Electrophysiological correlate of top-down attention bias in a realistic virtual shooting environment

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Two weeks *Visionair*-sponsored collaboration at the *Immersia* premises in Rennes, 27th October to 7th November 2014.

Introduction

One well-known source of sport performance variability is the shifting of the attention locus from the task due to a disturbing environment. In this collaboration, we aim at studying the neural correlates of such attentional shifts using scalp electroencephalography (EEG) in a virtual reality simulation. For this purpose we considered an Olympic virtual shooting scenario which requires a high degree of concentration and does not involve intense physical activity. The lack of physical activity ensures that EEG recordings will not be polluted with artefacts due to excessive movements. The experimentation was done at the *Immersia* platform which provided the optimal conditions to implement such a realistic sports scenario in virtual reality, assuring a high degree of immersion and providing an ecologically valid competition scenario.

The first objective of the collaboration is to better understand, on a group level, how cortical processes are impaired by the distracting environment causing a shift in the attention locus and leading to degraded performance. Electrophysiological signals can than be correlated with shooting accuracy while controlling for the amount/strength of distracting stimuli. The second objective is to attempt to find neural markers of successful shots before the shot is actually fired, by looking at the characteristics of the brain signals at a single trial (shot) level.

Experimental design

The experiment followed a two by two factor design. The first factor, distraction (2-levels), relates to the presence or not of virtual opponents and a constant background noise caused by a virtual crowd. The second factor, reward (2-levels), relates to whether each shot score is accumulated (competition) or not (training).

A trial (shot) starts when the system detects that the participants raised his pistol and is aiming at the target. Participants are only allowed to shoot after five seconds of aiming and a minimum of four seconds is enforced by the protocol. After the shot, the participants are instructed to wait for one second before receiving score feedback and resting. A shooting session consists of four blocks of ten shots (one block per condition). In order to avoid ordering effects both factors were counterbalanced. A small break is proposed between sessions.
In total, participants performed 40 shots lasting around 40 minutes. Ten subjects were recruited during the second week of the collaboration.

The experiment has an additional purely motor control condition, where participants are be instructed to shoot without aiming the target. This control, apart from serving as training, allows possible contrasts between conditions to be compared to a condition with similar motor characteristics but without the cognitive control and visuomotor integration induced by aiming. Two minutes eyes-opened and eyes-closed baselines are recorded at the beginning of the experiment to compute resting-state baselines.

Data recording

For each trial, we recorded the score and the time spend before shooting. In addition, the aiming error (distance between the aiming projection and the centre [bull’s eye]) was constantly monitored. Shooting scores are used as a behavioural measure of performance while aiming time is used as a measure of the effectiveness of attention manipulation.

Regarding the physiological data, electrophysiological signals were recorded using a 64 channel Biosemi system. Additionally, three sensors record horizontal and vertical electrooculographic signals and two bipolar electromyographic recordings track muscular activity of the forearm.

Data analysis and prior hypotheses

Based on current literature and previous studies, we make the hypothesis that top-down attentional process can bias electrophysiological signals on various levels, depending whether the bias influences cognitive control, motor control or visuomotor integration.

Cognitive control bias

Extensive evidence has shown that frontal midline theta carries information related to executive tasks, as action monitoring, reinforcement learning or conflict detection [Trujillo et al. 2007, Cohen et al. 2008, Cavanagh et al. 2012, Cavanagh et al. 2014]. It is probable that an increase in action monitoring during aiming due to increased reward expectation and/or less distraction from virtual opponents and public will lead to an increase in spectral power in the theta band over frontal midline sensors.

Motor control and visuomotor integration bias

Event-related desynchronisation (ERD) in mu and beta bands is known to take place prior to movement onset in motor areas situated in the cerebral hemisphere contralateral to the moving limb and spread to the ipsilateral during the movement [Pfurtscheller and Berghold 1989, Alegre et al. 2003]. This ipsilateral contribution has been shown to be higher in closed-loop movements with sensory feedback and to be modulated by movement complexity but also and most importantly by attentional demands [Serrien et al. 2006 for a review]. Since aiming comprises continuous visual feedback to position the arm for shooting, we can hypothesise that this visuomotor integration based closed-loop adjustments will lead to increased ipsilateral ERD contribution and could be modulated by top-down attentional biases. Nonetheless, left parietal cortex was also demonstrated to play an important role in a motor-attention cortical network [Rushworth et al. 2001] so we cannot rule-out that differences could be found in the contralateral hemisphere. Finally occipital spectral power as well as fronto-occipital synchronisation in the alpha band are known to be related to increases in visual attention and could be modulated by our experimental manipulation.

Preliminary results

Repeated measure ANOVA on behavioral data showed that the reward level (accumulating the score) had a significant effect on shooting times ($F(1,9)=11.097$, $p=0.009$) while the presence of avatars did not have a significant effect on shooting time ($F(1,9)=3.408$, $p=0.098$). Nonetheless, this analysis was done on a group level and subjects reported different behavioral adjustments to the increase of stress provoked by the presence of avatars, some of them increasing attention on the task while others got disappointed by losing against the avatars and lessened their engagement in the task. EEG data analysis is ongoing.

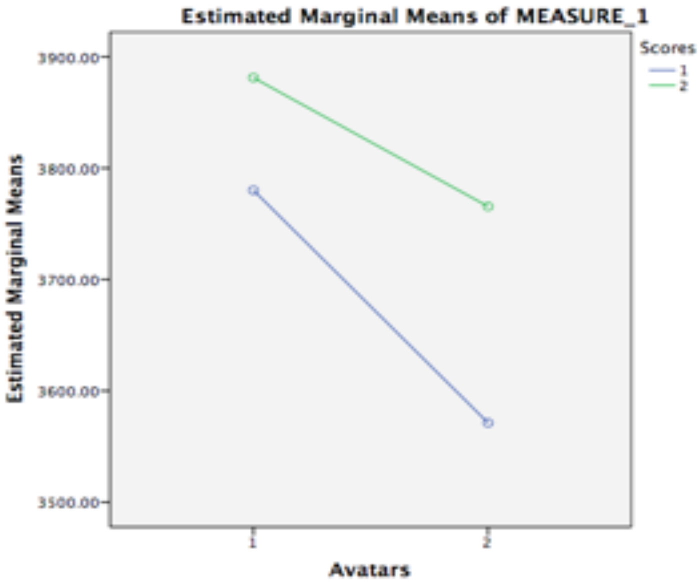

Figure 1. Mean shoot time in milliseconds for the presence (2) or absence (1) of avatars and when counting (blue line) or not counting (green line) scores.

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