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Original Research Article

Modeling the 2D space of emotions based on the poincare plot of heart rate variability signal

Q1 *Sadaf Moharreri, Nader Jafarnia Dabanloo* *, *Keivan Maghooli*

Department of Biomedical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran

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ABSTRACT

Emotions mean accepting, understanding, and recognizing something with one's senses. The physiological signals generated from the internal organs of the body can objectively and realistically reflect changes in real-time human emotions and monitor the state of the body. In this study, the two-dimensional space-based emotion model was introduced on the basis of Poincare's two-dimensional plot of the signal of heart rate variability. Four main colors of psychology, blue, red, green, and yellow were used as a stimulant of emotion, and the ECG signals from 70 female students were recorded. Using extracted features of Poincare plot and heart rate asymmetry, two tree based models estimated the levels of arousal and valence with 0.05 mean square errors, determined an appropriate estimation of these two parameters of emotion. In the next stage of the study, four different emotions mean pleasure, anger, joy, and sadness, were classified using IF-THEN rules with the accuracy of 95.71%. The results show the color red is associated with more excitement and anger, while green has small anxiety. So, this system provides a measure for numerical comparison of mental states and makes it possible to model emotions for interacting with the computer and control mental states independently of the pharmaceutical methods.

1. Introduction

The human body is in direct interaction with his feelings and these two are inseparable; therefore any factor that affects one of these two, will creates responses in another and will makes variations in compare to normal mode [1]. Specially, most of these changes occur when the person is under stress and excitement and is out of normal condition [1]. Today, with a greater attention to the study of the relationship between psychological responses and emotional physiology, the activity of the Autonomic Nervous System (ANS) is considered as the source of these responses [2,3]. In this case, different physiological responses will be observed [4].

The human sensitivity to biological signals play a major role in many theories of emotion [5]. Physical changes directly follow the emotion of the stimulant, and the sense of these

* Corresponding author at: Department of Biomedical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran.
E-mail addresses: sadaf.moharreri@gmail.com (S. Moharreri), n.jafarnia.n@gmail.com (N.J. Dabanloo).

Abbreviations: HRV, heart rate variability; HRA, heart rate asymmetry; ECG, electrocardiogram; AV Plane, arousal – valence plane; SAM, self-assessment manikin; MSE, mean square error; ANS, autonomic nervous system; ADM, affective dimensional model.

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changes is called emotion, and these two relationships have a feedback [6]. In short, Human experiences emotions because he receives physical reactions [7]. The body is the base and the main stage of emotion directly or through the representation of the sensory structure. According to researches, the effects of psychological feelings on the biological signals of the body are received and understood with high precision that these biological signals include variations in blood pressure, heart rate, skin conductance, and so on [8]. Therefore, reception and perception of internal biological signals play a decisive role in many theories of emotion. But the basic question is which of the biological signals can have a more meaningful role in identifying and recognizing the different states of emotion?!

The second important problem in this regard is that the reaction of everyone in the same emotional state is not the same. In one and the same situation, a person may speak, smile, froze, wink, cry, and so on. Therefore, the most important issue is the definition of a general measurement criterion for different states of emotion in all circumstances that can be used as a comprehensive system for the diagnosis of various emotional states and then with full acknowledgement of this system, one can take steps to fully diagnose the emotional behavior of a human being.

The third important point is collecting data to identify emotions. Because in order to be able to obtain credible and reliable data, we need to ensure two aspects: One is that exactly the intended emotions be induced, and secondly, the feeling of induction is properly labeled by the person being tested. These two points are very important and necessary. Because in practice, we deal with humans who are sometimes so rigid that any attempt to cause certain emotional stimulation to them fails. Secondly, people may experience a certain feeling but they are unaware of it and cannot name it emotionally. Or they even prefer to keep their feelings hidden and not confess. To this end, it is important to provide a system that can describe the overall mental and psychological state independently of the declaration of the person under test, and is not limited to specific testing and induction.

Furthermore, there are many questions that have not been answered so far, including: Finding the effect of physiological-psychological relationship in shaping the electrical response of the signal, individual characteristics, statistical constraints in distinguishing two states of valence and arousal, and the type of experiments performed to stimulate desired emotions. In the following, these questions are answered in three sections using related previous studies and these responses are used in this research. Section 1.1 discussed about the first question to select the best biosignal which can have the more meaningful rule in recognizing emotions. The reasons for choosing color as a stimulant of emotions in this article are given in Section 1.2. Section 1.3 reviews the estimation and identification of emotions based on the two-dimensional model of emotion in past studies, and finally, in Section 1.4, the objectives of this study and the process of different stages of the work are described.

1.1. *Biological signals*

There are many theoretical and practical challenges associated with the diagnosis of emotions based on bio signals [9]. The outcome of the researches show that physiological signals are influenced by emotions [10]. In some researches facial expression [2,11,12], human speech [13,14] and motion of gestures [15,16] are used. But since these states are controlled by the individual, they are not suitable for the identification of emotions. For example, a person can easily hide his facial expressions or change his voice. Or, sometimes, some people are not able to express their feelings with speech or change their face or movement. Given these problems, Picard et al. showed that bio signals can be used for emotion detection [17]. Because emotions emanate from the central nervous system and the peripheral nervous system. Therefore, there is no possibility of mistakes or concealment of emotions in the vital signals of the body [17]. In addition, physiological signals are involuntary reaction of the body which provide continuous recording and frequent assessment of emotions. So various physiological signals have been used in different studies in order to discriminate emotions such as: EEG [18–21], ECG [8,22–25], HRV [2,4,26–32], GSR [8,9,22,23,27,33,34], EMG [8,9,27,35], skin temperature[8,36], blood volume pulse [8,33,34], and respiratory volume [8,34,36].

Among various physiological signals, HRV is a good signal for measuring emotional states [25,37]. Because this signal has a very high correlation with ANS that reflects the emotional responses of the human body [37–39]. Furthermore, a heart signal with a non-invasive recording has different responses to the induced emotions. Valenza et al. suggested that HRV could be an objective tool to achieve emotional response [40]. Wiem et al. used four different biological signals such as ECG, respiration volume, skin temperature and GSR and show that ECG is the best signal to detect human emotions [36]. Jones et al. showed that HR reflects emotional activity and is useful for separating arousal levels, positive and negative emotions [34]. Due to these results, this article focuses on the HRV signal for modeling the level of arousal and valence in emotions.

1.2. *The effects of color stimuli on heart in related works*

Man uses his five senses to communicate with the surrounding environment and receives the information he needs. But a normal person usually receives more than 90% of the information through vision. But what is seen is actually color, because everything that is seen is due to the way the light is reflected from the objects to the eye. Each color has a certain wavelength and energy. The light receptors in the retina, called cone receptors, convert these energies to the sensation of color by the brain. The retina has three types of cone receptors for blue, green, and red. When the energy of colors enters the body, it stimulates the pituitary glands and pineal glands. This stimulation can release hormones that affect the physiology of the body and this can be due to the association of colors with the physical and mental states of the body. Experts believe that these states do not relate to the physiological culture and condition of the person [41]. Therefore, due to the specific wavelength and energy, colors have certain meanings and can transmit certain information. The meaning of each color has two main sources: 1. the meanings derived from the experiences of life and related to the culture and traditions of the place of residence, 2. Biological meanings of colors; each color produce definite physiological and psychological

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