ANNEXES

Annex A

Frequency band analysis

Even though the MRCPs and low frequencies are commonly used, there is no a fixed frequency band where the EEG should be filtered. Thus, 2nd order butterworth passband between (0.1-1) Hz [López-Larraz et al., 2014], (0.1-2.5) Hz, (0.05-3) Hz, (0.05-10) Hz [Niazi et al., 2011] and lowpass at 6 Hz can be found in the bibliography.

Recently, an offline study about how MRCPs should be filtered, suggest that it is necessary to use a bandpass filter around (0.1-1) Hz [Garipelli et al., 2013]. This study was realized based on a zero phase finite impulse response (FIR) with order N = 10 x sampling rate. However, in an online application, this approach is not valid due to the non-causality of the zero phase filtering. On the other hand, most of the MRCP-based decoders use temporal features in order to characterize the waveform. Hence, the phase response of the chosen filter could play an important role in the resulting decoding accuracy since a linear phase response filter will preserve the waveshape of the MRCP. In addition, although FIR filters present a linear phase response, there is no chance to use them in an online scenario due to the large delay produced by their higher order requirements. Thus, an analysis under pseudo-online conditions could lead to more realistic conclusions for future real-time MRCP-based applications. So that, we will evaluate several lower (0.01, 0.05, 0.1, 0.2 and 0.3 Hz) and upper (1, 2, 3, 5, 10 Hz) limits using the Garipelli et al [Garipelli et al., 2013] selected filter as a reference, i.e, when we study the lower limit, the upper limit will be fixed in 1 Hz.

A.1 Metrics

The grand average of the resulting filtered EEG trials will be computed in order to observe the waveshape differences produces for the analyzed filter. As mentioned bellow, all the trials will be aligned to the kinematic onset. Then, a baseline correction was applied by substracting the mean between -3 and -2 seconds.

A.2 Results

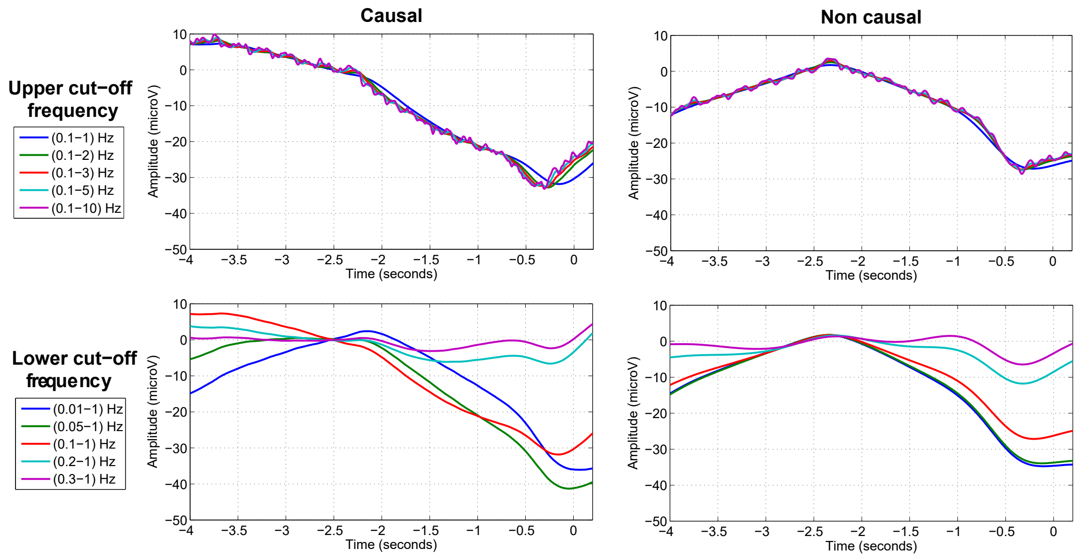

Figure A.1: Grand averages, channel 'Cz'. (First row: varying the upper cut-off frequency, second row: varying the lower cut-off frequency. First column : causal filters, second column: non-causal filters)

Figure A.1 shows Grand averages of the channel 'Cz' varying both upper and lower cut-off frequency and for causal and non causal filtering. Thus, the top-right subplot shows the Grand averages of the channel Cz non-causal filtered using a 2nd butterworth, for each upper cut-off frequency tested. All the frequency-bands tested shows a similar Grand average. On the other hand, the non-causal filtered signal for the lower-off frequency estudied shows important differences between the 0.2 and 0.3 Hz lower limit and the others, resulting in a more prominent MRCP for the lower cut-off frequencies bellow 0.1 Hz. On the other hand, the causal filtering shows more important differences among the filters studied. The upper cut-off frequencies analized shows a difference in the minimum peak location between the 1 Hz upper cut-off and the highers. Thus, the (0.1-1) Hz filtered Grand average present a delay of 160 ms with the upper limits above 1 Hz. Regarding the lower cut-off frequencies tested, the results are similar than in the non-causal analysis.

Annex B

Chance level of the multiclass classifier

Several tests were computed in order to check the correct implementation and performance of the decoder. The classifier was trained with the EEG signals right before the Kinematic activation and, posteriorly with the signals right before the EMG activation. However, an additional test can be done: train the classifier with the signals corresponding to the rest period. During this period, there is no brain information that allows the decoder to correctly discriminates among classes. Thus, a corrected implemented classifier will result in a random output if it is trained with the signals corresponding to this period.

Figure B shows the DA of the multiclass classifier trained using the signal corresponding to the rest period. Thus, the DA of the classifier stays at chance levels values during all the period showing that there is no discriminative brain information during the rest, as expected. This is also a good test to evaluate that our classified is no biased since a biased classifier could lead to a well-classified class although not all of them.

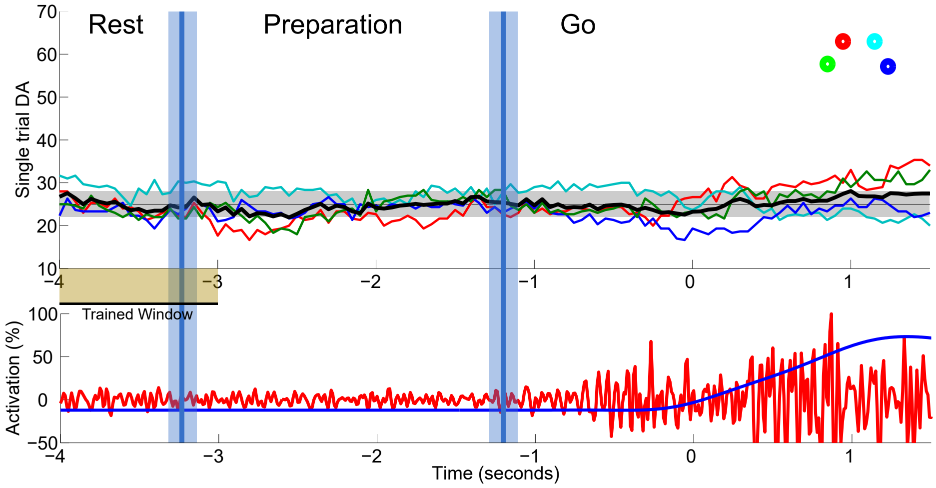

Figure B.1: Average DA, training with the epoch during the rest period, across subjects (black line) and target-specific DA (colored lines) in the top figure. Top-right corner shows the spatial distribution of the targets. Kinematic (blue) and EMG, biceps, (red) in the bottom. Blue vertical lines show the times when the cues were shown (Notice that these times are not fixed because the trials are aligned to the kinematic onset. Blue shaded areas represent this variability). Additionally, in the x-axis of the top figure, the window (epoch) used for training the classifier is shown as a yellow shaded area.