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Neural substrates of emotional interference: A quantitative EEG study

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ABSTRACT

Emotional stimuli are known to capture attention and disrupt the executive functioning. However, the dynamic interplay of neural substrates of emotion and executive attentional network is widely unexplored. The present study attempts to elucidate the areas implicated during emotional interference condition.

Fifteen right handed individuals [24.64 ± 2.63 years] performed two emotional interference tasks – Face Word Interference and Word Face Interference. Single trial EEG was recorded during baseline (eyes open) and during the tasks. The activity of the cortical sources was compared between the tasks and baseline for 66 gyri using sLORETA software.

Eighteen gyri in Face Word Interference and fifty-four gyri in Word Face Interference have shown significantly decreased activity [$p < 0.05/66$] with respect to baseline respectively.

Interestingly, in both the interference tasks, there was disengagement of fronto-parietal attentional networks (implicating the probable ability of emotional stimuli to disrupt cognition) and the areas associated with default mode network. Further, during baseline there was significant activity in premotor cortical areas, which may be due to active inhibition of motor movements associated with response.

1. Introduction

In day to day life, we face situations in which emotional interference affects cognitive control. Prioritized processing of emotional stimuli effect cognition and behavioural physiology.In the present study, cognitive attentional resources and cortical areas associated with the functional aspect of emotional interference has been mapped.

Emotional information might have privileged entree to neural resources if attentional capacity is intact [1–3] resulting in possible interference of cognitive goals [4]. This might indicate that emotive stimuli can momentarily access neural resources and manifest as disruption in cognitive process. On the contrary, B. T. Miller & D' Esposito in 2005 [5] and E. K. Miller & Cohen in 2001 [6] reported that an individual can perpetuate cognitive engagement despite distractions (emotional or non-emotional). This ability may be due to involvement of fronto-parietal cortical regions exhibiting “top-down” cognitive control.

The neural substrates studied in relation to emotion processing include amygdala for fear [7], orbito-frontal cortex (OFC) for emotion processing and stimulus–reward associations [8], whereas ventromedial prefrontal cortex (VMPFC) or the brainstem circuitry mediates emotionally relevant physiological changes of the body [9,10]. Modulation and controlling of emotional response [11,12] is associated with Dorsolateral prefrontal cortex (DLPFC) and the cingulate system. Both the divisions of anterior cingulate cortex (ACC) subserve different functions; the dorsal ACC is associated with cognitive control whereas the rostral ACC is associated with regulation of emotions [11]. ACC is implicated as a neural substrate for conflict monitoring and resolution in studies of cognitive control of emotional interference. ACC, ventrolateral prefrontal cortex (VLPFC) and DLPFC are implicated to activate response inhibition during cognitive-emotion interference tasks [13,14].

Modulation of emotion-cognition interaction has brought into limelight neural processes associated with attenuation of limbic-amygdala responses [15,16]. An amygdala–frontal circuit of emotion generation and regulation [17–19] has been discussed in literature widely.

Researchers have reported through anatomical tracing that there exist strong reciprocal connections between amygdala, ACC, OFC, VLPFC and dorsomedial prefrontal cortex (DMPFC) [20–22]. However, only few studies have documented the dynamic crosstalk between regions within the amygdala–frontal circuit. A top–down inhibitory effect of prefrontal brain regions on the amygdala [23–27] has been postulated as the mechanism for conscious down-regulation of emotion.

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Ochsner et al in 2002 [24] demonstrated a negative correlation of brain activity between VLPFC and amygdala during active reappraisal. Urry et al. in 2006 [28] recently demonstrated that attenuation of amygdala activation was associated with enhanced activation in VMPFC bilaterally during conscious regulation of emotion. Only one study in working memory domain has recently demonstrated the negative correlations between amygdala and the components of the dorsal frontoparietal task network during resting state [29]. However, there is no study demonstrating the cortical sources of emotional interference in direct comparison to resting state conditions. Thus, the effect of emotive stimuli on cognition (while performing emotional interference task) and cognition on emotive neural networks (resting state) is not well elucidated.

Hence, the present study was aimed to quantify and compare neural sources of activity during emotional interference task conditions and resting state (eyes open) conditions using high density quantitative electroencephalography (EEG).

2. Material and methods

Fifteen right handed healthy volunteers of either gender (7 males, 8 females, 24.64 ± 2.63 years) participated in this study. Participants were excluded if they self-reported any past or present history of psychiatric / neurological disorders. All the participants had corrected visual acuity of 6/6. This study was conducted at Stress and Cognitive Electro Imaging Laboratory (SCEL), AIIMS, New Delhi. Ethical clearance was taken from the institutes ethical committee of All India Institute of Medical Sciences, New Delhi (IECPG-214/24.02.2016).

2.1. Emotional interference task

An emotional interference task was used to elicit the phenomenon of emotional interference in laboratory settings. It was designed using IAPS (International Affective Picture System) pictures bearing human facial emotional expressions and emotional words from ANEW (Affective Normative English Words) were written across it using Adobe photo shop.

Ten pictures each belonging to three categories of emotion (negative < 4, neutral 4.5 < 6 and positive 6.5 >) were chosen from IAPS, which is a database of standardized set of pictures for studying emotion and attention [30], developed at the University of Florida [30,31]. Further, cross-cultural evaluation of the IAPS on an Indian population, done by Lohani et al in 2013 demonstrated that valence ratings of pictures do not significantly differ between Indian and North American population [31].

Three words were used on the basis of the valence ratings namely HAPPY (positive valence), SAD (negative valence) and BLAND (neutral valence) from ANEW, which is a set of verbal materials that have been rated in terms of pleasure, arousal, and dominance ;to complement the existing IAPS [32].The words were written horizontally across the face keeping the eyebrows, eyeballs cheeks, upper lips, lower lips unmasked so as to enable the recognition of the emotion of the face by the subjects. [33]. The colour of the word chosen was red as it is a less arousing colour [34].

Sixty trials, comprising of thirty congruent (emotion of the face and emotion of the word belong to same category) and thirty incongruent (emotion of the face and emotion of the word belong to different category) type of stimuli were designed for the current study for the following two types of tasks:

a) **Face Word Interference**: Subjects were asked to categorize the emotion of the facial expression while neglecting that of the word.
b) **Word Face Interference**: Subjects were asked to categorize the emotion of the emotional word while neglecting that of the facial expression.

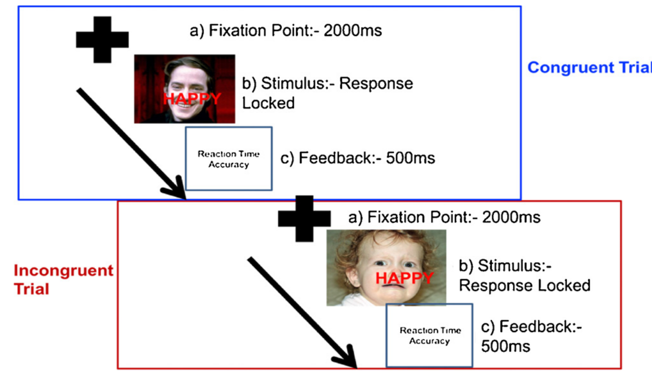

Fig. 1. The trial structure of emotional interference task. Two types of emotional interference stimuli were used, congruent and incongruent. a) Fixation point for 2000 ms followed by b) Stimuli which disappeared as soon as subjects responded followed by c) Feedback for 500 ms in terms of reaction time and accuracy percentage comprised of a single trial.

The Emotional Interference Tasks were designed on E-prime v2.0 to facilitate logging of trial related events on EEG Data. Random order of the presentation was done for congruent and incongruent trails in both the tasks. The trial structure is shown in the Fig. 1. The tasks were performed by the subjects in a single session wherein Face Word Interference task was followed by Word Face Interference task.

2.2. Stimulus presentation computer

A 17-inch flat panel liquid crystal display (LCD) monitor (Dell Professional P170S, refresh rate 60 Hz) was used as the monitor and subjects were seated 70 cm horizontally opposite to the screen.

2.3. EEG acquisition setup

A 128 channel Hydrocel Geodesic Sensor Net (HCGSN) from Electrical Geodesics, Inc. (EGI) was used for the placement of 128 active hydrocel electrodes on the subject's head for the acquisition of dense array electroencephalography (EEG) data. The HCGSN has dense-array hydrocel high impedance (50 kΩ) Ag/AgCl electrodes held in a tessellated geodesic forms a network that stretches across the head. The HCGSN is connected to the Net Amps 300 by means of a hypertronics connector. Net Amps 300 is a differential amplifier with an input impedance of 200 MΩ with a dynamic range of ± 200 mV, a 4000 Hz anti-aliasing in line filter. It uses a 24 bit analog to digital convertor to digitise the acquired EEG and transfers the digital data via firewire to the Data acquisition computer for storage and live display.

2.4. Electrical source imaging

The raw EEG Data was filtered into the 0.1 Hz–100 Hz band and was subjected to pre-processing. Geosource function of Netstation 5.2 was used for source localization.

Geosource utilises the Standardized low-resolution electromagnetic tomography (sLORETA) [35] method of constraining the weighted minimum norm inverse solution to calculate the intra-cortical electrical sources by solving the inverse problem without assuming an a priori number of underlying sources and hence computes electric neural activity as standardized current density (unit: nanoamperes per square meter, nAm/m^2) [36]. The finite differences head model was used for solving the forward problem [37,38]. The probabilistic location of grey matter in the average MRI atlas of the Montreal Neurologic Institute (MNI) Atlas [39] was used to constrain the location of 2447 source voxels. Three orthogonal dipole moments [x, y, z] were defined and solved for each of the source voxels. The source space was restricted to 2447 cortical voxels [7 mm^3] that were each assigned to a gyrus on the