Preventing Cognitive Decline in Elderly Population through Neurofeedback Training: A Pilot Study

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***Abstract*— Neurofeedback training (NFT) allows to self-regulate neural activity, having application on a wide range of disorders to improve cognitive functions. This work was aimed at designing, developing and testing a novel NFT platform to prevent cognitive decline due to normal ageing in elderly population. A closed-loop brain-computer interface based on electroencephalography (EEG) was implemented to measure brain activity in real time. The system is highly configurable and it includes engaging games and applications for visual feedback. In order to evaluate the efficacy of the platform, we performed experiments with 9 healthy subjects over 65 years. General cognitive functions and basal EEG activity were assessed before and after the experiments. Data analysis showed improvements in cognitive performance associated to physiological changes in the EEG. In spite of the promising results, this study has to be extended to extract further conclusions.**

I. INTRODUCTION

World population ageing is a growing problem whose critical point is yet to come. According to the Word Population Aeging 2019 report from United Nations [1], 1 in 6 people in the world will be over the age of 65 by 2050. This situation is accentuated in developed regions, where the percentage of people aged 65 years or over will be 22.1% by 2030, leading to social, economic and health difficulties that will put entire systems on edge [1]. In this context, efforts to mitigate pressure over health care systems are of crucial importance. Cognitive decline associated to normal ageing has been recognized as one of the most important risk factors in this population. However, efforts to find protective factors and therapies to mitigate cognitive decline have not been fully successful yet.

Neurofeedback training (NFT) allows to self-regulate brain activity through real-time feedback of neural activation parameters, usually obtained from the electroencephalography (EEG). NFT has emerged in recent years as a promising methodology to correct pathological states and behaviours such as attention deficit hyperactivity disorder, anxiety or depression, and even to improve recovery expectancies after suffering brain damage provoked by stroke or trauma [2]. Furthermore, NFT has also been proposed as a cognitive enhancement tool for healthy subjects [2]. This study is focused on investigating the use of NFT to prevent cognitive decline in the elderly. Previous attempts showed promising results, but more studies are needed to extract definitive conclusions [3]. This preliminary work was aimed at designing, developing and testing a novel NFT platform to enhance the general cognitive state in order to prevent the decline associated with normal ageing. To evaluate the efficacy of the platform, we performed a pilot study with 9 subjects aged 65 or over.

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II. MATERIALS AND METHODS

A. NFT platform

Our novel platform implements a closed-loop brain-computer interface (BCI) that analyses the subject's EEG and offers visual feedback in real time. The platform is highly configurable and implements a wide range of signal processing methods, allowing to design custom NFT protocols. Based on previous evidence, 4 training tasks were designed to enhance the general cognitive performance. The first three tasks were focused on memory, attentional control and conceptual activity executive functions, whereas the fourth task was intended to increase the overall cognitive performance. For the memory task, theta (4-8 Hz) and alpha (8-13 Hz) bands were stimulated in the frontal area of the cortex (electrodes Fz, F3 and F4) [4]. In the attentional control task, alpha and beta (13-30 Hz) bands were stimulated in the central region of the cortex (electrodes Cz, C3 and C4). Previous studies showed that this area regulates attention and concentration, and they could be enhanced through NFT [5]. For the conceptual activity task, the user had to stimulate alpha band in the parietal region of the cortex (electrodes Pz, P3, P4) [6]. In these 3 tasks (i.e, memory, attentional control and conceptual activity), the parameter used to offer feedback to the user was the relative power estimated by means of the power spectral density (PSD). Therefore, feedback applications have 1 degree of freedom (i.e, increase/decrease of the power), being positive feedback associated with an increase of the power. These applications are shown in Figure 1a. For the fourth task, the user had to modulate his activity in the two cerebral hemispheres independently using motor imagery (MI). Specifically, through the mental imagination of left and right hand movements, the user produced contralateral synchronization/desynchoronization events in the sensorimotor cortex in alpha and beta bands. These signals are known as sensorimotor rythms (SMR), and had been widely used in BCI. In this case, we used 2 classes, which

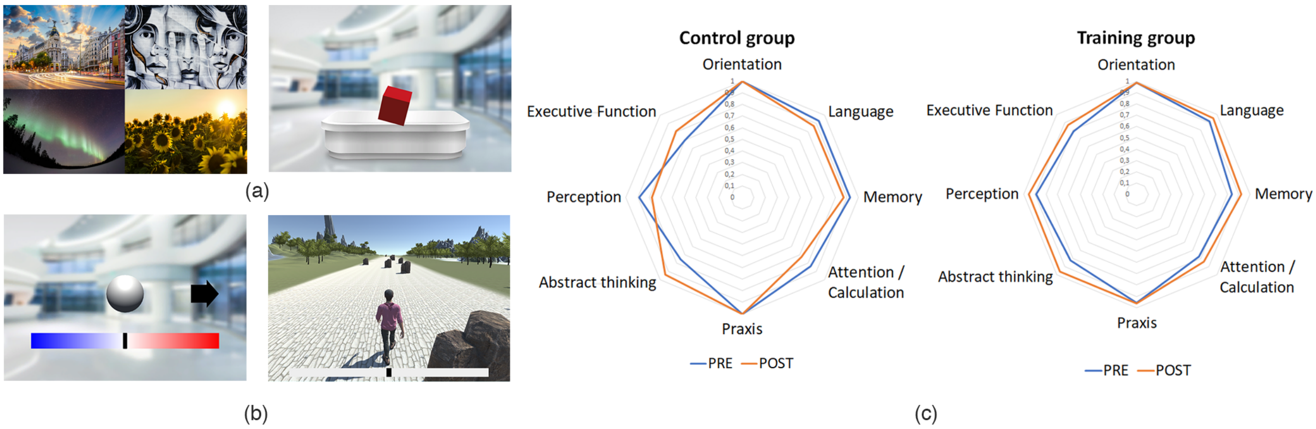

Fig. 1. Screeshots of the NFT platform and results of the cognitive function assessment. (a) Visual feedback with one degree of freedom for tasks 1-3. (b) Visual feedback with two degrees of freedom for SMR training in task 4. (c) Normalized scores of the Cambridge Cognitive Examination Revised (CAMCOG-R) for both groups of participants.

allows to control applications with two degrees of freedom. For the visual feedback, two applications of different difficulties were designed (see Figure 1b). This task require great concentration and mental effort, and previous studies have shown that SMR training could enhance the general cognitive state [3].

B. Experiment

A total of 9 healthy subjects aged 65 or over participated in this pilot study. Only participants that obtained 27 points or more in the Mini Mental State Examination (MMSE) were included in the experiment. Subjects were randomly divided into two groups: 7 were assigned to the training group (TG) and 2 to the control group (CG). Noteworthy, we had an initial population of 10 subjects per group, but only 9 finished the tests due to the COVID-19 situation. Subjects assigned to the TC performed 6 NFT sessions with the platform, whereas the CG did not take special training. For both groups, cognitive functions were assessed before and after the intervention. To this end, Cambridge Cognitive Examination Revised (CAMCOG-R) was applied by a qualified neuropsychologist. Additionally, in order to study physiological changes, 5 minutes of EEG in basal state (eyes closed) were recorded before and after the intervention for the TG. EEG signals were acquired with a g.USBamp (g.Tec, Austria) with 11 electrodes placed on Fz, F3, F4, Cz, C3, C4, Pz, P3, P4, T7 y T8 and a sampling rate of 256 Hz.

III. Results and Discussion

Results of the neuropsychological assessment are depicted in Figure 1c. As can be seen, the TG increased its overall cognitive performance after the intervention, improving in 5 out of 8 categories (i.e, executive function, perception, abstract thinking, praxis, attention/calculation, memory and language). Moreover, the CG did not showed the same tendency, improving in executive function and abstract thinking but reaching lower scores in the rest of categories. Additionally, the spectral analysis of the basal EEG recordings showed that the relative power in theta band decreased after the intervention for the TG (p-value = 0.018; Wilcoxon Signed Rank Test). In this regard, cognitive decline has been associated with increased powers in theta band [7]. Thus, cognitive improvements are associated with significant changes in theta band for the TG.

IV. Conclusion

This study presents a novel and preliminary NFT platform for cognitive training in elderly population. The developed platform includes attractive visual feedback applications and signal processing methods to design custom NFT protocols. Moreover, we performed a pilot study with 9 subjects. Results showed that the designed protocol increased the overall cognitive performance in the TG after 6 sessions of training. In spite of the promising results, this study has to be extended with more subjects in the TG and CG to extract further conclusions.

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