Prefrontal EEG Correlation During Tower of Hanoi and WCST Performance: Effect of Emotional Visual Stimuli

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ABSTRACT

Introduction. Emotional stimuli elicit changes in the electroencephalographic (EEG) activity of several brain structures. Prefrontal cortex is involved in the processing of emotional stimuli and executive functions. The correlation analysis of EEG provides information about the functional coupling between areas. It is reasonable to expect that emotional activation will modify prefrontal coupling during the performance of executive tasks such as Tower of Hanoi or Wisconsin Card Sorting Test (WCST).

Aim. Determine whether the prefrontal EEG correlation during the performance of the Tower of Hanoi and WCST is affected by previous exposure to videos with sexual or aggressive content.

Main Outcome Measures. Prefrontal EEG coupling was determined by the Pearson correlation. Valence and general arousal were evaluated by the Self-Assessment Manikin Scale and sexual arousal with a Sexual Arousal Scale. Computerized versions of the Towers of Hanoi and WCST provided data on prefrontal executive functions.

Methods. EEG from the left and right prefrontal zones was recorded during the performance of the Tower of Hanoi and WCST immediately after the subjects were exposed to one of the videos (neutral, aggressive, and erotic).

Results. There was no difference between videos in the task performance parameters. Only the erotic video produced an increased prefrontal coupling in the slow bands (delta and theta) during the performance of the Tower of Hanoi, whereas a decreased coupling in the delta, theta, and alpha bands was observed during the WCST.

Conclusions. Prefrontal coupling was changed after exposure to the erotic video, and it is likely that enhanced sexual arousal was the main cause of this change. The correlation patterns obtained could be associated with particular cognitive strategies or to functional adaptations while being sexually aroused. The results of this study may contribute to an understanding of the central nervous mechanisms underlying the cognitive effects of sexual arousal.

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Key Words. Prefrontal Cortex; EEG Correlation; Sexual Stimuli; Tower of Hanoi; Wisconsin Card Sorting Test; Sexual Arousal

Introduction

Previous studies have shown that both erotic and aggressive visual materials elicit changes in electroencephalographic (EEG) activity [1,2], in components of event-related brain potentials (ERPs) [3–5] and in the brain activation level [6–10] as compared with emotionally neutral scenes. These changes in brain activity are manifested in several brain structures, depending on the emotional scene content [5,11]. The prefrontal cortex (PFC) has been associated with the processing of relevant and emotional stimuli such as those associated with sexual behaviors, and some authors have suggested that the PFC participates in the processes involved in the sexual motivation/arousal state [3,8,9,12–14].

Using visual stimuli, Anokhin et al. [3] reported that anterior event-related potential (ERP) components in frontal, central, and parietal areas

showed a high selectivity for pictures with erotic content compared with other pictures regardless of their emotional valence (pleasant, neutral, and unpleasant). The divergence of ERPs elicited by erotic and nonerotic contents started at 185 milliseconds poststimulus in the fronto-central midline region [3]. Similarly, it has been reported that sexual arousal generated by the observation of erotic visual stimuli is related to high activation of the PFC. In particular, Leon-Carrion et al. [9] showed enhanced activation in the dorsolateral zone of the PFC (DLPFC) during erotic visual stimulation. This activation was maintained at least 20 seconds after the visual stimuli were ended [9].

PFC is an example of a brain region in which cognition and emotion interact [15]. The participation of the DLPFC in executive functions, such as working memory, planning, organizing, goal setting, and decision making among others, is also well known [16,17]. These functions have been evaluated with tasks such as the Tower of Hanoi or Wisconsin Card Sorting Test (WCST). The implication of the PFC in the performance of these tasks has been firmly established [18–20]. Although both the Tower of Hanoi and the WCST make use of the PFC, the cognitive demands of these tasks are not identical.

The EEG is a useful tool that permits the simultaneous recoding from several brain regions in precise temporal association with specific physiological states or cognitive processes. Increases in the theta or gamma EEG bands have been associated with cognitive functions [21], while increase in the delta and beta bands has been reported during emotional states [22]. It has also been suggested that complex goal-directed behavior, including cognitive test performance, requires a dynamic integration of anatomically distributed but functionally related neuronal groups. This spatiotemporal "binding" of activities in specialized cortical areas is achieved through coherent oscillatory processes in neural networks [23]. One way to estimate the synchronization among electrical activities is to determine the correlation among EEG signals at different electrode sites [24,25]. The correlation has been used by several investigators to determine if the functional connectivity between brain regions changes in relation to different motivational or emotional states in rats [14,26,27] as well as during diverse cognitive [28–30] and emotional processes [31] in humans.

Despite considerable interest in the neural basis of emotional and cognitive processes, the question of how emotional content affects brain functionality during cognitive processing has received little attention. However, considering that the PFC has been involved in the processing of motive-emotional states as well as in the performance of cognitive tasks, it is most likely that emotional activation modifies activity in this structure during the execution of such tasks.

Aim

Determine whether the prefrontal EEG correlation during the performance of the Tower of Hanoi and WCST was affected by previous exposure to videos with different emotional content.

Methods

Subjects and Design

Experiments were performed on 19 male and 21 female students. All were healthy, right handed, heterosexual, and 22.9 ± 3 (mean $\pm$ standard error) years old with a minimum of 13 years of education. They had no known neurological disorders and they were under no medication or drug known to influence the EEG. For the women, verbal report on the date of the first day of menstrual bleeding was used to schedule the test session for the late periovulatory or early luteal phase [32]. The mean $\pm$ standard error of the mean (SEM) days after the onset of menstruation were 15.26 ± 1.45. It is known that women do report the first day of menses with great accuracy [33]. The students were divided in two main groups: those who performed the Tower of Hanoi (HANOI group) and those who performed the WCST (WCST group) (Table 1). A between-subjects design was used in order to eliminate the possibility that one task affected the execution of the other. Each group was then divided in three subgroups, according to the video they observed:

1. Neutral subgroup (N = 12) viewing a 5-minute neutral video (a man walking through a multitude from "The Long Shadow") [34].
2. Aggressive subgroup (N = 15) viewing a 5-minute aggressive video (human torture and mutilation from "Hostel") [35].
3. Erotic subgroup (N = 13) viewing a 5-minute erotic video (erotic scenes and sexual interaction showing genitals from "The Catwoman") [36].

For the selection of the video fragments used here, videos and then specific fragments of videos