The Relation between Colors, Emotions and Heart Response using Triangle Phase Space Mapping (TPSM)

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Abstract

Emotion is the complex psychophysiological experience of an individual's state of mind as interacting with environmental influences. In this paper, we try to find the relation between colors, emotions and heart response using Triangular Phase Space Mapping (TPSM), a novel method for representation of heart rate. We used four colors as a visual stimulus while the lead II of ECG was recorded from 16 girls as subjects during the stimuli. The results show that colors blue, yellow, red and green induced emotions pleasure, sadness, anger and joy respectively. Kruskal-Wallis test was used to define the level of significance of each feature to demonstrate the usefulness of them in distinguishing responses to different colors and induced emotions. The results show that these features discriminate anger from sadness by p<1E-3; anger from joy by p<1E-5; anger from pleasure by p<2E-4; sadness from joy by p<2E-3; sadness from pleasure by p<1E-2; and pleasure from joy by p<1E-2.

1. Introduction

Many studies have linked color to emotional experience, although the exact nature of the association is not well understood [1]. Indeed, the idea that there is an association between color and emotion seems obvious to common sense [2]. Some colors may be associated with several different emotions and some emotions are associated with more than one color [3].

Emotion is the psychophysiological experience of an individual's state of mind as interacting with environmental influences [4]. 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.

In other hand, the Autonomic Nerve System (ANS) is responsible for short-term regulation of the blood pressure [5]. The ANS is a part of the Central Nervous System (CNS) which uses two subsystems, the sympathetic and parasympathetic systems [6]. The sympathetic system is active during stressful situations, in order to provide a higher heart rate [7]. Increased activity of the sympathetic nerves increases heart rate (HR) and force of contraction [8]. In contrast, the parasympathetic system is active during rest and can reduce the HR [5]. Sympathetic and parasympathetic systems typically function in opposition to each other.

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. So there is a strong relationship between physiological reactions and emotional states of humans.

In this paper, with the use of colors as stimulation, we try to find the relation between colors and emotions by analyzing the HRV recorded of the subjects. For relating colors and emotions, we use Self-assessment Manikin Test and 2D model of emotions. At last, we try to distinguish them by using the novel Triangular Phase Space Mapping (TPSM) on their HRVs'.

2. Measurements of emotions

It is not easy to judge about human emotions because all people express their emotions differently [9]. A useful way to describe and recognize the subjects' emotions is to have multiple dimensions or scales to categorize emotions [10]. 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. [11].

Two common scales are valence and arousal [12]. Valence represents the pleasantness of stimuli, with positive (or pleasant) at one end and negative (or unpleasant) at the other [12]. Another dimension is arousal (activation level). Researches in this field have been shown that some emotions can be distinguished depend on their arousal and valence level (12).

In this paper, for evaluating the induced emotions, we used Self-Assessment Manikin Test for quantification of valence and arousal level and for classification of emotions upon their valence and arousal value, we used two dimensional model of emotions, which are explained in the following.

2.1. 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 [4].

The SAM rating scale is comprised of three sets of graphic figures, respectively representing the three dimensions, are used to indicate emotional reactions [4]. As shown in Figure 1, the SAM figures range from frowning, unhappy to smiling, happy, on the valence dimension [4]. For the arousal dimension, the figures range from relaxed, sleepy to excited and wide-eyed [4]. For the dominance dimension, the figures range from small or dominated to large and controlling [4]. The subject can select any of the five figures comprising each scale.

In this study, the arousal and valence dimension of SAM is used to estimate emotions which are induced by color stimuli using 2D model of emotions.

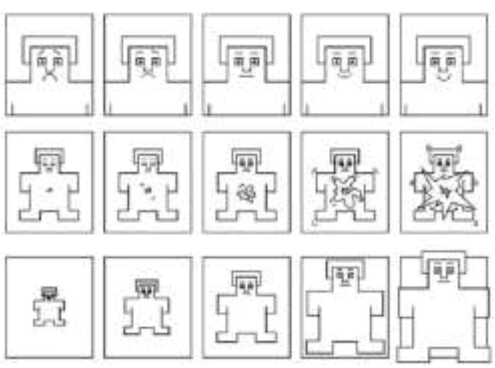

Figure1. Self Assessment Manikins (SAM Test)

2.2. 2D Model of Emotions

Once the accordant data is gathered, it's quite straight forward to classify emotions in the 2D valence-arousal space [13]. These facile ways of modeling emotions in two dimensions can be mapped nicely to the dimensions of user experience as shown in Figure 2 and thus provide a method for recognizing emotions.

Figure 2. 2D model of emotions

The different emotional labels can be plotted at various positions on a 2D plane spanned by these two axes to construct a 2D emotion model. This model provides a simplified representation of human emotions by two dimensions: arousal and valence [13].

2.3. Heart features

For distinguishing major emotions by their related ECGs', we used the TPSM which is explaining as following [14]:

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)), $i = 1, \dots, N$ (14). 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 [14].

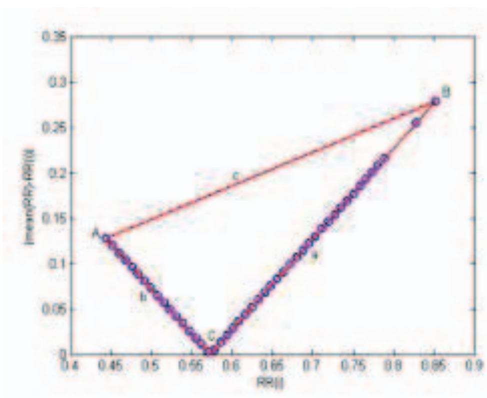

Figure 3. Estimation a triangle for point's distribution in TPSM

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

As mentioned before, the results divide in two categories: Emotion responses and Heart responses to color stimuli. For defining emotion responses, we used the results obtained from SAM Test and 2D model of emotions. For describing heart responses, we used eight features achieved from TPSM analysis of HRV, which are compared with emotion responses in order to quantify emotions and evaluate the relation between colors, emotions and heart. These steps are explained as follows.

4.1. Emotion responses to color Stimuli

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 green and red make the arousal level high while blue and yellow make it low. Moreover, Green and Blue make the valence level high while red and yellow make it low. These results are shown in Figure 4.

Comparing the results which are gained from SAM Test with 2D model of emotions, we can find out the similarity between colors and emotions responses. So we can conclude that colors green, red, blue and yellow are respectively associated with emotions joy, anger, pleasure and sadness.

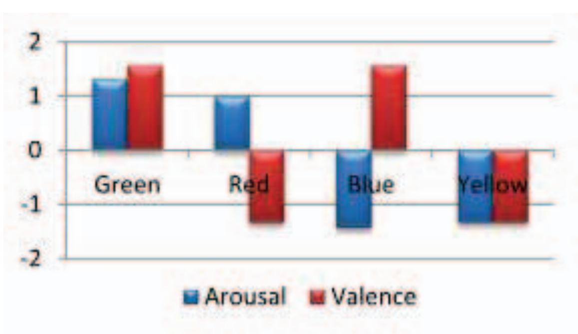

Figure 4. Mean values of arousal and valence for color stimuli

4.2. Heart responses to color Stimuli

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 *TPSM* features would show the significant difference between groups which *p* value is shown in Table 1.

By relating colors to emotions according to 2D model of emotions, the results show that these features discriminate anger from sadness by $p<1E\text{-}3$; anger from joy by $p<1E\text{-}5$; anger from pleasure by $p<2E\text{-}4$; sadness from joy by $p<2E\text{-}3$; sadness from pleasure by $p<1E\text{-}2$; and pleasure from joy by $p<1E\text{-}2$.

The results show that the slope of *c* and angle *A* has the best results and can discriminate these emotions by $p<0.0105$.

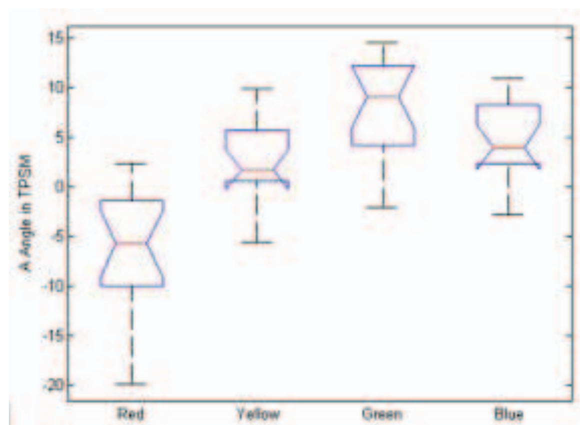

Figure 5. Box-Whiskers Plot of *A* angle of TPSM for two groups of emotions

5. Discussion

In this paper, we have used the color stimuli to define the induced emotions of subjects by analysing their HRVs. For this study, we have used the novel TPSM and the results show that its features are able to distinguish between four groups of induced emotions.

With our novel method, TPSM, we have used the function between current data of time series in relation to the mean of whole data. It was shown that this new mapping was able to differentiate these emotions

Table 1. *p*-Value Results for *TPSM* Features in response to color stimuli

TPSM Features	*Groups*					
	Blue, Green	Blue, Yellow	Blue, Red	Green, Yellow	Green, Red	Yellow, Red
Angle *A*	*0.0348*	*0.1223*	*2.211E-4*	*0.0033*	*1.735E-5*	*0.001*
a	*0.1416*	*0.7345*	*0.2136*	*0.2913*	*0.0704*	*0.2278*
b	*0.4739*	*0.4739*	*0.0116*	*0.2913*	*0.0083*	*0.0899*
c	*0.91*	*0.4739*	*0.0899*	*0.5977*	*0.1134*	*0.2744*
Triangle Peripheral	*0.9699*	*0.4287*	*0.0765*	*0.7063*	*0.1223*	*0.3089*
Triangle Area	*0.6785*	*0.6511*	*0.0899*	*0.8802*	*0.2744*	*0.3641*
Triangle Quality	*0.4510*	*0.0274*	*0.0023*	*0.1416*	*0.0014*	*0.0033*
Slope of *c*	*0.0317*	*0.0105*	*2.563E-4*	*0.0026*	*1.735E-5*	*0.001*

significantly and it seems that this kind of measurements can be used as a tool for quantifying emotions. The triangle model of HRV enables the user to test different geometric analysis on it and extract different features which each one may reflect different aspects of HRV behaviour. Another advantage of this triangle mapping is that the points in this map overlapped with each other as a kind of compaction and so this map deletes the extra and useless information and just keeps the useful ones. Hence, it seems that this kind of mapping may be used as an efficient method for emotional detection using heart responses.

Furthermore, the results proved the hypotheses of relation between colors and emotions and effects of them on heart function without awareness of subjects. So it seems that these kinds of colors are useful for using in biofeedback systems in different situations. 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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