

# Changes in electroencephalographic spike activity of patients with focal epilepsy through modulation of the sensory motor rhythm in a brain-computer interface

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## ABSTRACT

In epilepsy persistence of seizures, despite appropriate pharmacological therapy, motivates referral to surgery of epilepsy, currently the most effective treatment. Because surgery is not indicated for all patients, search for alternative therapies is ongoing. Preliminary data suggests the potential benefit of sensory-motor rhythm modulation on the epileptic activity. However, no controlled studies have been performed. Our study evaluates the benefits of sensory-motor rhythm training to reduce spike activity in Rolandic epilepsy patients with frequent spike activity. Using a Brain-Computer Interface, we obtained a statistically significant modulation of the Mu rhythm and variation of interictal spike activity.

## 1. INTRODUCTION

Epilepsy is one of the most prevalent neurological diseases and it is among the most common brain disorders worldwide, with no age, racial, social class, and national or geographic boundaries. More than 50 million people in the world today, 85% of whom live in developing countries, have it. The impact of epilepsy ranges from the person with epilepsy to the family and indirectly to the community. The burden of the disease can be due to physical hazards of the unpredictability of the seizures, social exclusion because of negative attitudes of others towards them, and stigma as children with epilepsy may be banned from school, adults may be barred from marriage, and employment is often denied, even when seizures would not compromise patients' work. At least 50% of new cases begin at childhood or adolescence and 70% to 80% of people with epilepsy could lead normal lives if properly treated (WHO, 2005).

Epilepsies are due to an abnormal electrical activation of parts of the brain, which produces not only local dysfunction but can also involve other normal areas and compromise to a variable extent the function of the all brain. Thirty to forty percent of epileptic patients still have seizures even after using several anti-epileptic drugs. Those are considered for surgery, which is an effective procedure, but not available to most patients. A significant number of cases remain that do not have their seizures controlled either by drugs or surgery (WHO, 2005). A number of alternative therapies are then considered which are in general less effective and with a still limited scientific basis. One of these is the modulation of the Mu rhythm by neurofeedback procedures.

Neurofeedback therapies have generated a lot of interest in connection to several pathologies and a therapeutical potential has been recognized in several disabilities such as attention-deficit/hyperactivity disorder (Levesque, 2006; Heinrich, 2004; Strehl, 2006), addictions (Raymond, 2005), cognitive disorders (Vernon, 2003), pseudoseizures (Swingle, 1998) or epilepsy (Kotchoubey, 2001; Monderer 2001; Sterman, 2006).

Neurotherapy based on neurofeedback is considered to be a brainwave biofeedback, as the participant can consciously know if a desired brainwave pattern is being obtained (Hammond, 2005). In this way and according to Kotchoubey (2001), achieving negative shifts of slow cortical potentials reflect widespread depolarization of apical dendrites of pyramidal neurons and decrease of threshold for paroxysmal activity.

Among those brainwaves, the modulation of the EEG sensory-motor rhythm (SMR) to decrease epileptic activity is a possible option. According to Sterman (2000), changes in SMR activity reflects on average 80% of patients were shown to display significant clinical improvements. The easy implementation of such a method and potential widespread availability deserves a more in depth evaluation of its potential role as an anti-epileptic.

An experimental quantification of the epileptic activity over the sensory-motor brain areas of patients with the syndrome of BRE (benign rolandic epilepsy) has been designed and is undergoing data acquisition. The origin of epileptic spikes in this epileptic syndrome is well known to originate in the rolandic fissure, which is also the most likely area of origin of a physiological EEG rhythm best seen in resting conditions known as Mu rhythm.

The ability to modulate the Mu activity has been well established and the suggestion that such modulation can have an antiepileptic effect (Sterman, 2006) generated interest for its potential therapeutic importance. Nevertheless the antiepileptic effects mentioned in the literature were not based in a sound quantification of EEG spike activity, but instead in seizure frequency reporting. The physiological mechanisms underlying such effects remain poorly characterized. The selection of a group of patients with epileptic activity in the area of maximal Mu activity can provide an important opportunity to better establish the power of Mu rhythm manipulation on the pathological activity and therefore test the previous claim.

Recent studies have reported cognitive impairment in patients with the BRE syndrome which could be related with the interictal spike activity. Such observations suggest that a benefit could be derived from reduction of such activity, independent of the effect in seizure events. Because our patients have very abundant interictal spikes while awake, they are primary candidates to benefit from the reduction of such pathological rhythms.

This on going study will to assess the viability of using a Neurofeedback Brain-Computer Interface (BCI) as an efficient brain SMR training device and evaluate its contribution to modulation of epileptic interictal activity recorded concomitantly.

## 2. METHOD

### 2.1 *Material*

Signal acquisition and BCI presentation were, respectively, obtained and presented on a Pentium IV Laptop computer, with a 2.4Ghz Intel processor and 1Gb RAM, equipped with NuAmps Acquire 4.3.3, a Brain-Computer Interface built around the BCI2000 software package. To acquire patient EEG rhythm, we used a NuAmps 40 channel LT40 Headbox and 12 (Ag/AgCl) scalp electrodes. A PowerPoint slide presentation was developed using two "Search for Waldo" books images. Matlab 6 was used to perform EEG data statistical analysis.

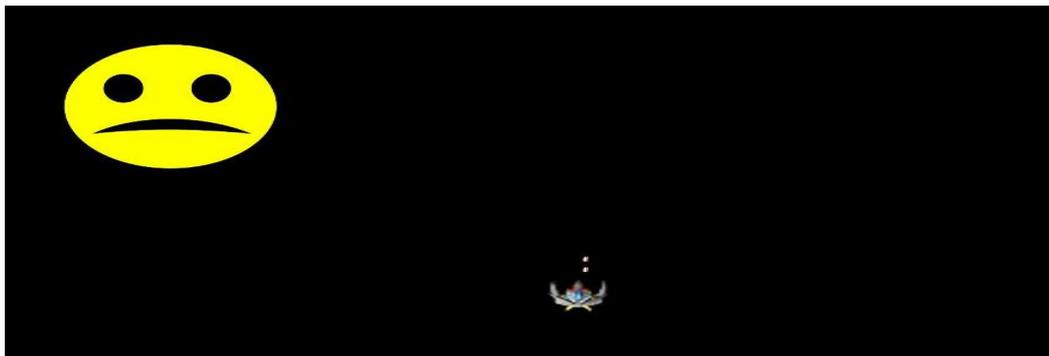
### 2.2 *Participants*

Six patients with the syndrome of Benign Rolandic Epilepsy (BRE) and attended in the outpatient clinics of the Pediatric Neurology Department of Hospital Dona Estefânia were included in the study. They were selected from a larger group of patients with the same syndrome by the requirement that they express abundant interictal spike activity in the awake EEG. No cognitive impairment or motor-sensory abnormalities in the neurological examination were detected.

In BRE patients express high amplitude interictal spikes over the central regions, with a maximum in the electrodes that best pick up the Mu rhythm (C3 and C4 of the 10-20 system). Both types of activity are thought to originate in the sensory-motor areas.

### 2.3 *Procedures*

Two conditions were designed in order to modulate the sensory motor rhythm. EEG was recorded on the two conditions to compare the number of epileptic seizures.



**Figure 1.** *Space Invaders-type game. Using sensory motor rhythm, the participant must control de cursor (space ship) in order to hit the target (yellow face).*

The first condition (Motor Condition) was assigned as the movement condition. For that, a Space Invaders-type game was created, with random targets in the left or right visual field. The sensory motor rhythm of the central electrodes was used to control the cursor in order to hit the (right or left) target. Both real hand movement and imaginary hand movement were analysed (see Fig. 1).

The second condition (Waldo Condition) was a non-motor condition, in which, several images of “Search for Waldo” were used in order to allow visual search for a target (Waldo) in a slide presentation.

Both conditions were alternatively presented throughout six trials. Each condition consisted on a five minute block so that in both the improvement in sensory-motor rhythm control and the effect of training in epileptic activity could be analysed.

The EEG was continuously recorded at 250Hz rate, using a Hjorth local derivation around the C3 and C4 positions of the 10-20 system of electrode placement. Along with EEG recording, the time of the events and responses from the patient were also registered. Signal was acquired using a 70Hz low pass filter, 1Hz high pass filter and 50Hz Notch. Ground electrode was attached to AFz position and FCz was used as reference.

Several measures of interest are derived from the EEG recording such as the power in the Mu band, amplitude of desynchronization and number of interictal spikes.

The Motor Condition (MC) allowed to create two Mu classes: high and low Mu classes. On the high Mu class the ipsilateral movement electrode activity (C3 for left movement and C4 for right movement) was analysed. The analyses of the contralateral movement electrode activity enabled the creation of the low Mu class.

The Waldo Condition (WC), not involving a motor task, allowed to create a baseline Mu class.

In order to compare these three different Mu classes, in the MC Mu classes, a 3 second-long epochs from the EEG recording were extracted when the visual target was hit. Both C3 and C4 activity were, also, recorded and classified as a decreased or increased Mu classes, for each hemisphere separately. For the baseline Mu class, 3 second-long consecutive epochs were extracted from the EEG recording while the patient visually “searched for Waldo”.

Using the bootstrap method, a time-frequencies coherence plot, with a significant level of 0,01, were produced for each relevant electrode channel. This analysis aimed at comparing pre and post stimuli onset spectral changes.

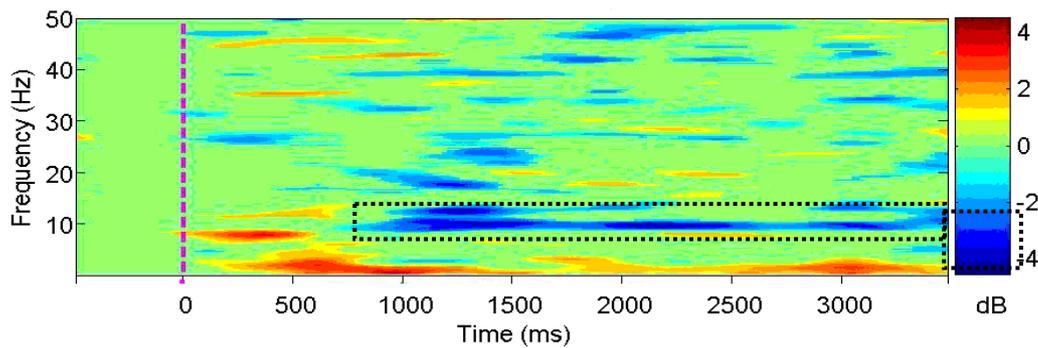
Epileptic spikes were, also, counted in every Mu class.

### 3. RESULTS

The experimental setup allowed a reliable modulation of the Mu spectral band. Through the Motor Condition (MC), participants were asked to continuously open and close their target side hand until the target was hit by the cursor. Since the contralateral electrode activity was analysed, a low Mu class was expected to be found due to SMR (sensory motor rhythm) desynchronization.

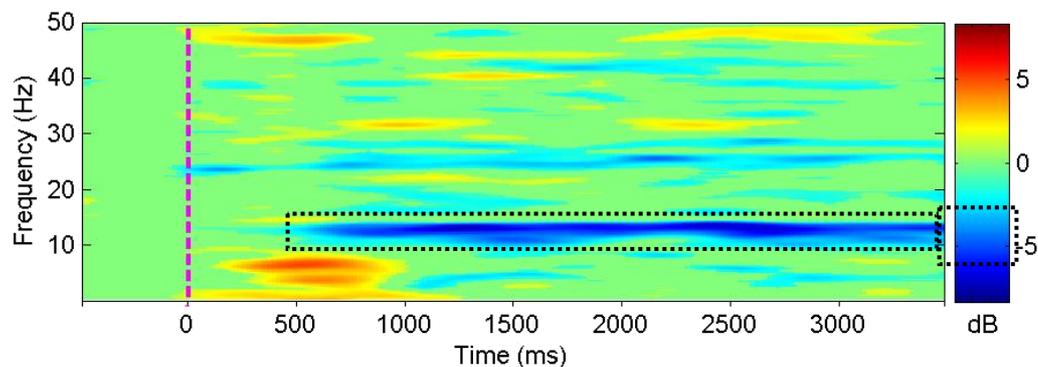
The Event Related Spectral Plot (ERSP) (Makeig, 1992) demonstrates a Mu band (10-12Hz) reduction around -3dB when the contralateral electrode activity was analysed (Fig. 2). When compared with baseline, the bootstrap technique showed significant spectral changes after 750 ms stimuli presentation. As seen in Fig.

1, about 750ms after stimuli onset, in this case a target appearance on the left side of the screen, there was a desynchronisation only noticed in this band pattern.



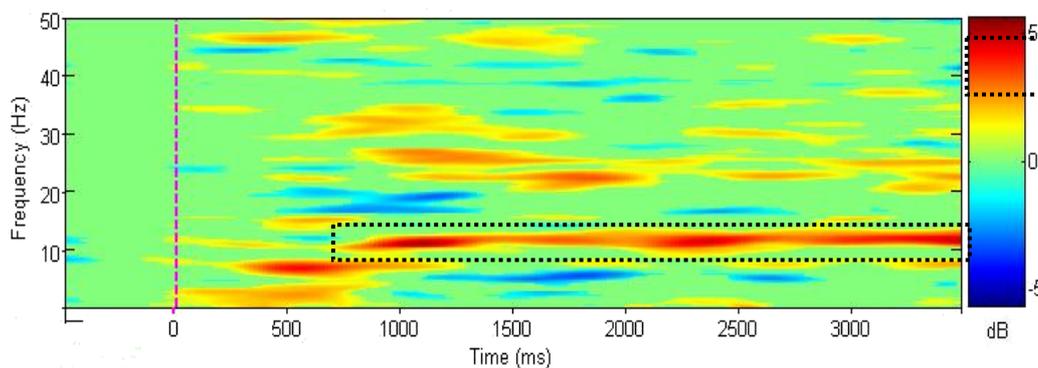
**Figure 2.** ERSP plot of significant reduction in the Mu band at contralateral electrode C4 by movement of the left hand.

Also on the Motor Condition, similar modulation of the Mu spectral band is noticed when the participant is asked not to move his target side hand, but only to imagine the movement. Imaginary hand movement also showed a desynchronisation in the 10-12Hz band, from 500ms after stimulus onset (see Fig. 3). A low Mu class was also found.



**Figure 3.** ERSP plot of significant reduction in the Mu band at contralateral electrode C4 by imagination of left hand movement.

On the other hand, when the ipsilateral electrode activity is analysed, the ERSP demonstrates changes in opposite directions, over the sensory-motor area (see Fig. 4). In this case, an increase of Mu spectral band is noticed at 10-12Hz.



**Figure 4.** ERSP plot of significant increase in the Mu band at ipsilateral electrode C3 caused by movement of the left hand.

Epileptic spikes in benign rolandic epilepsy (BRE) are easily recognized (Fig. 5) and of much higher amplitude than the background rhythms.



**Figure 5.** *Examples of epileptic spikes at electrode C3, demonstrating the typical morphology.*

Quantification of the spike activity throughout the sessions in each class of Mu rhythm will provide a means to perform statistical evaluation of the changes both across classes and in the same class through the training process.

#### 4. DISCUSSION

The present study points towards a consistent way to modulate sensory-motor rhythm (SMR) and quantify such changes in order to compare three different Mu rhythm classes. Also, the obtained results showed that no real movements are needed as in imaginary movement protocol, significant Mu rhythm changes were obtained.

At a 0-50Hz spectral band analysis, only the 10-12Hz band as statistically significant changes throughout the designed protocol. Therefore, other brain waves influence may be excluded since there are no statistically significant changes at Delta frequency band (0.5-4Hz), Theta (4-8Hz), and Beta frequency (14-30Hz). Also Alpha waves (8-14Hz) are excluded since there are only statistically significant changes after the stimuli onset.

Furthermore, the experimental task has not been contaminated by electromyographic activity artefacts, since no statistically significant changes have been found at high spectral band (above 30Hz). In that way, quantification of spike activity can be strongly associated with Mu rhythm modulation.

The designed protocol also produced different Mu classes that can be compared. As expected, when movement was required or imagined, a significant Mu desynchronization was obtained in the contralateral electrode electrical.

A significant modulation of SMR was also obtained when the ipsilateral electrode electrical activity was analysed. In fact, the results showed an increased SMR using both real and imaginary movements.

The condition where the participant has to visually search for a target and non-movement was required, allowed a baseline Mu rhythm comparison, has to analyse a possible placebo effect provoked by sustainable attention.

Training effect was also analysed in order to evaluate if a growing number of sessions provoked a better Mu rhythm control, translated to a better space-invaders game results. Motivation for consistent training to modulate SMR is required. A space-invader like game proved to be a good neurofeedback method, since it seems to be considered a game and not a therapeutic session for these age group participants.

#### 5. CONCLUSIONS

An experimental test of the anti-epileptic effect of sensory-motor rhythm modulation is undergoing, using a BCI optimized for use in a group of young patients with benign rolandic epilepsy and frequent interictal epileptic activity in the EEG. Preliminary analysis of the data suggests that the BCI produced consistent power changes of the sensory motor rhythm and a reliable quantification of the epileptic activity throughout the training process.

Although the expenses associated with the EEG acquisition and needing well-trained and experienced technicians are somehow disadvantages of this neurofeedback technique, any advance in alternative epilepsy therapy beside anti-epileptic drugs and surgery, is considered a major breakthrough. In that way, it seems relevant to assess the effect of this technique.

## 6. REFERENCES

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