½ the sampling frequency. Thus if data was sampled at 200 samples per second, Acknowledge plots the frequency components from 0 Hz to 100 Hz.

B. Smoothing

The smoothing function is a transformation that computes the moving average of a series of data points and replaces each value with a mean value of the moving average "window" [5]. This has the same effect as a crude low pass filter, with the advantage being that smoothing is typically faster than digital filters. Acknowledge software allows us to set the width of the moving average window (the number of sample points used to compute the mean) to any value larger than three. Mean value smoothing is the default and should be used when noise appears in a Gaussian distribution around the mean of the signal. The mean value smoothing formula is shown below, where 'm' is the number of points in the window and 'n' is the sample number.

$$f_{output}(n) = \sum_{k=n-\left(\frac{m}{2}\right)}^{k=n+\left[\frac{m-1}{2}\right]} finput(k)/m \qquad \text{……….(2.1) [5]}$$

Fig. 4 shows the waveform after smoothing. Measurements on the top of the graph indicate the maximum value of the graph and the frequency at which the graph has maximum value. Similarly, FFT for the mental states MR and EM is obtained and shown in fig. 5 and fig. 6 respectively. FFT for BP signal for rest state, MA State and TH State is shown in fig. 7, fig. 8 and fig. 9 respectively.

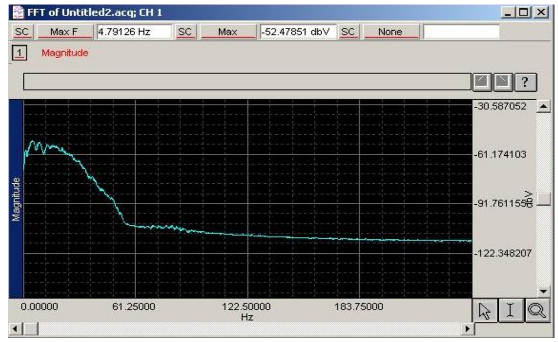

Fig. 4 FFT of ECG after smoothing for rest state

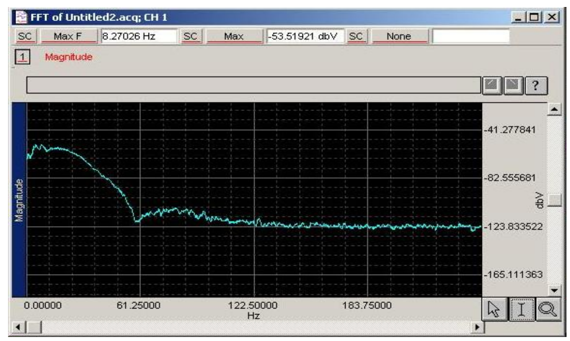

Fig. 5 FFT of ECG for MR State

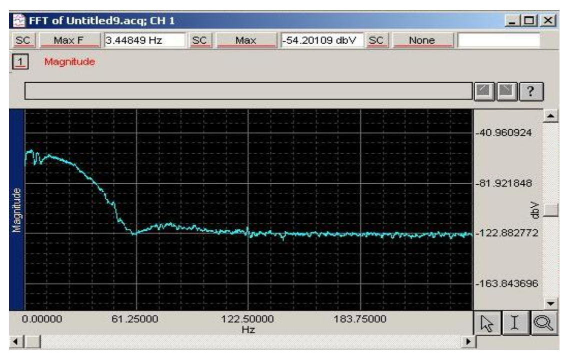

Fig. 6 FFT of ECG for EM state

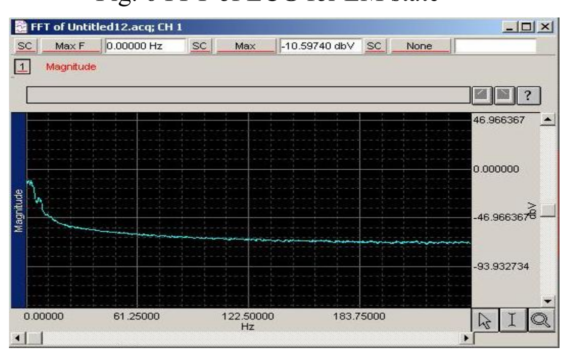

Fig 7 FFT of BP signal for the rest state

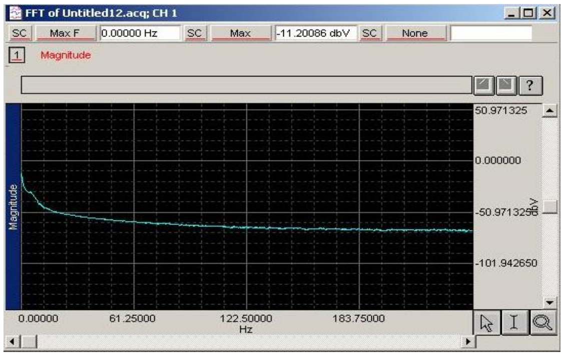

Fig. 8 FFT of BP signal for MA State

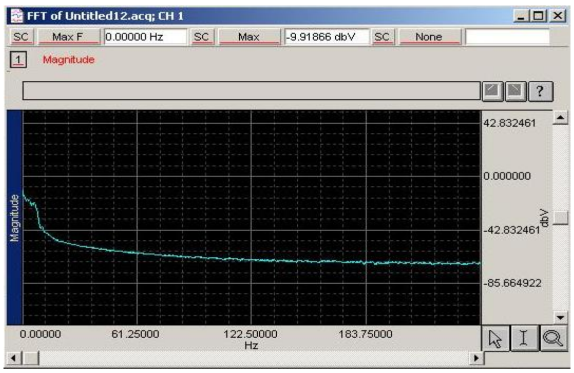

Fig. 9 FFT of BP signal for TH State

IV. RESULTS

From the analyzed results using FFT, significant changes have been found in ECG and BP for various mental states. In case of ECG signal, the frequency for which the graph has maximum value (Max F), increases for MR state and decreases for EM state when compared with the rest sate. This is because multifaceted mental stress induces cardiovascular responses [3]. In case of BP signal, the maximum value of the graph (Max) is less for MA State and it is high for TH State when compared with the rest state. This is because the BP response relies on the types and the degree of difficulty in performing the task [3]. The analyzed results for BP signal and ECG signal are shown in table II and table III respectively.

Table II. ANALYZED RESULTS FOR BP SIGNAL

Mental State	**Maximum value of graph (dBV) for BP signal**
Rest State	-10.60
MA State	-11.20
TH State	-09.91

Table III. ANALYZED RESULTS FOR ECG SIGNAL

Mental State	**Max F (Hz) for ECG signal**
Rest State	4.79
MR State	8.72
EM State	3.45

V. DISCUSSIONS

In this paper, we presented a method to find the effect of various mental states on blood pressure and ECG. These results can be used for classification of four different mental states of a person.

In our future research, we plan to include additional sources of information including EEG and GSR. We want use these results for the designing of an adaptive interface. The adaptive interface may be applied for making comfort to a disabled or an aged person.

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