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COMPARING EEG SIGNALS AND EMOTIONS PROVOKED BY IMAGES WITH DIFFERENT AESTHETIC VARIABLES USING EMOTIVE INSIGHT AND NEUROSKY MINDWAVE

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Abstract. The paper is part of a broader study to verify some hypotheses about the relationship between the aesthetic characteristics and the emotions that an image provokes. Here we will not go through a survey where respondents would communicate their emotions, but we will use EEG signal monitoring devices. The main objective is to compare options and outputs from the Brain devices when examining emotions in images with different aesthetic characteristics.

Keywords: brain computer interfaces, aesthetic characteristics, electroencephalogram, EEG signals

Mathematics Subject Classification: Primary 00A66; Secondary 68U35.

1 Introduction

An instrument for recording the electrical activity of the brain, usually by means of electrodes distributed on the scalp, is called an electroencephalograph. The recording produced by such an instrument is called an electroencephalogram, commonly abbreviated EEG. The measurement of neurological signals was first used by Vladimir Pravdich-Neminsky, who measured the activity of a dog's brain in 1912. He used the term “electrocerebrogram”. Hans Berger first measured human brain signals 10 years later. The electrode positioning system was designed by Herbert Jasper in the 1950s.
In this paper, we will try to introduce cheap devices to monitor the EEG signal. These devices are known as Brain-Computer Interface (Furthermore, only BCI). These devices enable measuring of human brain activity. At the same time, we give an overview of software for processing the obtained EEG signal. There is a device designed by an Australian entrepreneur Tan Le called Emotiv Insight for the price of 299 USD. Another option is a device called NeuroSky mindwave for the price of 79.99 USD, which was developed in California. These headsets differ in the number of sensors and the possibility of getting raw data. Of course, these systems do not achieve the quality of professional medical devices. Both headsets are wireless. For the Emotiv Insight device, wave measurement is a paid service (99 USD/month)

and only the characteristics derived from them can be obtained directly. These characteristics are: Engagement, Excitement, Interest, Relaxation, Stress, Focus. The Neurosky mindwave offers delta, theta, alpha, beta, and gamma wave tracking. These waves are part of the electroencephalogram.

The Emotiv Insight headset offers five EEG sensors, and two reference sensors. The Neurosky mindwave offers 2 EEG sensors. These headsets are shown in Fig. 1.

Fig. 1. Fotography of headsets: Emotiv Insight and Neurosky Mindwave. Source: [7], [8]

Affective computing is a very modern interdisciplinary field that tries to study and develop systems and devices that can recognize, interpret, process, and simulate human affects. The main objective of our paper is to compare options and outputs from the BCIs when examining emotions in images with different aesthetic characteristics. BCIs use different measures for a description of the user’s emotions. Researches also developed other approaches for measuring, cf. [4].

Now, we will describe the concept of realizing a sample survey in which we will measure the emotions of viewers watching the picture. Klinger and Salingaros stated that the aesthetic impression of an image was determined by the variables Life and Complexity. They proposed the hypothesis; that by measurements L and C for patterns in the image, it is possible to determine the overall impression of the image. Klinger and Salingaros in article [5] considered these emotions: relaxing–distressing; pleasant–unpleasant; exciting–gloomy; arousing–sleepy.

We will try to measure these emotions using the above BCIs. In paper [5] Klinger and Salingaros form the hypothesis that aesthetic parameters can be used for explanation of emotion provoked by images. Much more information can be found in paper [6]. Using of brain-computer interfaces, opens space for testing of Klinger-Salingaros hypothesis.

Of course, it is possible to test the hypothesis even based on a direct description of emotions from the audience, but the headset provides an interesting option for verifying the hypothesis. If the hypothesis is confirmed, it will allow us, in the future, to create an image causing the selected emotion.

Based on the Klinger-Salingars approach, cf. [5], several images with different values of aesthetic characteristics L and C were generated. From these images, we select several paintings to analyze the suitability of using EEG devices to measure audience emotions.

The viewer will be looking at the painting “Colors on a grid” by Ellsworth Kelly, the painting “Echiquier I” by Aurélie Nemours and another six of our paintings. Each painting was viewed for one minute, and the EEG feature vector will be measured.

1.1 Electrophysiological features

With its detection of brain electrical activity over a wide frequency range, the brain computer interfaces detect several electrophysiological features. These include the alpha, beta and gamma rhythms. Devices are capable of detecting signals at frequency range 0.1 – 4 Hz (delta), 4-7 Hz (theta), 8-12 (alpha), 12-30 Hz (beta), 31 and higher (gamma). Cf. [1] (page 1216) and [2] (page 3).
Sometimes a more detailed division is used, so the alpha band can, for example, be divided into alpha 1 and alpha 2.
EEG comprises a set of signals, which may be classified according to their frequency. Cf. [1], [2]. Well-known frequency ranges have been defined according to distribution over the scalp. These frequency bands are referred to as delta (δ), theta (θ), alpha (α), beta (β), and gamma (γ) from low to high, respectively. Relevant characteristics of these bands are detailed in Tab. 1, their interpretation is presented in Tab. 2.

Delta	Observed in babies, decrease as they age. In adults only during their deep sleep.
Theta	Observed in young and older children, and in drowsy, meditative or sleep state adults.
Alpha	Primarily reflect visual processing in the occipital brain region. Increases when the eyes close and the body relaxes.
Beta	Associated with motor activities. During real movement or motor imagery are desynchronized.
Gamma	The presence in the brain activity of a healthy adult is related to certain motor functions or perceptions.

Tab 1. The characteristics of the frequency bands.

	Small value	Large value	Optimal value
Delta	Inability to revitalize the brain, poor sleep	Brain injuries, learning problems, inability to think	Natural healing, restorative/deep sleep
Theta	Anxiety, stress	Depression, hyperactivity, impulsivity, inattentiveness	Creativity, intuition, relaxation
Alpha	Anxiety, high stress	Daydreaming, inability to focus, too relaxed	Relaxation
Beta	Daydreaming, depression	Adrenaline, anxiety, high arousal, stress	Conscious focus, memory, problem solving
Gamma	Depression	Anxiety, high arousal, stress	Information processing, learning, REM sleep

Tab 2. The amount of the measured values of EEG waves and their most common causes.

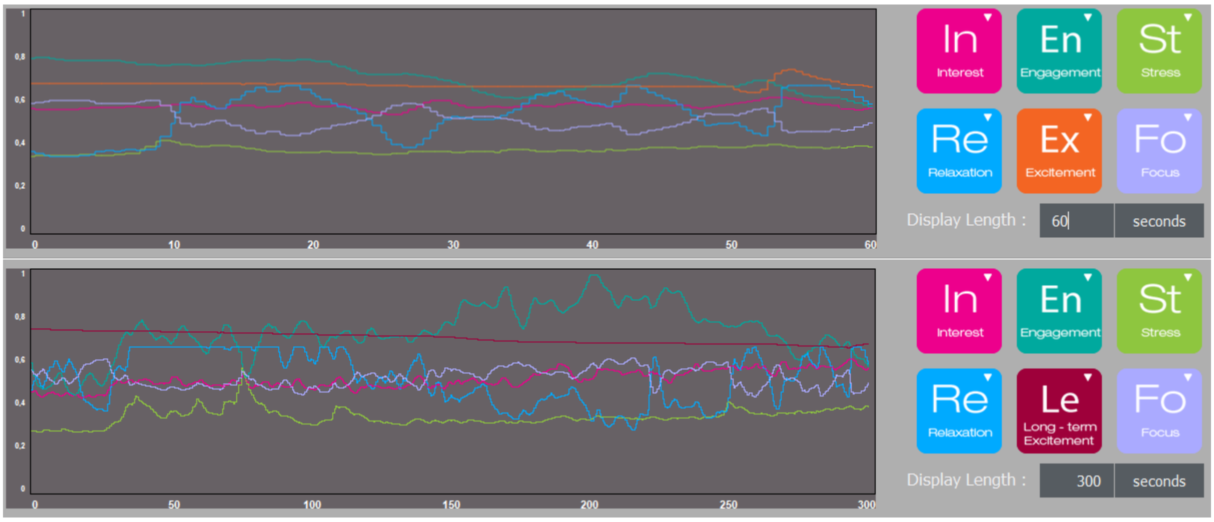

Fig. 2. Emotiv Xavier Control Panel: Detections performance metrix.

2 Brain Computer Interfaces

Now, we will summarize the properties of used BCI's, and their software. Cf. [3].

2.1 Emotiv Insight

This BCI monitors and records the degree of six key cognitive and emotional metrics. Those measures are focus, stress, excitement, relaxation, interest and engagement.
For using of this BCI a long calibration of the sensors is needed, and it requires application of saline substance to capture brain signals with high precision.
The application Emotiv Xavier ControlPanel allows you to view a chart of emotional measures. See Fig. 2.

2.2 Neurosky Mindwave

User mental activity in this BCI is measured by the following waves: delta, theta, low alpha 8-9Hz (alpha 1), high alpha 10-12Hz (alpha 2), low beta 13-17Hz (beta 1), high beta 18-30Hz (beta 2) and low gamma 31-40Hz (gamma 1), high gamma 41-50Hz (gamma 2) waves. See Fig. 3 and Fig. 4. This headset is simple, and it does not require callibration of sensors and application of a saline substance.

However, with the current software NeuroExperimenter, it is possible to recognize brain waves. Mental states, such as attention and meditation, are evaluated in percentages. See Fig. 3.
Attention and Meditation are calculated directly by the device and it is not possible to obtain the formula used in their calculation.
Based on information captured from user's brain, this software can be used to draw graphs of brain waves.

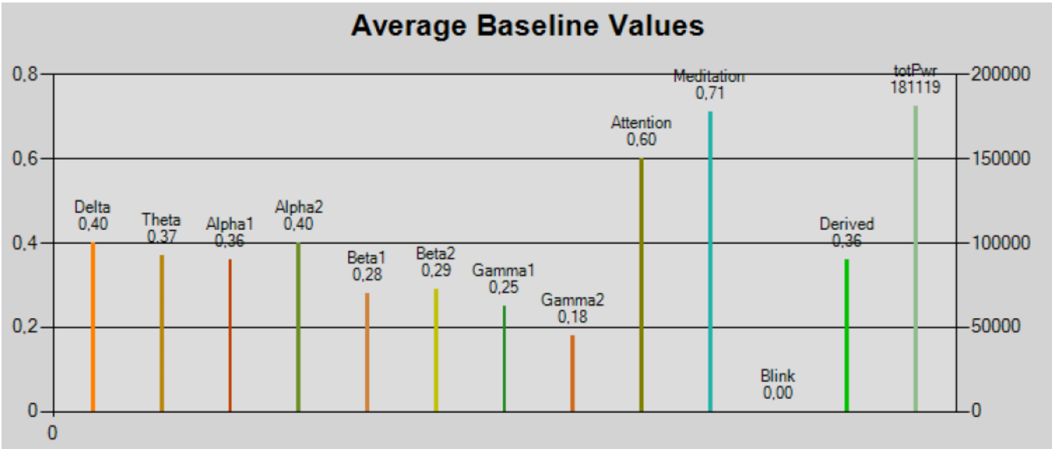

Fig. 3. NeuroExperimenter: derived variables.

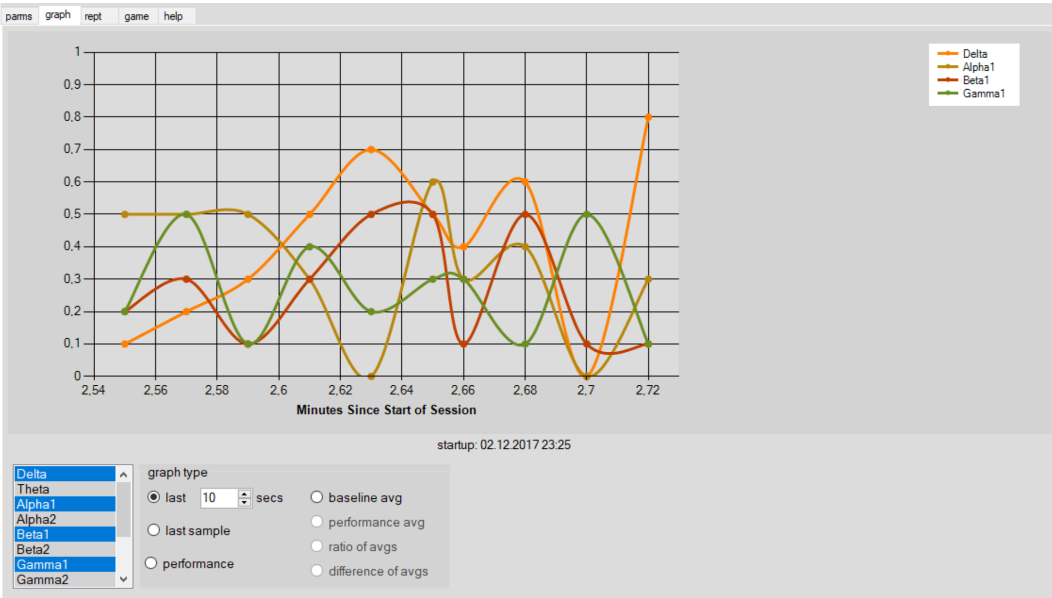

Fig. 4. NeuroExperimenter: measured signals.

3 Experiment

3.1 Choice of test images

Methods for constructing square images with different aesthetic features of Life L and Complexity C were presented in paper [6]. The algorithm for calculating these aesthetic characteristics is described in [5] and [6].
To monitor emotions using the brain computer devices, we select eight images (see Fig. 5). Figure (g) was created by Ellsworth Kelly and picture (h) was painted by Aurélie Nemours.

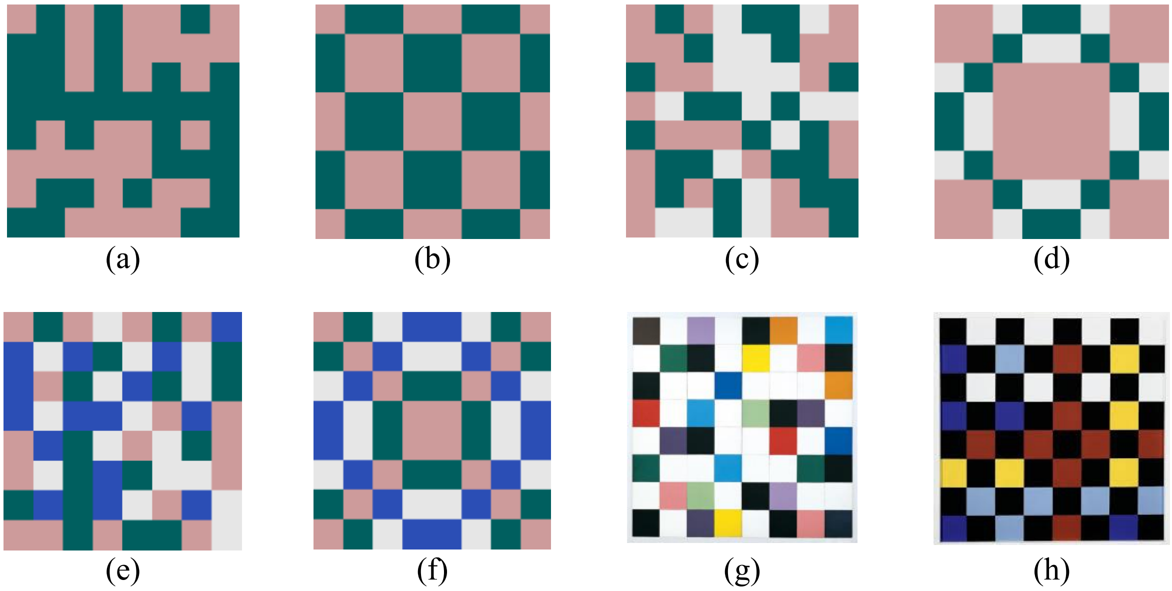

Fig. 5. Testing paintings (a), (b), (c), (d), (e), (f), (g), (h).

The other six paintings are our own and have been designed so that their L and C characteristics are as extreme as possible. In Tab. 3 the aesthetic characteristics of paintings, according to paper [5] are calculated.

Painting/characteristic	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
L	0.839	7.0	0.458	9.75	0.0	14.0	1.288	2.594
C	7.786	2.0	16.042	3.75	25.125	7.0	68.274	28.531

Tab 3. The aesthetic characteristics of paintings.

3.2 Measured signals

For testing of those BCIs, an experiment was made with one person. He needed to look at paintings from Fig. 5. Our all measurements were performed during one hour. Each session involved measuring variables for every image over a 60-second period.

Painting/characteristic	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	avg
Engagement (En)	73	66	71	65	67	73	70	55	67.500
Excitement (Ex)	73	70	69	68	68	66	62	63	67.375
Interest (In)	47	51	53	54	54	54	55	58	53.250
Relaxation (Re)	27	32	34	31	33	27	32	34	31.250
Stress (St)	58	58	58	58	58	58	58	58	58.000
Focus (Fo)	70	66	66	66	65	66	62	62	65.375

Tab 4. Measuring of emotions by Emotiv Xavier Control Panel.

We present the results in Tab. 4 and Tab. 5. We will particularly comment on whether the EEG signals are within a similar shape for paintings with different aesthetic characteristics.

From Tab. 4, it seems that Emotive Insight is unable to distinguish differences in perception of images. The measured values are almost constant (for example Stress).

Interesting is the comparison of the measurements by the second device. See Tab. 5. Symmetric paintings (i.e. (b), (d), (f)) had an average value of attention equal to (0.68+0.81+0.72)/3 = 0.74. While the unsymmetrical paintings (i.e. (a), (c), (e)) had an average value of attention equal to (0.46+0.58+0.43)/3 = 0.49. Similarly, we can see, that symmetric paintings (i.e. (b), (d), (f)) had an average value of meditation equal to (0.39+0.59+0.45)/3 = 0.48. While the unsymmetrical paintings (i.e. (a), (c), (e)) had an average value of meditation equal to (0.81+0.69+0.78)/3 = 0.76.

Painting/characteristic	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	avg
Delta	0.44	0.46	0.55	0.48	0.37	0.40	0.49	0.40	0.44875
Theta	0.38	0.38	0.35	0.38	0.39	0.38	0.43	0.37	0.38250
Alpha 1	0.36	0.34	0.27	0.32	0.42	0.34	0.31	0.36	0.34000
Alpha 2	0.35	0.33	0.35	0.35	0.42	0.35	0.35	0.40	0.36250
Beta 1	0.27	0.27	0.26	0.27	0.29	0.29	0.27	0.28	0.27500
Beta 2	0.31	0.30	0.26	0.30	0.29	0.33	0.26	0.29	0.29250
Gamma 1	0.23	0.26	0.22	0.24	0.21	0.27	0.19	0.25	0.23375
Gamma 2	0.17	0.19	0.14	0.17	0.15	0.19	0.14	0.18	0.16625
Attention	0.46	0.68	0.58	0.81	0.43	0.72	0.31	0.60	0.57375
Meditation	0.81	0.39	0.69	0.59	0.78	0.45	0.61	0.71	0.62875

Tab 5. Measuring of emotions by Neurosky mindwave.

3.3 Dependency between EEG based measures, emotions and aesthetic characteristics

First, we examine the correlation between Emotiv Insight variables and aesthetic characteristics. Then we determine the correlation between Neurosky Mindwave values and L, C characteristics. Values of Pearson’s correlation coefficient

$$r_{x,y} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad (1)$$

are calculated in Tab. 6.

Emotiv	Engagement	Excitement	Interest	Relaxation	Stress	Focus
L	0.0894	-0.0577	0.0973	-0.4982	NaN	0.1107
C	-0.0812	-0.7358	0.4591	0.3605	NaN	-0.7196

Neurosky	Delta	Theta	Alpha 1	Alpha 2	Beta 1	Beta 2
L	-0.16	-0.08	-0.12	-0.41	0.31	0.70
C	0.089	0.73	-0.08	0.25	-0.02	-0.67

Neurosky	Gamma 1	Gamma 2	Attention	Meditation
L	0.75	0.70	0.79	-0.77
C	-0.74	-0.62	-0.77	0.23

Tab. 6. Correlation coefficients.

We can see that dependence between Emotiv Insight variables and Life and Complexity characteristics have very small correlation coefficient values. When using the Neurosky variables, great absolute values of correlation are between L and Attention, L and Meditation, C and Attention. These correlation coefficients are close to 0.7 and -0.7 respectively. From this, we can conclude that images with larger values of the L characteristic and small values of the C characteristic were observed with greater attention. However, watching pictures with a low L characteristic had greater calming and relaxing effects, so that pictures had a greater value of the Meditation variable.

3 Conclusion

It is now possible to purchase many brain computer interfaces (EEG metering devices) for which emotional measurement software is available. In this paper, we compared outputs and inputs of two devices: Neurosky Mindwave and Emotiv Insight. We analysed the possibilities of using them to compare emotions that images, with different aesthetic characteristics, provoke. For widespread use of those BCIs, it is necessary to explore the current limitation and precision of obtained signals. Our recent research was focused to testing of the Klinger-Salingaros hypothesis. We tried to analyze a dependency of the human psyche frame on aesthetical characteristics. When positive emotional paintings were presented the viewer EEG characteristics were higher for attention. We found that the Neurosky Mindwave is more suitable for verifying the effect of aesthetic characteristics on the emotions of the viewer.

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