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EXTERNAL STIMULATION IN NEURAL MATRIX RECOVERY

BY

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Abstract. External stimulation of the skin generates different levels of activity in neural network, levels that can lead to neural regeneration matrix. These levels are coordinated by algorithms that generate epidermis stimulation. By observing the activity of neural network through 2D and 3D topographic analysis and time-frequency analysis, we can decide which functions of the algorithm must be maintained, updated or removed in order to have a maximum neural stimulation and reply. This analysis is intended to improve the initial set of data constituting the initial matrix in the process of neural stimulation and the forming of initial matrix for various neural disorders. The accuracy of these matrixes will decrease the response time of the patient with the applied stimulation algorithms and will improve the quality of response and motor cortex.

Keywords: algorithms; epidermis; sensors.

1. Introduction

Cerebrovascular accident (CVA) occurs when the blood flow to a part of the brain is stopped. CVA is categorized in ischemic or hemorrhagic: ischemic CVA occurs when the blockage stops the blood flow and hemorrhagic when a blood vessel suffers a rupture. Both ischemic and hemorrhagic CVA will reduce the blood flow and oxygen level in the portion of brain where CVA is located.

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Blocking the flow of blood to any part of the brain for just a couple of minutes will lead to the death of neural endemic cell (not only) and thus, the affected areas will reduce their functions and activities (Duvinage *et al*., 2013; Kandel *et al*., 2000).

This raises a question. Is reducing the activity not a reversible process somehow? Perhaps these functions can be active again once the creation and initialization of initial operating conditions take place. Can the functional memories and the functions once thought lost be reversed, not only by setting initial conditions, but also by rebuilding the entire process of learning?

When the motor cortex is damaged, neuromotor functions are diminished and so the patient will be unable not only to coordinate daily activities but also to determine recovery activities (Badcock *et al*., 2015; Graimann *et al*., 2010).

The actions to be taken in case of a CVA, regardless of its type, hemorrhagic or ischemic, require rapid intervention and not just medication. Non-action after CVA can generate permanent damage to brain function, permanent disabilities, most often without being able to be remedied within the life span of a patient suffering what CVA.

In support of these actions, the research of methods that can be used to stimulate the patient, correlated with the research of neural activity in response following stimulation, may show new methods of treatment and rehabilitation of the patients who suffered CVA.

Mathematical directed and coordinated stimulation on the patient's epidermal level after an initial matrix generates a response in the motor cortex areas F3, FC5. Thus, we highlight the function of stimulus defined on an initial matrix with values in the motor cortex.

2. Hardware Equipment

To demonstrate the existence of this function, we will use a device that generates mechanical impulses according to a reference matrix (initial matrix). The second part consists from mathematical modeling of signals emitted by the brain and captured with an EmotivEpoc + Row device, 14 channels.

The components are listed in the Table 1.

Table 1
Equipment's

Monitoring	Stimulation	Capturing
Lenovo T520		EpocEmotiv+ Row
Beagle Bone Black	StD	
4DCAPE-70T		

The operating system and the software packages are mentioned in the Table 2:

Table 2
Operating Systems

SO	Capturing	Modelation
Linux	Open Vibe	Open Vibe
Windows	Emotiv	Mat Lab
		Open EEG

External Stimulation Device (ESD) is the device that will convert the starting matrix into stimuli that will be applied on the patient. It consists of a Beagle Bone Black board running Linux, Debian distribution to which it is connected an electronic system StD (Fig. 1).

Its role is to read the initial matrixes and the replication of matrix values in impulses sent to the epidermis, through its connection with sensors L and R.

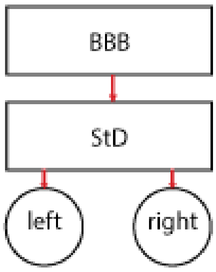

Fig. 1 – ESD - Main Board BBB, StD (hardware).

ESD can monitor the status of the patient by collecting data such as: temperature, luminous flux, movement of patient, etc. For monitoring, it is used Python, with the MathPlotLib library. For stimulus transmission, two vibrating elements, left - right are used.

When EDS is used in practice, it communicates directly with the patient and its role is to observe the most sensitive changes.

EmotivEpoc + is a device used for capturing the electrical activity of the brain, using 14 channels and two references. It is used to measure visual response and can be used to highlight the event related potential (ERP).

Epoc headset is composed of 14 sensors, two references, a wireless transmitter and sensors AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4. M1 and M2 act as ground reference point in order to be able to measure the output (Fig. 2).

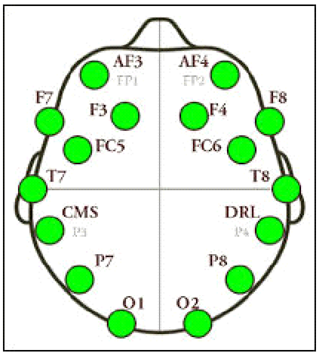

Fig. 2 – Electrodes.

Epoc uses a notch filter (50Hz-60Hz) and a low-pass hardware filter and the signal is sent with a resolution of 128 bits (Fig. 3).

Fig. 3 – EmotivEpoc+ Row device.

3. Theory

3.1. Calibration

The initial phase is to ensure a maximum relevant to the hardware device Epoc + , that will be used to reveal the samplings that will be analyzed and modeled mathematically.

Before starting to capture neural waves, the Epoc device must be calibrated because it does not have enough sensors on the middle area of the motor cortex and so the F3 and FC5 sensors must be repositioned, closer to the median on the Epoc device.

Once the F3 and FC5 sensors are positioned so that the reference of the signal function is positive and the Epoc device reports a positive level connection (green flag), we start to capture the first samples.

Once we have the first samples, we must ensure that these represent real, not fake, data even if the notifications reported by Epoc are green on each of the sensors (this indicates that the sensors work in parameters and the captured signals can be modeled, representing the real data).

3.2. Capturing Neural Signals

In this stage, we intend to capture neural activity from all areas available allowed by Epoc + device, particularly in the AF3, F7, F3 and FC5 areas, that represents the maximum area of interest.

We note with N1 and N2 the samplings we obtain by capturing neural activity and with A1 and A2 the algorithms that will generate the external stimulation of the skin through the StD device. The ΔLAn is the notation for the time interval corresponding to the external stimulation for the left part – left hand stimulation and ΔRAn the time interval for the right part – right hand stimulation.

These data may be represented in the following table as we can see:

Table 3
StD Initial Data Set

Δ(L|R)A	L, [sec]	R, [sec]
	0.5	0.0
	1.0	1.0
	1.2	0
	0.0	1.0
	...	

In this stage, we seek to capture neural responses as function on the external stimuli generated by ESD and correlate them with the responses obtained from mathematical modeling performed on the obtained N1, N2 samplings.

This correlation will help us to create a stimulus - response (SR) correspondence, which associates a mathematically modeled response to the time period generated by the StD.

Thus, we can say that an Nkx response corresponds to an Akx interval and so, this response is due to external action generated by StD, where k = 1,2, x = 1,j, j <= N, N is the counter of values from Table 3. Table 3 has four values, so in this case N = 4. In practice, values of N are 30 – 50 in order to have sufficient external stimuli.

Next phase is to upload the algorithm in ESD, start the ESD and capture the brain electric signals.

ESD will generate left-right external stimulations following the next flow that has the distribution: ID, BL, TL, BR, TR.

ID = Stimulation ID,

BL = 1; 0-0 stop; 1 send stimulus on the left,

BR = 1; 0-0 stop; 1 send right stimulus,

TL = float (x, y) - the number of seconds in which the left side stimulus is activated,

TR = float (x, y) - the number of seconds in which the right side stimulus is activated.

And so, a string of this form:

0, 1.2, 1, 1.5 means only right side stimulation for a period of 1.5 sec.

While a string of the form:

1, 0.5, 1, 0.7 means left side stimulation for 0.5 sec and right side stimulation for 0.7 sec.

For obtaining the N1 and N2 samplings, Epoc + is initialized and OpenVibe is started. OpenVibe will capture neural flows and it will save them in the OpenVibe format. For this, we use a simple script that reads data from Epoc + driver and converts it into an open format with Vibe.

In this way, samplings (data) will be loaded into the modeling phase and the results will be associated with the Ax intervals corresponding to each stimulus applied to the skin. The stimulus will generate neural feedback and this will prove that to the intervals: delta la and delta ra correspond specific neural feedbacks. These feedbacks will prove changes in the neural matrix, generated by external stimulation.

3.3. Mathematical Modeling

This step involves the existence of N1, N2 samplings obtained from external stimulation with the evaluation of the response in the motor cortex.

To analyze these samplings, we will use the OpenVibe application in which a scenario S will be created which when running on samplings N1, N2 will show (Fig. 4):

Fourier distribution on the areas F3, FC5

2D Topographic Map - VC1

Time Frequency Map - VC2

Mathematical modeling of samplings lies in:

The reading of the samplings saved in GDF

Filtering the signals depending on the frequency of study (0, 12 Hz, 12-17 Hz)

Spectral analysis (FFT)

Data display

2D Topographic Map

TFM - Time Frequency Map

The scenario thus defined will run on the files obtained (Sampling files) and we will see each result Pk, k = 1, n, n <= N (N = number of datasets from Table 3) that correlates the time of OpenVibe with the StD time.

To be reminded that this correlation is possible because the start time was synchronized with StD and data logging using Epoc +.

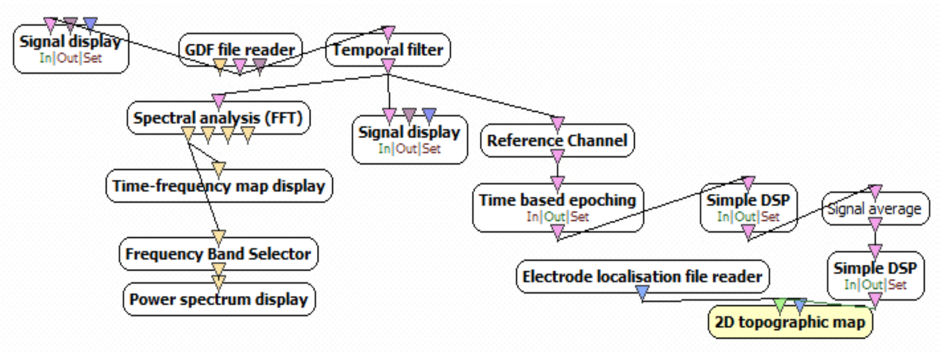

Fig. 4 – Scenario.

With Epoc + device configured, calibrated, initialized, ready for recording, the StD is started and Delta StD is withheld from OpenVibe. Now is possible the correlation between the events X noticed by modeling and the StD time, when the external stimulation is held.

By running scenario S on the samplings Nk (k = 1.2 in this case) we will be able to observe changes which took place in the motor cortex. These observations are made by detecting changes in VCSi, VCTi, VTTi, where:

VCS_i – Signals at the time T_i, from sampling N_k (Fig. 5)

VCT_i – 2D Topography at the time T_i, of sampling N_k (Fig. 6)

VTT_i – Time Frequency Map at the time T_i, from sampling N_k (Fig. 7)

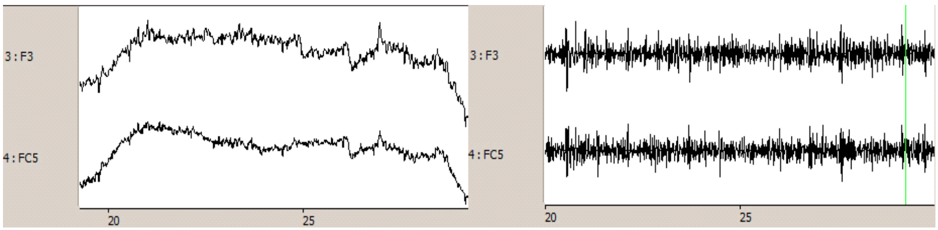

Fig. 5 – Signals – $VCS_{i,}$, i = 1.

By comparing the time periods when changes occur in the cortex with the time periods from Table 3, we find that there is a correlation between these events, so we can infer that the observed changes in the motor cortex are due to the external stimuli of StD.

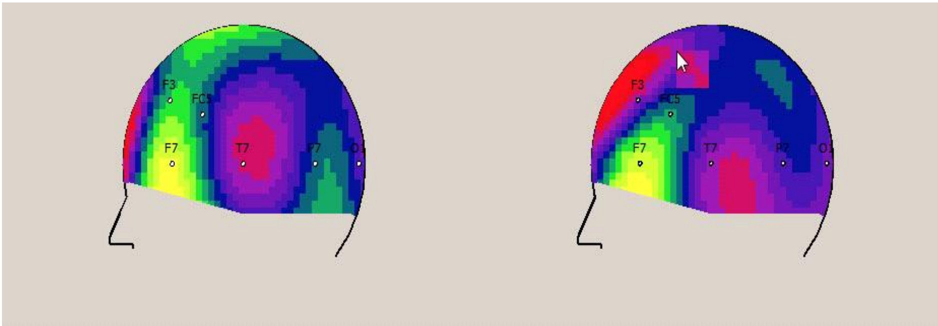

Fig. 6 – 2D Topography – $VCT_{i,}$, i = 1.

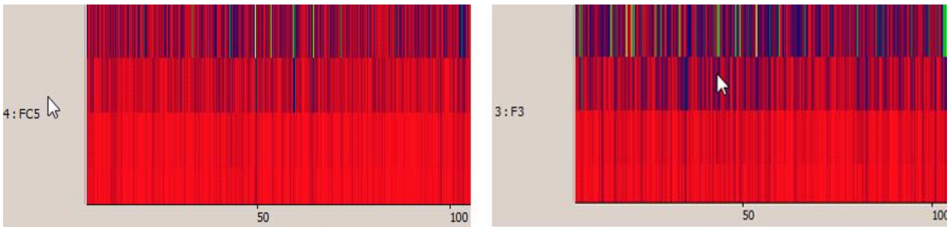

Fig. 7 – TFM 2CH – VTT_i, i = 1.

The next stage is to analyze whether the changes that we observe through the shaping of the motor cortex activity may be correlated with stimulation times defined in ESD for the A_{left} and A_{right} values.

If until now we have shown that the external stimulation produces changes in the motor cortex, we intend to show that these changes can be coordinated according to the algorithm tried in ESD.

Thus, a series of the form

$$\prod_{k=1}^{n} AL_k \,|AR_k \qquad (1)$$

where AL_k is the value for the left side and AR_k is the value for the right side, will determine the distinct electrical activity, depending on the AL_k and AR_k value changing.

This change in the motor cortex activity, dependent on the values of external left and right stimulation, makes us propose to find the values for which the CM activity is maximum.

These values can complete Table 3 or can even replace the initial data of the table, becoming thus the standard protocol for starting the restoring CM program.

It is recommended like these changes be backed up by observations on the state of patients on which stimulus and PET analysis algorithms will be applied as a more objective picture of the state and patients evolution.

Depending on the input algorithms and the observations on patients, arrays of initial data can be defined. These can be loaded in StD depending on the initial state of the patient and according to initial medical evaluation.

4. Conclusions

External stimulation in the epidermis involves motor cortex activity responses, responses that are driven mostly by changes during left right stimulation.

The initial start matrix has to be updated in order to obtain the maximum result from the CM activity. In the update process, the observation and the evolution of the patient have an important role. Also, the changes to the CM obtained by PET scan are important.

The sum of these observations, their conversion into start matrixes and their segmentation depending on the types of neural disorders constitute the main engine in medical rehabilitation of patients.

The external stimuli used in this experiment were rudimentary, but nonetheless the results confirm the theory of generating an activity to the CM through mathematically directed and coordinated external stimulation. The use of external stimulation equipment (equipment that can generate quick response feelings) leads to the improvement of algorithms and patient response and thus to an improvement of motor activity in the process of recovery and medical rehabilitation.

The notions presented are the basis of building a medical device that can provide a viable solution in the process of recovery and medical rehabilitation, a process that is treated most often with indifference in the wake of CVA or other neural dysfunction.

Along with running multiple experiments to obtain initial data matrices (for implementation in StD) changes can be observed at the state of patients suffering from Alzheimer, etc.

Following tests and establishing data matrices, the StD system can run by itself on the patient, the data gathered about patient's progress being sent to a server that will change algorithms depending on patient progress.

In this way, patients who have suffered a CVA or neural dysfunction may have the chance of recovery and rehabilitation considering that this process does not require high costs and the fact that this process of recovery and rehabilitation is continuous 24/7/365.

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STIMULAREA EXTERNĂ ÎN RECUPERAREA MATRICII NEURONALE

(Rezumat)

Stimularea externă la nivelul epidermei generează diferite nivele de activitate în rețeaua neuronală, nivele ce pot duce la regenerarea matricii neuronale. Aceste nivele sunt coordonate de algoritmii care generează stimularea epidermului. Astfel, prin observarea activității neuronale, și anume prin analiza topografică 2D, 3D și timp-frecvență putem decide care dintre funcțiile algoritmului trebuie menținută, actualizată sau înlăturată, pentru a avea un maxim de stimulare neuronală și răspuns. Această analiză are rolul de a îmbunătăți setul inițial de date ce constituie matricea inițială în procesul de stimulare neuronală și de formare a matricii inițiale pentru diverse tipuri de afecțiuni neuronale. Acuratețea acestor matrici va duce la micșorarea timpului de răspuns al pacientului pe care se aplică algoritmii de stimulare pentru îmbunătățirea răspunsului și calității cortexului motor.