Detection of the Human Stress Response to Auditory Noise

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Abstract

This paper presents results of an investigative study to detect, measure and analyse human stress response under the presence of different intensities of external modifiers (white noises). Subjects' responses under the stressors have been detected and analysed using various bio-signals, such as Eelectrocardiography (ECG) and skin conductance. Applying different intensities of auditory stimuli to the participants while they are undertaking cognitive tasks, may induce certain levels of 'stress'. In order to analyse the level of stress efficiently, having an intelligent system is essential. The primary objective of this research is to develop such an intelligent system. Using bio-signals as an input, the system detects, recognises and classifies any psychophysiological change in human behaviour under different auditory conditions. The outcome of this research work has a wide range of benefits for the community and particularly in the area of clinical research.

Introduction

Various research works have shown that exposure to noise constitutes a health risk. Noise exposure may induce hearing impairment, hypertension and ischemic heart disease, annoyance; sleep disturbance, high blood pressure and a decrease in human performance. A number of research works have demonstrated that high intensity noise may also cause psychological depression and emotional illness [1-3].

City and town designers and planners have an urgent need to quantify the effects of noise on people. Quantifying those variables is becoming a requirement during designing and developing a layout for new housing or deciding where a new by-pass has to be routed. When quantifying effects, various features and characteristics of the noise have to be considered. A relationship between these features and objective measurements of human response may lead to a parameter and unit in which the noise exposure level may be quantified.

In the past, to investigate human response towards artificially produced or environmental sounds, different methodologies and analysis techniques were implemented [4] [5]. The most common technique is the use of questionnaires. But it is evident that these are very subjective tests, not an accurate measure and often not reproducible [6].

There are a number of biological markers that are known to change with changes in the emotional state of the person, such as the blood composition, respiration and hormonal changes to name a few [6, 7]. Non-invasive biological indicators such as Electrocardiogram, skin conductance, brain activity, are known to be affected by human emotions and have been used by researchers for determining the emotional state of people [6-10]. Electrocardiography (ECG) and skin conductance level (SCL) have also been widely used as an indicator of human response or reaction towards to noise. ECG is one of the techniques used to measure the stress response from humans. The applied stimuli may be viewed as potent stressors of the cardiovascular system. Studies in spontaneously hypertensive humans, for example, have shown an abnormal response to acoustic startle [6-7].

Skin conductance, which is considered to be a function of the sweat gland activity, has also been used as an indicator. Sweat gland activity is controlled in part by the sympathetic nervous system. It has been well documented that when a subject is exposed to stress, there will be a fast increase in the skin's conductance [6-7].

This paper reports on the use of these non-invasive, easy to record biological electrical activity with sound stimuli that have known impact on the human emotions. The long-term goal of this research is to determine objective measures of the response to sound on people to help identify the stress causing sounds on people.

This paper investigates the psychophysiological human response under different intensities of noise levels. Two bio-signals ECG and SCL were used as the stress descriptors.

Method and Materials

Five healthy male participants were selected. The average age of subjects was 29 yrs. None of the subjects suffered from hearing disorders. The participants did not receive any financial benefit for their participation. A strict experimental procedure, which was approved by the university ethics committee, was followed. Screening of the participants was carried out for smoking and drugs that may alter cardiac activity. The participants were prohibited from taking any caffeine within six hours of the experiment. The participants were requested not to talk or laugh during the recording process. Throughout the recording procedure, subjects were also asked to perform a cognitive task such as word test (mental fatigue, perception and attention test) or English grammar correction.

No.	Stimulus	Level dB (a)
[A1]	Silence (baseline condition)	40-52
[A2.1]	Continuous white noise	65
[A2.2]	Continuous white noise	75
[A2.3]	Continuous white noise	85
[A2.4]	Continuous white noise	90

Table 1 Auditory Stimuli

Auditory Stimuli

The noise stimuli selected are shown in Table 1. The stimuli were produced based on evidences in references [11] [12]. The white noise was created and recorded on an audio CD and was calibrated according to the desired sound levels. The desired levels of stimuli were measured using an integrated impulse sound level meter of (CEL 383 from Lucas CEL Instrument Ltd England), located close to the subject's head. The stimuli were presented to the subjects through two speakers kept 2.5 meters from the participant. The experimental setup was kept fixed for all the experiments. The participant was allowed to adjust to the stimuli for 30 seconds before the signals were recorded.

Signal recording

To acquire ECG signals, Ag/AgCl electrodes (AMBU Blue Sensors from MEDICOTEST) were used. After cleaning the skin, the electrodes were affixed at the fourth intercostal space on the right and left side of the sternum on the chest of the subject.

Skin Conductance level was measured using an AT–64 monitor. The signal was smoothed while digitized with a sampling rate of 200 Hz. All signals were recorded using AMLAB bio-amplifier with flexible real time signal conditioning.

Experimental Procedure

Experimental subjects were always sitting alone on a chair and had no eye contact with the experimenter. In order to divert their attention, all subjects were also provided with cognitive tasks and they were fully aware that noise would be part of the experiment. This was necessary to minimize defensive reflexes due to sudden introduction of the noise.

The noise stimulus was delivered for a duration of 1 minute while the biosignals were recorded. A 30 sec adjustment period was also given and bio-signals for the period were registered before and after delivering the stimuli. The noise stimuli were presented starting from low (65 dB (a)) to high level (90 dB (a)). At the end of the session, subjects were provided with a questionnaire for ranking the auditory stimuli on a 1 to 5 scale according to level (low, medium and high). All bio-signals were recorded together in line with the above-mentioned procedure.

Data processing and evaluation was performed off-line using Matlab software. To relate the activity with the level of the noise and for an immediate observation, the R-R interval of ECG was calculated. This was done first by detecting valid QRS complexes. The ECG was first band pass filtered so that signal-to-noise ratio increases. Further, the signal was differentiated and squared. Finally, a moving-window integral was implemented and the threshold was set to detect the peak estimate and the R-R interval.

Results and Discussion

An example of the experimental results is displayed in Fig. 2 for subject no 2 at 75 dB (A). This shows the raw ECG and skin conductance signals. As shown in the results, at the commencement of the stimulus, there is an increase in the skin conductance while a deceleration (an increase in the heart rate) can be seen in the R-R interval. All changes in the bio-signal activities exhibit a linear relationship with respect to the level of the noise. From the results of testing five subjects, the following observations can be made:

- Subjects differ in their baseline values of RR interval and Skin Conductance Level.
- Upon commencement of the cognitive task, these initial values change (not-significant level).
- Upon noise stimulus presentation there is a marked change of these from the baseline values.
- The results of the analysis indicate that exposure to higher levels cause an increase in the heart rate and can be seen in the R-R interval.
- The results from the five subjects show that the skin conductance level increases during the exposure to the higher levels.

Further Work

Currently, the authors are working with a larger number of experimental subjects. Further work involves collecting psycho physiological data from the subjects exposed under different levels of artificial and environmental noises. Fig 1 shows the schematic diagram of the future development work on the stress evaluation intelligent system.

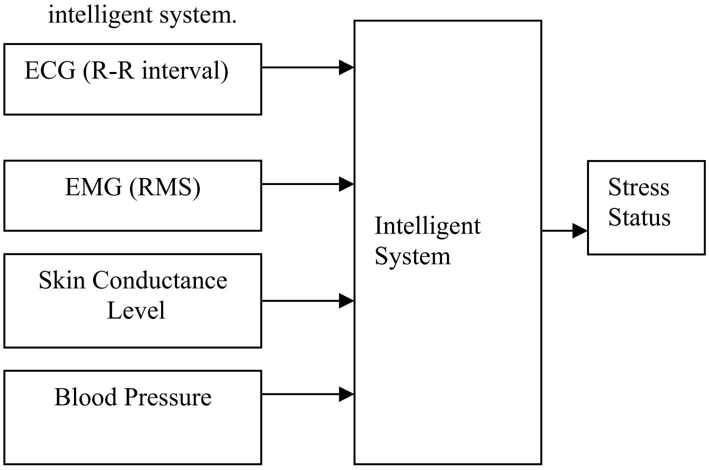

Fig 1. Schematic Diagram of Future Development Stress Evaluation Intelligent System

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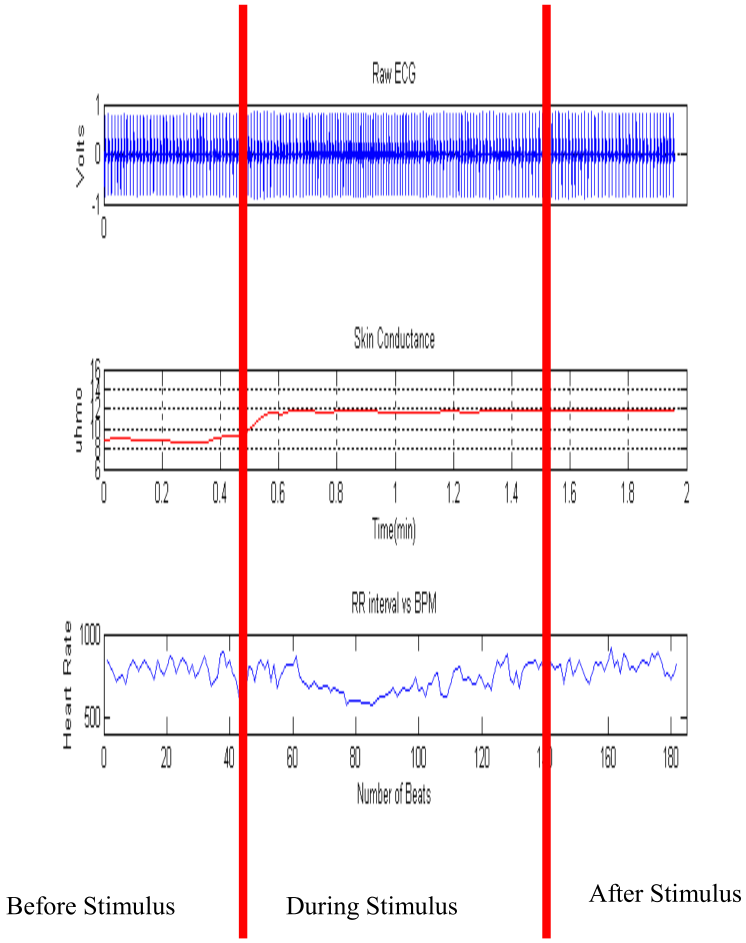

Fig 2.Biosignal descriptors extracted from the signals for subject no 2 at 75 dB (a)