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Visual event-related potentials in elite and amateur athletes

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Abstract

In the present study, we tested the hypothesis that the neural synchronization estimated in visual cortex during visuo-spatial demands shows different features in elite karate athletes when compared to amateur karate athletes and non-athletes. EEG recordings (56 channels; EB-Neuro) were performed from 17 elite karate athletes, 14 amateur karate athletes, and 15 non-athletes, during the observation of pictures with basket and karate attacks. They clicked a right (left) keyboard button for basket or karate attacks at right (left) monitor side. Results pointed to no difference of late occipital VEPs/ERPs after basket versus karate attacks in the non-athletes (300–800 ms post-stimulus). In the amateur karate athletes, occipital VEPs/ERPs at 300–450 ms post-stimulus (P3–P4 components) were lower in amplitude for the karate than basket attacks. In the elite karate athletes, the occipital VEPs/ERPs further declined in amplitude at 300–450 ms post-stimulus (P3 and P4 components) and enhanced at about 800 ms post-stimulus ("N2" component) for the karate than basket attacks. A control study showed that in 10 elite fencers, the same was true for the fencing compared to the karate attacks. These results support the hypothesis that peculiar mechanisms of occipital neural synchronization can be observed in elite athletes during visuo-spatial demands, possibly to underlie sustained visuo-spatial attention and self-control.

Keywords: Visual evoked potentials (VEPs)/Event related potentials (ERPs); Sport science; Elite athletes

1. Introduction

Building expertise in a sport is based on the formation and, subsequently, on the fast retrieval of proper motor routines in response to a specific sensory context. From a neurophysiological viewpoint, an occipito-parietal-premotor dorsal stream is involved in the visuo-spatial analysis of environmental stimuli [9,21] and in the visuo-motor transformations aimed at selecting proper reaching, interception, grasping, and handling actions [22]. Motor skill learning independently occurs in loop circuits encompassing cortex-basal ganglia [11,15] and cortex–cerebellum [10,18].

Visual aspects of sport expertise are related to visual attention processes, whose neural correlates are reflected by posterior visual evoked potentials (VEPs) or event-related potentials (ERPs), denoting synchronous activation of cortical pyramidal neurons. It has been shown that early positive and negative VEP components such as P1 (P: positive), N1 (N: negative), and P2 are modulated by attention to spatial features [19,27]. Whereas, late VEPs/ERPs such as P3, P4, and N2 are mainly sensitive

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to subject's mental state (i.e., attention, expectancy, and closure of stimulus elaboration) [1,13]. Under certain circumstances, repeated presentation of visual stimuli induces an increase of sensory threshold that is accompanied by smaller occipital VEPs [14]. After a visual training (without consolidation), a decrement of sensory threshold is associated with enhancement of occipital VEPs at about 100–300 ms post-stimulus [23,24].

Several lines of evidence have shown that VEPs/ERPs reflect peculiar features of cortical neural synchronization in athletes. Firstly, it has been observed that neural synchronization estimated in occipital lobe after visual stimulation was enhanced in athletes; this effect was followed by late changes in the neural synchronization estimated in frontal cortex, possibly in relation to stimulus discrimination, response selection, and/or motor inhibition processes [5]. Secondly, the neural synchronization estimated in primary motor cortex of athletes after visual stimulation was affected by long-term physical training [7]. Thirdly, the neural synchronization estimated in occipital cortex of athletes after visual stimulation appeared to depend on acute and habitual exercise [20]. Fourthly, the neural synchronization estimated in visual cortex before and after visual stimuli predicted how quick was the athletes' motor responses to those stimuli [8]. Furthermore, that neural synchronization appeared to be earlier in latency in athletes than in non-athletes [25]. Fifthly, the neural synchronization estimated in somatosensory cortex after median-nerve stimulation was correlated with the years of athletes' training [26]. Keeping in mind these findings, it is unclear whether the neural synchronization in visual cortex is enhanced during visuo-spatial demands in elite athletes when compared to amateur athletes other than to non-athletes. In the present study, we tested the hypothesis that this is the case in elite karate athletes as contrasted to amateur karate athletes and non-athletes. The visual neural synchronization was reflected by occipital VEPs/ERPs elicited by the observation of pictures showing basket and karate attacks to which the subjects had to respond.

2. Methods

2.1. Subjects

Seventeen (6 women) elite karate athletes, 14 (3 women) amateur karate athletes, and 15 (4 women) non-athletes control subjects were recruited. Elite karate athletes were part of Italian national karate team regularly attending to international competitions. All elite karate athletes practiced karate from more than 10 years, and they usually practiced 5 times a week. None of them played basket at competitive or amateur level. The amateur karate athletes practiced karate from 2 to 3 years, and they usually practiced two times a week. None of them played basket at competitive or amateur level. The control subjects did not play basket, karate or sports similar to karate (i.e., kung fu, etc.) at competitive or amateur level. The mean subjects' age was 23.6 years in the elite karate athletes (±1.1 standard error, S.E.; range from 19 to 31 years), 21 years in the amateur karate athletes (±0.6S.E.; range from 18 to 26 years), and 28.8 years in the non-athletes (±1.1S.E.; range from 22 to 34 years). To take into account age differences, this variable was used as a covariate in the subsequent statistical analysis. Education range was also very similar in the three groups: it spanned 13–18 years in amateur karate, elite karate and non-athletes groups. All subjects were right-handed except that one elite karate athlete who was left-handed. Furthermore, we recruited additional 10 (6 women; mean age of 27.6 ± 1S.E.) non-athletes and 10 (6 women 26.1 ± 1.5S.E.) elite fencing athletes (i.e., all fencing athletes were members of the Italian national fencing team regularly attending to international competitions) for a control study evaluating if the effects on VEP/ERP amplitude can be generalized to other classes of elite athletes.

All subjects gave their informed consent according to the Declaration of Helsinki and were free to withdraw from the study at any time. The procedure was approved by the local Institutional Ethics Committee.

2.2. Procedure

The subjects comfortably sat in an armchair in front of a computer monitor. The distance between subjects and monitor was of 90 cm. They were presented with a series of 180 different pictures, depicting basket (50%) or karate (50%) attacks taken during real actions in elite athletes (Fig. 1). The dimension of the basket and karate picture was 500 × 500 pixels. Global luminance of the monitor, as measured by Tektronic J17 and J1800 Series LumaColor Photometer, was similar in basket and karate pictures. Each picture was shown for 1 s with a random inter-stimulus interval ranging from 4.5 to 5.5 s. A central cross was always present as a target for eyes gaze. In all pictures, the attacking athlete was at the center of the monitor about in frontal view. Left or right basket attack was defined by the side in which the athlete was attacking from the viewpoint of the participant. Specifically, attack side was indicated by the side of basketball or attacking arm/leg. In both conditions, the subjects were requested to immediately respond by pressing "v" or "n" buttons of the computer keyboard with left or right finger, respectively (the motor task was included to motivate the subjects to maintain the visual-attention level high across the session and to have a behavioral index of that). Subjects' responses were classified as follows: (i) "wrong" responses when they pressed the incorrect button of the computer keyboard (i.e., "v" button for right attacks and "n" button for left attacks); (ii) "anticipatory" responses when they pressed the button of the computer keyboard before or within 100 ms after the appearance of the karate or basket pictures; (iii) "correct" responses when they pressed the correct button of the computer keyboard (i.e., "n" button for right attacks and "v" button for left attacks) at least 100 ms after the appearance of the basket and karate pictures. A proper software (Presentation; Neurobehavioral Systems, http://nbs.neuro-bs.com/) was used to register the side of the pressed button, the response time (i.e., the interval time from the stimulus onset to the response), and accuracy of the response for each trial. For further analyses, we only considered the response time and the EEG data associated with the correct responses. Of note, it was impossible to pair the basket and karate attacks as spatial features. Indeed, the karate attacks were just characterized by an athlete performing upper- or lower-limb projections, whereas, basket attacks were characterized by a player in action with the additional presence of the basket-ball. This issue was taken into account in the interpretation of the results (see Section 4). Finally, for the control study, we repeated the above-described procedure using pictures of fencing and karate attacks in non-athletes and elite fencing athletes.

2.3. EEG recordings

EEG data were continuously recorded (bandpass: 0.01–100 Hz, sampling rate: 256 Hz; EB-Neuro Be-plus) from 56 scalp electrodes (cup) according to an augmented 10–20 system (electrical reference between AFz and FCz; ground electrode between Pz and Oz). Electrode impedance was kept smaller than 5 kΩ. Bipolar electrooculogram data (EOG; bandpass: 0.1–100 Hz; sampling rate: 256 Hz) were acquired to monitor blinking and eye movements. Electromyogram (EMG; bandpass: 0–100 Hz; sampling rate: 256 Hz) of bilateral *extensor digitorum* and first dorsal *interosseum* muscles were recorded to monitor movements required by the task as well as involuntary mirror movements or other unspecific muscle activations.

2.4. Preliminary data analysis

Artifact-free EEG data were segmented in single trials from −2 s to +4 s with reference to the zerotime, defined as the onset of the visual stimulus (i.e., pictures of basket or karate). Data epochs with ocular, muscular and other types of artifacts were identified by a computerized procedure using EEG, EOG, and EMG signals as an input [16]. The EEG data affected by ocular artifacts were