Continuous decoding of Motor Attempt and Motor Imagery from EEG Activity in Spinal Cord Injury Patients

Eduardo López-Larraz[1], Javier M. Antelis[1], Luis Montesano[1], Angel Gil-Agudo[3], Javier Minguez[1, 2].
[1] I3A and University of Zaragoza, Spain. [2] Bit&Brain Technologies SL, Spain. [3] Hospital Nacional de Parapléjicos de Toledo, Spain.

Introduction

Problem Statement

Spinal cord injury (SCI) associates brain reorganization with a loss of cortical representation of paralyzed limbs. This effect is more pronounced in the chronic state, which can be reached approximately 6 months after the lesion. As many of the brain-computer interfaces (BCI) developed to date rely on the user motor activity, loss of this activity hinders the application of BCI technology for rehabilitation or motor compensation in these patients.

Purpose of the Study

This work is a preliminary study with three quadriplegic patients close to reaching the chronic state, addressing two questions: (i) whether it is still possible to use BCI technology to detect motor intention of the paralyzed hand at this state of chronicity; and (ii) whether it is better for the BCI decoding to rely on the motor attempt or the motor imagery of the hand as mental paradigm.

Conclusions

The results show that one of the three patients had already lost the motor programs related to the hand, so it was not possible to build a motor-related BCI for him. For the other patients it was suitable to design a BCI based on both paradigms, but the results were better using motor attempt as it has broader activation associated patterns that are easier to recognize.

Subjects and Experimental Setup
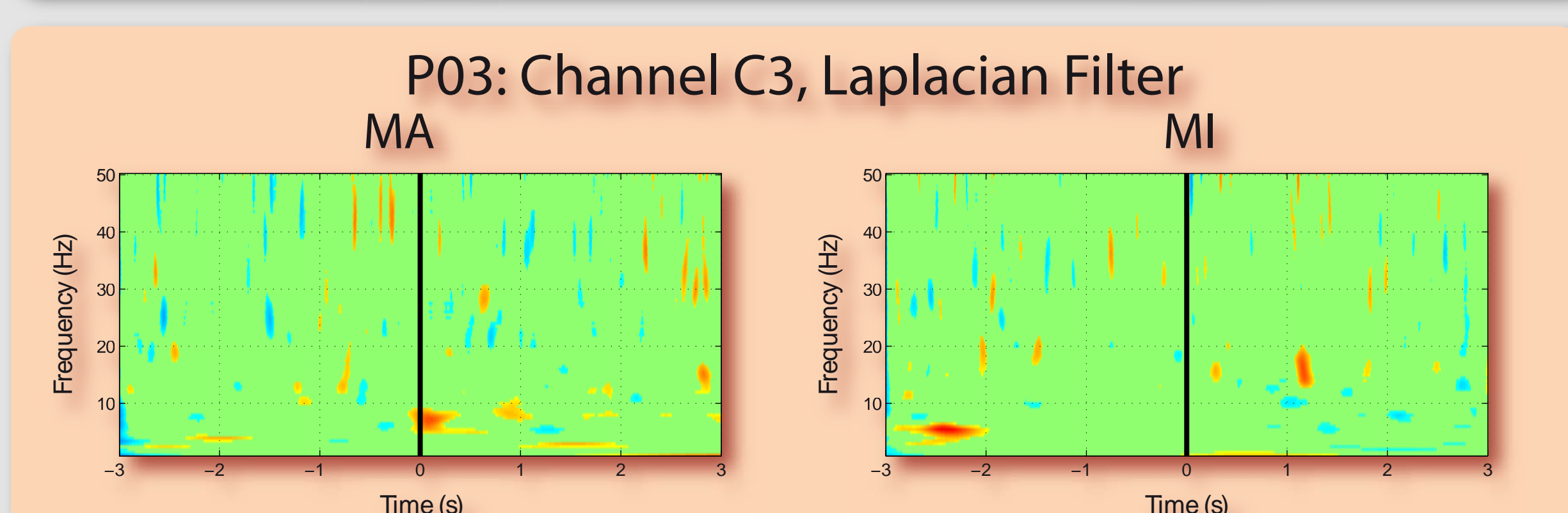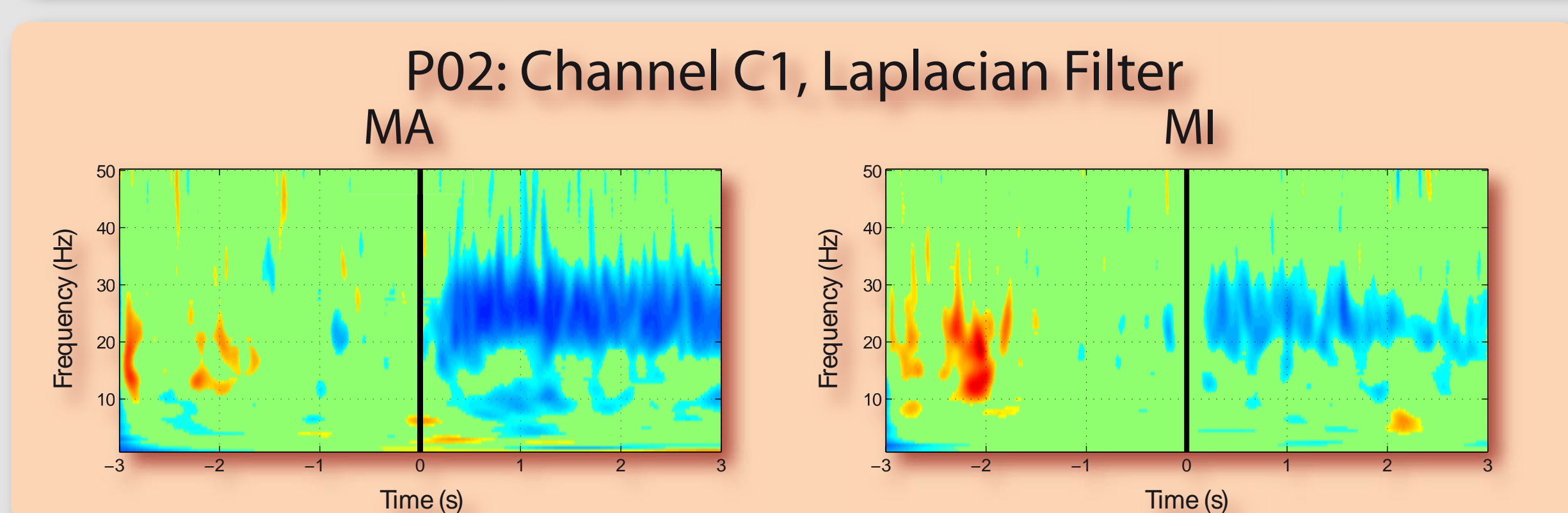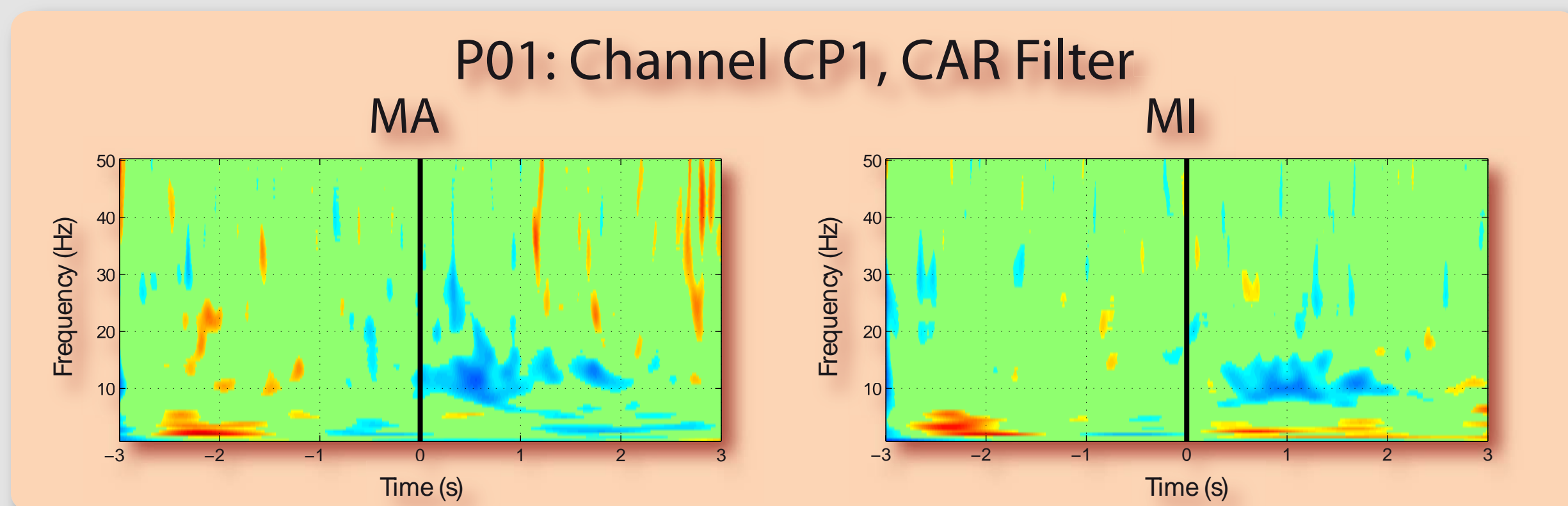
Patients characteristics

	Age (years)	Time since lesion (days)	Level of Injury	ASIA Impairment Scale
P01	33	150	C6	B
P02	34	156	C4/C5	A
P03	32	136	C4/C5	A

• Three male quadriplegic patients performed the experiments. All of them were unable to perform grasping movements.

• EEG was recorded with 16 active electrodes during the execution of the tasks.

• The experiment consisted of two different tasks: (i) motor attempt (MA) of grasping with the right hand, and (ii) motor imagery (MI) of grasping with the right hand.

• Visual cues were given during the different stages of the experiment: 1) relax and prepare for the next cue; 2) start the attempt or the imagination of movement; 3) trial end.

• 90 Trials of each condition were recorded.
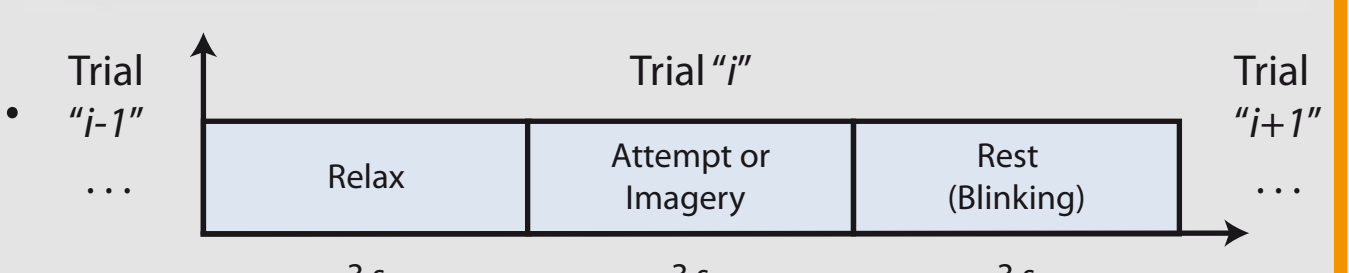
ERD/ERS Analysis

• Trials were trimmed to the window [-3, 3] s, with respect to second cue, and bandpass-filtered from 0.5 to 50 Hz.

• Laplacian and CAR filters were independently explored for each patient.

• Temporal power spectra was computed using the complex Morlet's Wavelet.

• ERD/ERS maps were computed taking window [-2, 0] s as baseline.

• Statistical significance was verified by applying a t-percentile bootstrap statistic, with $\alpha = 0.05$.

P01: Channel CP1, CAR Filter — MA / MI

P02: Channel C1, Laplacian Filter — MA / MI

P03: Channel C3, Laplacian Filter — MA / MI

MA/MI Detection

Features

• Channels over the motor cortex and frequency bins in α and β bands were individually selected by visual inspection for each patient.

• The spectral power was computed using a 16th order autoregressive model.

• Different time-window lengths ($\delta\omega$) to compute the spectral power were evaluated to assess the impact in the classifier performance.

Classifier

• Support Vector Machine (SVM), with a radial basis function kernel.

• Classification performance was evaluated by ten-fold cross-validation.

• Labels were predicted every 50ms in each test trial. Note that at time t, the features are computed using exclusively the EEG activity from $[t - \delta\omega, t)$.

P03 was excluded from decoding analysis since did not provide better-than-random results with any $\delta\omega$.

P01: $\delta\omega = 0.75$ s

P02: $\delta\omega = 0.5$ s