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A study on EEG-based brain electrical source of mild depressed subjects

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ABSTRACT

Background and objective: Several abnormal brain regions are known to be linked to depression, including amygdala, orbitofrontal cortex (OFC), anterior cingulate cortex (ACC), and dorsolateral prefrontal cortex (DLPFC) etc. The aim of this study is to apply EEG (electroencephalogram) data analysis to investigate, with respect to mild depression, whether there exists dysregulation in these brain regions.
Methods: EEG sources were assessed from 9 healthy and 9 mildly depressed subjects who were classified according to the Beck Depression Inventory (BDI) criteria. *t*-Test was used to calculate the eye movement data and standardized low resolution tomography (sLORETA) was used to correlate EEG activity.
Results: A comparison of eye movement data between the healthy and mild depressed subjects exhibited that mildly depressed subjects spent more time viewing negative emotional faces. Comparison of the EEG from the two groups indicated higher theta activity in BA6 (Brodmann area) and higher alpha activity in BA38.
Conclusions: EEG source location results suggested that temporal pole activity to be dysregulated, and eye-movement data analysis exhibited mild depressed subjects paid much more attention to negative face expressions, which is also in accordance with the results of EEG source location.

1. Introduction

A World Mental Health Survey conducted in 17 countries found that on average about 1 in 20 people reported having an episode of depression sometime in their life [1], and it is estimated that depression will constitute the second largest burden of disease by the year 2020 [2]. A large amount of brain imaging research has been focused on the neural correlates of depression using experiments that monitor emotions [3–5]. The emotion-based studies found that some brain regions, such as amygdala, orbitofrontal cortex (OFC), anterior cingulate cortex (ACC), dorsolateral prefrontal cortex (DLPFC), tends to generate abnormal activities in depression [6].

The functional magnetic resonance imaging (fMRI) and magnetic resonance imaging (MRI) techniques have high spatial resolution, but suffer from relatively low temporal resolution. On the other hand, EEG (electroencephalogram) has higher temporal resolution, is inexpensive, and simple to use. EEG is therefore commonly used as an input to techniques

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that investigate brain activity. Meanwhile, research [7] proposed new method to help solve the inverse source imaging technologies. Another example is sLORETA which uses source EEG to compute images of neuronal activity. These images are then used to accurately identify the 3D distribution of the neuronal activity [8]. Other examples include work by Farahbod et al. that demonstrated a more pronounced lateralization effect in normal healthy controls than those of MDD (major depressive disorder) subjects when changing from a resting (eyes-closed) condition to viewing faces without emotional valence [9]. Ricardo-Garcell et al. reported that both hemispheres could be affected by MDD, but abnormal EEG sources can be found more frequently in the right side, with the maximal abnormal inverse solution at the alpha and theta bands in frontal and parietal cortices [10]. Other researches have also proved differences between mild depressed subjects and healthy controls in delta, theta, alpha and beta bands with EEG source location techniques [10–14].

To our knowledge, current research has focused on the severely depressed, with mild depression receiving considerably less attention. Taking into account the previous research on major depression disorders (MDD), we suppose that, like MDD, mild depression subjects would also have a bias towards negative face expressions, but with the typical brain activity less pronounced. Hence, the aim of this study is to test this hypothesis by observing the abnormal brain regions of mildly depressed subjects during the viewing facial expression pictures.

2. Methods

2.1. Subjects

Thirty seven subjects were recruited from a local university to participate in this study. All of them were right-handed, with normal or corrected-to-normal vision. In order to classify the emotional state of the subjects, several measures of depression and anxiety were used: 18 participants (3 females and 15 males) were chosen based on Beck Depression Inventory-II (BDI-II) [15] scores they completed before the tasks. A BDI score of $\geq$13 was considered to indicate a depressive state; <9 was considered to indicate a non-depressive state. The subjects were also asked to give information with respect to an OASIS(Overall Anxiety Severity and Impairment Scale) measure. OASIS [16] is a five-item self-rating scale which can be used to access anxiety disorders. Subjects are judged to have significant anxiety symptoms when their score is greater than 8. K10 (Kessler Psychological Distress Scale) [17] was also used to measure anxiety and depression, a score greater than 20 was considered to be evidence of depression or anxiety. All participants gave informed consent and were rewarded for their participation.

2.2. Task and experimental procedure

The stimulus materials were selected from Chinese Facial Affective Picture System (CFAPS) [18] which has 870 Chinese affective facial pictures of 7 types of emotions, including 74 of anger, 47 of disgust, 64 of fear, 95 of sadness, 150 of surprised, 222 of calm, and 248 of happy. The 15 negative pictures used were randomly selected from the system except calm, happy, and surprised. CAFPS contains face pictures of undergraduates indicating several types of emotion.

The whole experiment includes two blocks which take approximately 3 min each. Each block contains 15 trials, therefore the experiment consists of a total of 30 trials. Block 1 contains 15 trials with two neutral Chinese facial expressions shown simultaneously. Block 2 contains 15 trials with one neutral Chinese facial expression on one side and one negative emotional expression (sad, angry, depressed, terrified) on the another. The pictures appear randomly in each block.

Stimuli were displayed on a black background screen. At the beginning of the experiment, participants were given 5 practice trials from a separate set of images to ensure that they understood what to do.

2.3. EEG and eye-movement recordings

The experiment took place in a sound-attenuated, light-dimmed, and air-conditioned room. The EEG was acquired with a 128-channel HydroCel Geodesic Sensor Net, and Net Station software, version 4.5.4. All Electrode impedances were maintained below 70 kΩ [19]. All channels were referenced to Cz during acquisition. The continuous EEG signals were recorded at sampling rates of 250 Hz. We chose the following 70 electrodes: F10, AF8, AF4, F2, FCz, FP2, Fz, FC1, FPz, AFz, F1, FP1, AF3, F3, AF7, F5, FC5, FC3, C1, F9, F7, FT7, C3, CP1, FT9, C5, CP3, T9, T7, TP7, CP5, P5, P3, CPz, TP9, P7, P1, Pz, P9, PO7, PO3, O1, POz, Oz, PO4, O2, P2, CP2, PO8, P4, CP4, P10, P8, P6, CP6, TP10, TP8, C6, C4, C2, T8, FC4, FC2, T10, FT8, FC6, FT10, F8, F6, F4.

Eye movements were recorded synchronously by an Eyelink1000 eye-tracking system (SR Research, Ottawa, Ontario, Canada), which uses infrared video-based tracking technology, to record the left eye movement trajectory of each participant. Participants sat approximately 60 cm from the screen. Data was sampled at 250 Hz and the visual angle corrected to no more than 0.5 degrees error. The eye-tracker was paired with a 17-in. display screen at a resolution of 1024×768, with a chin rest to minimize the head movements. Data viewer software was used to extract fixation and pupil characteristics during the observations for later offline analyses.

2.4. EEG data preprocessing

A band-pass filter of 1–40 Hz and a notch filter of 50 Hz were applied to the data to reduce noise and eliminate ocular artifacts. Raw EEG data of each participant was separated into 30 segments (each segment corresponding to one trial) and analyzed offline using the MATLAB R2010a software package.

2.5. Eye movement data processing

Eye movement tracking has proved to be an important tool for the study of attentional biases in depressed and non-depressed individuals. The following fixation and pupil characters from the raw data were collected by the eye tracking