

EEG Mapping Shows Changes in Brainwave Spectrum in Children with Cerebral Palsy During and After Masgutova Neurosensorimotor Reflex Integration Therapy

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Abstract

The rehabilitation of children with impaired motor function due to a damaged central nervous system can be performed using a variety of methods. One of them is Masgutova Neurosensorimotor Reflex Integration (MNRI®), often used with children suffering from cerebral palsy. The objective of this report is to demonstrate the effectiveness of MNRI® therapeutic methods by means of mapping the brain. The paper presents the case of a 13-year-old boy with cerebral palsy. EEGs were performed using ASA Lab's ANT Software BV data acquisition system. Nine measuring sessions were performed before, during, and following an MNRI® session of seven specific therapeutic exercises. Spontaneous EEG activity was recorded in a 10-20 electrode system using 32 leads. The recording automatically underwent an elimination of artifacts, after which the software produced qualitative descriptions as well as mappings of the EEG frequencies. The fast Fourier transform (FFT) algorithm and ASA Lab's mapping software were used in the computer analysis. Spectral maps were compared in relative and absolute scale for the measured signals obtained before, during, and after MNRI® rehabilitation. Pre- and post treatment results showed changes in the spatial distribution and relative amplitude of alpha and rapid beta activity taking place under the influence of the therapy. It is concluded that neurosensorimotor reflex integration (MNRI®) stimulated the child's central nervous system by activating the cortical centers of his brain, thereby causing modification of spontaneous activity.



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Introduction

Childhood cerebral palsy (CP, paralysis cerebri infantum), also known as Little's disease, is a syndrome of various disorders of movement and posture resulting from permanent, non-progressive brain damage in the early stages of development (Zablocki, 1998). Childhood cerebral palsy can be defined as a set of chronic and non-progressive central nervous system disorders resulting from damage to the brain during pregnancy (20%), during the perinatal stage (60%) or in the first years of life (20%). Causes of CP include: abdominal injuries to the mother, chronic disease during pregnancy, malformations, fetal hypoxia, infection, the influence of ionizing radiation, drugs or toxins including cigarette smoking and alcohol consumption, perinatal trauma, prematurity, brain injury, hypoxia after birth, severe neonatal jaundice, and neuro-infections (Zablocki, 1998).

Four main forms of the disease can be distinguished, depending on the area of damage and the symptoms: spastic (pyramidal) and dyskinetic (extrapyramidal) forms, and atactic (brain) and mixed forms, which are the most numerous (Michalowicz, 2001).

One of the most important tasks in treating a child with CP is finding an effective method of rehabilitation. Among the many interventions for children with locomotor and nervous system disabilities are those of: Vojta, Bobath, Doman-Delacato and the Wroclaw Improvement System (Vojta, 1964; Bobath, 1958; The Doman-Delacato method, 1968). An alternative for these is the relatively new method of Masgutova Neurosensorimotor Reflex Integration (MNRI®), described in various works (Masgutova, 2005; Masgutova, Akhmatova, 2004; Masgutova, Regner, 2009).

An assessment of the impact of different methods of rehabilitation on the central nervous system can be made in an objective manner using electrophysiological procedures. Such tests are carried out by the Medical University's Department of Pathophysiology in Wroclaw, under the direction of Professor Witold Pilecki. With regard to the effect of MNRI® on childhood cerebral palsy, examinations of brainstem auditory evoked potentials have already been used, as presented in other research (Pilecki, Masgutova S., Kowalewska, Masgutov D., Akhmatova, Poręba, Sobieszczanska, Koleda, Pilecka, Kalka, 2012). In the present study we used a different electroencephalographic technique – EEG mapping, introduced to the study of the brain by Duffy et al (Duffy, Burchfiel, Lombroso, 1979).

Purpose

The object of this study is to demonstrate the effectiveness of MNRI® using mapping of brain wave frequencies performed in a computer system, based on multi-channel EEGs recorded in a child with cerebral palsy.

Material

A 13-year-old boy diagnosed with mixed form CP, with a distinct component of the spastic form, but without other chronic diseases, was treated with exercises from the MNRI® protocol. Choosing a child with chronic spasticity as part of the MPD was important because this is the most common form associated with damage to the cerebral cortex, and the EEG mapping allows one to observe the spatial distribution of bioelectrical activity in precisely that part of the brain.

Rehabilitation involved the modification of a typical MNRI® therapeutic process and included 7 consecutive progressive exercises chosen in such a way as to affect various parts of the body and to activate various motor functions. MNRI® repatterning exercises relating to the following exercises were used:

1. Foot Tendon Guard Reflex (automatic dorsal flexion of the foot) – right limb
2. Foot Tendon Guard Reflex (automatic dorsal flexion of the foot) – left limb
3. Leg Cross Flexion-Extension Reflex – right limb¹²⁴
4. Leg Cross Flexion-Extension Reflex – left limb
5. Hands Supporting (parachute) reflex – both sides
6. Asymmetric Tonic Neck Reflex
7. Spinal Galant
8. Breathing Reflex for mobilizing the diaphragm.

The time spent conducting the exercises was only about 45 minutes, whereas typically a therapeutic session would last more than an hour. This change was necessary due to technicalities involved in conducting EEG measurements after each exercise. Three separate EEG recordings were done: phase 1: before exercises,

phase 2: after each of the seven exercises, and phase 3: a final measurement a few minutes after the end of the session.

For the measurements, we used an ASA (Advanced Source Analysis) measurement and diagnostic system from the Dutch firm A.N.T., which consists of the ASA-Lab's computerized data acquisition system combined with an electroencephalographic amplifier from TSMI Refa-8 (*ASA User Manual* version 4.6, 2008). Thirty-two silver-plated cupped electrodes were placed against the child's scalp, in accordance with the international standard of 10-20 leads (Fp1, Fpz, Fp2, AFz, Fz, F3, F4, Fc1, Fc2, Fc5, Fc6, F7, F8, C3, Cz, C4, Cp1, Cp2, Cp5, Cp6, T7, T8, P7, P8, P3, Pz, P4, POz, O1, Oz, O2) and configured in a unipolar system with the reference electrode placed on the left ear lobe and grounded on the forehead. During the measurements, the impedance was held between the skin and the electrode $< 5k \Omega$. The sampling frequency was 625Hz.

Method

The study was carried out in four phases:

Phase 1: EEG measurement before rehabilitation

Phase 2: EEG measurements during rehabilitation (immediately following each of the 7 MNRI® exercises.)

Phase 3: EEG measurement a few minutes after completion of the MNRI® session

Phase 4: Calculations, production of brain mapping images and analysis of results

The calculations were made off-line on the ASA computer system (*ASA User Manual* version 4.6, 2008). The preprocessing of signals was applied through low-pass filtration with a Butterworth filter 0.53 Hz, providing automatic detection of artifacts outside the range of amplitude $-150 - 150\mu V$. The elimination of interference was necessary because artifacts of locomotive origin are a significant problem during the rehabilitation of motor functions from an electrophysiological point of view. Only selected portions of the recording containing undisturbed EEG activity were chosen for the calculations by opting for the fragmentation of signals on windows 1s. Every 1s window containing artifacts detected by the software was eliminated (Fig. 1). A compromise

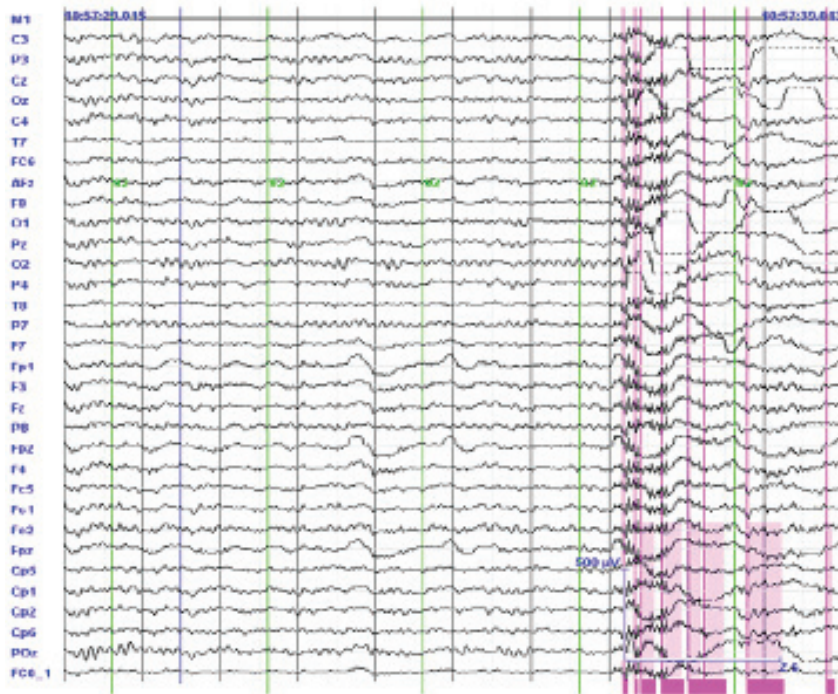


Figure 1: Detection of artifacts in the ASA program. Interference marked on the right side was automatically cut from EEG recordings before performing calculations.

between the frequency resolution of the calculations, and records sufficiently clean of artifacts was agreed on.

Each EEG signal's spectrum was calculated for the purpose of demonstrating the frequencies generated by the brain's neural structures in each stage of the study. For this purpose we used the so-called Discrete Fourier Transform (DFT) as determined by introducing the ASA algorithm of Fast Fourier Transform (Fast Fourier Transform, FFT) into the system (Brigham, Oran, 1988). The average spectrums were calculated in windows 1s. The

spectrum frequencies of EEG signals for each lead obtained in this way, after the application of the appropriate interpolation techniques, allowed for the creation of a spectral power map of EEG signals in selected frequency bands, and thus imaging their spatial distribution in each phase of the study.

We analyzed the EEG spectrum from 0.5 Hz to 30Hz, divided into five sub-ranges: 0.5 - 3.5 Hz (delta), 3.5 - 7.5 Hz (theta), 7.5 - 12, 5 Hz (alpha), 12.5 - 20 Hz (free beta, beta 1) and 20 - 30 Hz (fast beta, beta 2). For these sub-bands we performed spectral distribution maps in 3D, using interpolation techniques and the standard model of the head as found in the functions library of the ASA software. It was decided to create maps in two scales: absolute [$\mu\text{V}^2/\text{Hz}$] and relative [%]. Absolute maps allow one to compare the spatial distribution of signals in the different ranges of the energy spectrum in terms of amplitude (the same as in research by the electroen-

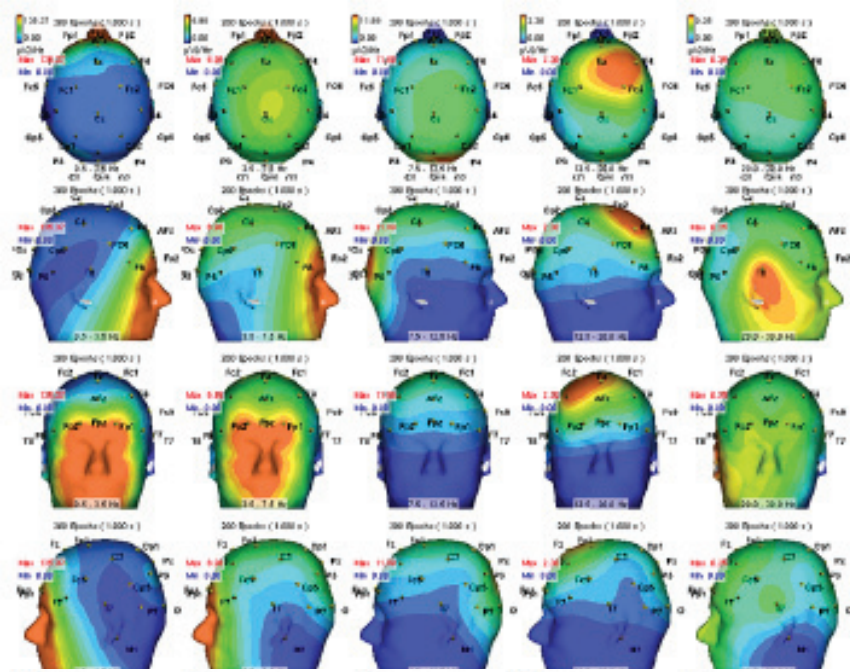


Figure 2: Maps of the spatial distribution of the power spectrum expressed in absolute units [$\mu\text{V}^2/\text{Hz}$] for resting EEG performed at the outset of the experiment. In subsequent columns different projections are shown in 3D using a standard model of the head for the frequencies: delta, theta, alpha, beta 1, and beta 2.

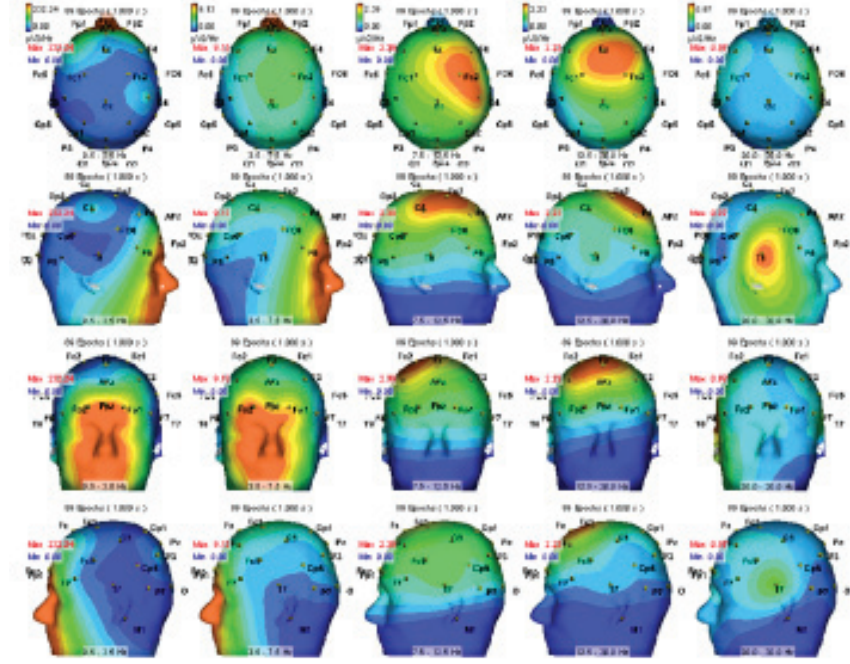


Figure 3: Maps of the spatial distribution of the power spectrum expressed in absolute units [$\mu\text{V}^2/\text{Hz}$] for one of the EEG recordings made during phase 2 (after MNRI® work involving the limbs). Subsequent columns show the different projections in 3D using a standard model of the head for the frequencies: delta, theta, alpha, beta 1, and beta 2.

cephalograph) and it shows areas that are mostly intensely activated in the sub-ranges of the spectrum. In contrast, representing the transmitted energy of the signal in a given frequency range relative to the energy of the entire spectrum allows one to determine which areas are primarily responsible for EEG activity in a particular sub-range. Images are presented in an automated scale using the RGB color scale.

Results

A qualitative analysis of EEG records from phases 1, 2, and 3 (before, during, and after rehabilitation by MNRI®), show certain differences among results. A symmetrical record was achieved, with no seizure activity, showing a mixture of slow delta-theta waves mainly in the frontal and parietal leads, alpha waves mainly above the occipital leads, and a correct halting response. In addition, in the records taken during phase 2, rehabilitation, a greater admixture of fast beta waves is found in fronto-temporo-parietal leads.

Through EEG frequency mapping we obtained images of the distribution of the spectral power of the EEG signal for each of the 9 registrations. Due to the short scope of this study we present only selected images, presenting the results for recordings done in phase 1 (Figs. 2 and 5), in phase 2 after the Galant Reflex exercise (Figs. 3 and 6) and in phase 3, after the whole rehabilitation session (Figs. 4 and 7). Figs. 2 to 4 present maps in absolute scale [$\mu\text{V}^2/\text{Hz}$] and Figs. 5 to 7 are drawn in relative scale [%]. Each series of images was analyzed separately.

Mapping of the recorded output in an absolute scale shows the dominance of low frequencies in the upper frontal leads, and the lowest amplitude in the vicinity of the temporo-occipital leads. Alpha activity is correctly located mainly in the occipital region. Fast frequencies from beta waves are of the highest amplitude in the fronto-parietal leads. This information leads to presupposition that the quality of focusing, presence, and awareness in the patient can increase.

During rehabilitation, the minor periodic voltage fluctuations, delta and theta frequencies did not change

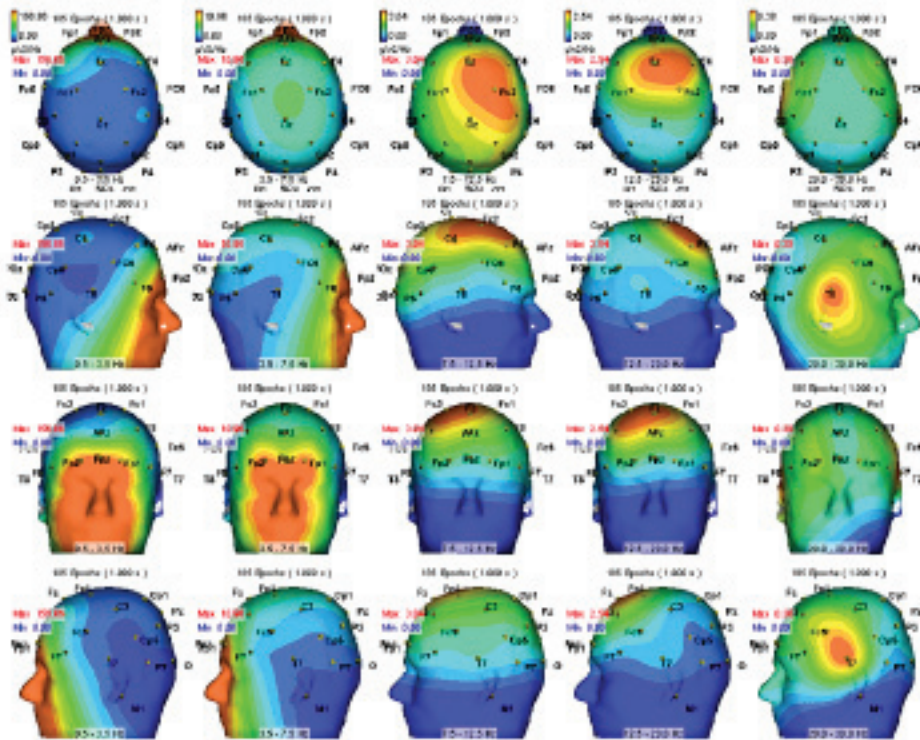


Figure 4: Maps of the spatial distribution of the power spectrum expressed in absolute units [$\mu\text{V}^2/\text{Hz}$] for an EEG performed after MNRI® rehabilitation. Subsequent columns show the various projections in 3D using a standard model of the head for the frequencies: delta, theta, alpha, beta 1, and beta 2.

significantly throughout all three phases.

Changes did occur in the alpha frequency range (7.5-12.5 Hz). Alpha activity initially observed (phase 1) in the occipital leads disappeared at the beginning of rehabilitation (phase 2). Subsequent phases of the study show clearly that there is a lack of alpha activity in this area, and at the same time the alpha activity did ap-

pear above the central leads (Fig. 3 middle column), mainly on the left side, although it had a relatively not high amplitude. This effect proved to be permanent, as it held until phase 3, the end of the experiment (Fig. 4 middle column). The result again shows a possibility of more proper organization of brain wave spectrum in the patient and a basis for improvement of the abilities to focus, increase awareness and critical thinking.

EEG frequencies in the range free beta (12.5 - 20Hz) did not change in spatial distribution or in average absolute values. Certain changes were observed for fast beta (20 - 30Hz): this stronger voltage appeared during phase 2, rehabilitation, (expiring after its completion) in the temporal leads of the dominant hemisphere (Figs. 3 and 4, last column).

Mapping in the relative scale brings additional information. As in the absolute scale, the dominance of delta activity asserts itself in the frontal leads; however, the theta function has the highest percentage (17%) in the central region, while low in the frontal leads. Clearly, this is related to the extremely high dominance of lower brain waves (delta and theta) in this area, approaching up to 89% (Fig. 5, first column). A second strongly expressed frequency in phase 1 is alpha activity above the occipital leads, filling 48% of the signal spectrum at

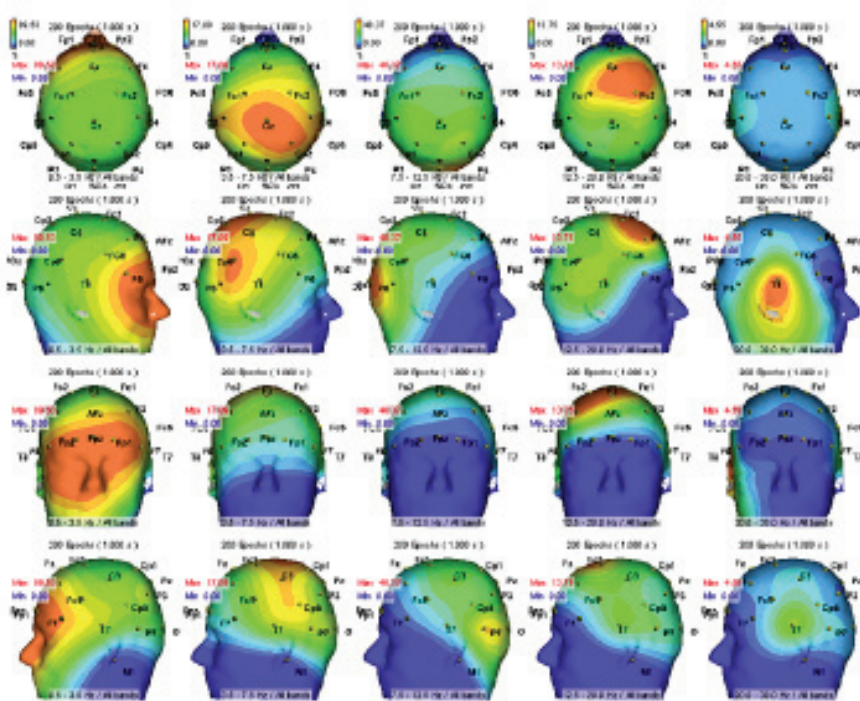


Figure 5: Maps of the spatial distribution of the power spectrum, expressed in the relative scale as the ratio of power in a given range of frequency to the power of the entire spectrum. Illustrations were made for resting EEG recorded in phase 1. Subsequent columns show various projections in 3D using a standard model of the head for the frequencies: delta, theta, alpha, beta 1, and beta 2.

this location (Fig. 5, middle column).

The percentage of free beta (12.5 - 20Hz) is strongly (13%) expressed in the frontal central leads. In contrast, the fastest EEG output frequency (beta), is localized in the temporal regions, mainly on the right side. It is also associated with low activity in the rest of the spectrum in these areas, which is not visible on the absolute scale maps. The percentage of the total spectral power of EEG output in this (beta) frequency range is the lowest of all and reaches just over 4% in channel T8.

During phase 2, rehabilitation, as before, no significant changes in either distribution or amplitude of delta and theta activity were shown. The disappearance of alpha activity in the occipital leads was confirmed. This frequency range strongly (several dozen %) saturates spectrum signals measured in the temporo-parietal electrodes, which is a new discovery. In contrast to the absolute scale maps, relative scale maps show a tendency of occipital alpha activity to revert after the exercises. This discovery suggests that MNRI® treatments temporarily arrest/inhibit alpha activity in its physiological location, while stimulating it in regions operationally linked to the motor cortex system as it works in a healthy brain (Fig. 6, middle column). It is interesting that, at the same time, it does not return to its phase 1 level immediately after phase 2. The absolute scale maps show this, as do

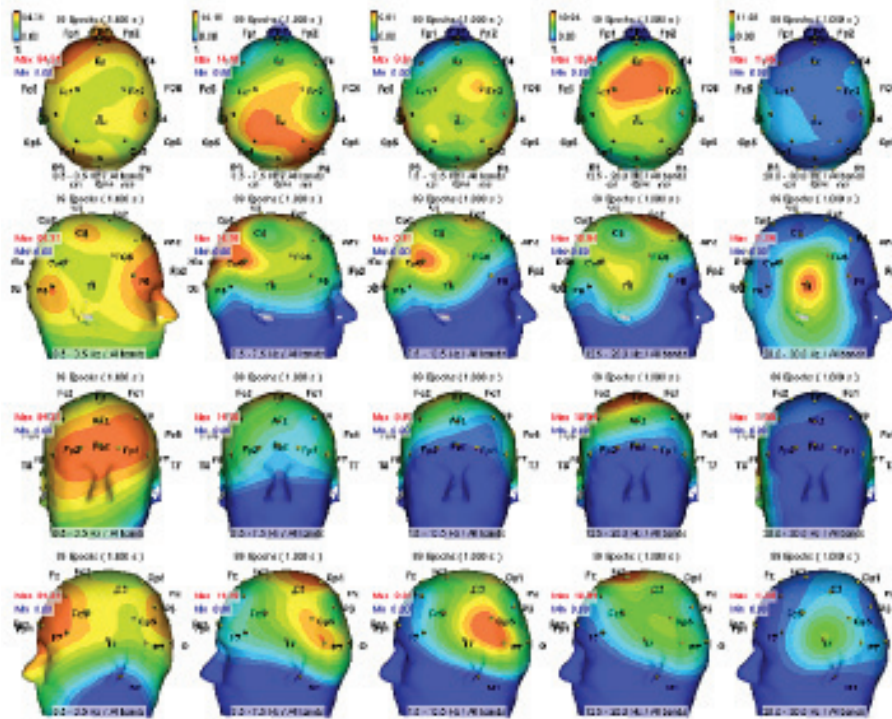


Figure 6: Maps of the spatial distribution of the power spectrum, expressed in a relative scale, as the ratio of frequency to the power of the entire spectrum signal. The illustrations were made for one of the EEG recordings taken during phase 2 (after stimulation of the limbs). Subsequent columns show various projections in 3D using a standard model of the head for the frequencies: delta, theta, alpha, beta 1, and beta 2.

the maps in Fig. 7 where alpha activity represents a lower percentage of the spectrum in phase 3, after MNRI®, than in phase 1, before. This can mean a tendency that MNRI® can reach a stable transition in the work of the brain waves.

Free beta activity of 12.5-20Hz does not change its spatial properties or relative amplitude during the test. However, maps in relative scale confirm the increase of rapid beta activity (20-30Hz) in the temporal leads (up to several percent), expiring after completion of MNRI® exercises focused on the extremities (Figure 6, and Figure 7, last column).

Conclusions

We conclude that rehabilitation using MNRI® in a child patient with cerebral palsy caused a reorganization of spontaneous electrical activity in his brain. This is observed in the alpha frequency range as well as in fast beta activity. Increased activity in these frequency bands during rehabilitation appears in the parietal and temporal locations. This may be connected with the positive and stable therapeutic effect of this method on motor disorders originating in the central nervous system. Our observations are consistent with the findings of other authors who have noticed changes in EEG mapping in children with CP during experiments related to

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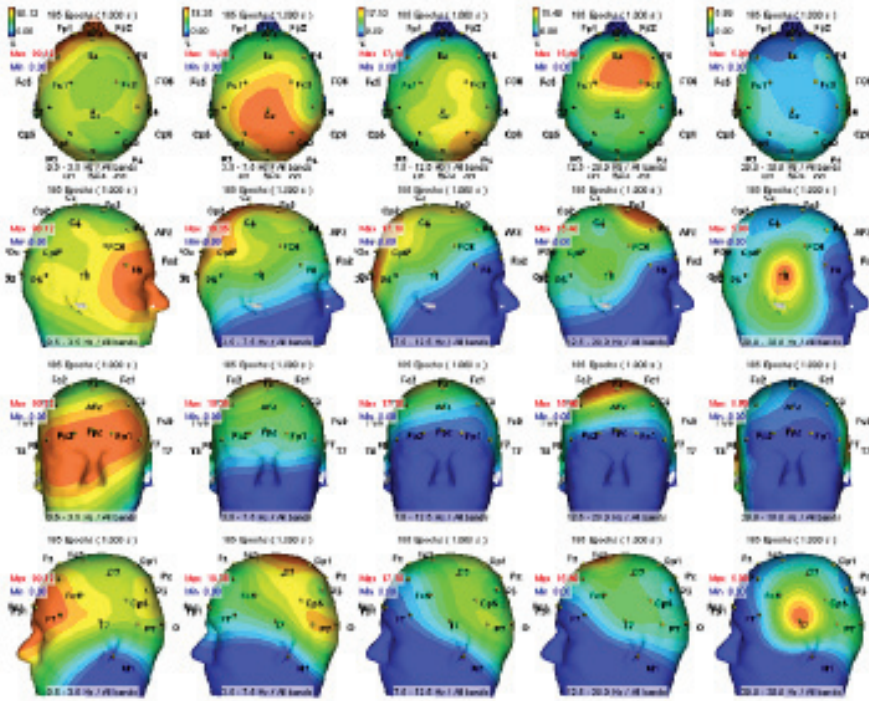


Figure 7: Maps of the spatial distribution of the power spectrum, expressed in a relative scale, as the ratio of power representing a given frequency range to the power of the entire spectrum of the signal. Illustrations were made for the final EEG (phase 3), performed after completion of the entire MNRI® session. Subsequent columns show the various projections in 3D using a standard model of the head for the frequencies: delta, theta, alpha, beta 1, and beta 2.

the motor system (Shin, Lee, Hwanh, You, Im, 2012).

It should be made clear that although the results presented in this analysis are positive, they apply only to a single case. Taking into account inter-individual variability and the influence of many external factors on EEG results, drawing objective conclusions about the physiological effects of MNRI® would require testing a homogeneous group of children with childhood cerebral palsy, and comparing mapping results to the results obtained in a control group of healthy children. A future publication by our team will be devoted to this issue.

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