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Autocorrelation based EEG Dynamics depicting Motor Intention

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Introduction: Movement intention detection is useful for intuitive movement based Brain-computer interfacing (BCI). Various oscillatory cortical processes are involved in voluntary movement generation. We explore the fundamental brain processes underpinning movement intention by studying the temporal dynamics of EEG. A novel autocorrelation based feature was used to identify movement intention on a single trial basis. Autocorrelation analysis results were compared with well-established Event Related Desynchronisation (ERD) and Movement Related Cortical Potential (MRCP) neural correlates of movement.

Material, Methods and Results: A voluntary index finger tapping task was chosen for EEG experiments on fourteen individuals (26±4 years, 7 female, 2 left handed). In each of the 40 trials recorded, an instruction to make a right/left tap or rest was displayed. Participants were given a 10 s window to perform the finger tap at a random time. Bipolar channels F3-C3, Fz-Cz, F4-C4, C3-P3, Cz-Pz and C4-P4 were used for analysis.

The autocorrelation function estimates the temporal dynamics of EEG by describing how it relates to itself. Previous studies have suggested that the autocorrelation function changes during movement [1]. To capture the evolution of autocorrelation, an exponential curve was fitted to the autocorrelation estimated from a 1s window of the EEG and the procedure repeated for each window shifted by 100 ms. The exponential curve represented the relaxation process captured by the autocorrelation and its decay constant (an estimate of how fast or slow the autocorrelation decayed) was used as a feature for classification (see Fig. 1a). ERD [2] and MRCP [3] features were also extracted from single trials for comparison. Autocorrelation and ERD was extracted from five frequency bands because they span a wider range whereas MRCP was extracted from its' range of 0.1 to 1Hz.

Table 1. LDA classification sensitivities

Method	Left Tap %	Right Tap %
Autocorr 0.5-30Hz	78.25 (±9.58)	78.48 (±8.36)
ERD 8-13Hz	88.27 (±7.54)	84.54 (±9.43)
MRCP 0.1-1Hz	70.60 (±5.93)	68.90 (±5.26)

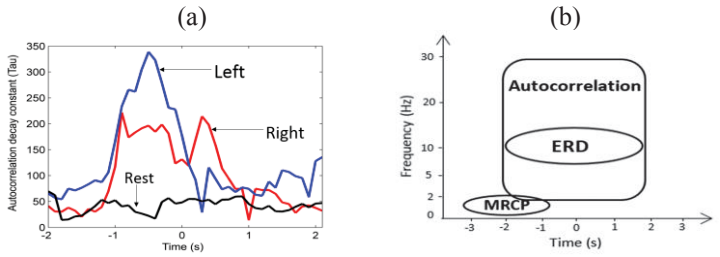

Figure 1. *(a) Autocorrelation decay constant (C3-P3) - right tap (red), left tap (blue) and rest (black). Movement at 0s. (b) Autocorrelation, ERD, MRCP feature space.*

Autocorrelation decayed slower during movement intention and execution and faster otherwise. Table 1 shows the comparison of the grand average classification sensitivities for all the participants obtained using a Linear discriminant analysis (LDA) classifier. All results were significantly better than chance ($p < 0.05$).

Discussion: ANOVA indicated that the sensitivities of the autocorrelation, ERD and MRCP were significantly different ($p < 0.001$). Low MRCP sensitivities suggest that it may not be suitable for single trial. Autocorrelation performed equally well across all frequency bands whereas the performance of ERD was best in the μ band (8-13Hz). The movement prediction timings and spatial locations for autocorrelation, ERD and MRCP are different. Fig. 1b shows the spread of features with respect to frequency and time. The features also exhibit different spatial distributions; ERD and MRCP are restricted to the motor cortex, while autocorrelation has a broader spread, predominantly over central and parietal cortical regions. This shows that autocorrelation occupies different space, providing information about movement intention complementary to that contained in ERD or MRCP.

Significance: We have introduced a new neural correlate of movement intention, depicting different information from ERD and MRCP. These autocorrelation features could be used, along with ERD and MRCP, in a hybrid classifier for constructing a robust online BCI with improved accuracy. Autocorrelation reflects slow dynamics of the amplitude decay of EEG and the modulations of oscillations. Different morphologies of the autocorrelation could also be indicative of different metastable-states in the brain, which will be investigated further.

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