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Research article

Athletes versus video game players: A predictive contextual processing study

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ABSTRACT

We investigated the effect of abstract and real life meaningful images from sports on predictive contextual processing in professional athletes and video gamers. EEG was recorded in three groups: professional basketball players (BP), professional athletes of individual sports (IA) and experienced action video game players (VG). Two recording sessions, each with a different set of visual stimuli was presented: either triangles facing left, up, right or down or four images of a basketball player throwing a ball. Recording blocks consisted of targets preceded by randomized sequences of standards and by sequences including a predictive sequence signaling the occurrence of a subsequent target event. The gradual increase of P3b amplitudes across the predictive sequence was greater in BP compared with VG, when stimuli consisted of real life images of a basketball player. For the basketball session, we observed increased local modularity and stronger functional connectivity within frontal attentional networks in BP and VG compared with IA, during the processing of the predictive sequence. Our findings suggest increased top-down attentional allocation, during the processing of predictive visual stimuli, in basketball players compared with video gamers and individual sports athletes.

1. Introduction

There is a growing body of evidence demonstrating that video game playing has a positive effect on tasks that require top-down attention, allowing video game players to allocate attentional resources more flexibly [1–3]. These findings have been shown both when comparing experienced video game players with non-players [1,3–5] and after a period of video game training [1,6,7], specifically for action or shooting video games, that require players to make predictions regarding future events [2,7]. Parallel studies in skilled athletes have shown that these individuals show both sport-specific and generalized cognitive enhancements [8–10], related to the extraction of environmental cues [11–15], compared with non-athletes. Thus, overall there is evidence to suggest that extensive daily training of either video games or physical training, specifically those that require quick decision making, may induce cognitive enhancements [5,8]. However, the mechanisms underlying these enhancements remain elusive.

In the current study we focused on the cognitive function involving the ability to process contextual information, a crucial component of working memory, which enables extraction of relevant information from the environment in order to facilitate the selection of appropriate task-specific responses [16,17]. We employed a previously reported paradigm [18] to investigate the effects of processing predictive contextual information on target detection, in professional athletes and video game players. We evaluated the P3b, an ERP component associated with target detection. The P3b has a posterior-parietal scalp distribution, and its amplitude is influenced by the attentional allocation to a stimulus [19–21]. Previous studies have shown that predictive local context facilitates target detection [22,23], and that P3b amplitudes are enhanced in professional basketball players compared with individual sports athletes during the performance of this task [18]. P3b has been shown to be affected by physical exercise [24,25] and its amplitude is increased in professional athletes compared with non-athletes [8,12,13,26]. Past studies have demonstrated increased P3b amplitudes in video game players [3], and as a result of video game training [7].

In the present study, we used electrophysiological measures, to evaluate the processing of predictive contextual information in experienced action video game players, and in two groups of professional athletes: one group relying on dynamic extraction of information to guide their behavior while playing (basketball players), while the athletic performance of the other group did not depend on time constrained cue utilization (e.g. swimmers). To our knowledge this is the first study directly comparing top-down cognitive abilities of professional basketball players with experienced action video game players, as both may have superior abilities in dynamic second by second

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extraction of information and decision-making. In the current study subjects performed two sessions of the same task, one with stimuli consisting of triangles [22], and another with images of a basketball player throwing a ball [18], in order to determine whether the observed differences are specific to representative stimuli from the practiced sport (basketball), or are generalized to abstract stimuli. In addition, we evaluated the event-related EEG functional connectivity across the groups, to investigate whether the differences across the groups are associated with processing task-relevant stimuli within top-down attentional networks. Functional connectivity studies in video game players have been performed primarily using fMRI, showing enhanced recruitment of top-down networks in video game players compared with non-players [5,6]. Enhanced connectivity has also been demonstrated in elite athletes compared with novices using fMRI [27,28] and EEG [29]. In the current study, we hypothesized that increased attentional allocation during processing of the predictive sequence would be associated with increased P3b amplitudes as well as with increased functional connectivity within frontal top-down networks [23,30].

2. Method

2.1. Subjects

Thirty-seven subjects participated in the study. Thirteen subjects were professional basketball players (BP) (mean age ± standard error of mean = 23.2 ± .9 years, 7–17 years experience, all male); twelve subjects were experienced action video game players (VG) (mean age = 24.3 ± 1 years, 7–16 years experience, 1 female); and twelve subjects were professional athletes of individual sports (IA) (mean age = 23 ± 1.5 years, 6–13 years experience, 1 female): 7 swimmers, 2 exhibition wushu athletes, 1 rower, 1 triathlete and 1 skater. The data from eight BP and six IA subjects were reported in a previous study [18]. All the subjects had daily practices of at least 3–4 hours of the specified sport or video game playing, and all the athletes participated in national-level competitions. The athletes from individual sports did not have experience in basketball or in other sports that require dynamic second by second decision-making, the video game players did not practice any type of sports or physical activity, and none of the athletes played video games. The video game players all played action video games, specifically first person shooter games. Subjects had normal vision and had no history of psychiatric or neurological problems. The Ethics committee of University of A Coruña approved the study.

2.2. Task

Subjects sat 110 cm in front of a 21-inch PC-computer screen. Stimuli were presented in the center of the visual field. Two sessions were performed by each subject (see Fig. 1): a session with visual stimuli consisting of triangles [18], and a session consisting of images of a basketball player throwing a ball towards a basket (adapted from Aglioti et al. [14]). Sessions were counterbalanced across subjects. Subjects were asked to centrally fixate throughout the recording. Stimuli consisted of 15% targets and 85% of equal amounts of three types of standards. In each block a total of 78 stimuli (12 targets, 22 of each standard type) were presented each for 150 ms and inter-stimulus interval (ISI) of 1 s. Recording blocks consisted of targets preceded by either randomized sequences of standards or by sequences including a three-standard predictive sequence. In the triangle session the target was a downward facing triangle and the three standards were triangles facing left, upwards and right, at 90 ° increments. The predictive sequence in this session always consisted of the three standards of triangles facing left, up and right, always in that order (see Fig. 1A). In the basketball session the 4 stimuli were four consecutive time points during the throw of a basketball. The target was the last frame, in which the ball is in the air. The three standards are the three preceding images (see Fig.1B). The predictive sequence consists of these three frames (before the ball is in the air) displayed in consecutive order. Fig. 1 illustrates an example of a target preceded by a randomized sequence of standards and a target preceded by the predictive sequence of standards for each of the sessions. Each block consisted of 6 different randomized sequences of standards (3–8 standards long) preceding the target; and 6 sequences of standards (3–8 standards long) with a predictive sequence preceding the target in each. Each recording session consisted of 10 different blocks, displayed in randomized order, each approximately 1.6 min long.

Subjects performed a brief training session to ensure they were able to detect the target accurately. Subjects were then shown the predictive sequence and were told that it would be a 100% predictive of a target, but that targets would also appear randomly throughout the block. Subjects were asked to press a button each time a target was presented, to pay attention and look for the predictive sequence, and to avoid premature responses. Subjects then performed another brief training session to ensure that they were confident in the detection of the predictive sequence as well as the targets, before each of the recording sessions began. Stimulus presentation and response recordings were controlled using E-prime (Psychology Software Tools, Inc., Pittsburgh, USA).

2.3. Recording

EEG was recorded from a 64 Ag-AgCl electrode array using the ActiveTwo system (Biosemi, The Netherlands). Signals were amplified and digitized at 512 Hz. Post processing and ERP analysis of the data was performed using Brain Vision Analyzer (Brain Products GmbH, Germany). All channels were re-referenced to averaged linked earlobes.

2.4. Behavioral analysis

Accuracy was defined as the percentage of targets for which a button press was detected (150–1150 ms post-stimulus onset). Reaction times were calculated by averaging correct trials for predicted and random targets in each subject for each session, using E-prime (Psychology Software Tools, Inc., Pittsburgh, USA).

2.5. ERP analysis

Prior to ERP analysis blinks were defined using ICA (64 EEG electrodes were included), and the component identified as a blink was removed using the linear derivation function in Brain Vision Analyzer. Epochs containing misses (no button press 150–1150 ms post-stimulus onset) and eye saccades were excluded from further analysis. EEG signals were filtered at 0.1–30 Hz for subsequent analysis. EEG signals were sorted and averaged relative to the stimulus onset, with epochs set from -200 to 1000 ms relative to stimulus onset. EEG epochs with amplitude of more than 75 μV at any electrode were excluded. For each condition, a minimum of 35 trials, were used to evaluate the ERPs in each subject.

2.6. P3b

P3b was determined as the most positive point in the latency range of 300–600 ms. For each subject peak P3b amplitudes (measured in μV) at AFz, Fz, FCz, Cz, CPz, and Pz were evaluated for 6 conditions in each session: targets after predictive sequences (predicted), targets after non predictive random sequences (random), random preceding standards (standards excluding those comprising the predicting sequence) and the three standards consisting of the predictive sequence: the last most-informative standard (n-1), the middle standard (n-2) and the first least-informative standard (n-3) of the predicting sequence. In order to restrict the number of comparisons an omnibus ANOVA was first performed. In this ANOVA we used the P3b peak amplitude at electrode