Title: **EEG based brain-computer interface in chronic tetraplegics**, **to actuate a robotic arm device**, **as assistive technology – clinical survey and long-term post trial follow-up**

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Abstract

Study Design: Clinical "acute" survey, on a group of 9 chronic, post spinal cord injury (SCI) tetraplegics; interviews/ correspondence within long-term post-trial follow-up.

Objective: To assess the efficiency of the use of an Electroencephalography-based Brain Computer Interface (EEG-BCI) for reaching and grasping assistance in tetraplegic patients, through a robotic actuator/ arm device. To our knowledge this is the first wide patient study to also investigate technological (mechatronic) uses of EEG BCI.

Settings: The Physical and (neuromuscular) Rehabilitation Medicine (Pn-mRM), the Cardiology and the Neurosurgery Clinic Divisions of TEHBA and respectively the UMPCD, in Bucharest, Romania, in collaboration with the "Brain2Robot" team of researchers (composed of the European Commission-funded Marie Curie Excellence Team by the same name, hosted by the Fraunhofer Institute-FIRST in Berlin, Germany).

Methods: The enrolled patients underwent specific EEG-BCI training sessions, aiming to ultimately control a robotic arm device, as functional assistive technology (Brain Machine Interface –

BMI). The analysis of the data obtained included multiple linear regressions as to evaluate probable predictors of BCI ability on individual spectral power components of each subject's typical EEG spectrum and to assess the dependence of the "answer" variable EEG-BCI performance on a set of independent variables. Furthermore, cluster analysis was performed to graphically represent the factors influencing BCI performance. Finally, long-term follow-up, including a questionnaire – referring to the patients' own perception on their capacity to control, by BCI, the cursor and/or the robotic arm device – was carried out within 14 months after the experiments.

(main) **Results**: EEG-BCI performance classification trial accuracy averaged 80.99%, with median 79.2%, while feedback training performance sessions accuracy reached an average of 70.51% with a median of 68.79%, for the 8 subjects who completed the 'feedback' BCI trials. According to our follow-up questionnaire, 7 (77.7%) of the 9 subjects, reported having had the feeling of control over the cursor while 3 (33.3%) subjects felt they were also able to voluntarily control the robot through their movement imagination.

According to multiple linear regression, on spectral power components - in order to identify probable predictors of BCI training accuracy from potentially pre-recorded clinical data - BCI performance was positively correlated with beta (13-30 Hz) spectral power density (coefficient 0.432, standardized coefficient 0.745, p-value = 0.025); another factor of potential influence was the sensitive AIS score (*sensitive*) (range 0-224, maximal level of deficit being 224 coefficient -0.177, std. coefficient -0.512, p=0.089). The rest of the assessed independent variables in the model (including subject age: p=0.31, AIS motor score, and time since SCI injury) had negligible regression coefficients.

Conclusions: The potential for chronic tetraplegics to be self-assisted by EEG-BCI based mechatronic/robotic devices is mainly related to beta EEG component (positively, i.e. increasing therewith) and to AIS sensitive score (negatively). A factor such as beta EEG component positively influencing BCI ability, i.e. the higher the proportion of beta power, the better the BCI performance - could be used for patient pre-selection based on available clinical data.

Keywords: spinal cord injury, brain computer/machine interface, electroencephalogram, mechatronic/robotic arm device, quality of life.

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