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Amplitude and latency of EEG Beta activity during real movements, discrete and continuous motor imageries

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Motivation
Motor imagery (MI) modifies the neural activity within the primary sensorimotor areas of the cortex in a similar way to a real movement [1]. More precisely, beta oscillations (18-25 Hz), which are often considered as a sensorimotor rhythm, show that the amplitude of brain oscillations is modulated before, during and after a MI. Before a MI, compared to a resting state, there is a gradual decrease of power in the beta band of the electroencephalographic signal, called event-related desynchronization (ERD). Moreover, from 300 to 500 milliseconds after the end of the MI there is an increase of power called event-related-synchronization (ERS), or post-movement beta rebound, with a duration of approximately one second [2]. A large number of Brain-Computer Interfaces (BCIs) are based on the detection of MI in the electroencephalographic signal [3]. In most MI-based BCI experimental paradigms, subjects realize continuous MI, i.e. a prolonged intention of movement, during a time window of a few seconds with the objective to increase the detection of ERD and ERS. However, when the subjects imagine a succession of movements, several ERD and ERS are generated, with lower amplitudes than those elicited by a single MI [4]. Here, we employ a simple short MI to detect the ERD and the ERS.

Material

• 11 right-handed subjects performing three tasks: a real movement, a discrete (or short) motor imagery and a continuous (or 4s-) motor imagery of an isometric flexion movement of the right hand index finger (fig. 1).

• 9 channels (FC3, FC2, FC4, CP3, C2, C4, CP3, CP2, CP4) sampled at 256 Hz.

• 3 sessions of 4 runs each containing 100 trials per session (fig 2).

Methods

• Here the ERD/ERS% is the oscillatory power estimated with respect to the power of the resting period 30 seconds before the each runs. It is computed every 125 ms for a 2-second window, for all channels separately.

Results

- Fig. 1. Schematic representation of the experiment. A low frequency beep indicates the start of the (real or imagined) movement. A high frequency beep indicates the end of the continuous imagined movement. Nine electrodes collect electrical potentials. A Refa EEG acquisition system (AMP) amplifies the signals. The OpenVBE software (OV) records the digitized potentials.

- Fig. 2. Timing schemes of a trial for each task: Real Movement (top); Discrete Motor Imagery (middle); Continuous Motor Imagery (bottom).

- Fig. 3. Grand average (n = 11) ERD/ERS% curves estimated for the real movement (top), the discrete motor imagery (middle) and the continuous motor imagery (bottom) within the beta band for electrode C3.

- Fig. 4. Topographic map of ERD/ERS% of subject 4 in the beta band during real movement, (top) DMI (middle) and CMI (bottom). Red corresponds to a very strong ERD (+40%) and blue to a very strong ERS (-70%).

- Fig. 5. Topographic map of ERD/ERS% (grand average, n=11) in the beta band during real movement, (top) DMI (middle) and CMI (bottom). Red corresponds to a strong ERD (+40%) and blue to a strong ERS (-40%).

Conclusion

The results suggest that both discrete and continuous MIs modulate ERD and ERS components. The ERS is very similar in both cases, but the ERD generated by a discrete MI is easier to detect due to its higher power (35 ERD/ERS%) and lower variability (σ = 25 ERD/ERS%). Moreover, continuous MIs generate a later ERS, as well as a more variable (σ = 50 ERD/ERS%) and less detectable ERD (15 ERD/ERS%). These results show that discrete motor imageries may be preferable for BCI systems design in order to reduce users fatigue and to decrease the response time.

References