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Pre-stimulus alpha rhythms are correlated with post-stimulus sensorimotor performance in athletes and non-athletes: A high-resolution EEG study

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Abstract

Objective: In this study, we tested the hypothesis that a pre-stimulus brief (1 min) 10-Hz audio-visual flickering stimulation modulates alpha EEG rhythms and cognitive-motor performance in elite athletes and in non-athletes during visuo-spatial demands.
Methods: Electroencephalographic (EEG) data were recorded (56 channels; EB-Neuro) in 14 elite fencing athletes and in 14 non-athletes during visuo-spatial-motor demands (i.e. subjects had to react to pictures of fencing and karate attacks). The task was performed after pre-stimulus 15- (placebo) or 10-Hz (experimental) flickering audio-visual stimulation lasting 1 min and after no stimulation (baseline).
Results: With reference to the baseline condition, only the 10-Hz stimulation induced a negative correlation between pre-stimulus alpha power and reaction time in the fencing athletes and non-athletes as a single group. The higher the enhancement of alpha power before the pictures, the stronger the improvement of the reaction time. The maximum effects were observed in right posterior parietal area (P4 electrode) overlying sensorimotor integrative cortex. Similar results were obtained in a control experiment in which eight elite karate subjects had to react to pictures of karate and basket attacks.
Conclusions: The present results suggest that a preliminary 10-Hz sensory stimulation can modulate EEG alpha rhythms and sensorimotor performance in both elite athletes and non-athletes engaged in visuo-spatial-motor demands.
Significance: Identification of the EEG state of sporting experts prior to their performance provides a plausible rationale for the modulation of alpha rhythms to enhance sporting performance in athletes and sensorimotor performance in patients to be rehabilitated.

Keywords: Audio-visual flickering stimulation; Electroencephalography (EEG); Alpha rhythms; Sport science; Elite athletes

1. Introduction

Previous electroencephalographic (EEG) studies have shown that alpha brain rhythms (about 8–12 Hz) constitute an important neural substrate for human cognition (Klimesch, 1997, 1999; Vogt et al., 1998; Klimesch et al., 1998, 2001, 2003, 2004; Sauseng et al., 2002). Alpha rhythms

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can be influenced by EEG characteristics in the pre-stimulus interval of a memory task (Fingelkurts et al., 2002). In the pre-stimulus period, high power of alpha rhythms predicts a good cognitive performance, namely completing a specific task with fewer errors and greater efficiency (Neubauer and Freudenthaler, 1995; Klimesch, 1999). Successful retrieval of information from semantic or episodic long-term memory would depend on the decrease of posterior alpha power, reflecting the functional mode of thalamo-cortical and cortico-cortical feedback loops (Klimesch, 1999; Pfurtscheller and Lopes da Silva, 1999). A general rule is as follows: the stronger pre-stimulus alpha power and the better the cognitive performance (Neubauer and Freudenthaler, 1995; Klimesch, 1999).

To test the hypothesis that pre-stimulus alpha rhythms are concerned with cognitive performance, previous studies have tried to enhance them by repetitive transcranial magnetic stimulation at the frequency of alpha rhythms (Klimesch et al., 2003). Similar effects have been observed enhancing the power of alpha rhythms by neuro-feedback in real time (Hanslmayr et al., 2005). On the whole, results of these studies have shown that cognitive performance improved only in the subjects in whom the mentioned procedures enhanced the power of pre-stimulus alpha rhythms (Klimesch et al., 2003; Hanslmayr et al., 2005).

Power of EEG alpha rhythms and cognition might also be modulated by the use of flickering visual stimulation at about 10 Hz. Previous evidence in humans has documented that brief visual flicker stimuli at 10 Hz, given before trigrams, specifically enhanced both 10-Hz occipital EEG power and recognition memory; this did not happen at adjacent (about 9 and 12 Hz) stimulation frequencies (Williams, 2001). Also, it has been shown that brief 10-Hz flickering visual stimulation induced a peculiar increment of recognition memory in healthy elderly subjects (Williams et al., 2006).

The above results are in line with evidence showing that prolonged photic stimulation has induced more absolute EEG alpha power in healthy elderly subjects than in patients with Alzheimer's disease (AD), suggesting a failure of stimulation-related EEG synchronization associated with a severe cognitive impairment (Kikuchi et al., 2002). Furthermore, they extend previous evidence showing that visual flicker stimuli of variable frequency (2–70 Hz) have evoked EEG oscillations at same frequency in cat visual cortex (Rager and Singer, 1998) as well as in human relay thalamic nuclei and visual cortex (Krolak-Salmon et al., 2003). In the same vein, repetitive visual stimulation has induced a steady-state visual-evoked response (SSVER) in human occipital leads (Regan, 1966). Furthermore, visual flicker stimuli at frequencies from 1 to 100 Hz have elicited SSVER with the largest amplitude at 15 Hz (da Silva et al., 1999; Herrmann, 2001). More recently, a multi-modal EEG-PET approach has demonstrated that the amplitude of SSVER in occipital regions peaked at 15-Hz stimulation, and that the amplitude of SSVER corresponded to increased synaptic activity, specifically in primary visual cortex (Pastor et al., 2003).

Alpha rhythms seem to be also implicated in sporting performance of athletes. In precedence, marked differences in alpha rhythms have been observed between expert sportsmen and non-athletes (Hatfield et al., 1984; Collins et al., 1990; Salazar et al., 1990; Crews and Landers, 1993; Radlo et al., 2002). Specifically, left-hemisphere alpha rhythms (8–12 Hz) were quite high in power during shot preparation of skilled marksmen (Hatfield et al., 1984), and were higher before the best than worst shots of elite archers (Salazar et al., 1990). High power of resting alpha rhythms would indicate a reduction of left-temporal cortical activation and, possibly, of the relative covert verbalization. As a consequence, visual-spatial processes of right hemisphere would predominate information processing (Salazar et al., 1990). However, this explanation has been challenged by other evidence showing a bilateral increase of alpha power in correlation with the performance of karate experts (Collins et al., 1990), and a power increase of right-hemisphere alpha rhythms in association with the performance of skilled golfers (Crews and Landers, 1993). Finally, there has been no clear modification of alpha rhythms as a result of neuro-feedback training in pre-elite archers (Landers et al., 1991).

A possible explanation of the above conflicting results is that the analysis of extended alpha range (8–12 Hz) might hide effects occurring at alpha sub-bands. Indeed, low- (about 8–10 Hz) and high-frequency (about 10–12 Hz) alpha rhythms are diversely related to global attentional processes and task-specific processes as triggered by task demands (Klimesch, 1999). Furthermore, amplitude of resting alpha might depend on training level of athletes (Liu et al., 2003; Vernon, 2005).

In the present study, we investigated the effects of a pre-stimulus (1 min) 10-Hz flickering stimulation on alpha EEG rhythms and cognitive-motor performance in elite (fencing) athletes and in non-athletes during visuo-spatial-motor demands. The working hypothesis was that after the end of that 10-Hz flickering stimulation, the power of pre-stimulus alpha rhythms and the cognitive performances are modulated in both athletes and non-athletes.

2. Methods

2.1. Subjects

Fourteen (8 females) fencing athletes and nine (9 females) non-athletes participated in the present study. The fencing athletes were members of the Italian national fencing team who regularly attended international competitions. The non-athletes were healthy subjects who never played fencing at amateur or competitive level. The mean subjects' age was 26.1 years (±1.5 standard error, SE; range from 19 to 37 years) in the fencing athletes, and 27.6 years (±1 SE; range from 21 to 32 years) in the non-athletes. Inclusion criteria for both athletes and