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Assessing Neural Oscillations during Erotic and Negative Emotional Pictures Viewing: An Event-Related Potential Study

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Abstract

The present study was designed to determine whether or not there are components of the ERPs that discriminate the erotic and negative pictures during affective picture processing. Participants viewed erotic, negative and neutral pictures form the International Affective Picture System (IAPS). Eighteen right-handed volunteer students from North-Eastern University participated in the experiment. Electrode from the frontal site (F3 and F4), C3 and C4 (central electrodes), P3 andP4 (parietal electrodes) and O1 and O2 (occipital electrodes) were averaged with the stimuli type and brain hemisphere. The change in spectral power of the brain signal and its main spectral bands of theta (3-7.5 Hz), Alpha (7.5-13 Hz) and Beta (13-25 Hz) were analyzed. Erotic stimuli showed ERP components deflected more negatively at the frontal electrode site than the negative picture stimuli during the time window of 200-300 ms whereas the negative valence stimuli processing reflected a positively twisted amplitude at the time window of 120-300 ms. The erotic and negative valence emotional picture stimuli show a significant difference in the spectral power of theta, alpha and beta frequency bands for the left *vs.* right hemisphere and frontal *vs*. occipital sites. Nonetheless, the time-frequency plots show us those emotionally valence visual stimuli triggered an increase of alpha band (7.5-13 Hz).

Keywords: Alpha power; Electroencephalography (EEG); Emotion; Event-Related Potential (ERP); Spectral power

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Introduction

Humans have interacted with their environment with the sensory information [1]. The human brain constantly samples and integrates information from the surrounding environment in order to obtain a clear representation of the outer world. Most of the sensory information in life can be guided by the emotional state through their influence on the cognitive process by visual processing of information. Consequently, the integration of novel information relies on the formation of a new association between perceptual information to form a coherent spatio-temporal representation of the environment. Therefore, human develop the ability to detect that sensory information and respond to certain challenges and opportunities [2,3] and the brain process information between specially distributed but functionally linked region [4,5]. One of the best methods used to nursing the brain activity is the electroencephalogram (EEG) from the single-unit recordings to large scale cortical dynamics [6].

Emotional human experience and the brain response could result in dysfunctions of emotional processes or disorders which may be reflected through changes in neural activities. Consequently, assessing the special distribution of emotion evoked ERPs is necessary and the identification of the emotional expression from visual information is very important for every communication [7]. There is a considerable evidence that various stage of processing of emotional stimuli is correlated with amplitude modulation of ERPs in specific time range around 100 ms post stimuli interval typically results in increased amplitude of some ERP components. The ERP can be used to classify different visual stimuli and unrelated emotional state of the stimuli [8]. It is widely defined as the temporal process involved in emotional event processing and it is the measured brain response with electroencephalography that is the direct result of a specific event and the most widely used method in cognitive neuroscience research. Over the last 15 years, ERP has been used to investigate the neural mechanism underlying risk-related decision [9]. Therefore, to measure a change of scalp electrical activities towards the emotional content of visual stimuli, the brain event-related potential (ERP) is used. As Leuchs, et al., also explains, the ERP can be used to assess emotional conditioning and have numerous useful properties: ERP gives a direct and fast response of the central nervous system with an onset latency of around 300 ms. There are many investigations that used ERP techniques in human subjects for analyzing the time course with which various types of stimuli are processed [10-12]. N, P, and EPN (Early Posterior Negativity) were some of the reliable markers of the emotional processing from the ERP component [13].

The way the human brain relies on visual processing to underlying the neural oscillatory activity during the processing of erotic and negative valence emotional stimuli is to be explored. Therefore, the current study was designed to determine whether or not there are components of the ERPs that distinguish the erotic and negative pictures during affective picture processing. Participants viewed erotic, negative and neutral pictures form the International Affective Picture System (IAPS). We measured the ERP amplitude in accordance with the mean ERP topographies and amplitude. Investigation of such emotional states and their effect on ERP components and oscillatory rhythm can be processed by many toolboxes. From the freely available toolbox, we used EEGLAB and ERPLAB for analyzing ERP components during visual processing. Variation in latencies, frequencies based on topography and amplitude of those ERP components were analyzed. The pattern of oscillations for the three different frequency bands, theta (3-7.5 Hz), alpha (7.5-13 Hz) and beta (13-25 Hz) associated with erotic and negative valence emotional stimuli responses were analyzed.

Materials and Methods

Participants

Eighteen right-handed volunteer students from North-Eastern University were recruited and participated in this experiment. We took samples from the university students and their age range was from 24 to 31 years. All of the participants were without any history of neurological or psychiatric disease. All the subjects were reported as normal hearing and normal/corrected-to-normal vision. Participants were asked to abstain from alcohol, drug use, caffeinated beverages, and food prior to attending the experiment. Detailed instructions about the experiment were given for the participant and all of them were given written informed consent at the beginning of the experiment. Then, participants were asked to perform an oddball paradigm of the erotic and negatively valence visual stimuli. All the participants have no idea about the content of the experimental stimuli when they perform the experiment.

Stimuli materials

A total of 90 pictures were collected from the IAPS (International Affective Picture System) [14] for the experiment. Of these images, 30 depicted erotic events (erotic depictions of heterosexual couples), 30 depicted neutral events (e.g., vegetation, household objects, and buildings), and 30 depicted negative events (e.g., wreckage, a snake, and a horrible face). The erotic, neutral, and negative pictures used for the current study were selected from IAPS (International Affective Picture System) [14]. The picture-rating tasks were selected from the IAPS. The negative pictures had a low valence (≤4) and high arousal (≥6), neutral images had a moderate positive valence (≥ 4 and 7.2) and low arousal (between 2 and 4) and erotic pictures had a high valence (≥ 5.24 and 7.6) and high arousal (≥3.36 and 6.67) based on the IAPS score. The experimental Images with the highest arousal ratings from the negative and erotic picture categories as well as those with the lowest arousal ratings from the neutral category were selected. All the pictures used for the experiment were the same in size and brightness.

Erotic, negative, and neutral pictures were collected from the IAPS (International Affective Picture System) [14] were selected with the following catalog numbers. Erotic: 4001, 4002, 4005, 4006, 4007, 4008, 4071, 4150, 4220, 4225, 4233, 4311, 4325, 4500, 4510, 4559, 4604, 4619, 4625, 4626, 4628, 4641, 4643, 4645, 4650, 4653, 4660 4677, 4693, 4695 Neutral: 5201, 5210, 5215, 5220, 5250, 5220, 5600, 5725, 5726, 5780, 5833, 7002,7004, 7009, 7255, 7260, 7350, 7450, 7460, 7472, 7375, 7477, 7480,7489, 7495, 7500, 7505, 7508, 7530, 7950 Negative: 1019, 51114, 1300, 2691, 2694, 2695, 2704, 2780, 2800, 2811, 2981, 3019, 3059, 3100, 3168, 3185, 3219, 3225, 3280, 3300, 3310, 3500, 6520, 6540, 6550, 6563, 8400, 23522, 30051, 35501

Experimental design and data collection

Participants come to the laboratory and the application of the EEG experiment was briefly explained, after this activity written informed consent was obtained. Before the EEG data collection began, the picture rating task was described. The electrodes were fitted into an elastic cap following the international 10-20 system. Two separate electrodes were used as ground electrodes and four additional electrodes, placed near the outer canthi of the eyes and above and below the right eye, measured horizontal and vertical eye movements (Electro-Oculogram, EOG).

The task was presented with STIM 2 software and displayed on a 21-inch computer LCD screen with a full resolution of 1280 × 1024 pixels at a distance of around 80 cm. The inter-stimuli interval of the experiment was 1000 ms and each stimulus was seen for 2000 ms. EEG was recorded from 32 Ag/AgCl BioSemi active electrodes (BioSemi, Inc., The Netherlands) at a sampling rate of 1000 Hz during a visual oddball paradigm based on an international 10-20 system. Participants responded with a keyboard for the target stimuli pictures. The picture stimuli were presented in to three blocks. Order of the picture stimuli within each block was random for every participant and the order in each block was counterbalanced across participants.

To examine signal distribution across the scalp, the data were averaged into a frontal (F3, F4), central (C3, C4), parietal (P3, P4) and the occipital (O1, O2) electrode clusters **(Figure 1)**.

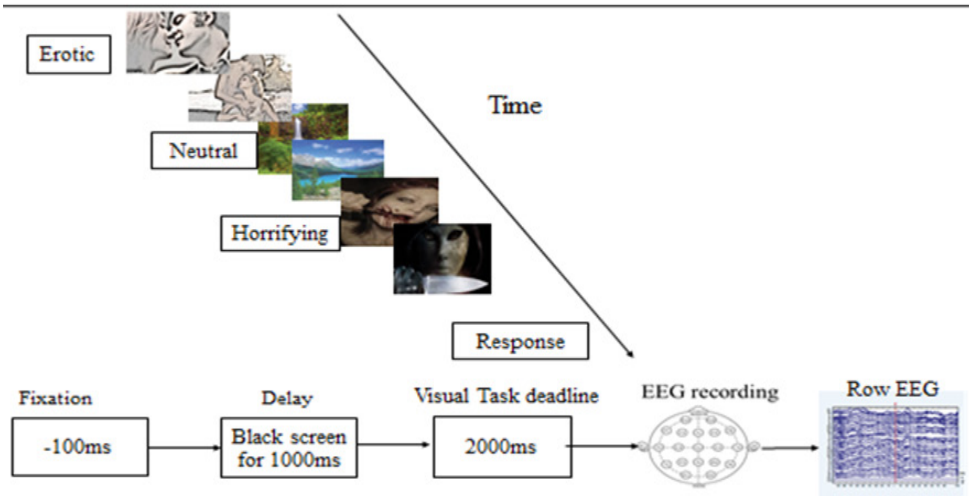

Figure 1 Block diagram of the experiment.

Pre-processing and Epoch extraction

EEGLAB and ERPLAB were used for the data processing and detection of ERP components [15]. The EEG signals collected from the experimental conditions were imported into EEGLAB software to extract epochs. The continuous EEG data were assigned based on electrode coordinates, re-referenced to Cz and, after removing linear trends, filtered with separate hamming window. We applied a band pass filter from 0.1 to 40 Hz by using the ERPLAB toolbox. Data epochs with high artifacts were removed with visual inspection and then the independent component analysis was performed for feature extractions. The epochs were covered a time interval from -100 to 600 ms (pre and post stimuli interval). The cleaned EEG epochs were processed by ERP Lab for further analysis. For each condition, the averaged ERP was computed for both erotic and horrible picture stimuli. The data entered in a repeated measure ANOVA with respect to channels and three conditions (erotic, neutral, and horrible). The mean percentage of valid epochs for the relevant electrodes was 92%. The change in spectral power of the brain oscillation and its main spectral bands of theta (3-7.5 Hz), alpha (7.5-13 Hz) and beta (13-25 Hz) were analyzed for all affective stimuli.

ERP and spectral power analysis

ERP and spectral power analysis were performed to evaluate the effect of erotic and negative emotional pictures on the electrical activity of the human brain. Cleaned and filtered EEG data epoch (form -100 to 600ms) was taken for further analysis. The mean value of the ERP amplitude (P2, N2, P3, and EPN) and the spectral power were interred into statistical analysis with a hemispheric difference (left *vs.* right) and (frontal *vs.* occipital). The ERP components (i.e., N2, P2, N3, P3, and EPN components) were taken as a dependent factor and erotic and negative valence emotional stimuli as independent factors for the statistical analysis. Thus, mean amplitude was interred into a statistical analysis and comparison was done between each brain hemispheres. In addition, the statistical analysis of spectral power was analyzed in terms of each frequency bands (i.e., theta, alpha and beta bands).

Results

Behavioral performance

The response time and percentage of correct response (accuracy rate) were compared across all trial type. The participants were faster to judge emotional pictures (especially the erotic pictures) than the neutral images. Female subjects were more accurate for the negative emotional pictures than male subjects (96% *vs.* 93%). The female participants also have a faster reaction time for the negative scene than the male participants. When we compare across conditions, the accuracy and the reaction time was slower for erotic picture stimuli than the negative pictures. According to Grass et al., emotionally negative stimuli can initiate a rapid response than the neutral one [16]. The behavioral results of the current study show that male participants were faster and accurate when the erotic pictures were displayed while females were slow in response time but high in response accuracy for the negative emotional pictures **(Figure 2)**.

ERP analysis

The brain event-related potential (ERP) and neural oscillations during erotic and negative valence emotional stimuli were analyzed. ERP have been widely used to examine the time course of neural activity associated with affective picture processing [17,18] and it is the most effective method. Electrode voltage from F3 and F4 (frontal electrodes), C3 and C4 (central electrodes), P3 and P4 (parietal electrodes) and O1 and O2 (occipital electrodes) were averaged with the stimuli type and brain hemisphere (left *vs.* right and frontal *vs.* occipital. ERP amplitude was measured in accordance with the mean ERP topographies (in terms of time and frequency analysis). The ERP component with the time window of P2 (150-275 ms), N2 (200-270 ms), P3 (350-500 ms), and EPN (120-200 ms) were analyzed. The EPN was analyzed at the occipital area (O1, O2 and O2) with a time window of 120-

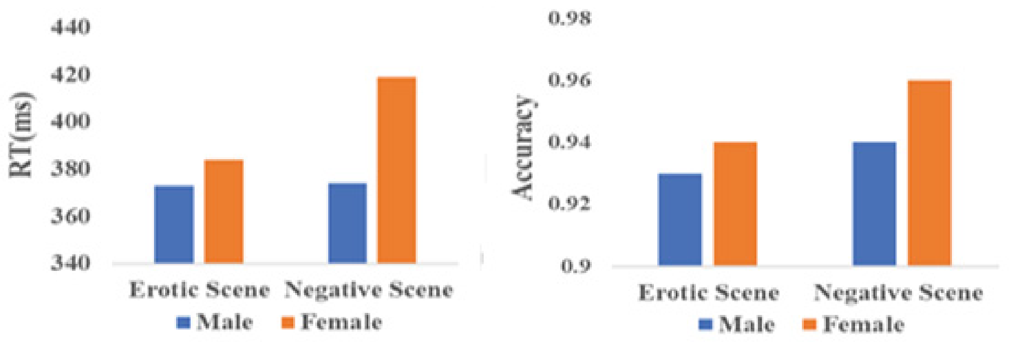

Figure 2 Grand average event-related potentials elicited by emotional visual stimuli at selected.

200 ms while the N2 amplitudes were identified at the frontal electrodes (F3, Fz and F4) at the latency range of 200-270 ms.

According to Freunberger et al., P2 is related to attention, and memory, it varies at a latency between 150-275 ms [19]. Erotic stimuli showed more negatively deflated amplitude at all brain sites than the negative valence picture stimuli during P2 latencies. There is a high pick amplitude around 175 ms for the two conditions, the erotic stimuli exhibited shorter latency with a high P2 pick amplitude than the negative picture stimuli. While the parietal electrodes (P3, Pz, and P4) showed positively deflected ERP waveforms at the time window of 100-300 ms for horrible pictures. Here, erotic pictures elicited a negatively deflected amplitude at the time window of 60-120 ms and 250-300 ms. Likewise, a negative picture also elicited a negatively deflected amplitude at the time window of 60-120 ms. The statistical analysis showed as the ERP waveforms for an erotic stimuli trials deflected more negatively than those on horrible over at the range of parietal electrode sites (p=0.002) and at occipital electrode sites (p=0.02) during the P1 time-window (80-120ms). During the N2 (200-270ms) time-window, the main effect of emotional expression persisted with a high amplitude (p=0.05). The N2 amplitude was associated with attention history and the effect was independent of emotion. In addition to the association with attention control enhanced N2 was also observed in situations where attention was directed to novel stimuli.

The current study shows there is an association of P3 amplitude with the emotional valence and brain sites. The amplitude of P3 was low for the erotic picture stimuli than the negative valence emotional stimuli at all brain regions except the frontal sites **(Figure 3)**. Nevertheless, the central region of the brain shows a significant difference in P3 amplitude. According to Lapsekili et al., task-related cognitive processes like attention are related to P3 and it measures the process of memory and attention of the neural activity [20]. The P3 analysis is done in terms of amplitude and latencies which indicates attention and speed of classification of the given stimuli. A reduced amplitude and prolonged latency of P3 indicated cognitive function disorders. The brain network property or network efficacy is correlated with large P3 amplitude evoked in the P3 task [21]. Thus, there is a decrease in P3 amplitude during the visual processing of the current study which indicates a decrease in the neural efficacy. In addition, early posterior negativity (EPN) amplitude for similar conditions might reflect more allocation of attentional resources during emotional processing. And the change in EPN amplitude could help to understand the role of emotional information during the early attentional process. So, here we tried to interpret the role of affective contextual effect on the emotional influence of the particular stimuli processing and its ERPs correlates. As shown in **Figure 3**, erotic pictures can prompt higher amplitude of EPN than the horrible stimuli. While negative pictures processing shows a positively deflation from 100 ms but there is no switching effect obtained at the occipital electrode sites.

The time-specific response and phase synchronization of the brain activity is dependent on ERP averaging measures. The result of the current study showed that when we are exposed to emotional (but different in arousal and valence) stimuli, there is an enhancement of N1 of the post stimuli onset and an N3 was elicited within the time window of 250-350. As the topographical plot in **Figure 3** showed erotic stimuli show a more pronounced power than the negative stimuli except for the P3 component. The occipital brain site showed a high power when the participants were exposed to negative valence stimuli. EPN is one of the ERP components that we have seen here, but there is no significant difference between the negative and positive valence emotional stimuli.

The topographic plot of the P3 showed a higher power as shown in **Figure 4**. T-test results also revealed negative valence pictures showed a significant main effect (P<0.01) which indicates a negative picture elicited a greater late positive potential than the erotic stimuli. Nonetheless, the ANOVA result tells us the erotic picture induces a higher amplitude for all selected electrode than the horrible pictures. Simple effect analysis suggests that for the left active electrodes, horrible pictures induced larger P3 amplitude than the erotic picture but not significantly. The same thing happens for the right electrodes too. While the central groups revealed a difference in the amplitude of P3.

Change in spectral power

Electroencephalographic analysis of spectral power plays a predominant roll in the recognition of emotion to reflect activity differences among multiple brain regions [21]. The positive and negative valence emotional picture stimuli show a significant

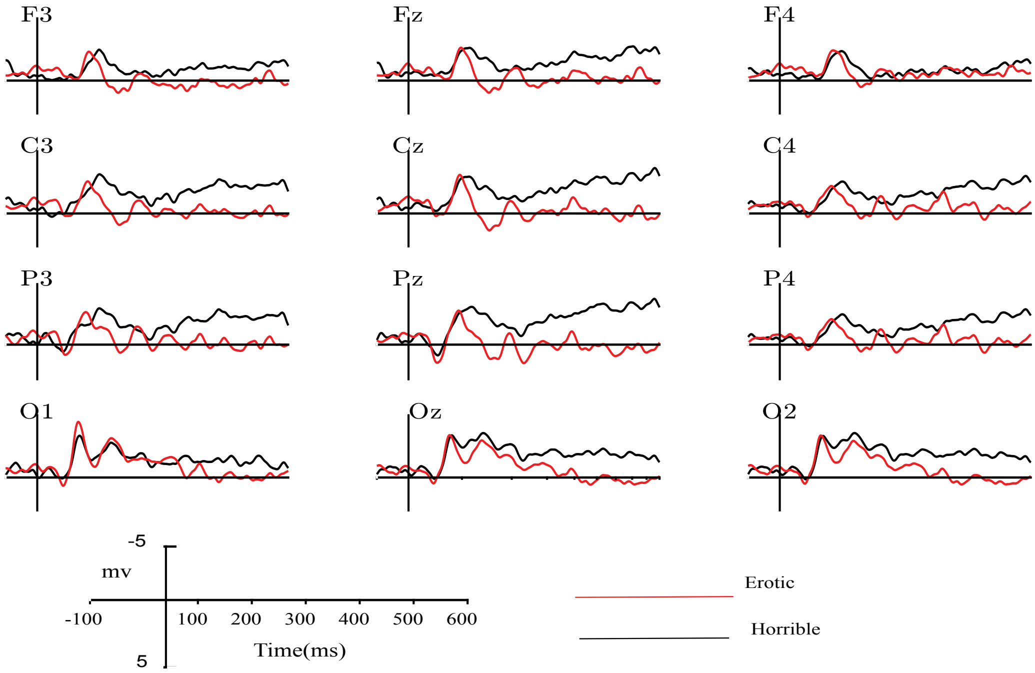

Figure 3 Grand average event-related potentials elicited by emotional visual stimuli at selected.

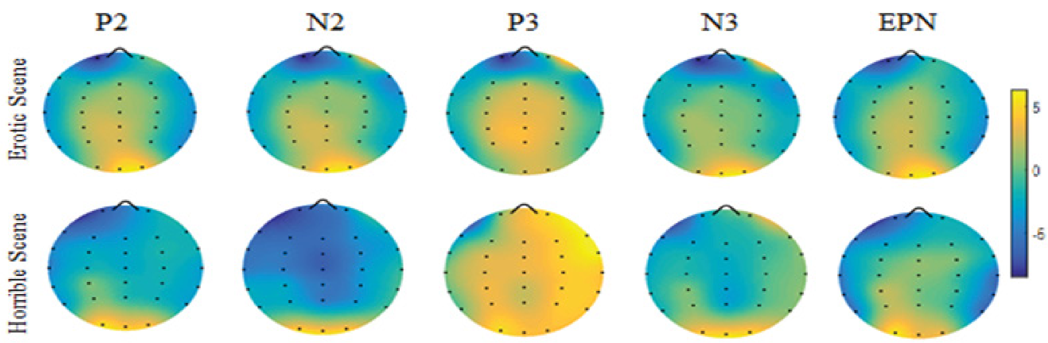

Figure 4 The topographic plot which shows the ERP components performed for comparison. Those visual stimuli were performed and show a clear effect on the P3 time window.

difference in the spectral power of theta, alpha and beta frequency bands for the left *vs.* right hemisphere and frontal *vs.* occipital sites. Nonetheless, the time-frequency plots show us the visual stimulus triggered an increase of alpha band (7.5-13 Hz) during an emotional picture processing. Meanwhile, the alpha power was concentrated at the occipital area during the negative valence picture processing and at the fronto-central and parito-occipital area during the processing of positive valence pictures. Although a decrease of theta band power (4-7.5 Hz) was observed. A low theta power was induced in the frontal area during negative picture processing. Similarly, a relatively low beta power was observed at the left hemisphere as shown in **Figure 5**. The power distribution on the topographical plot showed that there is a typical local maximum of the alpha frequency band as compared to theta and beta bands.

The fronto-central theta band activity showed a change in emotion ($p<0.05$). Theta band activity peaked when participants view the horrible picture stimuli. The parioto-occipital electrodes revealed low suppression with emotion ($p<0.01$). Whereas the beta band activity showed no main effect for the emotional content of the stimuli both at the frontal or occipital area. But there is some spectral change that appeared to the left hemispheric position of the brain **(Figure 5)**. The ANOVA test showed that there is no significant interaction was observed between emotion and lateralization. The electroencephalographic power was highly reducing at beta frequency bands especially at the right hemisphere for both conditions.

Discussion

The purpose of this study is to examine the neurological responses for emotional visual stimuli by using erotic and negative pictures. Our assumption was the processing of the erotic and negative

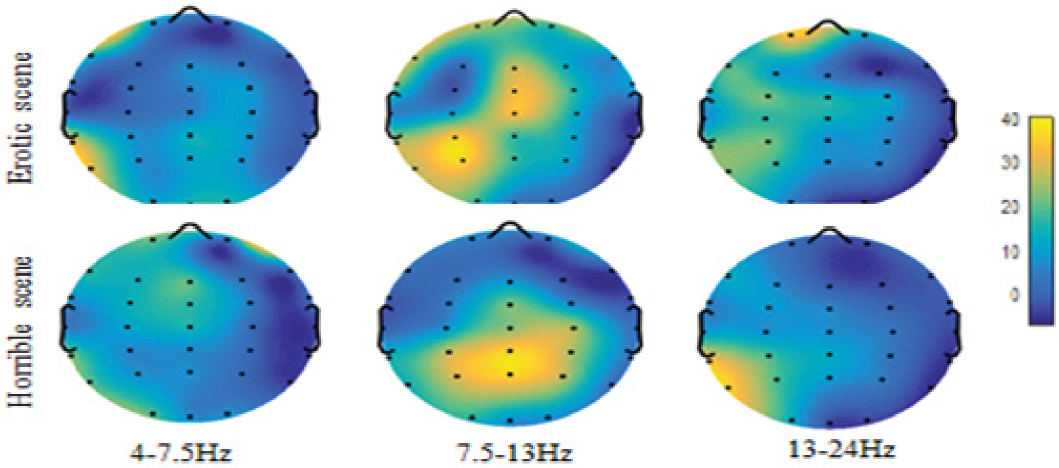

Figure 5 Time-frequency analysis of EEG signals between erotic and horrible scene. The topographic plots show the effect of emotion difference on alpha-band power.

emotional stimuli varies on the latencies, amplitude and spectral power of the components. Emotional pictures were used widely as a stimulus in numerous researches but there is lack of standardization for erotic picture stimuli. Those visual stimuli might have an association between a numbers of psychological problems and sever impairment of neurological functions. Therefore, the aim of the present study was to use a set of erotic and negative emotional picture to understand weather there is an effect on neurological functions. Participant perception towards the stimuli as positive and negative can increase the motivational significance of the stimuli which leads to an enhanced brain response. Researchers showed that the reconfiguration of the brain network is related to once cognitive behavior [22,23]. The late visual processing is associated with late visual processing modulated by salience and attention [24]. **Figures 3 and 4** in the current study shows that a significant difference between erotic and negative emotional stimuli for P2, N2, P3, N3, and EPN. The differences in the processing of the given emotional stimuli were reflected by the latencies and amplitude of those ERP components. According to Paulmann. et al., the difference in the basic emotions can be differentiated during an early event-related potential (ERP) component and this difference in the amplitude of an EEG signal occurred by the difference of neural engagement in response and the degree of their synchronizations [25]. The current study also showed a significant difference between N1 and N2 ERP components. The occipital area showed a decrease in the amplitude of the late ERP components (i.e., N3 and P3 component). This is supported by Tracy et al., which shows that the LPP was smaller following negative interpretation at the posterior recording sites while larger at the anterior (frontal) sites [26]. When we see the reaction time, reaction time is influenced by emotional valence and the positive valence emotional stimuli elicited high amplitude within a shorter time range. This result is supported by Schocht and Sommer [27]. They described that positive valence emotional stimuli have shortened reaction time than that of the negative valence emotional stimuli.

The spectral analysis of the current study showed that alpha power is more prominent and showed a typical hemispheric lateralization effect when participants viewed erotic pictures. As indicated by the periodic visual stimulation during an EEG study can probe a frequency-specific brain activity [28,29]. For this study, alpha power was prominent for both conditions but higher for erotic stimuli. The presence of high alpha power indicates that there is lower cortical excitability and predicted decreased stimulus detection. In addition to this, the parieto-occipital alpha-band power is linked with the perceptual process [30] and some recent studies suggested that alpha-band can be synchronized to the visual stimulation [31]. Another study also describes as the posterior alpha oscillations were suppressed in the presence of visual input [32] the existing study showed that there is a suppression of alpha oscillation when participants view an erotic scene. Negative valence emotional stimuli showed a higher alpha oscillation at the occipital area and according to Ruzzoli and Faraco the appearance of alpha-band at the posterior parietal cortex is also related to special attention shift of different sensory modes, whereas the occipital alpha band is related with preparatory attentions [33,34].

Conclusion

Different researches on human emotional stimuli processing has been conducted to understand how the human brain react with them and how it functions during processing. We analyzed the influence of erotic and negative valence emotional stimuli processing and its correlation with the ERP component. Our ERP analysis revealed that there is a significant difference between a negatively and positively valence emotional stimuli in the case of time window, amplitude and spectral power and it is because the affective context of the emotional stimuli can influence the nature of the ERP components.

Ethical Consent

Healthy volunteer participants were recruited to attend the

EEG experiment. All participants filled an informed consent in accordance with the declaration of the Helsinki and agreed to perform the experimental paradigm.

Conflict of Interest

We declare that, we don't have any significant computing interest that might have influenced the performance and presentation of the work described here.

Acknowledgement

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