Chapter 11

Analysis of ECG Signals to Investigate the Effect of a Humorous Audio–Visual Stimulus on Autonomic Nervous System and Heart of Females

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ABSTRACT

This chapter is an attempt to understand the effect of audio-visual stimulus with a humorous content on the cardiac electrophysiology. Electrocardiogram (ECG) signals were acquired from 11 female volunteers under the pre- and the post-stimulus conditions. Artificial neural network (ANN)-based classification of the ARMA model coefficients computed from the RR interval signals suggested significant variation in the autonomic nervous system activity. Analysis of the Gabor denoised ECG signals indicated a change in the electrical activity of the heart in the post-stimulus condition, which was confirmed by the ANN-based classification. Recurrence analysis of the RR interval suggested plausible differences of the cardiac activity amongst both the conditions. The audio-visual stimulus has resulted in significant alterations in the ANS and the cardiac physiology.

INTRODUCTION

The sinoatrial (SA) node, located in the upper region of the right atrium, is a collection of self-excitatory cells. These cells are responsible for the rhythmic contraction of the heart. Because of this unique property, SA node is also known as the natural pacemaker of the heart. This regulation is achieved by the nerve innervations of the Autonomic Nervous System (ANS) into the SA node. Based on the various external stimuli sensed by the sense organs and the internal conditions, ANS issues either excitatory or inhibitory signals to the SA node through sympathetic or parasympathetic nerves. This helps in achieving the required alteration in the heart rate and the duration of the consecutive cardiac cycles. The variation in the cardiac cycles can be measured by monitoring the variations in the time duration of the consecutive ‘R’ peaks. Such a recording with respect to time is regarded as RRI (RR interval) time series. The ECG signals divulge information about the electrical activity of the heart (Zaidi, Ahmed, & Bakibillah, 2017) and the RRI time series has been reported to describe the ANS activity noninvasively (Salvioli, et al., 2015).

Exposing an individual to stimuli like audio-visual clips has been reported to alter the physiological activities of the individual, including the ANS and the cardiac activities (S. Nayak, Champaty, Ray, & Pal, 2014; S. K. Nayak, et al., 2016; Proverbio, et al., 2015). Studies have been preformed to assess the human emotions like sadness, happiness, fear, disgust and neutral in volunteers due to their exposure to audio-visual clips by analyzing their ECG signals (Murugappan, Murugappan, & Zheng, 2013). Some researchers have employed stressful audio-visual stimulus to understand and estimate the measurable physiological changes that occurs in body as part of the “fight-or-flight” response (Bloomer, Hitt, Olson, & Wruck). It has been shown that stress activates sympathetic nervous system by releasing stress hormones (Hayashi, et al., 2008; Kemeny, 2003) that causes the physiological changes in the conduction pathway of the heart. The audio-visual stimuli have also been exploited to evaluate the effect of weeping and laughing on the ANS activity and the mood states (Sakuragi, Sugiyama, & Takeuchi, 2002). Many researchers around the world have hypothesized that the audio-visual stimulus elicits a greater change in the heart rate, galvanic skin response and respiration as compared to the auditory stimulus, due to a larger baseline deviation but only a few studies have been conducted in the support of this hypothesis (Tkaczyszyn, et al., 2013).

In this study, we report the effect of a humorous audio-visual clip on the ANS and the heart physiology of females. In normal healthy females, the gonadotropic hormone levels undergo continuous change during the menstrual cycle. A change in the level of these hormones not only affects the reproductive organ, but also influences the ANS. In order to maintain the effect of this hormonal changes constant, all the females involved in the study were exposed to the audio-visual stimulus when they were on the day 1 of phase-1 (i.e. follicular phase) of their menstrual cycle.

BACKGROUND

Sakuragi et al. (2002) conducted an experiment with 10 female volunteers in order to estimate the effect of comic and tragic videos on the mood states and the autonomic nervous system of the volunteers (Sakuragi, et al., 2002). The above stimuli caused the participants to laugh and weep. Both the respiration curve and ECG of the participants were recorded before and after watching the videos. In order to