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New approach based on frequency features of EEG signals when obstacles suddenly appear during walking

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Introduction: The study of cerebral activity allows a better understanding of the cognitive processes and control external devices for disabled people. In this regard, the use of BCI is actively investigated in rehabilitation tasks of lower limbs through exoskeletons [1]. Several studies have worked on this aspect by detecting the start/stop of gait or attention levels while walking [2]. In [3] it was found out that an EEG potential is generated after the visualization of the obstacle and before the user physically reacts. The goal of this work is to evaluate the frequency domain features of this potential to know if the previous results can be improved.

Material, Methods and Results: In order to register suitable data, a treadmill has been used to keep a constant velocity. The obstacle is presented as a background color change in a screen placed in front of the user. Even though the obstacles are presented visually, this work studies the reaction of the users after the obstacle appearance and before their physical reaction. Therefore, electrodes on the visual cortex are not included in the study. The user is asked to suddenly stop the gait when the obstacle appear and then, after a few seconds continue walking. Inertial Measurement Units placed on the lower limb have been used to know when the user stopped the gait. To register the EEG signals, the ActiCHamp equipment at a frequency sample of 500 Hz has been used. 21 active electrodes distributed over the scalp following the 10/10 International System have been used.
Six healthy users and two i-SCI performed these experiments (users 4 and 6 also participated in the previous study). Each user performs 8 repetitions where 7-8 obstacles appear randomly. The first five repetitions have been used to create a specific model for the user. Windows from 150 to 650 ms after the obstacle appears are selected as *reaction* class and the same number of windows of periods where the users were walking normally are selected as *no reaction* class. A CAR spatial filter is applied to all the windows. Then, 7 electrodes are selected (Fz, FC1, FCz, FC2, C1, Cz, C2) following the study performed in the previous work [3]. Afterwards, the frequency features through the FFT of the 7 electrodes is obtained. A study of several combinations of these frequencies is performed. The best results are obtained with the sum of three frequency bands (from 10 to 20, from 20 to 30 and from 30 to 40). This implies the use of 3 features per electrode having a total of 21 features. Finally a Support Vector Machine (SVM) classifier has been used. After creating the model, the last 3 repetitions have been analyzed in pseudo-online to obtain the results. The pseudo-online analysis takes windows of 500 ms each 200 ms. Each window is processed and classified as commented before. The output corresponds to *reaction* or *no reaction* class. This analysis emulates real time. In order to improve the results, a reaction is detected only when 2 consecutive windows are classified in this class. This way, the false positives are widely reduced. Results from Table 1 show an average of 51.6% of true positives and 22.6 false positives per minute.

Table 1. *Results of the pseudo-online test. TP: True Positives, FP/min: False Positive per minute.*

	Healthy users						i-SCI patients			
	1	2	3	4	5	6	7	8	**Average**	**Previous work**
TP	60%	55%	45%	53%	58%	50%	41%	51%	**51,6%**	**61,5%**
FP/min	21,0	24,0	22,8	12,0	19,2	24,6	27,0	30,0	**22,6**	**11,5**

Discussion: The results regarding the TP are similar to the ones obtained with the previous work, but the FP/min are higher. This implies that extracting temporal features on this kind of signals improve versus frequency features. Therefore, new technics and features should be explored to improve the results, mostly in terms of false positive reduction during real time conditions.

Significance: In this paper the evaluation of EEG signals when a user reacts to an unexpected obstacle has been addressed. The signals have been analyzed using frequency features in order to compare with previous works where temporal features were used. Although TP results are similar, the FP/min increases, and as a consequence the temporal features have more useful information that the frequency features.

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