Analysing Brain Response to Affective Pictures from Electroencephalogram

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Abstract

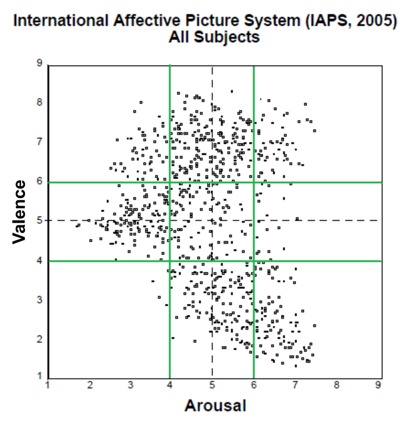
This project investigates the relationship between emotion and scalp brain activity. The aim is to **verify claims on affective correlates** by previous neurological studies. The study involves **eliciting the emotions of subjects** when they **view affective pictures** from the International Affective Picture System (IAPS) database, known to reliably alter emotional state. They are asked to rate how they feel based on **valence (positive/approach versus negative/withdrawal)** and **arousal (calm versus excited)** states of emotion. Scalp brain signals or electroencephalogram (EEG) are measured and recorded. Analysis and evaluation of the EEG data collected showed that an **increase in midline theta** (4-8 Hz) **power,** as well as **frontal alpha** (9-12 Hz) **asymmetry** and **low theta** (4-6 Hz) **asymmetry** is closely correlated with **increase** in **valence**. In addition, the result also showed that an increase in **beta** (12-35 Hz) **to alpha** (9-12 Hz) **ratio from the frontal lobe** is correlated with **increase in arousal**. These results agree with neuroscience studies in the literature and shows prospect of developing brain-computer interfaces to detect and respond to human emotions.

Purpose of Research

To investigate **feasibility of using affective information** obtained from brain-computer interface systems to determine and **analyse people's preferences** and **emotions**. Future applications of the study include design of more visually appealing products or enhancement of the interaction between humans and computers.

Background Information

In Lang's **two-dimensional scale of emotion**, emotions are mapped according to their **valence (positive/approach versus negative/ withdrawal)**, and **arousal (calm versus excited)** (Lang, 1995). For instance, fear is categorised under low valence and high arousal while contentment is categorised under high valence and low arousal. Pictures from IAPS database can be classified into **nine** categories based on **three levels** of valence and arousal.



Objectives

This experiment aims to **verify correlations between brain activity and states of valence and arousal** found in studies. The hypothesis is that the following correlates will be found upon analysis of data.

Table 1 – Valence Correlates

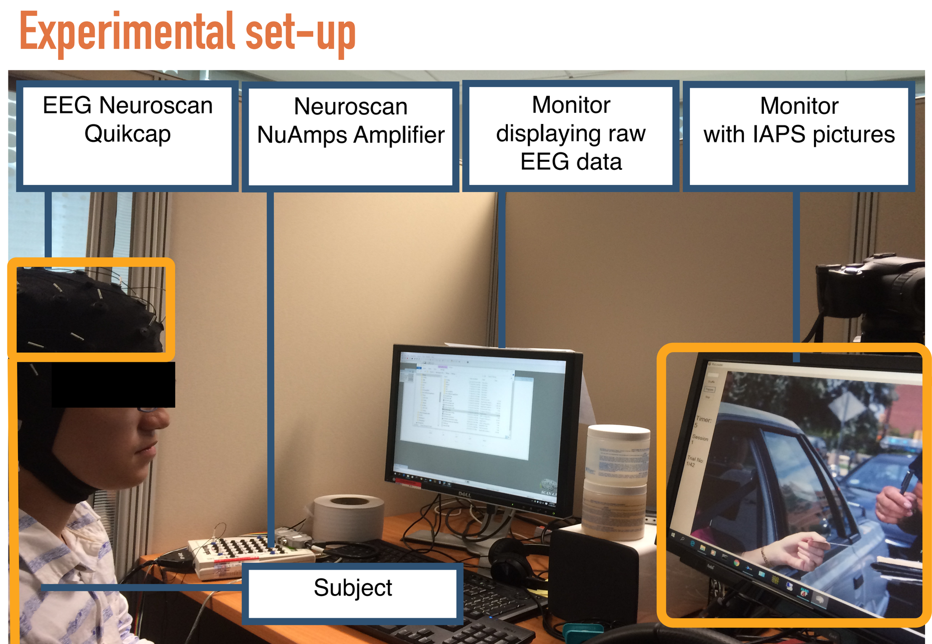
Feature/Region	Low valence or Withdrawal	High valence or Approach
Frontal activation (Reuderink et al, 2013, Harmon-Jones et al, 1998)	Right frontal cortex activation	Left frontal cortex activation
Left frontal region	Higher alpha and higher theta	Lower alpha and lower theta
Right frontal region	Lower alpha and lower theta	Higher alpha and lower theta
Frontal alpha asymmetry index, and theta asymmetry index (Aftanas et al, 2001)	More negative	More positive
Fronto-medial theta power (Sammler et al, 2008, Aftanas et al, 2001)	Lower frontal medial theta power for negative music stimuli	Higher frontal medial theta power for positive music stimuli
Medial theta power (Krause et al, 2000)	Lower midline theta power	Higher midline theta power for anger (an approach-related response)

Table 2 – Arousal Correlates

Feature/Region	Low arousal state or calm	High arousal state or excited
Frontal lobe	Lower activation	Higher activation
Frontal beta power (Oude, 2006)	Lower beta	Higher beta
Global alpha power (Barry et al, 2009)	Lower alpha	Higher alpha
Frontal beta-alpha ratio	Lower beta-alpha ratio	Higher beta-alpha ratio
Posterior region (Aftanas et al, 2002)	Higher theta	Higher theta
Right posterior region (Sarlo et al, 2005)	Low beta	High beta

Methodology

Experimental set-up



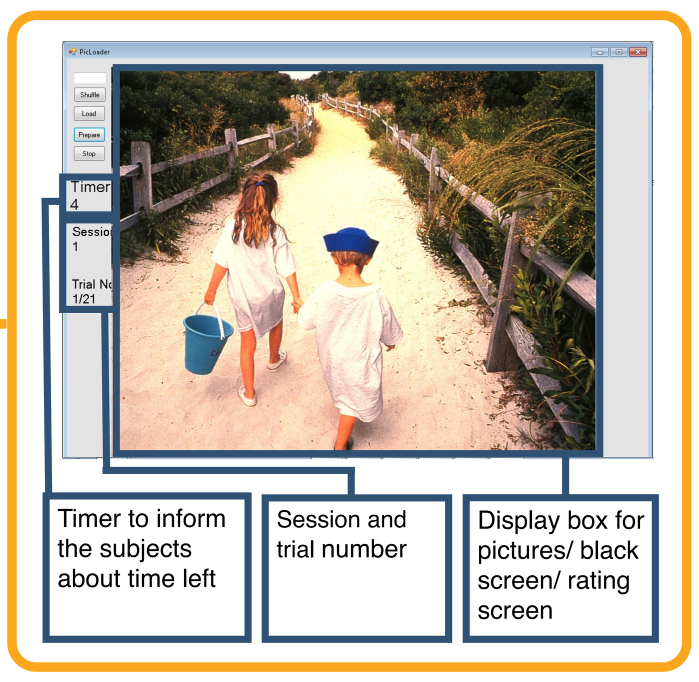


Figure 1 (top) : Subject, with EEG Neuroscan Quikcap on his head, viewing IAPS pictures from nine categories through a monitor.

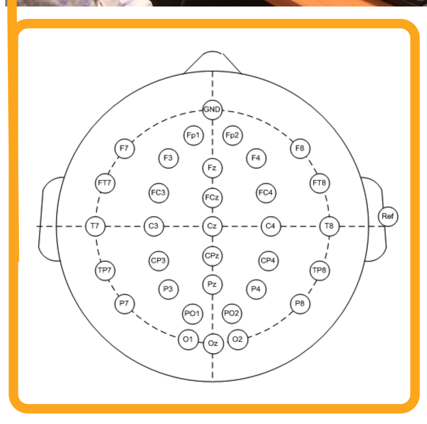
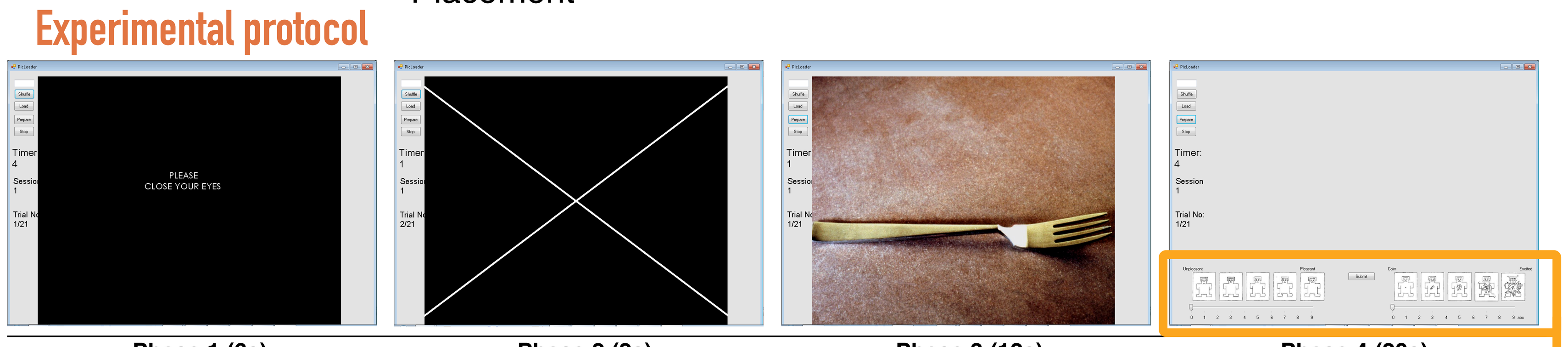


Figure 2 (left): 10-20 System of Electrode Placement

Figure 3: Program designed to display 126 pictures in random order to the subjects, to communicate with the EEG Neuroscan NuAmps Amplifier and software to send commands e.g. when to start and stop recording EEG, and to record subject ratings.

Experimental protocol



Phase 1 (6s)	Phase 2 (2s)	Phase 3 (12s)	Phase 4 (20s)
Eyes closed for subject to rest and to return their normal mental state	Eyes open to avoid accustoming and to attract the subject's attention	Affective images displayed for subjects to view	Subject evaluates feelings using SAM pictorial assessment technique

Figure 4: Timeline for the four phases of one trial. The experiment for each subject was comprised 126 trials. In each trial, subjects view and rate one picture.

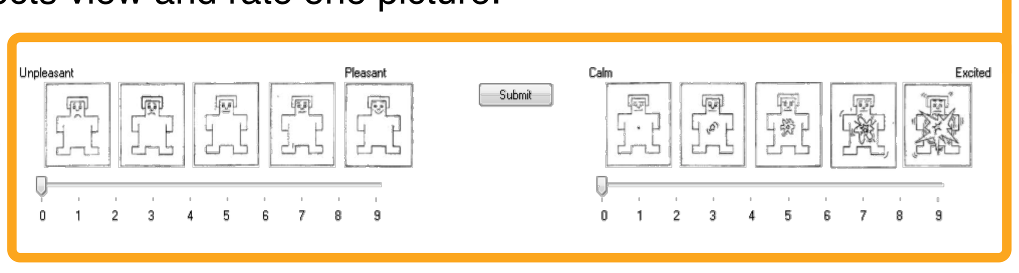
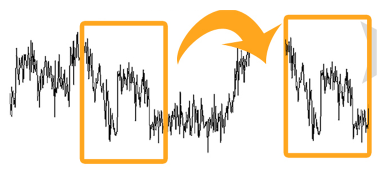


Figure 5 (right): SAM pictorial assessment technique (Lang, 1980) used to collect subject ratings (1-9) to account for varying valence (left) and arousal (right) induced by IAPS images.

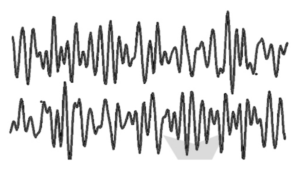
Data Analysis

1 Signal Extraction



6 seconds of picture viewing was extracted from EEG recording for further analysis

2 Bandpass Filtering



Bandpass filter was applied to **remove specific frequencies** to filter only the frequencies of interest

3 CAR Filtering

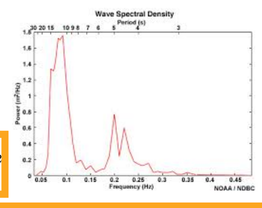
$$V_i^{CAR} = V_i^{ER} - 1/n \sum_{j=1}^{n} V_j^{ER}$$

V_i^{CAR}-voltage amplitude of the signal of the ith channel after CAR filtering
V_i^{ER} -potential between the ith channel and reference
n -number of electrodes used.

Common average reference filter is applied by subtracting the mean amplitude of the signals of the entire electrode montage from the signal of interest.

4 Power Computation

$$P_i = \frac{1}{T} \sum_{t=1}^{T} X_i(t)^2$$



P_i-power of the channel
T-total number of time samples (6s x 250Hz)
$X_i(t)$-voltage amplitude recorded for one time sample in the channel

Power computed represents the **average energy** of the entire 6-second signal for one EEG electrode.

5 Asymmetry Index/

$$A_{(R, L)} = \log(P_R) - \log(P_L)$$

$A_{(R, L)}$-alpha asymmetry between electrodes R and L
P_R and P_L-band powers at the R and L electrodes respectively.

-used to measure relative band powers across homologous electrodes.
-higher $A_{(R, L)}$ score **indicates more right alpha activity** and thus represent a **left hemispheric activation**
-should increase with **increasing valence**

Beta-Alpha Ratio

$$R_{BA} = P_B / P_A$$

R_{BA}-Beta-alpha ratio of an electrode
P_B and P_A-beta and alpha band powers at an electrode respectively.

-used as **indication of brain activation** (since beta waves are present during an alert state of mind, whereas alpha waves are more prevalent in a relaxed brain)
-Hgher R_{BA} score indicates **more brain activation**
-should increase with **increasing arousal.**

6 Averaging by category

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i$$

$\bar{x}$-Average value for the category
N-number of trials in category
x_i-Power values, asymmetry indices, beta-alpha ratio of the ith trial

Trials were divided into **three categories** based on arousal or valence either using IAPS rating or subject's SAM rating. The **average power value, asymmetry indices,** and **beta-alpha ratios** were then taken for all trials in that category.

7 Difference taking

HIGH RATING – LOW RATING

-Differences between the extreme categories were computed by subtracting average of the lowest-rating category from the average value of the highest-rating category
-Positive value indicates increasing trend

Results and Analysis

Midline Theta

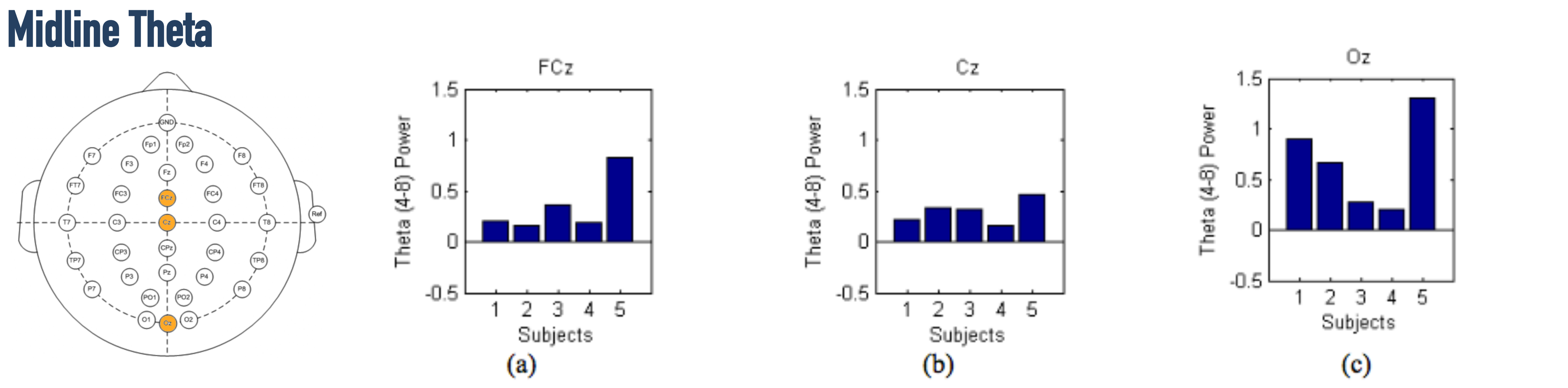


Figure 7: Graphs of **difference between average theta power** of **high (8-9)** and **low (1-2) self-reported valence ratings** for EEG channels **FCz, Cz, and Oz along the midline**. The result shows a consistent increase in theta power across all subjects along the midline electrodes as the subjects viewed pictures of increasing valence.

Frontal and Theta Asymmetry

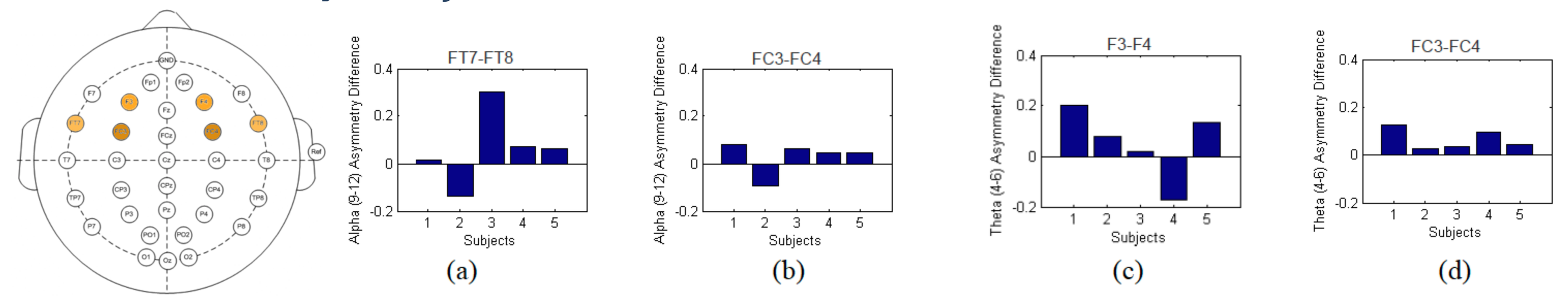


Figure 8: Graphs of **difference between average alpha asymmetry** of **high (8-9)** and **low (1-2) self-reported valence ratings** for frontal EEG channels pairs **FT7-FT8** (a) and **FC3-FC4** (b) and graph of **difference between average low theta asymmetry** of **high (8-9)** and **low (1-2) IAPS valence ratings** for frontal EEG channels pairs **F3-F4** (c) and **FC3-FC4** (d). The result shows an increase in alpha asymmetry power across 4 out of 5 subjects at channel pairs FT7-FT8 and FC3-FC4 as the subjects viewed pictures of increasing valence. The result also shows an increase in low theta asymmetry power across all subjects for channel pairs FC3-FC4 and across 4 out of 5 subjects at channel pairs F3-F4 as the subjects viewed pictures of increasing valence.

Beta-Alpha Ratio

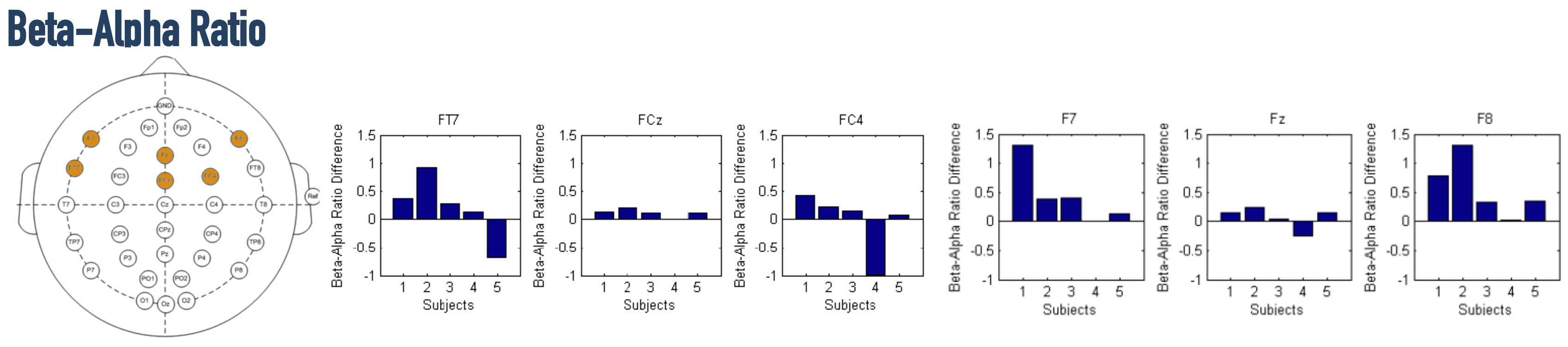


Figure 9: Graphs **of difference between average beta-alpha ratio** of **high (8-9)** and **low (1-2) self-reported arousal ratings** for frontal EEG channels **F7, Fz, F8, FT7, FCz, and FC4**. The result shows an increase in beta-alpha ratio as the subjects viewed pictures of increasing arousal.

Conclusion and Future Recommendation

The study **affirmed the results observed in other neurological studies** in the literature. The **increase in midline theta** observed was similar to the results found in neuroscience studies (Krause et al, 2000 , Aftanas et al, 2001) where it was observed that midline theta power increased with increasing valence. The result also agrees with neuroscience studies (Reuderink et al, 2013, Harmon-Jones et al, 1998, Aftanas et al, 2001) that observed **increased activation in the left frontal hemisphere** and **right frontal hemisphere** for **positive and negative valence respectively**. Finally, the results also agree with neursocience study (Oude, 2006) that reported **increased frontal beta-alpha ratio with increasing arousal**. In future, more data can be collected for a more comprehensive study. Experimental conditions and signal filtering process can be improved. Duration of picture display can also be lengthened in order to elicit a stronger emotion.

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