Extended Abstract

Neurofeedback In Ischemic Stroke Rehabilitation

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***Abstract* – The main goal of this project is to study the efficiency of the neurofeedback in the ischemic stroke rehabilitation in a subject who has suffered from it for more than 6 months. Besides, its aim is also to develop a compact training protocol. A case study was developed in a 61-year-old man who had suffered from a left middle cerebral artery ischemic stroke in 2014. The protocol of the study accomplished 5 interviews. They consisted on the recording of the EEG baseline signal. It also consisted on the accomplishment of 4 tests which evaluated the motor and sensorial capacity, the static and dynamic balance, the cognitive capacity and the psychological state. There were neurofeedback intensive trainings during 8 days. At this period of time 31 sessions were performed. The patient got better in the grasping level. It could be verified a positive trend during the interviews in the baseline signal in C3 electrode. It could also be observed an IAB increase in the Oz electrode which was not the training electrode. It seems that there is a positive relation between the C3 alpha training and the grasping results. Its training influences not only the alpha amplitude in this electrode but also in the Oz electrode.**

***Keywords* -** Neurofeedback, Stroke, EEG, *Somnium*, Compact protocol

Introduction

Stroke represents, according to the World Health Organization (WHO), the second cause of death and it is also responsible for great part of morbidity all over the world. It is responsible for causing physical, mental and social disturbs. (WHO - World Health Organization, 2014) (O'Brien JT, 2003)

According to WHO, stroke is caused by the interruption of the blood supply to the brain, usually because a blood vessel bursts or is blocked by a clot. This cuts off the supply of oxygen and nutrients, causing damage to the brain tissue. The damage caused depends on the affected region. It can cause motor, sensorial, speech and others damages.

Neurofeedback training is a biofeedback modality that allows the user to change specific brain rhythms by means of an operant conditioning paradigm. The feedback can be obtained through visual or audio signals. (López-Larraz, Escolano, & Minguez, 2012)

Previous neurofeedback studies in stroke patients revealed great results in the social and psychological areas and speech. However, it is difficult to establish a cause-and-effect relationship, mainly in the motor level.

The main aim of this study is to implement and to produce a project of stroke patient rehabilitation. In order to get this goal, it is

necessary to use the feedback plugin from a software (*Somnium*) and it is also essential to develop a compact training protocol.

Methodology

A. Study case and Experimental Design

The participant is a 61-year-old man who presents some deficits in his right hemibody. In 2012, he suffered an ischemic stroke that reoccurred in 2014 which affected the middle cerebral artery.

This patient was duly told about the entire protocol and gave informed consent.

The experiment consisted on 5 interviews, 2 training sessions and 31 neurofeedback sessions.

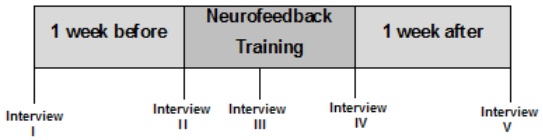


Figure 1 – Interviews plan

The interviews consisted on recording a baseline signal of all the electrodes located on the scalp according to the International 10–20 System and the application of 4 evaluation assessments: Fugl-Meyer Assessment, Tinetti Gait & Balance Assessment, Mini Mental State Examination and Hospital Anxiety and Depression Scale. (Maki, et al., 2006) (Lourenço & Veras, 2006) (Silva, Almeida, Cassilhas, Cohen, Peccin, & Tufik, 2007) (Pina, 2013)

There were 2 sessions of user control training in order to help the patient be used to the neurofeedback software. The neurofeedback 31 training sessions occurred during 8 days.

B.Signal Acquisition

EEG signals were acquired on the C3 and Oz electrodes according to the International 10-20 System. The 2 reference electrodes were placed on the mastoids (M1 and M2) and the ground on the Nasion.

The signals were amplified by an EEG amplifier (Vertex 823, Meditron Electomedicina Ltda,SP,Brazil), that compounded the hardware EEG COMPACT 723, with an analog band-pass filter from 0,1 to 70 Hz. The signals were recorded by the software *Somnium* (Cognitron,SP,Brazil) at a 256Hz sampling frequency. They were filtered by a band-pass filter from 0,5 to 30Hz, and a notch filter at 50Hz. The impedance of the electrodes was maintained below 10kΩ. (Wan, Nan, Vai, & Rosa, 2014)

C. Neurofeedback Procedure

The training focused on the enhancement of the Individual Alpha Band (IAB) activity over the C3 electrode.

It was necessary to calculate the IAB before the neurofeedback training by crossing the baseline resting signal information obtained with the eyes opened and closed.

After defining the IAB, the “EEG Feedback” function of *Somnium* was opened to performe the training. The training parameters were defined in 10 trials that were performed during 20 seconds each, there were a 5 second-interval among them.

It was used the following equation to calculate the IAB relative amplitude:

$$relative\ alpha\ amplitude = \frac{\frac{\sum_{k=LTF}^{HTF} X(k)}{HTF - LTF}}{\frac{\sum_{k=0.5}^{30} X(k)}{30 - 0.5}}$$

Equation 1 – Equation to calculate the IAB relative amplitude

Where the HTF is the High Transition Frequency, the LTF is the Low Transition Frequency and the *X*(*k*) is the frequency amplitude spectrum calculated by fast Fourier transformation (FFT).

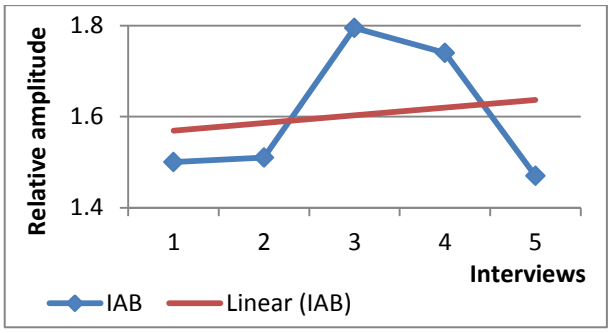
Results

A. Interviews - Tests

The patient showed the same results in the 3 tests that were applied to him in the 5 interviews. Although this didn't happen in one test, Fugl-Meyer Assessment. The total difference in the results was obtained by the category that evaluated the superior member motor function. This was clearly observed in the items that tested the patient's capacity of grasping.

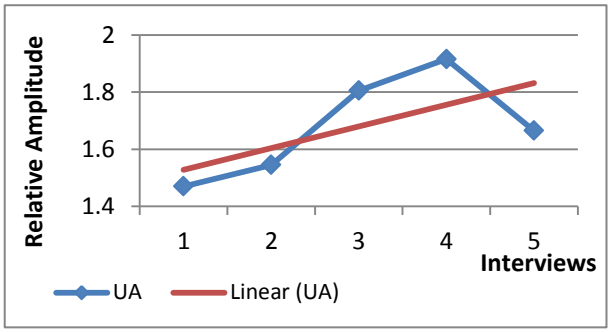
B. Interviews - Baseline Signal

In each baseline sinal recording, the signal was recorded during 8 minutes, two periods of 2 minutes with the eyes opened and 2 minutes with eyes closed. The relative amplitudes of IAB, Lower Alpha 1 (LA1), Lower Alpha 2 (LA2), Upper Alpha (UA) and Alpha were calculated for each signal. It was calculated the average of the two periods of the baseline signal in order to obtain the result graphics.



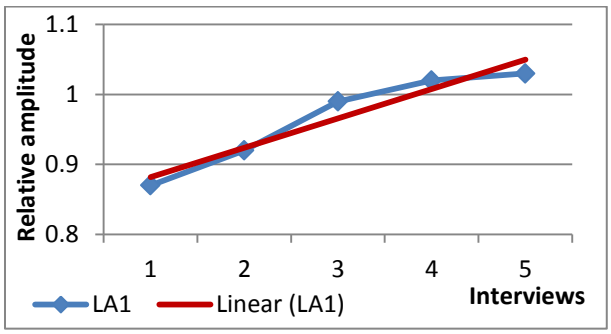
Graphic 1 - C3 | IAB – Eyes closed

Graphic 1 shows the variation of the IAB in the interviews. The IAB value was influenced by the relative amplitude of its components. This positive trendline was mainly influenced by UA.



Graphic 2 – C3 | UA – Eyes closed

It was verified that the bigger increase of IAB was with the eyes closed. However, the opened eyes graphics showed more evidence in the LA1 positive growth.



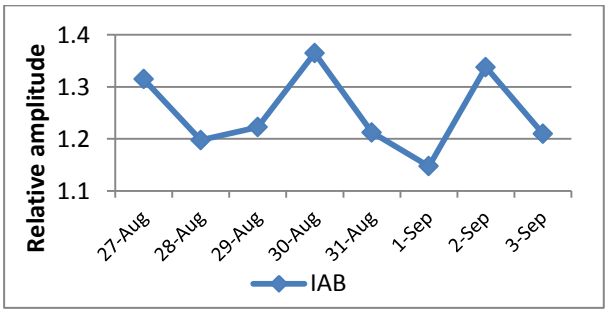
Graphic 3 – C3 | LA1 – Eyes opened

In spite of the training sessions not being done in the Oz electrode, the signal obtained

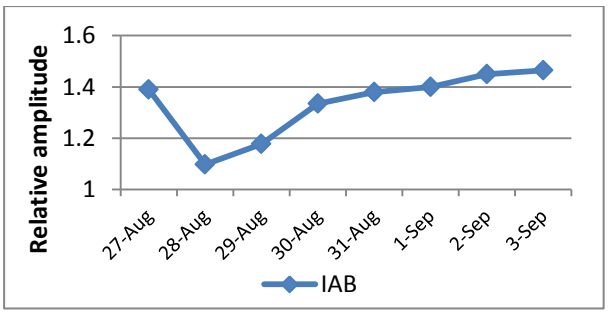
with this electrode was recorded just to be compared with the signal obtained with the C3 electrode. The graphics got by the Oz electrode signals showed a positive trendline during the interviews.

C. Neurofeedback signals

It was calculated the daily average of the same parameters analyzed in the baseline signals considering that 2, 4 or 5 neurofeedback sessions were done a day. The signal was also recorded in the Oz electrode.



Graphic 4 – C3 | IAB



Graphic 5 – Oz | IAB

The graphics above show the progress of the IAB relative amplitude average during the training days in the C3 and Oz electrodes.

Discussion

As observed in the results item, the only assessment that has showed different results along the interviews was the Fugl-Meyer assessment.

This way, the patient presented higher values in the grasping items of the right hand during the third (applied in the middle of the training) and the fourth (applied on the last day of the training) interviews. Suggesting that the neurofeedback training in the C3 region can be related to a better grasping function.

When analyzing the graphic trendlines of the C3 signal obtained with closed eyes, we could observe that the IAB amplitude increased. It was showed a growing trend although these values had varied during the 5 interviews. It was also observed that all the Oz graphics showed a positive trend.

In general, the value of the IAB relative amplitude was always above the baseline signal IAB values analyzed with opened eyes. This means that the aim was achieved.

There was also a progressive increasing in the IAB amplitude when analyzing the Oz training graphics.

Final appreciations

A. Conclusions

In conclusion, the IAB enhancement in the C3 electrode seems to be related to the improvement of the grasping function, with the growth of the IAB baseline signal recorded with closed eyes. It has also been observed positive interferences in the relative amplitude recorded on the Oz electrode.

B. Futures studies

It is suggested to join other evaluation methods like electromyography. In order to know if this training protocol influences other parts of the brain, it is suggested to do a signal acquisition on more electrodes. It is also

suggested the use of an specific scale for the motor function hand evaluation.

This study case presented potential positive indications to patients with middle cerebral artery ischemic stroke with more than 6 months of evolution. A study with more subjects should be done to confirm this fact.

References

WHO - World Health Organization. (May 2014). Obtained on November 15th, 2015, in http://www.who.int/mediacentre/factsheets/fs310/en/

López-Larraz, E., Escolano, C., & Minguez, J. (2012). Upper Alpha Neurofeedback Training Over the Motor CortexIncreases SMR Desynchronization in Motor Tasks. *34th Annual International Conference of the IEEE EMBS* (pp. 4635-4638). San Diego, California USA: IEEE.

Lourenço, R. A., & Veras, R. (2006). Mini-Exame do Estado Mental: características psicométricas em idosos ambulatoriais. *Revista de Saúde Pública*, 712-719.

Maki, T., Quagliato, E., Cacho, E., Paz, L., Nascimento, N., Inoue, M., et al. (2006). Estudo de confiabilidade da aplicação da escala de Fugl-Meyer no Brasil. *Revista Brasileira de Fisioterapia*.

O'Brien JT, E. T. (2003). Vascular cognitive impairment. *Lancet Neurology*, 89-98.

Pina, J. d. (2013). *A pessoa com depressão pós Acidente Vascular Cerebral.* Setúbal: Instituto Politécnico de Setúbal.

Silva, A., Almeida, G. J., Cassilhas, R. C., Cohen, M., Peccin, M. S., & Tufik, S. (2007). Equilíbrio, coordenação e agilidade de idosos submetidos à prática de exercícios físicos resistidos. *Revista Brasileira de Medicina e Esporte*.

Wan, F., Nan, W. N., Vai, M. I., & Rosa, A. (2014). Resting alpha activity predicts learning ability in alpha. *Frontiers in human neuroscience*.