Proceedings of the IASTED International Conference
Biomedical Engineering (BioMed 2012)
February 15 - 17, 2012 Innsbruck, Austria

EMOTION RECOGNITION BASED ON UTILIZING OCCURRENCE SEQUENCE OF HEART RATE'S PHASE SPACE POINTS

Nader Jafarnia Dabanloo[1], Gholamreza Attarodi[1], Sadaf Moharreri[1.2], Saman Parvaneh[1.2], Ali Motie Nasrabadi[3],
[1] Department of Biomedical Engineering, Science and Research Branch, Islamic Azad University
[2] Young Researchers Club, Science and Research Branch, Islamic Azad University
[3] Shahed University
Tehran, Iran
N_jafarnia@yahoo.com, Attarodi@yahoo.com, Sadaf.moharreri@gmail.com, parvaneh@ieee.org ,
a_m_nasrabadi@yahoo.com

ABSTRACT
In this paper, we have used the color stimuli to define the valence level of subjects by analyzing their heart rate variability (HRV). For this analysis, we have used the novel features, Global Occurrence Matrix (*GOM*) and Co-Occurrence Matrix (*COM*), and try to distinguish two groups of positive and negative emotions. The results show that cold colors are associated with high valence level and hot colors are in relation with low valence level.

KEY WORDS
Color stimuli; Global Occurrence Matrix (GOM); Co-Occurrence Matrix (COM); valence; emotions; HRV.

1. Introduction

Emotion is the psychophysiological experience of an individual's state of mind as interacting with environmental influences[1]. A related distinction is between the emotion and the results of the emotion, principally behaviors and emotional expressions. People often behave in certain ways as a direct result of their emotional state, such as crying, fighting or feeling.
Physiological signals have significant advantages. We can continuously gather information about the user's emotional changes while they are connected to biosensors. The most benefit of using physiological reactions is that they should be more robust against possible artifacts of human social masking since they are directly controlled by the human autonomous nervous system [2]. So there is a strong relationship between physiological reactions and emotional states of humans.
Valence, as used in psychology, especially in discussing emotions, means the attractiveness (positive valence) or aversiveness (negative valence) of an event, object, or situation. However, the term is also used to characterize and categorize specific emotions. For example, the emotions popularly referred to as "negative", such as anger and fear, have "negative valence". Joy has "positive valence". Positively valenced emotions are evoked by positively valenced events, objects, or situations.
In this paper, with the use of colors as stimulation, we try to find the relation between colors and valence level of emotions by analyzing the HRV recorded of the subjects. For relating colors and emotions, we use Self-assessment Manikin Test. At last, we try to distinguish them by using the novel features Global Occurrence Matrix (*GOM*) and Co-Occurrence Matrix (*COM*).

2. Heart Rate Variability abd Autonomic Nervous System

The Autonomic Nerve System (ANS) is responsible for short-term regulation of the blood pressure [3]. The ANS is a part of the Central Nervous System (CNS). It uses two subsystems, the sympathetic and parasympathetic systems [4]. The sympathetic system is active during stressful situations, in order to provide a higher heart rate up to 180 beat per minute (bpm) [5]. Increased activity of the sympathetic nerves increases heart rate (HR) and force of contraction [6]. In addition, the rate of conduction through the heart is increased and the duration of contraction is shortened. When sympathetic activity increases, there is a latent period of up to 5 seconds before there is an increase in HR, which then reaches a steady level after about 30 seconds [4]. In contrast, the parasympathetic system is active during rest and can reduce the HR down to 60 bpm [3].

3. Measurements Emotions and Heart Response

3.1 Self-Assessment Manikin Test (SAM TEST)

As all people express their emotions differently, it is not an easy task to judge about human emotions. A useful way to describe and recognize the subjects' emotions is to have multiple dimensions or scales to categorize emotions

[7]. Instead of choosing discrete labels or words, observers can indicate their impression of each stimulus on several continuous scales, for example, pleasant-unpleasant, attention-rejection, simple-complicated, etc. [8].

Two common scales are valence and arousal [9]. Valence represents the pleasantness of stimuli, with positive (or pleasant) at one end and negative (or unpleasant) at the other [9]. Another dimension is arousal (activation level).

SAM Test is a series of pictograms to judge the affective quality of stimuli. SAM is a nonverbal, culture-fair rating system based on a three- dimensional system of emotion [10].

The SAM rating scale is comprised of three sets of graphic figures, respectively representing the three dimensions, are used to indicate emotional reactions. As shown in Figure 1, the SAM figures range from frowning, unhappy to smiling, happy, on the valence dimension[11]. For the arousal dimension, the figures range from relaxed, sleepy to excited and wide-eyed [11]. For the dominance dimension, the figures range from small or dominated to large and controlling [11]. The subject can select any of the five figures comprising each scale.

In this study, the valence dimension of SAM is used to measure valence level of each color stimuli.

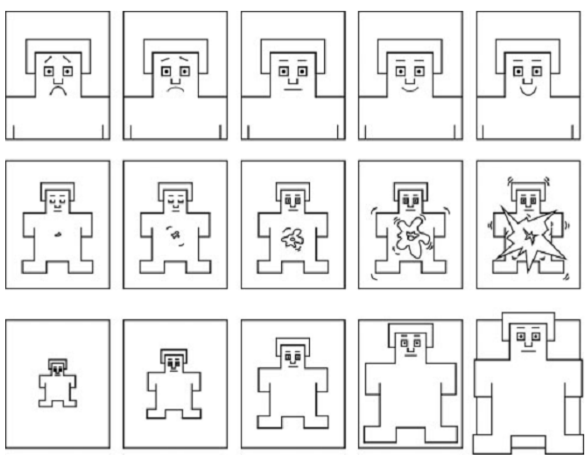

Figure1. Self Assessment Manikins (SAM Test)

3.2 Heart Response to Color Stimuli

For distinguishing these two groups of emotions by their related ECGs', we used our new features: Global Occurrence Matrix (*GOM*) and Co-Occurrence Matrix (*COM*) which are explaining as following [12]:

Both of these features are defining in the base of point's distribution in relation to the line of identity in Poincare plot of RR intervals.

The line of identity in the poincare plot is defined as the line that passes through the origin at an angle of 45^o with *x*-axis [13]. We have defined our new features in a poincare plot dependent of the line of identity i. e. decision about a point is made based on its position with respect to the line of identity on the 2D poincare plot. In the proposed *GOM*, the points of the plots are partitioned into three parts (Figure 2):

- Points which are up the line of identity (U);
- Points which are on the line of identity (O);
- Points which are down the line of identity (D).

The decision about a point as to whether it belongs to one of the above three classes is made based on the point's distance to the line of identity.

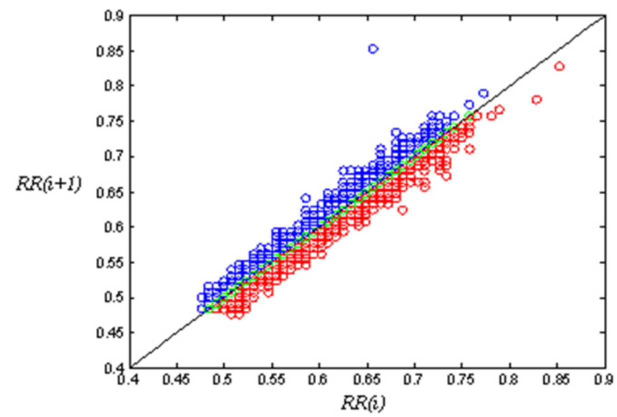

Figure 2. Three classes in calculating *GOM*

These three classes are shown in Figure 2. After defining the classes of all the points, we counted the members of each class for constructing *GOM*.

GOM is a 3×1 matrix which elements are defined as follows:

$$GOM = [N_U \; N_O \; N_D] \qquad (1)$$

In which N_U is the number of points in class U, N_O is the number of points in class O, and N_D is the number of points in class D.

For defining the second feature, we focused on local temporal behavior of the points in relation to each other dependent on the line of identity. For this purpose, we used the same definitions which were mentioned in *GOM* such as three different classes U, O, and D. But the difference is that in *COM*, we considered two following points P_i and P_{i+1} and so the analysis corresponds to at least three consecutive RR intervals of the RR interval time series. Therefore, in *COM* we should count nine different behaviors dependent to points' classes in relation to each other and line of identity which is defined as follows (Figure 3):

- $If\ (P_i \in U)\ \&\ (P_{i+1} \in U)\ then\ UU = UU + 1$
- $If\ (P_i \in U)\ \&\ (P_{i+1} \in O)\ then\ UO = UO + 1$
- $If\ (P_i \in U)\ \&\ (P_{i+1} \in D)\ then\ UD = UD + 1$
- $If\ (P_i \in O)\ \&\ (P_{i+1} \in U)\ then\ OU = OU + 1$
- $If\ (P_i \in O)\ \&\ (P_{i+1} \in O)\ then\ OO = OO + 1$
- $If\ (P_i \in O)\ \&\ (P_{i+1} \in D)\ then\ OD = OD + 1$
- $If\ (P_i \in D)\ \&\ (P_{i+1} \in U)\ then\ DU = DU + 1$
- $If\ (P_i \in D)\ \&\ (P_{i+1} \in O)\ then\ DO = DO + 1$
- $If\ (P_i \in D)\ \&\ (P_{i+1} \in D)\ then\ DD = DD + 1$

Hence, *COM* is a 3×3 matrix which elements are defined as follows:

$$COM = \begin{bmatrix} UU & UO & UD \\ OU & OO & OD \\ DU & DO & DD \end{bmatrix} \qquad (2)$$

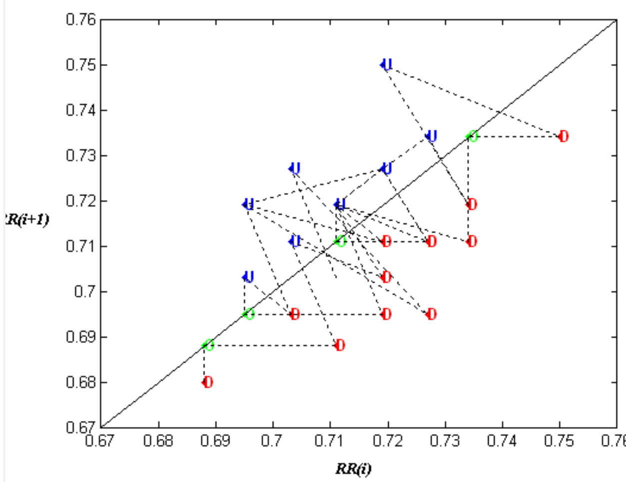

Figure 3.Temporal Variations in *COM*

3.3 Color Stimulation

Sixteen female students, without earlier experience of laboratory experiments, with the age between 23 and 27 participated in the study (24.75±1.43). The participants were seated on a chair and the lead II of ECG was recorded from them during the stimuli.
For color stimuli we used the laptop screen which was placed one meter far from the subjects and each color of red, yellow, green and blue were presented on it for five minutes separately. Between each color stimuli there was a resting time for canceling the effects of previous stimulation (10 minute). After each stimulus, the subjects answer the SAM test which was explained to them before the experiment. This test was used to compare the results of HRV analysis with the feeling that each subject sense.

4. Results

4.1 Results of SAM Test

After analyzing the answers of SAM test which were given by the subjects in the experience, the results show that most of the subjects determine that warm colors, red and yellow, make the valence level low and have relations with negative emotions while the cold colors, blue and green make the arousal level high which means they induced positive emotions.

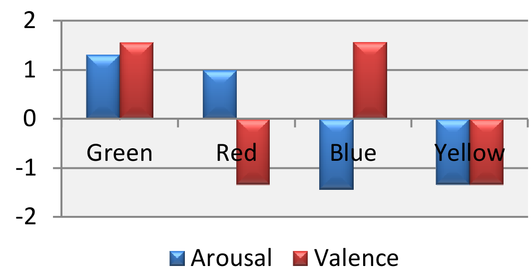

Figure 4. Mean values of arousal and valence for color stimuli

4.2 Results of *GOM* and *COM*

In this study, we have used Kruskal-Wallis test to define the level of significance of our measured features.
Kruskal-Wallis test is a nonparametric version of the classical one-way ANOVA, and an extension of the Wilcoxon rank sum test to more than two groups. The assumption behind this test is that the measurements come from a continuous distribution, but not necessarily a normal distribution. The test is based on an analysis of variance using the ranks of the data values, not the data values themselves.
In our study, this test has been used to evaluate the hypothesis for each feature separately. The p values obtained from Kruskal-Wallis analysis are shown in Table 1 and Table 2 for features which are obtained by analyzing *GOM* and *COM*.
In case of $p < 0.05$ to be considered as significant, we can see that our features would show the significant difference between groups which p value is shown in Table 1 and Table 2.
The results show that utilizing occurrence sequence of heart rate's phase space points features (*GOM* and *COM*), discriminate positive and negative emotions by proper p-values and especially in *COM* parameters with $p < 0.001$.

Table 1. p-Value Results for *GOM* Parameters

***GOM* Parameters**	**Positive & Negative Emotions**
U	0.0105
O	0.0236
D	0.3061

5. Discussion and Conclusion

In this paper, we have used the color stimuli to define the arousal level of subjects by analyzing their HRVs. For this study, we have used the novel TPSM and the results show that its features are able to distinguish between two groups of emotions, calm and energetic. The results show that cold colors are associated with low arousal level and the color stimuli effects on heart function without awareness of subjects. So it seems that these kinds of colors are useful for using in biofeedback systems for calming heart. So colors would be evaluated in most cases and compared with clinical results to detect their more advantages in emotion detection and biofeedback systems.

Table 2. *p*-Value Results for *COM* Parameters

COM Parameters	Positive & Negative Emotions
UU	0.000501
UO	0.00321
UD	0.6412
OU	0.00190
OO	0.090
OD	0.000033
DU	0.02864
DO	0.005
DD	0.0041

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