

**ELECTROENCEPHALOGRAPHIC (EEG) CORRELATES
OF SOME ACTIVITIES WHICH MAY ALTER CONSCIOUSNESS:
THE TRANSCENDENTAL MEDITATION TECHNIQUE,
MUSICOGENIC STATES, MICROWAVE RESONANCE RELAXATION,
HEALER/HEALEE INTERACTION, AND ALERTNESS/DROWSINESS**

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Abstract. A key problem of finding the most complete and useful theory of consciousness may revolve around how to empirically determine different styles or states of consciousness and how to incorporate these within a single paradigm. This was our motivation to start examination of EEG correlates of some activities or substates of consciousness which occur spontaneously or are induced artificially. Our investigations demonstrated more or less characteristic features in 25 subjects practicing the Transcendental Meditation program (increased β power in prefrontal region, increased θ power in left frontal and right temporal regions, increased α power in both temporal regions, and correlation between increased α power and decreased correlation dimension), 6 subjects with 4 types of spiritual music provided to induce musicogenic states (with significant changes in only 3 cases out of 24, where increased θ and α power was observed in only those subjects who have described their musical experiences as very pleasant), 28 subjects of relaxation induced by microwave resonance therapy applied to corresponding acupuncture points (with slightly decreased EEG power in all frequency bands, especially in the left central region, which can be ascribed to higher activation of the stimulated left circulatory part of the acupuncture system; it should be also noted that persons not previously subjected to this treatment responded stronger, presumably as a consequence of the more imbalanced acupuncture system), 5 healer/healee, noncontact interactions (with increase in the maximum mean coherence of their EEG patterns in the α band observed only in short 4s time intervals), and 30 subjects for monitoring alertness/drowsiness level (with implemented automatic procedure of the neural network classifier to assess the correlation between EEG power spectrum fluctuations related to changes of vigilance level, demonstrating linear separability of the states of alert wakefulness and drowsy wakefulness, allowing very fast data processing and possible real time applications in clinical practice). New technologies applied to the EEG may permit rapid and reproducible identification of different styles or states of consciousness. Such a tool might be useful in evaluating the effectiveness of different techniques for stress reduction and for altering expressions of consciousness.

Keywords: EEG correlates, consciousness, altered states, transcendental meditation, musicogenic states, microwave resonance relaxation, healer/healee interaction, alert wakefulness and drowsy wakefulness.

1. INTRODUCTION

The key problem of any future theory of consciousness is how to incorporate altered states of consciousness [1-3] (REM sleep, meditation, hypnosis, psychedelic drug influence, some psychopathological states, near-death experiences,...) within a new paradigm. It should be pointed out that purely biochemical mechanisms of the extended reticular-thalamic activating system (serving as a selector and amplifier of the conscious content out of many other currently processed nonamplified contextual unconscious contents) are not accelerated up to several orders of magnitude, as the subjective time sense is dilated in altered states of consciousness - in respect to the normal awake state. According to the biophysical model for altered states of consciousness (proposed by one of us, D. R. [4-6]), the electromagnetic (EM) component of ultralowfrequency (ULF) brainwaves, related to "subjective" reference frame of consciousness, enables perfect fitting with narrowed-down limits of conscious capacity in normal awake states and very extended limits in altered states of consciousness - due to the biophysical relativistic mechanism of dilated subjective time base. In this model, consciousness is subtle internal display in the form of EM component of the "optical" microwave (MW)/ULF modulated quantum holographic neural network-like acupuncture ionic system, in which a complete information (both conscious and unconscious) is permanently coded from brain's neural networks, as a spatio-temporal pattern resulting from changes of the electrosynaptic interconnections in the neural networks of the brain.

Then, according to this model, altered states of consciousness are a consequence of partial displacement of the MW/ULF ionic acupuncture system outside the body (when the embedded EM component of ULF brainwaves is propagating through this weakly ionized structured gaseous medium of low-dielectric relative permittivity, $\epsilon_r \approx 1$), while normal states of consciousness (alert state, non-REM sleep, ...) are achieved when there are no such displacements (when brainwaves are propagating only through the structured brain tissue of high-dielectric relative permittivity, $\epsilon_r \gg 1$)! The

displaced ionic structure in this model must have a form of weakly ionized gaseous “optical” MW/ULF neural network, for continually inflowing ULF information from the brain’s neural networks to be “subjectively” recognized. Also, such ionic neural network may behave as an optical sensor, which can even perceive an environment extrasensory, as reported by reanimated persons [3].

Even most peculiar spatio-temporal transpersonal interactions are predicted in transitional states of interchange of normal and altered states of consciousness (when brainwaves traverse from high-dielectric ($\epsilon_r \gg 1$) to low-dielectric ($\epsilon_r \approx 1$) state or vice versa, the relative velocity $v = c_0 / \sqrt{\epsilon_r}$ of “subjective” reference frame being therefore subjected to abrupt change in short transitional period $\tau \sim 0.1$ s, with “subjective frame” acceleration $\sim c_0 / \tau \sim 10^9$ m/s²) - due to the relativistic generation of so-called wormholes in highly noninertial “subjective” reference frame - fully equivalent, according to Einstein’s Principle of equivalence, to extremely strong gravitational fields where generation of wormholes (or Einstein-Rosen space-time bridges, whose entrance and exit could be in very distant space-time points) is theoretically predicted [7]. It should be pointed out that apart from the EM field, the displaced part of ionic acupuncture system (in the form of MW/ULF ionic neural network, having the “optical” sensory function), must also be tunneled in such (acausal) interactions of consciousness with distant events in space-time!

This was our motivation to start examination [8] of EEG correlates of transcendental meditation, musicogenic states, microwave resonance relaxation, healer/heelee interaction, and alertness/drowsiness, as some of relatively easily reproducible altered states of consciousness.

2. METHOD

Electroencephalographs were recorded in electromagnetically shielded room by a MEDELEC 1A97 EEG machine, with lower and upper band-pass filter limits set at 0.5 Hz and 30 Hz, respectively. Ag/AgCl electrodes with impedance less than 5 k Ω were placed at 16 locations (F7, F8, T3, T4, T5, T6, Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2) according to the International 10-20 system with average reference. The EEG outputs were digitized with 12-bit precision at a sampling rate of 128 Hz per channel using A/D converter Data Translation 2801.

The length of each EEG-trace was 60 s (7680 points). Time-varying EEG spectra (spectrograms) with 0.5 Hz resolution were calculated by the MATLAB program using a 256-point FFT algorithm performed on 2 s Hamming-windowed, half-overlapped epochs. An array of EEG partial power spectra for each subject and each derivation was computed by integration by the trapezoidal rule of the spectrogram over the five frequency bands: δ (1-4 Hz), θ (4-8 Hz), α (8-13 Hz), β_1 (13-18 Hz), and β_2 (18-25 Hz).

2.1 Transcendental meditation

In transcendental meditation (TM), normally practiced for periods of twenty minutes twice a day, the subject is instructed to sit quietly with eyes closed and is then taught to repeat a certain type of sound or “mantra” according to a particular definite set of instructions. The mantras are a set of short speech sounds, meaningless in themselves, preserved by an ancient vedic tradition and assigned to individuals by the instructor on the basis of a set of objective rules which is trained to apply. They are chosen so as to “resonate” with the structure of an individual nervous system.

Subjectively, the meditator usually reports an immediate sense of bodily quiet and relaxation. An important feature of the subjective experience of the TM technique is the “expansion” of consciousness [9]. As the mantra is experienced in successively finer stages, subjects report that the spatial extent of conscious self-awareness, which ordinarily seems to be localized in the area of head and upper body, undergoes a progressive expansion.

Wallace, Orme-Johnson, and Farrow [10], among others, have reported physiological changes during the practice of the TM technique that are consistent with these predictions, such as reduced oxygen uptake, reduced CO₂ elimination, constant respiratory quotient, reduced respiratory minute ventilation, reduced respiratory frequency, reduced hearth rate, increased basal skin resistance, and EEG changes indicative of alertness. Wallace was led to propose that the TM technique produces a fourth major state of consciousness in which the mind remains alert while mental activity reaches a least excited state.

The study was carried out on 25 healthy adult volunteers who had been practicing the TM technique from 0.2 to 25 years, with a mean of 7.2 years. There were 15 males and 10 females, whose ages ranged from 17 to 68 years with a mean age of 32 years. All subjects were free of any medication. Prior to the experiment, subjects were informed verbally about all aspects of the experimental procedure.

The experiment was conducted in a soundproof room, dimly lit for observation. Subjects were seated comfortably. Each recording session was divided into two sequential periods: (1) relaxing 5 min with eyes closed and (2) meditating 15 min. During those periods two random samples, one minute each, were recorded for every subject. The EEG record was stored on a hard disk.

2.2 Musicogenic states

The study of the perception of music is a paramount example of multidisciplinary research, in which musicians, psychologists, neurobiologists, physicists, and engineers must communicate and work together. This study comprises three broad problem areas [11]: (a) perception of musical tones; (b) interpretation of acoustical information relevant to music; and (c) emotional response to musical messages. In the past two decades, a considerable mutual integration of

these three problem areas has taken place, due to the progress in the understanding of general human brain functions, and the recognition that in the conscious state even the simplest perceptual events are bound to trigger operations that involve the brain as a whole.

It should be also pointed out that one of the most profound consequences of the evolution of human brain functions (and human consciousness itself!) has been the emergence of systematic postponing of behavioral goals and rearrangement of behavioral priorities. This led to conflicts between cortical functions and those of the limbic system: while in animals the limbic system is mostly activated by environmental and somatic input, in humans it can also respond to internally evoked images displayed on the cortex during the process of thinking. As motivation and emotion are integral manifestations of limbic function (assuring that all cortical processes are carried out so as to be of maximum benefit of organism, through the extended reticular-thalamic activating system [12]), in humans they can be triggered with no relationship to the instantaneous state of the environment. It is along this line that we should seek a lead toward understanding the human emotional response to music (and to art in general!), when the messages therein seem to be of no obvious survival value [11]. It might even be that deep artistic experiences of spectators could have strong spiritual note through spontaneous spectator's mental addressing on the masterpiece (exciting him in altered state of consciousness), and through it on the illuminating idea related to the artist in the moment of masterpiece creation [5].

This motivated us to address our question on similar possible neurobiological origin of musicogenic altered states of consciousness, induced by deep spiritual music of different cultures [13], and its possible EEG correlates. The analogous more frequently used physical mechanisms for sound-induced altered states of consciousness is an introspective repeating of a certain type of sound or "mantra", which is chosen so as to "resonate" with the structure of an individual nervous system [9]. The sound resonances within the human lobe would be then achieved through a formation of standing sound waves, with principal harmonic (of ~ 1000 Hz) having its maximal amplitude in the centre of the lobe cavity, i.e. around the region of limbic system - therefore inducing the local stimulation of thalamic formation through some mechanochemical receptors (to be still specified therein).

The study was carried out on 6 healthy adult volunteers. There were one male and five females, whose ages ranged from 18 to 29 years with a mean age of 25 years. All subjects were free of any medication. Prior to the experiment, subjects were informed verbally about all aspects of the experimental procedure.

The four types of spiritual music were provided to the subjects during experiments: (1) The Indian Bhajan in Sanskrit, (2) The Byzantine Easter liturgy in Greek, (3) The Maronit Song in Arabian, and (4) Mozart's Requiem in Latin.

The experiment was conducted in a soundproof room, with only one music a day. Each recording session was divided into three sequential periods: (1) relaxing 5 min with eyes closed; (2) listening of the music 10 min; and (3) after listening, 5 min. During those periods three samples, one minute each, were recorded for every subject. The EEG record was stored on a hard disk.

2.3 Microwave resonance relaxation

The application of microwave resonance therapy (MRT) in biomedicine is a new trend [14,15], revealing sharply-resonant characteristic eigenfrequencies and sensory responses of the disordered human organism, when applied upon acupuncture points. Such quantum-like coherent characteristics of MRT inspired Sit'ko and coworkers to propose a quantum physics of alive [15,16], considering biological structures as a macroscopic quantum systems with nonlocal selfconsistent macroscopic quantum potentials, giving rise to nonlinear coherent EM MW long-range maser-like excitations of biological nonlinear absorption medium with the cells as active centers. This quantum picture can be more simply visualized [17] considering acupuncture system as a dynamic structure assembled at the locations of maximums of de Broglie interference three-dimensional (3D) standing waves resulted in reflections from the skin of the nonlinear coherent EM MW Fröhlich excitations [18] of strongly polarized molecular subunits in the cell membranes and cytoplasmatic proteins, supported also by other investigations which suggest that gating and assembly of gap junctions (of higher density at acupuncture points and meridians [19]) is a dynamic process sensitive to electrochemical potential of the cell [20] - which might be therefore stimulated at spatio-temporal maximums of MW EM field of the organism [17].

In the above context the explanation for the efficiency of the MRT, as a noninvasive biophysical medical treatment, should be sought [17]: some disorders in the organism (related to local changes of dielectric properties of tissues and organs) give rise to deformation in the standing wave structure of the MW EM field of the organism, which influences corresponding changes in the spatio-temporal structure of the acupuncture system, and consequently resonance frequencies of its meridians, resulting in some disease. During MRT therapy, applying the MW source at a corresponding acupuncture point the excited meridian of patient's acupuncture system relaxes to the previous healthy condition, while reaching its normal resonance frequency responses upon the wide spectrum MW source - and following physiological mechanisms of acupuncture regulation (via nervous and endocrine systems [21]) the organism biochemically overcomes the disease.

The MRT was applied by the wide spectrum apparatus POROG-3, and the measurement of frequency was achieved by the narrow spectrum apparatus AMRT-01, adjusted manually. The frequency range of the POROG-3 is 52-78 GHz. Up to 10 mW low-power microwave generators, of the output power density of $0.2-5 \mu\text{W}/\text{cm}^2$ - much lower than biologically limited $10 \text{ mW}/\text{cm}^2$ during 8 hours, as prescribed by USA National Standards, or $10 \mu\text{W}/\text{cm}^2$ during 8 hours, as prescribed by Russian and Ukrainian National Standards [22] - are power supplied by the $220\pm 22\text{V}/50\text{Hz}$ a.c. or the autonomous 4.5V d.c. The output power density as well as the seance duration significantly influence the MW absorbed dose and corresponding MRT bioeffects, which can be biostimulative for low-level therapeutically recommended doses of typical 20-minute daily MRT treatments (causing local temperature increases up to 38°C , with maximally fast bioef-

fect), and biodepressive and even biodestructive for much higher doses (causing much higher and harmful local temperature increases) [22]. MRT generator was applied on acupuncture points in following order: Du 20, and the left-side points Li 4, Pc 6, H 7 and Ap 55, which resulted in relaxation, similarly to the parasympathic effect [21]. The choice of the acupuncture points for the relaxation seance was achieved on the basis of well known principles of acupuncture stimulation, characteristics of the chosen points, and the therapist experience.

The study was carried out on 28 healthy adult volunteers (13 males and 15 females).

The experiment was conducted in a soundproof room, dimly lit for observation. Subjects were laid comfortably. Each session was divided into three sequential periods: (1) relaxing 5 min with eyes closed; (2) MRT 20 min; and (3) relaxing 5 min with eyes closed. During the first and third periods two random samples, one minute each, were recorded for every subjects. The EEG records were stored on a hard disk.

2.4 Healer/Healee interaction

The transitional states of consciousness [5,6] are presumably the basis of most transpersonal phenomena [23] - being really described by seldom practitioners as not subjected to spatio-temporal limitations [24-26] - providing also explanation for their transitional nature and poor reproducibility: they elapse only ~ 0.1 s, and spontaneous conditions for them are achieved only every 1.5-2 hours, with periodicity of ultradian rhythms which govern the interchange of normal and altered states of consciousness [27]. However, it should be noted that the non-low-dielectric barriers in interaction with the low-dielectric displaced part of ionic acupuncture system are helping in overcoming themselves in such induced transitional states - quite opposite to normal experience in usual mechanical interactions - enabling even their deliberate control and prolongation [24,25]!

It should be also pointed out that the ionic nature of the acupuncture system suggests the possibility that ions in air (prana, qi, pneuma!?) can be physiologically effective [28], just through the acupuncture ionic system and biophysical mechanisms that lie in the basis of acupuncture regulation [21] (out of them, the positive ions have an catabolic influence (yang!?) and the negative ones an anabolic influence (yin!?) [28]). So, qi (sometimes erroneously referred as a new kind of biological energy, bioenergy) can be related to ions flowing through the ionic channels of the acupuncture system in the form of MW/ULF ionic currents, with informational content coded in spatio-frequency form of currents and EM fields. It should be pointed out that a lot of experimental phenomena related to external qi gong treatment [29] can be reconciled with the ionic nature of qi. Hence, it seems that the healing process can be related with the transfer of ions between the healer and healee, and/or transfer of the MW/ULF EM information patterns responsible for normal functioning of acupuncture system and overall health [4,5]. Also, even distant displacements of healer's ionic structure in remote diagnosis and healing [25] could be expected in transitional states of consciousness.

This was our motivation to start examination [30] of EEG correlates of the healer/healee interactions, as presumably most intriguing and relatively easily reproducible transpersonal phenomena [29]. This paper presents preliminary results obtained during five healing sessions of one healer. Obtained results will be used to set-up framework of future research.

The study was carried out on one healer and five healthy adult volunteers. There were 3 males and 2 females, whose ages ranged from 24 to 30 years with a mean age of 26 years. All subjects were free of any medication. Prior to the experiment, subjects were informed verbally about all aspects of the experimental procedure.

The experiment was conducted in a soundproof room. Healer and healee were in relaxed state with eyes closed. Subjects had no physical contact. Each recording session was divided into three sequential periods: (1) before the healing session (2 min with eyes closed, healer had no activity); (2) during the healing session 3 min; and (3) after the healing session (2 min). During those periods EEGs of healer and healee were recorded and stored on a hard disk.

2.5 Alertness/Drowsiness

Two interesting and to great extent related problems are automatic scoring of sleep stages, and detection of EEG segments of reduced vigilance level during awake stages.

The same standards for the visual classifying of sleep stages have been in use over 30 years [31,32]. These standards suffer from severe limitations, and therefore automatic procedures that implement them cannot give satisfying results. Hence, despite the advance of computer technology over the past decades, automatic scoring of sleep stages is far from being solved till now [33]. Man/machine agreement of even the best methods is limited by poor interscorer agreement obtained by comparing results of visual inspection of different electroencephalographers.

The situation is even more vague with the detection of reduced vigilance level segments from EEG recordings. Different approaches have been used to classify the degree of alertness during the awake stages, from subjective ratings, performance tests and neurophysiological measures. Subjective ratings are unreliable because of the fact that feelings such as alertness or drowsiness are poorly defined. Methods based on monitoring performance level like measuring reaction time to some stimuli, cannot give satisfying results as such measurement itself influences the subject's vigilance. It is evident, therefore, that it is the EEG on which the vigilance level estimation should be based. However, there are no universally accepted standards for visual classification of vigilance level during the awake stages, based on EEG traces. This is in contrast to the fact that the changes in EEG frequency bands, and occurrence of patterns assigned to changes of vigilance level, are assumed to be known. Different authors have used different approaches to combine these known characteristic changes in order to form meaningful rules, so further efforts should be obviously directed toward modeling underlying biological processes [33].

An effort in this work is done toward finding underlying functional relationship between power spectrum fluctua-

tions related to changes of vigilance level (not used predetermined relationships) in order to estimate vigilance level. This is done by means of neural network classifier. Employing neural network classifier as a structure with modifiable parameters is of benefit for the following reasons: (a) underlying relationships which are assumed to exist, are not known, and are to be found; (b) by supplying the neural network with training sets obtained from recordings on single subjects, the network “learns” individual patterns characteristic for lower vigilance; and (c) the method can be adjusted to correspond to the results obtained by visual inspection of different experts. This allows interaction between electroencephalographers and machine, that will lead to better understanding of underlying principles and therefore to more efficient standards.

Electroencephalograms of 30 healthy young subjects were recorded. Subjects were aged 20-28 (median: 25), 22 males and 8 females, and have passed neurological screening. Uniformly aged subjects were chosen because EEG changes with age, and universal rules for automatic detection of vigilance level should require much bigger experimental group. Recordings were performed between 2-4 p. m. Subjects were not sleep deprived, nor had any deviations from their usual circadian cycle, and they took no drugs.

Recordings lasted from 15 to 30 minutes, depending on subject’s level of drowsiness i. e. frequency of occurrence of low vigilance segments on corresponding EEG traces. Subjects were not allowed to fall asleep (i. e. further from stage I of slow wave sleep – drowsiness). We required at least two minutes of low vigilance level in total EEG time. EEG signals were analyzed off-line, and epochs without artifacts, characteristic for full wakefulness and for lower vigilance were cut by experienced electroencephalographer and pasted to form two-minute long segments used, one as a representative of normal fully awake state (alert wakefulness), and another one as a representative of drowsy wakefulness.

3. RESULTS

3.1 Transcendental meditation

The representative examples of spectral arrays in our subjects (N^os 1 and 12) with slow α activity and θ burst during meditation, respectively, are shown in Fig. 1(a, b).

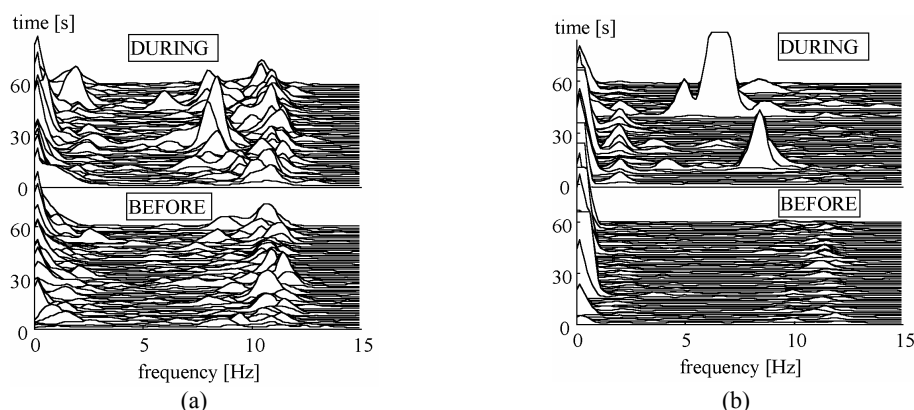


Figure 1. (a) Compressed power spectral arrays of the EEG for subject 1 obtained from the electrode P3 before and during meditation, showing the slow α waves at 8 Hz; (b) Compressed power spectral arrays of the EEG for subject 12 obtained from the electrode F3 before and during meditation, showing a θ burst at 6 Hz.

The comparison of the medians of partial EEG power for one derivation was performed using Wilcoxon matched pairs test. Fig. 2 shows the spatial distribution of the changes (z-scores) over the whole head. Shaded areas indicate the fields that have significant power increase. The primary sources of differences were the left frontal region (F3, $z=3.24$, $p=0.001$) in θ -band, right temporal region (T4, $z=2.65$, $p=0.008$) in α_1 -band, left temporal region (T3, $z=2.73$, $p=0.006$) in whole α -band, and left prefrontal region (Fp1, $z=2.59$, $p=0,01$) in β_1 -band.

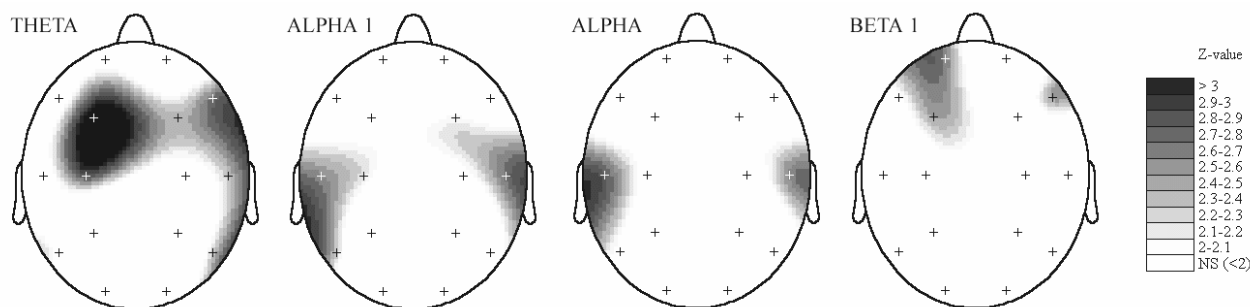


Figure 2. The topographic mapping of significant ($p<0.05$) z-values of partial EEG power for each frequency band for the meditation study: θ (4-8 Hz), α_1 (8-10.5 Hz), α (8-13 Hz), and β_1 (13-18 Hz); Wilcoxon matched pairs test; inverse distance method.

Spatial distributions of medians of correlation dimension over the whole head before and during meditation are given in Fig. 3. Although there are no statistically significant changes, a decrease in correlation dimension in right frontal and left parietal regions is obvious. In Fig. 4 the z-scores obtained by comparison of the medians of correlation dimension of each channel of every subject, prior and during meditation is given. Wilcoxon matched pairs test was applied.

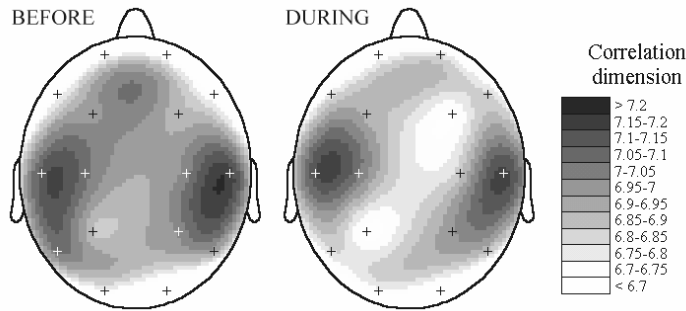


Figure 3. Spatial distribution of the correlation dimension before and during meditation.

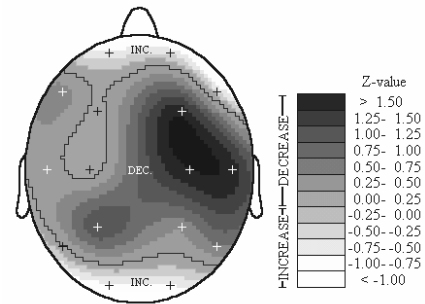


Figure 4. The topographic mapping of z-values of correlation dimension; Wilcoxon matched pairs test.

The present study confirms previous reports [10, 34-37]. The meditators as a group displayed a significant increase of θ activity ($z=2.00, p=0.046$) over the whole head. In particular, out of 25 meditators, 10 (40%) significantly increased their θ activity during meditation, and 4 (16%) significantly decreased. Analysis of each of the 16 derivations separately showed that the prominent θ wave activity is present in the frontal, central, and right temporal regions at frequency of 8 Hz (channel F3, $z=3.91, p=0.0001$). The patterns of θ frequencies fluctuated. Observed hypersynchronous θ bursts were similar to the θ bursts occurring during phases of emotional excitation [38,39].

The consistent changes in the other frequency bands were not observed in meditator group as a whole. Out of 25 subjects, 12 (48%) significantly increased their slow α activity (8-10.5 Hz) during meditation, and 4 (16%) significantly decreased. The prominent slow α activity occurred in right frontal, central and temporal regions. During TM, there was a significant increase of α activity in 13 (52%) experimental subjects and significant decrease in 7 (28%), most frequently in temporal region (T3-T4). The increase of slow α activity during the TM technique is apparently due to the nature of the technique, which according to adherents involves the increasingly abstract experience of quieter levels of mental activity, attained without concentration or procedures of controlling the mind [40]. Increased orderly functioning of the frontal and central regions of the brain may be correlated with this improvement in mental abilities, especially since these brain areas are known to be responsible for such activities as sensory-motor integration, memory, cognition, concentration, judgment, and volition [36]. Those changes may not necessarily occur in long-term meditators. The subjects also showed a significant increase of prefrontal β activity.

Many of the previously published papers have reported physiological changes during meditation that seem to characterize substates of wakefulness [9,38,41-43]. Those changes have been interpreted as a support for the fourth major state of consciousness, the *restful alertness state*, being a combination of restfulness (increase in α and θ activity) and alertness (increase in β activity). This is in accordance with the Ellias and Grossberg model of neuron [44], which predicts that higher input to brain neural network increases frequency and decreases amplitude of oscillations. In this case, appearance of significant θ component and the α rhythm slowing may be the result of deprivation of the sensory input. On the other hand, increased β power could be a consequence of the increased mental activity.

3.2 Musicogenic states

In Table 1, the results of the Wilcoxon matched pairs test for medians of EEG power of all 16 channels, prior and during the listening of music.

Table 1. The EEG power changes during the listening of music.

MUSIC	SUBJECT 1			SUBJECT 2			SUBJECT 3			SUBJECT 4			SUBJECT 5			SUBJECT 6		
	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	BAND	
1	θ	α	β_1	θ	α	β_1	θ	α	β_1	θ	α	β_1	θ	α	β_1	θ	α	β_1
2	-	-	0	0	-	0	-	+	0	+	-	0	-	-	-	0	-	-
3	0	-	-	-	-	-	-	-	-	0	0	0	-	-	-	x	x	x
4	x	x	x	+	+	-	-	-	-	0	-	0	0	-	-	-	-	-
5	0	-	-	0	-	-	-	-	-	x	x	x	0	-	0	x	x	x

+ sign. increase, - sign. decrease, 0 no sign. changes, x not recorded

In most cases, during the listening of music, the EEG power decrease is observed in various frequency bands. In the three cases (out of 24), a significant power increase in θ and α bands is registered, in accordance with an intense aesthetic experience in these cases; the two most prominent spectral arrays before, during, and after the listening of music are shown in Fig. 5 (a, b).

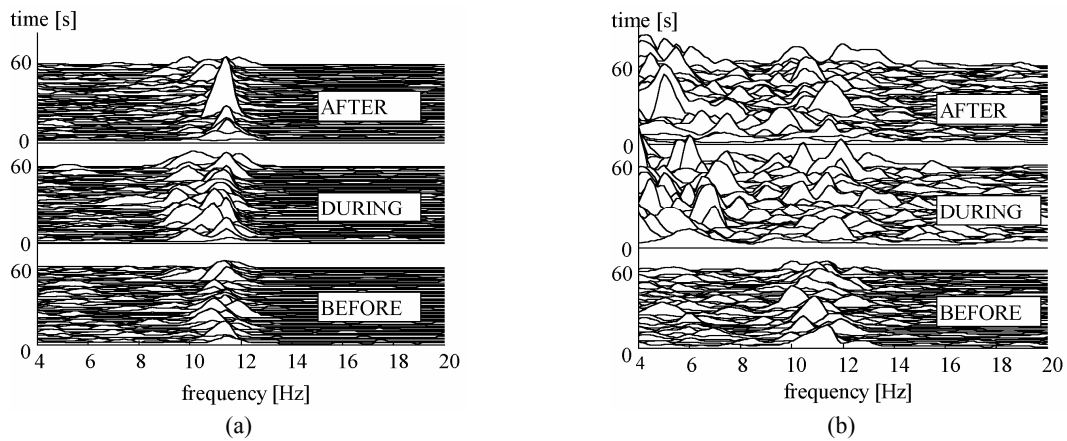


Figure 5. (a) The spectrogram with the observed EEG power increase in the α band and the appearance of slower α frequencies during the listening of music 1 in channel P3 of subject 3; (b) The spectrogram with the observed high EEG power increase in the θ band during the listening of music 1 in channel T6 of subject 4.

3.3 Microwave resonance relaxation

The subjects were classified in two groups: the group 1 (11 subjects) not previously subjected to the MRT treatment, and the group 2 (17 subjects) being subjected to the MRT in the past two years.

Both groups of subjects have significant changes in the EEG power over the whole head in the α and β_1 frequency bands, with observation that a percentage of subjects with minor reactions is much less in the group 1. The group 2 has also the significant EEG power changes over the whole head in a δ frequency range.

Within the whole frequency range (1-30 Hz), 37 channels in the first group and 22 channels in the second group with the power changes in more than 50% subjects are notified. The changes are evident in δ , α , and β_1 frequency bands. The most prominent power changes in all frequency bands are observed in the channels 3 (T3), 11 (C3), and 12 (C4) of the group 1, and in the channels 6 (T6), 9 (F3), 11 (C3), and 13 (P3) of the group 2. The channels 3 (T3), 11 (C3), and 15 (O1) of the group 1, and the channels 6 (T6) and 11 (C3) of the group 2 have power changes in more than 50% subjects in 4 out of 5 frequency bands. In both groups of subjects, a decrease in the EEG power is more frequently observed than an increase. As an illustration, in Fig. 6 (a-c) the topographic mappings of the number of subjects (in %) having the significant EEG power changes in the δ , α and β_1 frequency bands, for the two groups of subjects are presented.

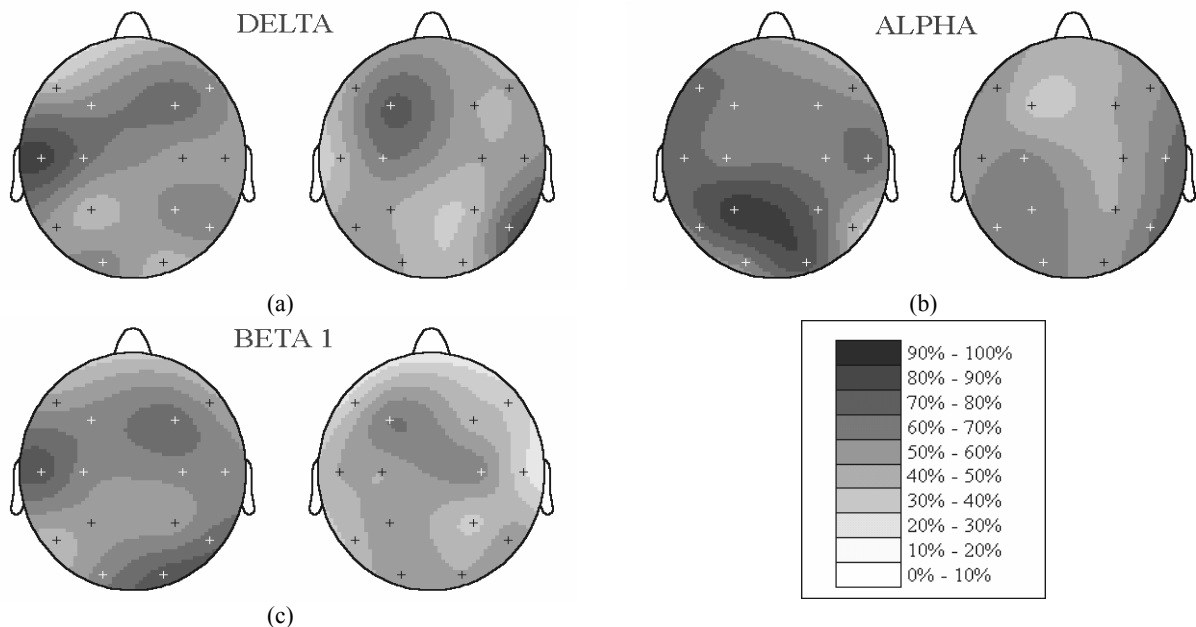


Figure 6. The topographic mappings of the number of subjects (in %) of the group 1 (left) and the group 2 (right), having the significant EEG power changes in the: (a) δ band (1-4 Hz), (b) α band (8-13 Hz), and (c) β_1 band (13-18 Hz). The gradual percentage changes are presented in various degrees of shading, as designated in the insert.

The changes in coherency are not too significant. Regarding the complete group of subjects, in δ frequency range the changes are observed in the backward temporal (T5 and T6), parietal (P3 and P4), and occipital (O1 and O2) regions in 25%, 25%, and 42 % of subjects, respectively. The changes in frontal region (F3 and F4) within α frequency band are observed in 29% of subjects, and in occipital region (O1 and O2) within β_1 frequency band in 25% of subjects. Most prominent changes, over the whole frequency interval (1-30 Hz), are registered in occipital region (O1 and O2). A decrease in the coherency is generally observed.

3.4 Healer/Healee interaction

The healer's EEG at the beginning of each of five sessions exhibited similar properties (Fig. 7). The specific pattern of this slow fluctuation is not due to the cortical activity, but to intensive neuro-vegetative reaction. This reaction is accompanied with the changes of skin resistivity, which is the greatest at the parietal and temporal brain sites.

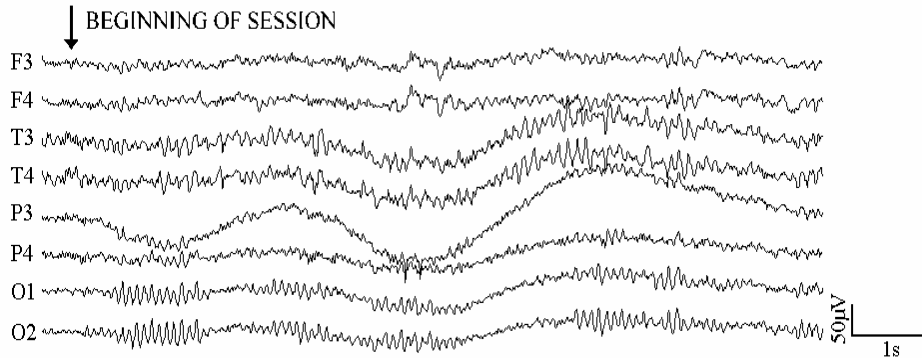


Figure 7. An example of healer's neuro-vegetative reaction at the beginning of session.

The healer's power spectrum exhibited some changes in θ region, the greatest being at frontal brain sites (Fig. 8(a)). The healee's power spectrum during the session exhibited changes in θ region at frontal brain sites too (Fig. 8(b)).

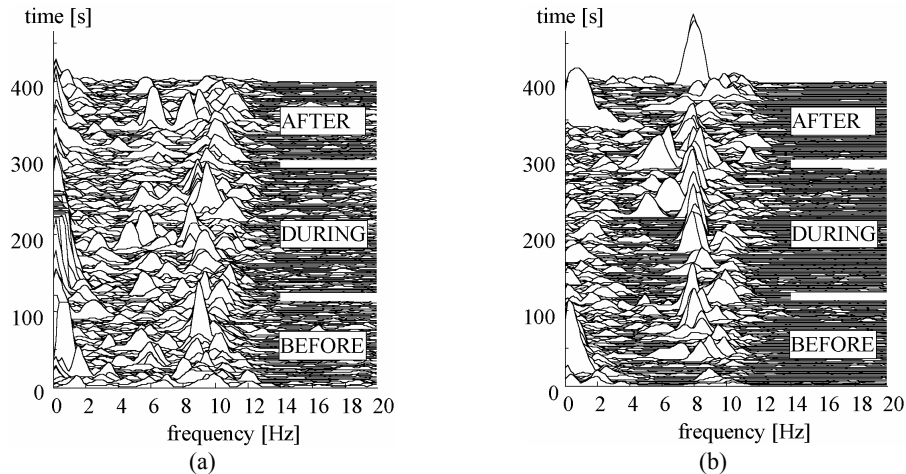


Figure 8. Spectrogram (channel T3) of (a) healer and (b) healee; increase in power is most pronounced in θ band during and after the healing session.

The Man-Whitney U-test was used to analyse coherence spectral arrays. Significant changes in 3 out of 5 experiments were observed. Changes were most pronounced at channel T3 (both healer's and healee's). However, due to their small values, medians of coherence time series (30-50%) were not taken into consideration. Increase of coherence occurred only in short intervals. Epochs of 4s, before and during the session were used to estimate maximum coherence value in α and θ bands. Results are summarised in Table 2. Increase of maximum coherence in α band was 6-13% for subjects 1, 2, and 3, while 4.4% for the whole group.

Table 2. Maximum mean coherence in θ and α bands for 4s time epochs, before, during, and after the healing session.

SUBJ.	θ BAND			α BAND		
	BEFORE	DURING	AFTER	BEFORE	DURING	AFTER
1	73%(T3-T3)	82%(F4-F4)	75%(T3-T3)	70%(O2-O2)	78%(F3-F3)	76%(P4-P4)
2	73%(P4-P4)	70%(O2-O2)	69%(P4-P4)	78%(T4-T4)	84%(O1-O1)	83%(T3-T3)
3	74%(F4-F4)	72%(P3-P3)	81%(T3-T3)	79%(O2-O2)	92%(O1-O1)	84%(O2-O2)
4	71%(F4-F4)	78%(F3-F3)	71%(F3-F3)	81%(F3-F3)	82%(O2-O2)	77%(P4-P4)
5	77%(F4-F4)	81%(P3-P3)	74%(O2-O2)	80%(T3-T3)	74%(F3-F3)	84%(O1-O1)
mean	74,6%	76,6%	74,0%	77,6%	82%	80,8%

An example of synchronized EEG signals of healer and healee 3 during the treatment, as well as the corresponding phase diagrams and coherence diagrams are shown in Fig. 9. The phase difference at frequencies with maximum coherence is 180° .

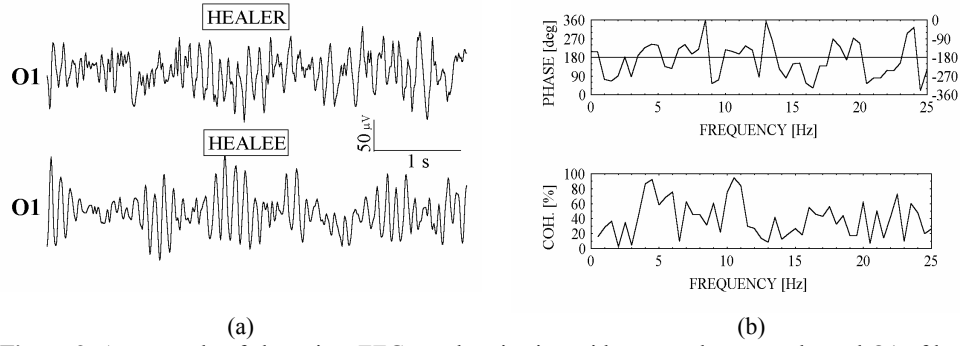


Figure 9. An example of short-time EEG synchronization with max. coherence; channel O1 of healer and subject 3; plots of (a) original signal and (b) phase and coherence diagrams.

3.5 Alertness/Drowsiness

Single layer perception neural network was used for vigilance level assessment. Training and test input vectors were made from one two-minute long segment of alert wakefulness and one of drowsy wakefulness. The state of alert wakefulness was assigned the value of 1, and the state of drowsy wakefulness was assigned the value of 0. These values were supplied to the network as desired output values during the training session.

Segments of 30 sec of both recording were used to construct training sets. The network was tested on the rest 90 sec of each recording. To achieve high processing speed it was necessary to make input vectors of low dimensionality. Also, it was necessary to make the components of input vectors to be easy to compute. Thus, the power spectrum characteristics were used to form input vectors. Spectral analysis is the most important and most common technique in EEG time series analysis [45]. Due to great inter-individual variations in total power, the relative values were computed, i. e. the power in each frequency band was divided by the total power in all bands.

The slowing of dominant α frequency and widening of α peak are assumed to be the most important signs of drowsiness. However, it is not possible to see these events through changes of relative power in α band. Therefore, α band was divided into two bands, α_1 (7.5-9.5 Hz) and α_2 (9.75-12.5 Hz). These boundaries are carefully chosen so that values of relative power in these bands carry the same amount of information, as does the shift of the dominant α frequency, and widening of α peak.

Boundaries of frequency bands used were as follows: 0.5-3.25 Hz (δ), 3.5-7.25 (θ), 7.5-9.5 Hz (α_1), 9.75-12.5 Hz (α_2), 12.75-18 Hz (β_1), and 18.25-25 Hz (β_2).

Since it is shown in earlier studies [46] that significant differences in EEG patterns between hemispheres during the drowsiness do not occur, power spectrum was computed from the one hemisphere (right).

Slight vigilance fluctuations can occur in time periods as short as few seconds. Therefore, short time epochs were used to compute power spectrum characteristics. The use of 4-sec long epochs provided a good compromise between time and frequency resolution. Frequency resolution was 0.25 Hz, which was good enough to successfully divide spectrum into bands. In order to improve time resolution, epoch overlapping of 2 sec was used. Thus, 28 epochs were used for training, and 84 epochs were used for testing.

In order to find the power spectrum characteristics that best reflect the expert's knowledge used for visual classification results from previous studies were consulted as well [46-52]. Characteristics that in combination with perceptron neural net proved to give the most satisfactory results are shown in Table 3. These values were used to form input vectors for both training and testing. Input vectors during the training phase were supplied to the network along with the desired values of output. During training cycle, perceptron neural network assigned the weighting values to each component of the input vectors. These weights were used in testing phase, in order to estimate the level of vigilance. Training network on each subject enabled the network to "learn" individual fluctuations in EEG spectrum.

Table 3. Combinations of power spectrum values and electrode positions used to form input vectors.

FREQUENCY BAND	α_2	α_1	θ	θ	β_1	β_1	β_1	β_2	β_2	θ/α	
ELECTRODE POSITION	O2	O2	O2	F4	F4	C4	O2	F4	C4	T6	O2+F4+F8+C4+T4

Numerical results were computed on a standard PC. Procedures for data manipulation and neural network implementation were developed in Matlab 4.2 environment [53]. Training and testing of the network took a few seconds of CPU time on PC 486/100 MHz.

Results of the procedure applied for five typical subjects are summarized in Table 4.

Table 4. Results of perceptron classification of vigilance level, for five typical subjects.

SUBJECT	TRAINING PHASE			TESTING PHASE		
	N ^o OF VECTORS	N ^o OF VECTORS SUCC. LEARNED	ERROR RATE (%)	N ^o OF VECTORS	N ^o OF VECTORS SUCC. CLASSIFIED	ERROR RATE (%)
1	28	28	0	84	79	5.95
2	28	28	0	84	81	3.57
3	28	28	0	84	83	1.19
4	28	28	0	84	81	3.57
5	28	28	0	84	84	0.00

4. CONCLUSIONS

Our investigations demonstrated that new technologies applied to the EEG may permit rapid and reproducible identification of different styles or states of consciousness. Such a tool might be useful in evaluating the effectiveness of different techniques for stress reduction and for altering expressions of consciousness.

4.1 Transcendental meditation

The EEG correlates estimated before and during meditation clearly distinguish the following characteristics: (1) Meditators as a group showed a significant increase of θ activity in meditation, dominantly in left frontal (F3) and right temporal (T4) regions at frequency of 8 Hz; (2) Slow α (α_1) and whole α activity increased significantly in temporal region (T3-T4); (3) β activity increased significantly in prefrontal region (Fp1-Fp2); and (4) Correlation dimension decreased not significantly, but there was significant correlation between decreasing of the correlation dimension and increasing of the partial EEG power in α_1 and α band. Appearance of significant θ component and the α rhythm slowing may be the result of deprivation of the sensory input, while the increased β power could be a consequence of the increased mental activity – supporting the previous interpretations of meditation as a fourth major state of consciousness, the restful alertness state.

4.2 Musicogenic states

According to our pilot study with six subjects and four types of spiritual music, it might be concluded that the EEG power changes during their listening are quite individual. In the three cases where significant raise of power (i.e. relaxation) in θ and α bands is observed, the subjects have described their musical experiences as very pleasant - in contrast to the cases with drop in EEG power and unpleasant musical experiences. The most prominent changes were observed in subjects 3 and 4 upon the influence of the music 1 (Bhajan, the Indian spiritual music, sang in Sanskrit); and somewhat less in subject 2 upon the influence of the music 3 (the Maronit spiritual music, sang in Arabian). Concerning the coherence increase, it seems not to be correlated with the aesthetic experience as, for instance, all subjects described their experience of music 2 as “slightly unpleasant”, while their coherence even being increased. In spite of the observed particular EEG changes upon some types of spiritual music, it might be that more conclusive results could be achieved only in the case of more careful choice of subjects, regarding their musical affinities and/or education.

4.3 Microwave resonance relaxation

Upon the MRT application, a decrease in the EEG power is observed in most subjects of the both groups - the first group not previously subjected to the MRT treatment (11 subjects), and the second group being subjected to the MRT in the past two years (17 subjects). The EEG power over the whole head is significantly changed in α and β_1 frequency bands in the both groups of subjects. The subjects of the group 1 had about 70% more MRT responding channels (reacting to MRT in over 50% subjects in all frequency bands) than the subjects of the group 2, especially in the α and β_1 frequency bands, which might be ascribed to the energetically more dysbalanced acupuncture system of subjects in group not previously under the MRT treatment, therefore revealing more relative changes towards the energetically normal acupuncture state. It should be added that in both groups of subjects the dominant power changes within the EEG channels in all frequency bands (with the exception of β_1 band in the group 2) are registered in the left hemisphere, which might be ascribed to higher activation of the left circulatory part of the acupuncture system, as a consequence of the systematic MRT stimulation of the left-side acupuncture points Li 4, Pc 6, H 7, and Ap 55.

4.4 Healer/Healee interaction

The main aim of our pilot experiment made on one healer and five healees was to establish experimental set-up for larger experimental group as well as methods for quantitative analysis. Due to small experimental group and nonstationarity of EEG signals, results obtained by dynamic analysis of power and coherence time series were not statistically significant. If the healer/healee interaction is related with the transfer of the EM/ionic information patterns, then it is to be established during short time intervals. This is suggested by the increase of the maximum mean coherence of the whole group in α band (4.6%), obtained by statistical analysis of the coherence of 4s long time epochs. Due to the nature of the underlying phenomenon it is necessary to perform data acquisition with the higher sampling rate (>256 Hz). Quantification of the observed changes in δ and subdelta band requires more elaborated signal processing procedures.

4.5 Alertness/Drowsiness

This research has shown that automatic detection of fast fluctuations (order of few seconds) of the vigilance level is possible. Moreover, phase space created by variables listed in Table 3 has the property of linear separability of the states of “alert wakefulness” and “drowsy wakefulness”. Therefore, it is possible to construct hyperplane that separate these classes. In this work, this separation is done by the perceptron neural network. Moreover, the simplicity of implemented procedure allows very fast data processing and near real-time processing, which is of great importance in clinical use. Potential application of the developed procedure is in the area of psychophysiology (cognitive testing during EEG re-

coding, and similar procedures), long-term monitoring of vigilance in clinical medicine (epileptology), and automatic elimination of low vigilance segments from EEG record when necessary.

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