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A Comparative Study on the Emotional Behavior of Humans towards Color using the P300 Component

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Abstract

Objectives: The paper is based on the P300 component of the Visual Evoked Potential. The objective is to collect visual responses of humans and categorize them by age and blood group. **Methods/Analysis:** The device used to collect data is a NeuroSky MindWave Mobile Headset along with an Android application: eegID. The data is manually compared with other individuals of the same age and blood group and the values showing similar peaks are picked out from the entire set. The data attributes is normalized by using the formula. The normalized values are then grouped according to age and blood group and plotted. **Findings:** The graphs plotted from the data show that the emotional characteristics of individuals belonging to the same age groups and blood groups are similar. Slight variations were noted among individuals of similar blood groups but different age groups. A similar experiment has been conducted for comparing emotions using audio stimulus. A questionnaire was created which was compared with the values achieved in the results. This showed similarities thus proving that the experiment achieved results matching individuals' personal choices. The existing and proposed system both used ERP generated by audio and visual stimuli respectively. The existing data can be combined with the data achieved in this paper to generate a more detailed study into the characteristics of individuals categorized by their blood group.

Keywords: Brain Computer Interface, EEG Emotional, P300, Quotient, Visual Evoked Potential

1. Introduction

A Brain Computer Interface (BCI) is a mode of the direct pathway of correspondence between a human being or wired brain and a computer. BCIs are aimed at research, assistance or repair of cognitive and motor functions. A BCI is a framework of communication and control that has no dependency of any sort on the human brain‛s normal neuro-muscular output yield channels. The human user‛s intention is conveyed or passed on to the computer by electrical signals generated by the brain, captured by an EEG machine, rather than by the peripheral nerves and muscles and these signals generated by the brain are not dependent for their generation on the brain's neuromuscular activity. A BCI establishes a real-time connection between the user i.e. the human being and the outside world[1]. A typical BCI system that is commonly used is shown in Figure 1.

Electroencephalography (EEG) is a method of measuring the electrical signal activity produced in the brain from its exposure to various environments of light, sound, sense, etc. and is recorded from the electrodes that are placed on the scalp. It is typically a non-invasive procedure wherein the subject wears a cap embedded with electrodes. It measures the changes in voltage generated due to current in the neurons of the brain. The brain generates a large amount of neural activity. An action potential in an axon causes the release of neurotransmitter

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into the synaptic junction. The neurotransmitter diffuses across the synaptic junction and binds to receptors in a post-synaptic dendrite. The similar activity of many types of receptors and axons results in a flow of ions into or out of the dendrite. It is these extracellular currents which are responsible for the generation of EEG voltages[2,3].

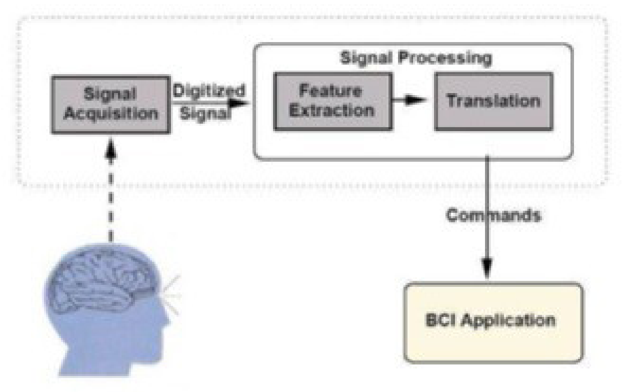

Figure 1. A typical BCI system.

The 10–20 Electrode Placement System is an internationally well known method that is used for the description and the application of the electrodes on the scalp in an EEG test or experiment. This system here is based on the relation between the placing of an electrode on the EEG cap and the cerebral cortex of the brain. Two main

Points used for the placing of the electrodes are the nasion, the area above the nose bridge and between the eyes, and the inion, the lowest part of the skull which is identified by a prominent bump[4]. It is shown diagrammatically in Figure 2.

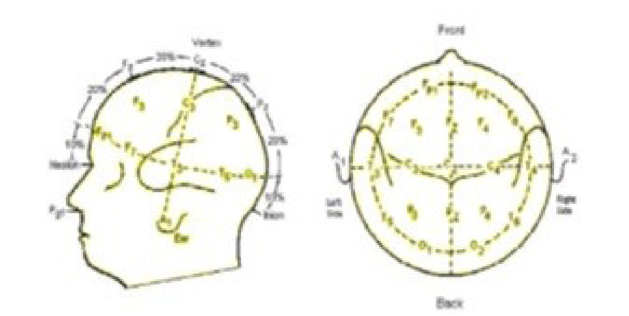

Figure 2. The 10-20 electrode placement system.

Visual Evoked Potential commonly known as VEP refers to the electrical potentials initiated by brief visual stimuli, which are recorded as signals from the brain on the scalp just above the visual cortex also known as the occipital cortex. VEP waveforms are then extracted from the EEG machine by signal averaging. VEPs are mainly used to test the functional efficiency of the visual paths from the eye through the retina to the optic nerves to the occipital cortex of the brain. VEPs better test the functionality of the visual paths than scanning methods or surgeries. Any abnormality found that can affect the visual paths or occipital cortex in the brain can also affect the brain VEP. A VEP can often be found in the background EEG that is recorded from the occipital cortex through the scalp following a visual stimulus like a flash of light or colour[4].

The P300 wave is an ERP component generated in the process of decision making. It is considered to be a potential generated within the brain cells or tissue, because its occurrence is not related to the characteristics of a stimulus, but how a person is affected by the stimulus. When recorded by an EEG machine, it comes out as a positive change in voltage with a delay, between stimulus given to the subject and response generated, of roughly 250 to 500 ms. The signal is usually more strongly measured from the electrodes that are covering the parietal lobe. The presence, measure, distribution and timing of this signal generated in the brain are often used as units to measure cognitive capacity of a person in the decision making processes. The P300 is positive amplitude which is calculated with a reference behind the ear with a peak at approximately 300ms and it varies in the delay depending upon the task performed. It is usually high over the parietal areas of the scalp[5].

H. Serby, et al. says that the best method of using a BCI is by basing it on the P300 values obtained from an EEG reading. The only issue which is the low Signal to Noise Ratio can be overcome by repeating the stimulus to improve user's performance. The number of trials should be balanced to the user's average performance in order to attain the desired accuracy. We set some thresholds which help in reaching a decision based on performance rather than a fixed number of trials[6].

A. Mejrad says that emotional influences of the human brain cause difference in EEG characteristic waves. It has been endeavored to conduct research the brain activity identified to emotion through analyzing EEG. The important features noted of the EEG signals are age and mental state of the subject, region of the brain, hereditary factors, influences of the brain and artifacts[7].

Nawrocka, et al. states that the most common method of capturing the human brain waves is the use of an EEG machine. The main merits of using this method or technique in BCI are that the brain activity is analyzed or evaluated in real time. One of the frequently used potentials is the P300 which is associated with the reaction and response of the person to an expected stimulus. This potential which is normally observed as a sudden boost appears in the EEG about 300 ms after the stimulus and is seen in the Parietal Lobe. Visual Evoked Potential (VEP) arises in the central nervous system due to stimulation or influence of visual stimuli on the retina. The main factor that determines the efficiency of a BCI is the Signal to Noise Ratio (SNR), which directly affects the accuracy at which the boost is detected[8].

Lai, et al. states that Chromatic Transient VEP (CTVEP) is emitted when visual stimulus in the form of color is presented at low frequency, i.e. less than 4 Hz and perceived within the visual field. Fast varying luminance of conventional visual stimulus can easily make the users tired or fatigued. The safety of this VEP is due to the change in the low frequency of the visual stimulation on one hand and no variance of lumination on the other which makes it more comfortable for human users than the conventional VEP[9].

Danny Oude Bos says that psycho-physiological research shows there is a very direct link between the amount of action in the left frontal and the right frontal lobes and the emotion resulting from it. A higher activity in the left frontal lobe region indicates a very positive reaction and high activity in the right anterior lobe depicts negative effect. The EEG features that are influential detected during various emotional stimuli are valence – positive and happy emotions that result in a higher frontal coherence noted in the alpha waves, and higher right parietal beta, when compared to a negative emotion i.e. arousal – excitation that presented a higher beta value and a coherence in the brain's parietal lobe, plus lower alpha power and dominance – the strength of an emotional state, which is expressed generally in the EEG as a peak or an increase in the beta / alpha activity ratio in the frontal lobe of the brain, plus an increase in the beta power at the parietal lobe[10].

2. Materials and Methodology

Emotional state of an individual can be understood from face, gesture, from text, from speech or biofeedback. An Event Related Potential (ERP) can be generated by visual stimulus also. Since emotions could be detected by audio stimulus, we can conduct a feasibility study to determine the emotional state of an individual. As visual stimulus is based on the optic nerve, where the response might differ by gender, age, blood group, we can categorize our subjects for a better understanding. The proposed system for this project is shown in Figure 3. Using the Valence – Arousal model as shown in Figure 4, the emotions can be classified into four groups. Using the values, the emotional quotient of the individual can be determined[11,12].

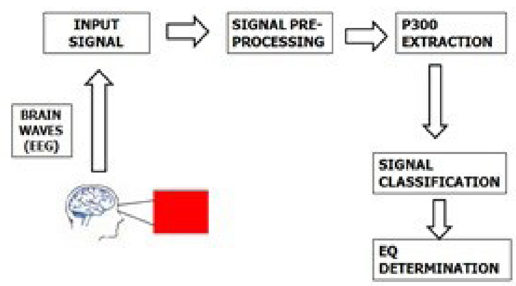

Figure 3. Block diagram of the proposed system.

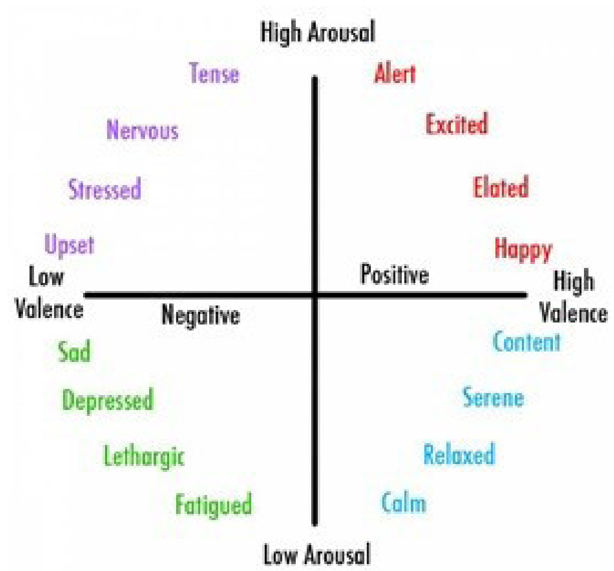

Figure 4. Valence arousal model.

The device that will be used in this project is the NeuroSky MindWave Mobile Headset shown in Figure 5. This device is the culmination of EEG biosensor technology research. The headset can be linked to any device using Bluetooth technology and can be controlled from PC or android applications. The device paired to the headset is an android mobile. The sensors mounted on the headset can detect faint brainwave signals safely and passively. This device uses a non-invasive method of recording brain waves. The technology embedded in the NeuroSky headset interprets the meaning of these recorded signals. These brainwave signals can then cause effects and results in an application. Here, the android application used iseegID, shown in Figure 6, which gives values for alpha, beta and gamma waves which can tell us the emotional state the subjects are in.

Figure 5. The NeuroSky brainwave headset.

Figure 6. The android application eegID.

In this project, we aim to isolate the brain waveform from EEG and digitize the same and use it for interfacing it with the computer for determining the emotional quotient of a person. Emotion recognition from EEG can be used to determine the emotional state a person is in or find out what emotion a color triggers in a particular individual. We aim to determine the emotional quotient of humans using EEG-based brain-computer interface system. Here we combine the property of EEG waves to detect emotions with the property of colours to trigger different emotions in humans to determine the emotional state of an individual. The current emotional state of a human is assessed using the EEG recordings and the person is asked to view different images. The consequent EEG recordings is compared with the initial recordings and his/her emotional state is determined. The person is made to view many other colors and the resulting change in colors is viewed. When the tests are done with all the colors, the experiment is completed.

The various emotions were classified using Valence and Arousal value as in Wei Wang (2011) and Danny Oude Bos (2010). The Valence and Arousal value was calculated using the Bayes' classifier and based on those values, the various emotions are classified. The Valence-Arousal dimension model is used to classify emotions.

- Happy/Pleasant emotion – Valence positive and arousal positive.
- Fear/Tension emotion –Valence negative and arousal positive.
- Depressed/Sad emotion – Valence negative and arousal negative.
- Normal/Satisfied emotion – Valence positive and arousal negativ

2.1 Data Acquisition

The data acquisition is a phase where the actual EEG recording of the subject is taken as per our desired activity. It forms the most important part of any BCI process because it is based on the acquired readings that the further steps are carried out. The first step in a data acquisition process is to alert the subject that the process is about to begin and ask him/her to relax and cooperate accordingly. A set of images where the chosen colors are dominant is played to the subject. This acts as the required stimuli.

As external stimuli, several images where the chosen colors are dominant are selected. The chosen colors are blue, red, yellow and green. These colors are selected specifically for certain purposes. Green is the natural color of mother earth. It symbolizes purity, growth, harmony and freshness. Green has very strong emotional relation with safety. Blue is taken as the color of the sky and the sea. It is often associated with feelings like depth and stability. It is a symbol of trust, confidence, faith, intelligence, truth and heaven. Red is the color of very fearsome images involving blood or fire, so it is often thought of with war, energy, danger, power, strength, determination as well as passion, love, desire, etc. Yellow is the color of brightness also the color of the sun. It is usually associated with joy, positive energy, happiness, etc.[13,14] .

The following questionnaire will be filled by each of the subjects before they sit for the tests:

- What is your age?
- Gender : M ☐ F☐
- What is your blood group?
- What is your post of employment?
- Do you suffer from any of the following?
- Blood Pressure ☐
- Diabetes ☐
- Tuberculosis ☐
- Any other ☐
- Are you under any medication?
- Have you been treated for any serious illness previously?
- What colors do you prefer?
- What memories does the preferred color evoke?
- Is there any specific color you do not like?

2.2 Extraction of P300 Values

The raw EEG is obtained from the EEG machine in the data acquisition phase. The EEG raw data of each subject is stored as a unique file. There are possibility of distractions and unwanted junk values caused due to flashes, noise, external disturbances, movements, involuntary reflexes and irrelevant activities. Hence, we would like to go for P300 extraction which is the process of extracting the useful or significant data from the entire raw EEG data that is recorded. After extracting the required data from the raw data, several excel sheets were obtained for each activity separately. Technically, the raw EEG data was translated to five frequency bands: Delta (1-4HZ), Theta (4-8HZ), Alpha (8-13HZ), Beta (13-30HZ) and Gamma (36- 40HZ) bands.

3.Signal Classification

In the Bayesian classification or epistemological interpretation, the probability measures the degree of belief. A very popular Bayes' theorem then relates the degree of belief in a proposition before and after accounting for evidence. For example, if somebody proposes that a biased coin is twice as likely to land on its heads than its tails. Degree of belief here might be 50%. The coin is then again flipped a number of times to accumulate evidence. The belief may increase to 70% if the evidence supports this proposition.

For proposition A and evidence B,

P(A), the prior, is the initial degree of belief in A.

P(A|B), the posterior probability, is the degree of belief having accounted for B.

P(B|A)/(B) represents the support B provides for A.

The Standard Deviation formula for calculation of valence and arousal is:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_1 - \mu\right)^2}$$

The influential EEG features detected during various emotionally triggered stimuli are: Valence – positive and happy emotions that result in a higher frontal lobe activity shown in alpha and higher value for right parietal lobe beta power, compared to negative or unhappy emotion and Arousal – which is excitation presented a higher beta power and coherence in the parietal lobe, plus lower alpha activity.

Bayes' theorem says P(A/B) = P(A1/B) ^ P(A2/B)…^P(An/B) /P(B).

P(A/B) – Valence value with respect to Arousal.

P(A1/B) – Frontal-Coherent-Alpha.

P(A2/B) - Right-Parietal-Beta.

P(A3/B) – Coherent-Alpha.

P(A4/B) – Coherent-Parietal-Beta.

Bayes' Theorem is defined as a theorem that describes how a conditional probability of each of the set of possible causes for a given noted outcome can be computed from the knowledge of the probability of each of the cause and the conditional probability of the result of each cause. It is stated mathematically as the following equation.

$$P(A/B) = \frac{P(B/A)P(A)}{P(B)}$$

4. EQ Determination

Emotional Quotient (EQ) also known as emotional intelligence is the ability of an individual to recognize their own and other people's emotions to know the difference between different emotions and identify them appropriately and to use emotional information to guide thinking and behavior. This module involves the process of determining the Emotional Quotient of an individual after the experiment. The values received after classification is then put into a scale and compared with the initial emotional state of the individual to determine how relaxed or how depressed the subject is.

For determining the Emotions of an individual, we use the Valence Arousal model depicted in Figure 4. This is also known as the circumplex model of emotion and was developed by James Russell. This model shows that emotions are distributed in a two-dimensional space, containing arousal and valence dimensions. Arousal is depicted on the vertical axis and Valence is represented on the horizontal axis. The centre of this circle is depicted as a neutral valence and a medium arousal levels. This model shows that any human emotion can be depicted as a certain level of valence and arousal or at a neutral level.

5. Experimentation

The experiment for the project is conducted in very careful and planned environments as the brain being a very sensitive organ, responds to every single stimulus. So in order to get a clear set of values, we ask the person to sit in a quiet and dark room. A light or a sound can trigger a stimulus thus resulting in noise in the experiment. The person is then explained about the project and the experimental steps. Asking the person to relax throughout the procedure is utmost necessary or that too, adds to noise in the values. Making sure the patient is very comfortable and relaxed in every step of the experiment is very essential[15].

The subject is asked to close their eyes and relax. The device is carefully fixed on the head and the ear-clip in position. The application is checked to see if it the device is in place and it is running well. The subject is informed to meditate on each of the colors that will be shown to them. The timer was set. Then, colors were shown to the subject. The person was asked to open their eyes, look at the color for 5 seconds and then close their eyes. During this time period, the readings were recorded in a tablular format. The person was then given a 1 minute break to relax again and the above step was repeated. A set of 4 colors were shown and the procedure was repeated 10 times and readings taken to ensure the subject was trained and in order to avoid Signal to Noise Ratio.

Rather than the technical and specialized advancements and gadgets or devices, the human being was considered as an important and critical factor in a successful BCI. BCI system involves as much collaboration from the human subject as from the BCI computing gadget. The subjects were chosen in accordance with the prerequisites of the work to be carried out. Since the session is purely dependant on analyzing the human emotion, a person with good psychological well-being is chosen. A progression of discussion is carried out with the subjects, investigating the psychological or mental state of the subjects. At the initial stage, a quantitative EEG was taken for the subject and it was analyzed and disclosed to the subject and later the subject was put through instructional sessions. The factors like external unsettling disturbances and line noise or earth ground potential can also affect the recordings. These factors were well considered amidst numerous trials before starting the actual sessions[16].

The above shown Figures 5 and 6 are the device and application, respectively, used in the experiment. The MindWave Mobile Headset has four sensors at the temporal and central lobes, namely, T3, C3, C4, T4. It has a reference electrode at the frontal-polar position, Fp1 and a ground electrode in the form of an ear-clip. The headset is connected to the application via Bluetooth technology. This application helps us to tabulate the readings after every experiment as it sends the values received via email. This application is very helpful even during an experiment to determine whether the device has been placed properly or not.

6. Results

The experiment was conducted for 60 subjects, both male and female, the ages varying from 19 to 29 years. The blood groups of the subjects belonged to the following groups: A+ve, A-ve, B+ve, B-ve, AB+ve and O+ve. The raw data was collected using the experiment and tabulated. For each subject, values were received for the following attributes, Alpha Low, Alpha High, Beta Low, Beta High, Gamma Low and Gamma Mid. The values were then normalized to bring them into a feasible range for calculation. This was done using the formula:

$$Normval = \frac{x - \min}{\max - \min}$$

where, x is the value w.r.t each subject.

Max and min are the maximum and minimum values of a particular attribute.

After normalization, the difference was found between Alpha Low and High values, Beta Low and High values, Gamma Low and Mid values to see the variation in these attributes to determine an estimate of the subject's reaction to the colors. These values are shown in Table 1.

Table 1. Normalized values for blue color

AGE	GENDER	BLOOD GROUP	ALPHA VALUES	BETA VALUES	GAMMA VALUES
25	F	B-	-0.999307	0.000630	0.035934
23	F	O+	0.001078	0.000386	0.015282
26	M	A+	-0.996814	-0.000317	0.034291
25	M	O+	0.000115	0.000095	0.005520
24	F	AB+	-0.000588	0.004082	0.094357
21	F	A+	0.000819	-0.000260	0.025382
23	M	B+	-0.000400	0.000055	0.007388

Table 2. Normalized values for green color

AGE	GENDER	BLOOD GROUP	ALPHA VALUES	BETA VALUES	GAMMA VALUES
25	F	B-	-0.000760	-0.002372	0.009664
23	F	O+	0.000620	-0.011090	0.004244
26	M	A+	0.000092	-0.016611	0.007261
25	M	O+	0.999037	-0.020396	0.023279
24	F	AB+	-0.000503	-0.005244	0.000838
21	F	A+	0.000428	-0.007450	0.007681
23	M	B+	-0.997948	-0.010992	0.024686

Table 3. Normalized values for red color

AGE	GENDER	BLOOD GROUP	ALPHA VALUES	BETA VALUES	GAMMA VALUES
25	F	B-	0.999238	0.000045	0.052968
23	F	O+	0.000098	-0.000081	0.003200
26	M	A+	-0.999284	-0.000595	0.049774
25	M	O+	-0.000056	0.000106	0.012252
24	F	AB+	0.000426	-0.000837	0.032876
21	F	A+	0.002034	0.000388	0.057868
23	M	B+	0.998728	-0.000184	0.023587

Table 4. Normalized values for yellow color

AGE	GENDER	BLOOD GROUP	ALPHA VALUES	BETA VALUES	GAMMA VALUES
25	F	B-	0.000893	-0.000421	-0.999082
23	F	O+	-0.001183	-0.000263	-0.000099
26	M	A+	-0.000058	-0.001240	-0.000390
25	M	O+	-0.038261	-0.015838	0.996610
24	F	AB+	-0.000332	0.000089	-0.000187
21	F	A+	0.000158	-0.000798	-0.000208
23	M	B+	0.012149	-0.004500	0.991160

The graphs obtained from these data values are shown below:

7. Discussion

From Figure 7, we can say that the high alpha values for Blue color for the blood groups, A+, A-, B+, O+ shows that these groups are very relaxed on seeing a Blue color compared to the other colors. Similarly, B+ and O+ groups are very relaxed towards Green color. B- group is very relaxed towards yellow color. A+ and AB+ are very relaxed towards Red color. The high alpha values represents the subject is in a very relaxed state of mind. The color triggers a happy emotion or a very relaxed memory.

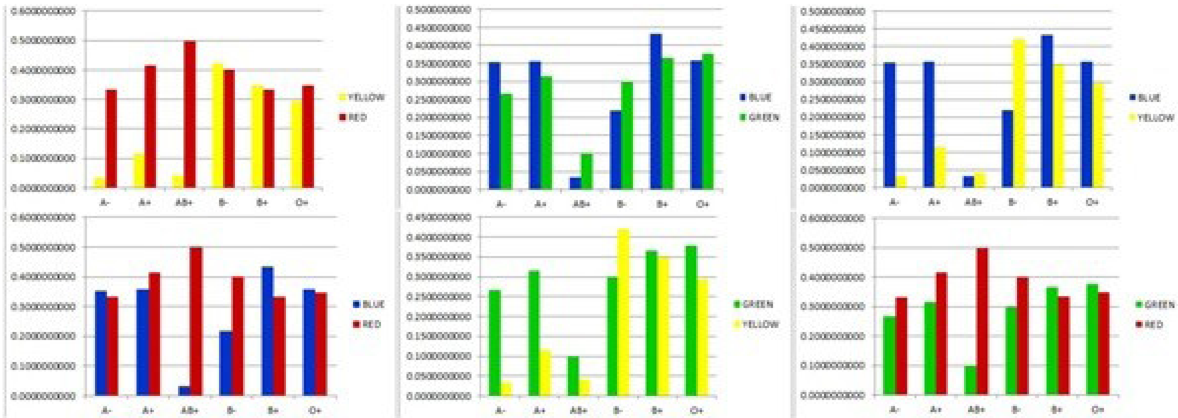

Figure 7. Color combination graphs for Alpha Values.

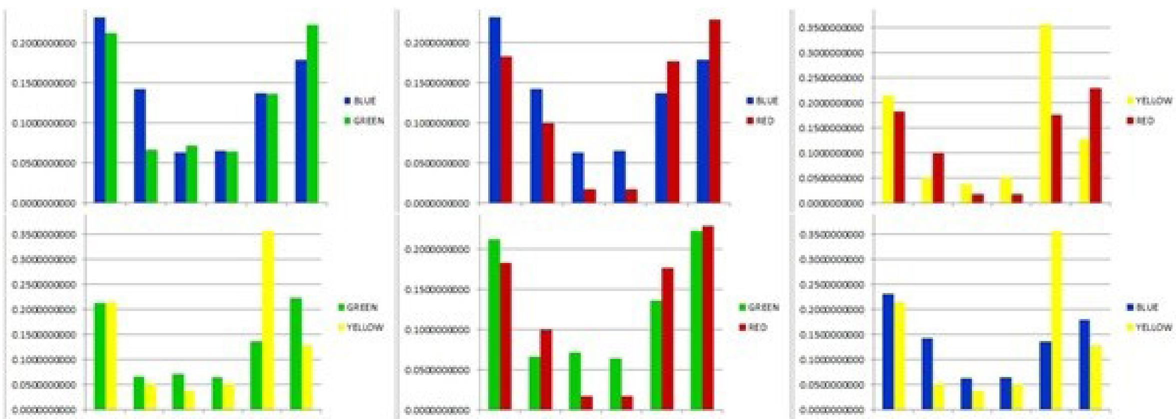

Figure 8. Color combination graphs for Beta Values.

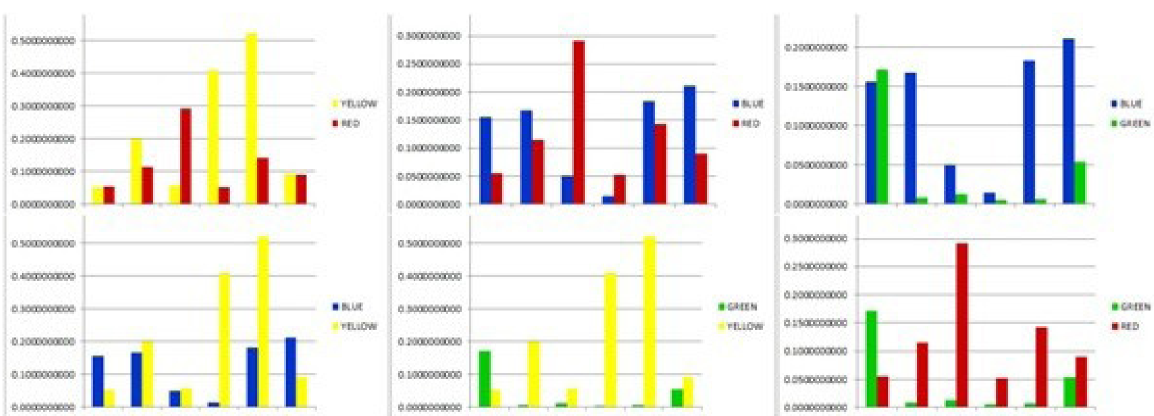

Figure 9. Color combination graphs for Gamma Values.

From Figure 8, the high value of Beta shows the brain is active, that is, in the thinking mode or that it evokes conscious mode in an individual. The high value towards a particular color shows high brain activity. The subject could be recollecting a memory with regard to the colors.

From Figure 9, the high gamma values shows high levels of excitement which means the person's aversion to that particular color. It could also be developed due to the intensity of the color which might provoke this emotion in a subject. Bright colors tend to provoke a reactive stimulus rather than a responsive stimulus in an individual.

8. Conclusion

This project is a feasibility study of human emotions towards colors and the dataset contains 60 values. The results show the relation between a subject's blood group and colors. However, to get a more precise conclusion, further experiments have to be conducted with age and a more varied subject pool. Colors are associated with memories. Hence, variations can occur with respect to the cultural background of an individual, the social status of an individual. A more detailed result could be obtained with more advanced devices where more number of electrodes can be placed for a more accurate reading in a subject.

The subject's concentration can be improved by increasing the number of trials. And a more prolonged session in order to let the subject be more comfortable. This study can again be related to the age category, the gender category and much more to obtain various relationships between the attributes of an individual and their reactions to colors. More colors can be added to see a more varied reaction.

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