How to Interpret Psychology from Heart Rate Variability?

Sadaf Moharreri[1,2], Nader Jafarnia Dabanloo[1]
Saman Parvaneh[1,2]
[1] Islamic Azad University, Science and Research Branch
[2] Young Researchers Club
Tehran, Iran
sadaf.moharreri@gmail.com; parvaneh@ieee.org

Ali M Nasrabadi
Shahed University
Tehran, Iran

Abstract— **In this paper, we have used the color stimuli to define the arousal level of subjects by analyzing their heart rate variability (HRV). For this analysis, we have used the novel Triangular Phase Space Mapping (TPSM) and try to distinguish two groups of emotions, calm and energetic. The results show that cold colors are associated with low arousal level and hot colors are in relation with high arousal level.**

Keywords- color stimul; Triangular Phase Space Mapping (TPSM); arousal; calm; energetic; psychology; HRV

I. INTRODUCTION

Every visual stimulus processed by the human perceptual system contains color information. Color has existed ever since life began, but its effects on humans have not been truly known until about one hundred years ago [1]. Colors have been associated with life, at the most basic, night and day, forever [1]. Man has been faced by darkness and light since the beginning of time, and these two environments have been associated with dark-blue for the night sky and bright yellow for the daylight ever since [2]. The dark-blue of night brought a time when action ceased and man rested, while the bright yellow of daylight brought about action and energy [2]. Therefore, dark-blue is "the color of quiet and passivity", and bright yellow is "the color of hope and activity" [2]. To this man, action took on two forms, either hunting or defending himself. The color red represents the actions of attack; defense and self-preservation are known by green, its complement. These four colors, blue, yellow, red, and green, are the basic colors in the psychology [1].

Indeed, the idea that there is an association between color and emotion seems obvious to common sense [3]. Some colors may be associated with several different emotions and some emotions are associated with more than one color [4].

Emotion is the complex psychophysiological experience of an individual's state of mind as interacting with environmental influences [5]. 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. If one can have the emotion without the corresponding behavior, then we may consider the behavior not to be essential to the emotion [4].

Many studies have linked color to emotional experience, although the exact nature of the association is not well understood [6]. In this paper, we try to find the relation between colors and two specific emotions, calm and energetic. These two are recognized as two kinds of emotion which have different arousal level.

Arousal is a physiological state of being awake or reactive to stimuli [7]. It involves the activation of the reticular activating system in the brain stem, the autonomic nervous system and the endocrine system, leading to increased heart rate and blood pressure and a condition of sensory alertness, mobility and readiness to respond [8].

Arousal is important in regulating consciousness, attention, and information processing [9]. It is very important in emotion, and has been included as a part of many influential theories.

In this paper, with the use of colors as stimulation, we try to measure the arousal level of the subjects by analyzing the HRV recorded of them. For relating the arousal level to the emotions calm and energetic, we use Self-assessment Manikin Test which is explained in section III. At last, we try to distinguish them by using the novel Triangular Phase Space Mapping (TPSM) on their HRVs'.

II. HEART RATE VARIABILITY AND AUTONOMIC NERVOUS SYSTEM

The Autonomic Nerve System (ANS) is responsible for short-term regulation of the blood pressure [10]. The ANS is a part of the Central Nervous System (CNS). It uses two subsystems, the sympathetic and parasympathetic systems [11]. The sympathetic system is active during stressful situations, in order to provide a higher heart rate up to 180 beat per minute (bpm) [12]. Increased activity of the sympathetic nerves increases heart rate (HR) and force of contraction [13]. 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 [11]. In contrast, the parasympathetic system is active during rest and can reduce the HR down to 60 bpm [10].

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III. MEASUREMENTS OF EMOTIONS AND HEART RESPONSES

A. Emotions

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 [14]. 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 [15].

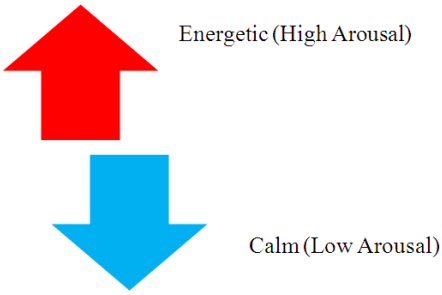

Figure1. Relation between arousal level and emotions (calm and energetic)

Two common scales are valence and arousal [7]. Valence represents the pleasantness of stimuli, with positive (or pleasant) at one end and negative (or unpleasant) at the other [7]. Another dimension is arousal (activation level). Researches in this field have been shown that two emotions calm and energetic can be distinguished depend on their arousal level [7]. As it's shown in Figure1, Energetic make the arousal high and calm is associated with low arousal level.

B. Self Assessment Manikin Test (SAM TEST)

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 [5].

The SAM rating scale is comprised of three sets of graphic figures, respectively representing the three dimensions, are used to indicate emotional reactions [5]. As shown in Figure 2,

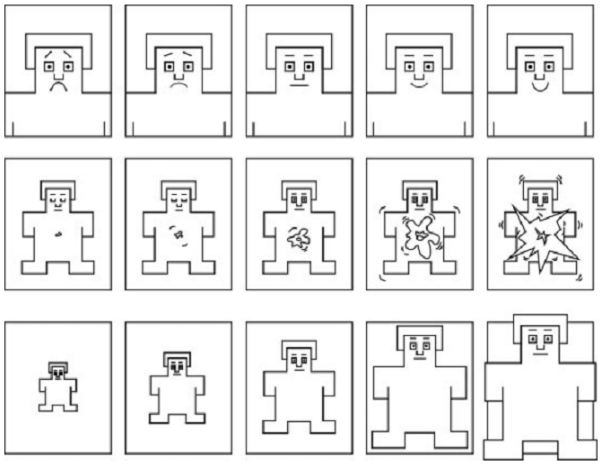

Figure2. Self Assessment Manikins (SAM Test)

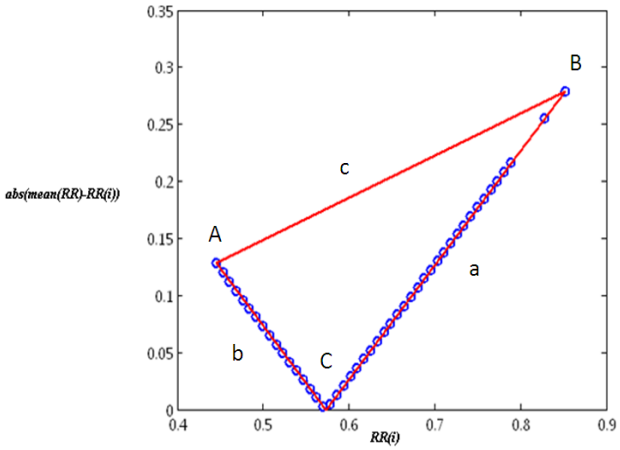

Figure3. Estimation a triangle for point's distribution in TPSM

the SAM figures range from frowning, unhappy to smiling, happy, on the valence dimension [5]. For the arousal dimension, the figures range from relaxed, sleepy to excited and wide-eyed [5]. For the dominance dimension, the figures range from small or dominated to large and controlling [5]. The subject can select any of the five figures comprising each scale.

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

C. Heart Response to Color Stimuli

For distinguishing these two major emotions by their related ECGs', we used the TPSM which is explaining as following [16]:

TPSM is a novel method for representation of heart rate which is obtaining by using RR interval time series signal to plot the triangle mapping consist of all the ordered pairs: (RR_i, abs (mean(RR) - RR_i)), $i = 1, \dots, N$ [16]. As shown in Figure 3, we obtained a triangle from the distribution of these points and by analyzing it, we could extracted some geometric features such as Angles, Area of the triangle, the slope of the line, the length of them and so on which are explained in details in [16].

In this mapping the slope of line a and b are 1 and -1 respectively. For measuring the slope of line c we have

$$m_c = \frac{y_B - y_A}{x_B - x_A} \tag{1}$$

in which x and y are the coordinates of triangle vertices. For calculating the length of the sides, we have

$$\begin{aligned} a &= \sqrt{(x_B - x_C)^2 + (y_B - y_C)^2} \\ b &= \sqrt{(x_A - x_C)^2 + (y_A - y_C)^2} \\ c &= \sqrt{(x_B - x_A)^2 + (y_B - y_A)^2} \end{aligned} \tag{2}$$

and for defining the angles, we have as shown in (3).

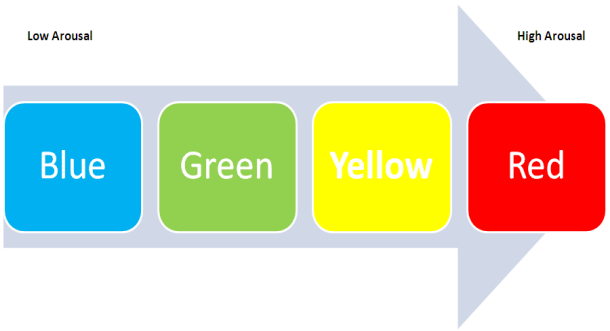

Figure 4. Relation between arousal level and Colors from low arousal to high arousal

$$A = \cos^{-1}\left(\frac{b^2 + c^2 - a^2}{2bc}\right)$$
$$B = \cos^{-1}\left(\frac{a^2 + c^2 - b^2}{2ac}\right) \quad (3)$$
$$C = \cos^{-1}\left(\frac{a^2 + b^2 - c^2}{2ab}\right)$$

IV. 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.

V. Results

A. 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 arousal level high while the cold colors, blue and green make the arousal level low (Figure 4).

It means that colors blue and green are associated with calm and colors red and yellow are associated with energetic.

Table 1. *p*-Value Results for *PSPM* Features

***TPSM* Features**	**Calm & Energetic**
Angle *A*	0.0105
a	0.0105
b	0.3938
c	0.0190
Triangle Peripheral	0.0190
Triangle Area	0.0330
Triangle Quality	0.2864
Slope of *c*	0.0105

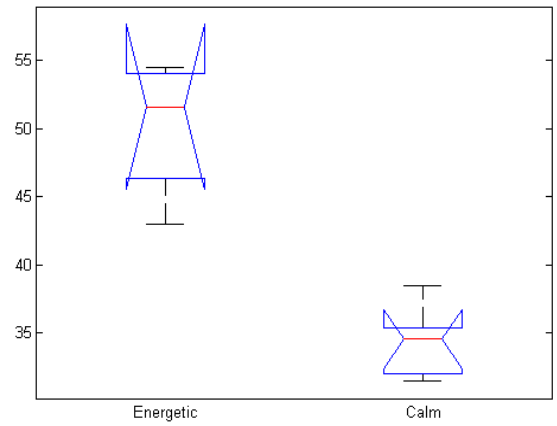

Figure 5. Box-Whiskers Plot of *A* angle of TPSM for two groups of emotions

B. Results of TPSM

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 for features which are obtained by analyzing TPSM.

In case of $p < 0.05$ to be considered as significant, we can see that *PSPM* features would show the significant difference between groups which *p* value is shown in Table 1.

The results show that angle *A*, side *a* and the slope of *c* has the best results (Fig. 5). They discriminate calm from energetic by *p=0.0105*. Although side *c*, Triangle peripheral and its area have good results too.

VI. Discussion

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.

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