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MEG Evaluation of the Function of Alpha and Beta Rhythms After Visual Stimulation

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ABSTRACT

Objective: In this study, we investigated the function of alpha and beta rhythms after visual stimulation using Magnetoencephalography (MEG) recordings.

Materials And Methods: Ten (10) Caucasian healthy volunteers (6 female, 4 male) aged (mean: 37.6±5.3) participated in the study. The subjects were measured with a 122-channel MEG system in a magnetically shielded room of low magnetic noise. We applied Fast Fourier Transform to all channels and evaluated the alpha and beta rhythm of the volunteers before and after visual stimulation.

Results: Before stimulation, the alpha rhythm was located at the occipital lobe due to mental relaxation and blocked attention. We observed also an activation of the beta rhythm at the frequency range 19-25 Hz due to thought processes. After stimulation, we observed an intense MEG field with a spread of the alpha and beta rhythms throughout the brain without specific location. The decrease in the alpha and beta rhythms is due to the stimulus because each stimulus entering the brain is maintained for a certain period of time representing the short-term memory of the particular stimulus.

Conclusion: The results suggest that the MEG is a efficacious modality in the investigation of alpha and beta rhythms after visual stimulation. This cortical activation might have applicability in modulation of brain status. This might be important to patients' groups because the alpha rhythm could be used as a neurophysiological marker for the activity of the pineal gland.

KEYWORDS

Meg; Visual Stimulation; Alpha Rhythm; Beta Rhythm.

INTRODUCTION

Magnetoencephalography (MEG) is a functional neuroimaging technique for mapping brain activity by recording magnetic fields produced by electrical brain currents, using very sensitive magnetometers and it gives improved spatial resolution with particularly high temporal resolution. Since the MEG signal is a direct measure of neuronal activity, its temporal resolution is comparable with that of intracranial electrodes. MEG complements other brain activity measurement techniques such as electroencephalography (EEG), positron emission tomography (PET), and functional magnetic resonance imaging (FMRI). It is a non-invasive method and uses no ionizing radiation, as opposed to PET. MEG can resolve events with a precision of greater than ten milliseconds (msec), while fMRI, can at best resolve events with a precision of several hundred milliseconds (msec). MEG is also being used to better localize responses in the brain. The responses in the brain before, during, and after the introduction of stimuli can be mapped with greater spatial resolution than was formerly potential used with EEG [1-13].

The pineal gland controls the hormone system and at night it is releasing one important hormone the melatonin in the

blood stream and from the blood stream to the brain. Sandyk reported a case of a patient with multiple sclerosis in whom visual perception worsened throughout the course of the day and improved at night [14]. These changes in vision appeared to correspond to the circadian secretion of melatonin which is coupled to the circadian temperature rhythms. Ter Huurne et al [15] investigated whether aberrant modulation of alpha oscillations contributes to attention problems in Attention-deficit/hyperactivity disorder (ADHD) patients with the use of MEG. They suggested that aberrant modulations of alpha oscillations reflect attention problems because of ADHD and might be related to the neurophysiological substrate of the disorder. Babiloni et al [16] investigated if simple delayed response tasks affect latency and amplitude of MEG midline alpha rhythms (6-12 Hz) in early dementia. They found that the alpha peak was later in latency in the demented and normal elderly subjects than in the normal young subjects and it was stronger in amplitude in the demented patients than in the normal subjects. Anninos et al [8] in a MEG study discussed the potential essential role of the pineal gland in the long term anticonvulsant effects of external artificial magnetic stimulation because the pineal gland has been shown to be a magnetosensitive organ which forms part of a combined compass-solar clock system and exerts an inhibitory action on seizure activity. Sandyk et al [17] based on MEG measurements suggested that patients with nocturnal epilepsy or those experiencing exacerbation of seizures premenstrually may benefit from the administration of agents which block the secretion or action of melatonin.

The aim of this study was to investigate the function of alpha and beta rhythms after visual stimulation by means of MEG recordings because this cortical activation might have applicability in the modulation of brain status and in clinical use.

MATERIALS AND METHODS

Subjects

The MEG recordings were carried out in ten (10) Caucasian healthy volunteers (6 female, 4 male) (mean age: 37.6±5.3 years) in a magnetically shielded room with a whole head 122-channel biomagnetometer (model: Neuromag-122, Helsinki, Finland) (Table 1) [1-13]. All subjects had normal visual acuity and were not on any medication. The first MEG measures represent the baseline without visual stimulation. Afterwards we applied visual stimulation with different information in order to find out how the brain elaborates them (Figure 1). Informed consent was obtained from the participants prior to the procedure. The research was approved by the Research Committee of the Democritus University of Thrace.

Table 1: Volunteers' profile (F:female, M:male).

A/A	SEX	AGE	WEIGHT	ETHNIC
1	F	35	71	Caucasian
2	F	43	75	Caucasian
3	F	39	70	Caucasian
4	F	45	65	Caucasian
5	F	39	69	Caucasian
6	F	30	76	Caucasian
7	M	40	85	Caucasian
8	M	38	78	Caucasian
9	M	39	90	Caucasian
10	M	28	79	Caucasian

Figure 1: The 122-channel MEG system in the magnetically shielded room. One of the images for the visual stimulation (small icon).

Data Acquisition

The MEG recordings were filtered with cut off frequencies at 0.3 Hz and 40 Hz. The MEG sampling frequency was 256 Hz and the associated Nyquist frequency was 128 Hz. We took 4 MEG recordings of 32 seconds each with 4 stimuli (icons). The images illustrated delicious sweets. As an experimental paradigm one picture is illustrated in Figure 1 (small image). We preferred coloured stimuli instead of neutral ones in order to have more profound effects. The time interval between each stimulus was 1 min. The total experimental time was about 5 min.

Data analysis

The MEG workstation software analyzes the MEG data and gives the isocontour field maps (ISO-fields) in the whole scalp. We used the Fast Fourier Transform (FFT) algorithm to obtain the power spectra of the MEG data. A software program has been developed in our lab in order to detect the 1st dominant

frequency of the power spectra of each channel after the application of FFT on the MEG raw data and construct a map for its spatial distribution over the scalp. Different colours in the maps represent different dominant frequencies. The numbers in the map squares represent the 122 MEG channels in every parts of the brain area according to Table 2.

Table 2: This table shows the brain regions and the corresponding channels.

Brain Regions	Channels
Right Temporal	1-14 , 111-120
Right Parietal	5-6,11-16,97-100, 109, 110 , 115-122
Left Temporal	43-50 , 55-62,67-74
Left Parietal	47-52,59-64,71-74,79,80,87-90
Frontal	17-42
Occipital	75-86,91-96 , 101-110
Vertex	13-16,49-54,61-66,73,74,89,90,99,100 ,117-122

RESULTS

The following results referred to the volunteer (no 8) as representative.

(Figure 2) shows the ISO-fields without external visual stimulation. (Figure 3A) exhibits the spatial distribution of the alpha rhythm (8-13 Hz) over the scalp for all the MEG channels without stimulation after the application of the FFT on the MEG raw data. (Figure 3B) shows the beta rhythm (14-25 Hz) before stimulus. We observed an activation of the channels between the frequencies 19-25 Hz due to thought processes. (Figure 3C) shows the overlapping power spectra from these 122 channels after FFT. We viewed a dominant frequency at 10 Hz that indicates the physiological state of the subject. The alpha rhythm is intense due to mental relaxation and blocked of attention. The alpha rhythm was located primarily at the occipital lobe (MEG channels: 75-86, 91-96, 101-110, Table 2).

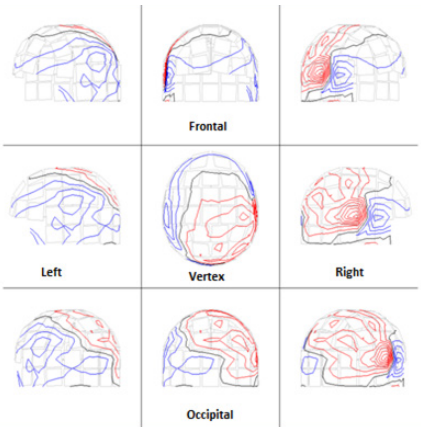

Figure 2: The scalp isocontour (ISO) field distribution without visual stimulation at the left - right temporal, left - right parietal, frontal , vertex and occipital regions . The red and blue lines indicate the incoming and outgoing magnetic field.

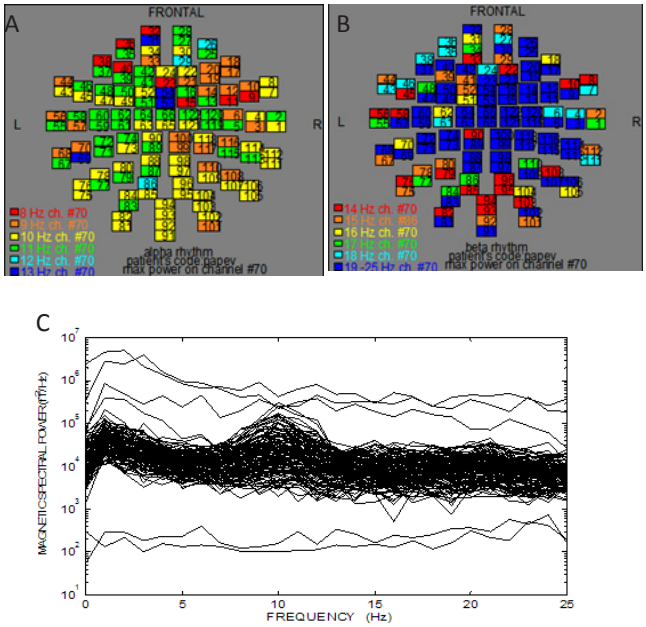

Figure 3: Frequency distribution from all channels without visual stimulation at all brain regions (Table 1). A) The spatial distribution of the alpha rhythm (8-13 Hz). Dominant alpha rhythm at the occipital lobe (MEG channels: 75 -86, 91-96, 101- 110). The numbers in each square represent the 122 MEG channels B) The spatial distribution of the beta rhythm (14-25 Hz). The squares represent the MEG channels C) Power spectra analysis: Overlapping the power spectra from all channels. Dominant frequency at 10 Hz.

Afterwards we applied external stimuli such as images with different information (Figure 1). Figure 4 shows the ISO-fields with external visual stimulation. We showed an intense activation of the MEG signals all over the scalp. Figure 5A exhibits the spread of the alpha rhythm throughout the brain due to the stimulus without specific location. Figure 5B shows the behavior of the beta rhythm after stimulus. We observed a spread of the beta rhythm without specific location. The activity of the frequencies 19-25 Hz has been decreased. Figure 5C shows the overlapping power spectra from these 122 channels after FFT. We viewed an attenuation of the alpha rhythm due to the attention to the stimulus. Comparing Figures 2,4 and Figures 3,5 we evaluated the alpha and beta activity in the maps before and after external visual stimulation at every region (Table 2).

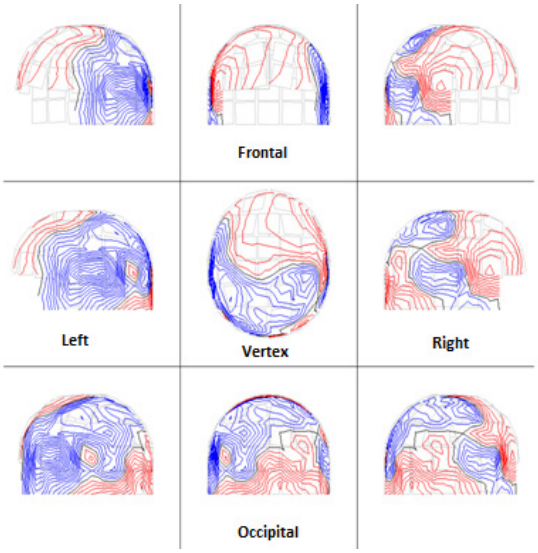

Figure 4: The scalp isocontour (ISO) field distribution after 352,7 ms visual stimulus at the left -right temporal, left -right parietal, frontal , vertex and occipital regions. We observe an intense activation of the MEG signals. The red and blue lines indicate the incoming and outgoing magnetic field.

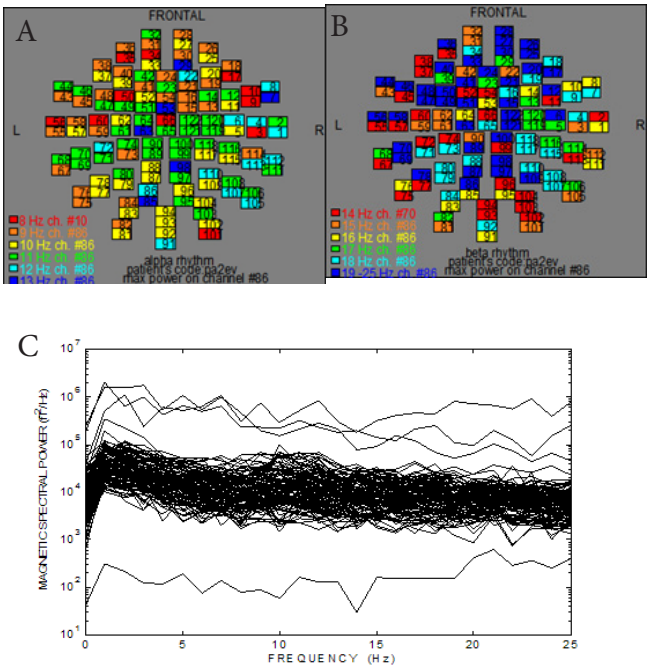

Figure 5: Visual stimulation after 352.7 ms. A) The alpha and the B) beta rhythm after optical stimulation at all brain regions (Table 1). The numbers in each square represent the 122 MEG channels C) Power spectra analysis : Overlapping the power spectra from all MEG channels. We observe an attenuation of the magnetic spectra power (fT2 /Hz) of the alpha rhythm as a result of stimulus.

DISCUSSION

From our measurements we extracted useful conclusions regarding the position and the intensity of the MEG recordings after the application of an external visual stimulus. Our raw data showed an intense activation of the MEG signals. This was clearly identified in the ISO-fields between (Figure 2 without stimulus) and (Figure 4 with stimulus). Comparing Figures 3,5 we observed an attenuation of the alpha rhythm at the occipital lobe and the widespread of the beta rhythm due to the visual stimulation.

Recently, the alpha-band activity (10Hz) has drawn a lot of consideration. Lange et al [18] suggested that reduced alpha-band power does not always predict improved visual processing, but rather increased excitability. Some researchers found that the power of pre-stimulus alpha-band activity in parieto-occipital areas was associated negatively with the individual perception in visual detection and discrimination tasks [19-21]. Other researchers found that intermediate levels of pre-stimulus alpha-power in the visual and somatosensory area increases perception and evoked responses while low and high levels have a negative effect [22-24]. Alpha-band power is reconciled by attention and has been associated to the inhibition of task unrelated areas [24-27].

Okazaki et al [28] examined brain oscillatory responses related to visual perceptual change of short-term duration in the absence of morphologic change by MEG. Two types of stimulus conditions were created, the 'face-target' (F-T) condition and the 'saxophone-target' (S-T) condition. They found significantly greater synchronization in the beta (14-30-Hz) frequency band, ranging from 250 to 450ms predominantly over the occipital and parietal regions, after stimulus alternation for the S-T condition than for the F-T condition. Kinsey et al [29] in a research study by MEG concluded that the role of alpha and beta activity in object processing might related principally to changes in visual attention.

In (Figure 5) we illustrated that the alpha and beta rhythms and the power spectra after 352.7 ms at the beginning of visual stimulation. An external stimulus prompts all the cortical neurons to fire simultaneously causing a spike to appear in some 300ms later. The alpha rhythm is classically described as a bilateral posterior rhythm of substantially constant frequency in the range of 8-13Hz and is enhanced by mental relaxation and blocked attention. Since the full expression of alpha rhythm has been shown to occur during puberty, it is possible that the establishment of alpha rhythm is subject to neuroendocrine influences. Nocturnal plasma melatonin levels have been shown to decline progressively throughout childhood reaching a nadir in puberty. This progressive decline in melatonin secretion during childhood facilitates the maturation of the alpha rhythm. Our study population was in adulthood (mean 37.6±5.3 years) because we had volunteers only at these ages.

In a number of studies Anninos et al [1-3, 5, 7, 8, 30-33] using an electronic device demonstrated the significant effects of pi-

co-Tesla (pT) (1pT=10-12 Tesla) external transcranial magnetic stimulation (pT-TMS) to patients with CNS disorders. Specifically, using an electronic device invented by them they were able to increase the abnormal (2-7Hz) frequencies of the brain activity towards frequencies of less than or equal to those frequencies of the alpha frequency range (8-13Hz) of each patient [30]. It is known that magnetic fields modify the activity of the pineal gland, which has been shown to control dopaminergic, and endogenous opioid functions [34, 35]. In addition, exposure of an organism or biological material to magnetic fields has been reported to induce mutagenic, immunological, metabolic, endocrine, morphological, developmental, behavioral and anticonvulsant effects [36, 37].

The monitoring of brain activity by MEG requires particularly sensitive sensors made superconductive by liquid helium and data acquisition in shielded rooms cutting out the ambient magnetic fields in order to obtain the best quality signals. The major limitation of the study is the high cost of the MEG system and the liquid helium for its operation.

Our results shown that MEG is a valuable tool for the estimation of the role of alpha and beta rhythms in healthy volunteers. The significant observation is that there is an intense activation of the MEG data and a decrease in the alpha and beta rhythms due to stimulus. This fact encourage the use of MEG for the estimation of the above rhythms in patients with CNS disorders (autism, dyslexia, personality disorders, epilepsy, schizophrenia, Parkinson etc.). This might be important and helpful to patients' groups because the presence of alpha rhythm could be used as a neurophysiological marker for the activity of the pineal gland and for the disorders associated with the absent or delayed maturation of it.

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