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Research Article

Alhpa-Wave Synchronization Observed In Subjects Practicing Relaxation Revealed an Individual Hyper Neural Network In Cognitive Activities

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ABSTRACT

There exist various theories of the functional role of EEG alpha-wave, including that viewing the wave in question as a reflection of the modulators of its frequency ranges recorded when this or that specific functional state sets in. A number of researchers (Sterman, M.B. & Mann, C.A., 1995; Nikishena, I. S. et al., 2004) linked altered alpha-wave parameters recorded as he subjects when doing cognitive tasks with the attention function and mental strain. While synchronization between specific cortical areas within the alpha range in various functional body states is a self-evident phenomenon (Ivanitsky, A.M., 2001; Nunez, P., 2001), the very nature of interactions between ranges of various ranges during synchronizations remains unstudied. Mechanisms underlying cognitive activities have been subject to the most laborious research to control their development and correction.

Keywords: electroencephalography; alpha-wave synchronization; cognitive activities efficiency; relaxation; psycho training

HIGHLIGHTS

Training a state of relaxation increases the plasticity of neurons.

Synchronization of cortical zones in alpha rhythm activates the neural network.

Cognitive performance is characterized by long alpha rhythm spindles.

The solution speed is associated with 2 peaks of the alpha rhythm frequency in the range of 11.4 ± 0.5 Hz and 8 ± 0.6 Hz.

OBJECTIVES

To study EEG alpha-wave synchronization processes that occur in subjects aged between 20 and 35 engaged in cognitive activities and practicing relaxation for a long time.

MATERIALS AND METHODS

Cognitive activity alpha-wave synchronization processes have been studied by the EEG in individuals aged between 20 and 35, who have been practicing relaxation for a long time. Group I was made up of fit males who played no sport, while Group II consisted of made subjects of the same ages, who practiced psychophysical relaxation sessions (PPRS) on a regular basis. The relaxation sessions included natural landscape visualizations, and concentration on sspecific body areas. The computer-assisted electroencephalograpy (EEG) included spectral, periodometrical, coherent, and correlation analysis.

RESULTS

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The research results suggest that relaxation sessions enhance the alpha-wave spectral power in the subjects both while at rest and while doing cognitive tasks. Alpha-wave synchronization covers more cortical areas, including frontal and central areas of both of the brain hemispheres in a subject being engaged in cognitive activities. Cognitive activities efficiency was higher in those practicing PPRS than in those who did not practice them. Criteria for alpha-wave synchronization have been identified in the subjects who demonstrated high efficiency in solving cognitive tasks, with their EEG patterns having long spindles and short spans in between, and two EEG alpha-wave frequency peaks within a range between 11.4 ± 0.5 Hz and 8 ± 0.6 Hz.

A conclusion has been made that the synchronization criteria identified can be of a diagnostic and prognostic significance in estimation of cognitive functions.

INTRODUCTION

There exist various theories of the functional role of EEG alpha-wave, including that viewing the wave in question as a reflection of the modulators of its frequency ranges recorded when this or that specific functional state sets in. E.g., (Bundzen, P.V., 2000; Gorev, A. C., 2012; Popova, T. V. et al., 2014) observed a slow-wave alpha-wave range of 7 to 9 Hz during relaxation sessions; (Klimesh, W., 2007; Moretti, D.V. et al., 2007) observed that there were predominantly high-frequency alpha-waves between 11 and 13 Hz in subjects being engaged in cognitive activities. A number of researchers (Sterman, M.B. & Mann, C.A., 1995; Nikishina, I. S. et al., 2004) linked altered alpha-wave parameters recorded as he subjects when doing cognitive tasks with the attention function and mental strain.

Alpha-wave modulation is initiated by the activity of the thalamic nuclei via the thalamocortical radiations (Jones, E.G. et al., 2000), as well as by the activity of pyramidal neurons and interneurons (Castro-Alamancos, M. A. et al., 2007; Ascoli, G.A. et al. 2008). The activation of an extensive neural network sprawling from the thalamus to the cerebral cortex safeguards the synchronization between activities of various cortical areas within the alpha-wave range, which can be observed, e.g., during an onset of relaxation states (Gorev, A.C., 2009; Popova, T. V. &Koryukalov, Y. I. 2014). The striatum plays a role in selective activation of thalamocortical connections required to accomplish a “task proposed” (Aleksandrov, Y. I.,&Anokhin, K. V., 2008, 2015).

While synchronization between specific cortical areas within the alpha range in various functional body states is a self-evident phenomenon (Ivanitsky, A.M., 2001; Nunez, P., 2001), the very nature of interactions between ranges of various ranges during synchronizations remains unstudied. Mechanisms underlying cognitive activities have been subject to the most laborious research by (Sviderskaya, N. E., &Korolkova, T. A., 1996,1987; Bushov, Y. V., 2007, 2009), who were able to observe spatial synchronizations between electrical activity of the brain at various alpha-wave frequencies by coherent analysis.

An increase in the spectral power of beta-1-range waves is also observed (Kozlova, I. Y., 2010) amid bioelectrical activity that occurs at one frequency while a subject is being successful with cognitive activities. According to(Korobeynikova, I. I., 2012), the efficient memorization of tasks of the same complicity also depends on the electrical activity synchronization level within the alpha band.

Understanding how bioelectrical activity of the brain functions in a subject engaged in cognitive activities will provide a basis under further elaboration on brain cognitive processes theory, and search for techniques for the cognitive process improvement, including those that occur under extreme stresses.

RESEARCH METHOD

Group I subjects were higher education institution students and graduates aged between 20 and 35, fit, and not playing any sport. Group II consisted of subjects of the same ages, who regularly practiced psychophysical relaxation session (PPRS).The research was conducted on voluntary informed consent of the subjects, in compliance with the Protocol approved by the Ethical Board of the Russian Academy of Sciences.

Relaxation is one of the primary means of psychophysical alleviation, including that provided to subjects when they are doing cognitive activities. Research of bioelectrical processes that occur in the brain provides understanding of mechanisms that underlie the impact of relaxation on cognitive process efficiency. The subjects commenced a PPRS, following the instructor’s verbal cues. Relaxation exercises included arbitrary muscle relaxation while visualizing scenic natural landscapes. As soon as feelings of relaxation set in 2 or 3 minutes into the session, the subjects, following the instructor’s lead, concentrated on their backbones and imagined flows of energy travel upwards out of their solar plexuses as they inhaled and to their pineal glands in their brains as they exhaled.

Multichannel EEGs were recorded by means of a "Encephalan-EEGR-19/26" in the modification of "Mini" (European certificate CE 538571 British Institute of Standards, BSI), from eight and sixteen cup electrodes connected to ear electrodes and positioned in accordance with the 10-20 system. The functional tests were as follows: background record (BR), open eyes test (OE), eyes closing (EC), solving arithmetical problems where they were to subtract 5 and 2 from 200 in turns, as well as the Torrens verbal test for compiling a set of words from a set of letters (Tunic, E.E. 1998). The EEG sampling rate was 250 Hz. Computer-assisted EEG included spectral, periodometrical, coherent, and correlation analyses conducted by using the software provided by the manufacturer company.

Registration was carried out in telemetric mode - to the computer's memory via the Bluetooth interface at the following leads: EEG_Fp1, Fp2, F3, F4, F7, F8, C3, C4, T3, T4, T5, T6, P3, P4, O1, O2 with sensitivity settings 70 μV / mm and a sweep speed of 30 mm / s. The frequency step was 0.25 Hz. The EEG record was automatically scanned for artifacts that were resolved using a regression procedure. Areas with an amplitude of more than 180 μV within a window of 650 ms were noted as a bad channel, areas with an amplitude of more than 140 μV were considered as a motor artifact, and more than 60 μV as a visual and muscular artifact. The selection of EEG data was carried out according to the epochs corresponding to the fulfillment of tasks. For each era, a spectrogram was calculated (squared modulus of the Fourier transform). The Fourier transform decomposes the signal into a number of harmonic components without any loss of information. Each harmonic includes three parameters: amplitude, initial phase and frequency. "Bulletin of Psychophysiology" No. 3 2019 26 The dependence of the amplitude and phase of harmonics on frequency is called the spectrum (Kulaichev A.P. 2007). Noisy eras reduced.

METHODS AND EQUIPMENT USED

Torrens verbal test for composing words from a set of letters (Tunic E.E., 1998). A mind subtraction test. Subjects within 90 seconds subtracted in their minds from 200 alternately 2 and 5 with pronouncing the results. Following the results of 90 seconds, the result was recorded. Electroencephalograph-recorder, computerized portable "Encephalan-EEGR-19/26" in the modification "Mini" (European Certificate CE 538571 of the British Institute of Standards, BSI) for stationary use of the ABP-10 patient unit. Statistical data processing was implemented on the basis of standard IBM SPSS Statistics 22. The spectral power parameters were calculated over the entire EEG frequency range (0-40 Hz). To identify inter-level differences in the EEG power spectrum, the nonparametric Wilcoxon test was used for dependent samples, since the average power spectrum did not correspond to the normal distribution (Shapiro-Wilk test).

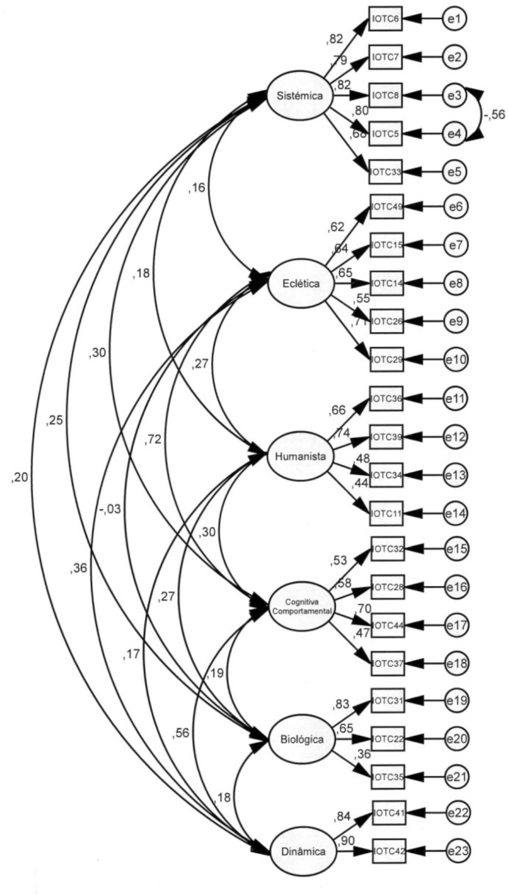
RESULTS AND DISCUSSION

Analysis of the background bioelectrical activity of the brain conducted while at rest with the eyes open (EO) suggests that there were certain differences between the subjects of the two Groups. E.g., EEG discovered alpha-wave activity in the initial (background) state (BR) in almost all of Group II subjects who practiced PPRS, in sharp contrast to Group I, where the same alpha-wave activity was only found in 1/3 of the subjects who practiced no relaxation, their average alpha-wave amplitude being 15 to 20 μV, the alpha-wave index ranging between 5 and 15%, in sharp contrast to Group II, the PPRS Group, where the amplitude in question and the alpha-wave index were higher by 25 to 40 % on average and were 20 to 35 μV and 15 to 45% respectively.

The dominant alpha-wave frequency was 10 to 0.5 Hz in both Groups, with the second power peak detectable from EEG spectral analysis at frequencies between 8 ± 0.8 Hz in the fronto-central deflections in Group II subjects (those practicing PPRS). Based on the presence of two alpha-wave peaks found in the same EEG deflections, it is fair to assert that activity in a number of alpha-wave generators can be observed while at rest in subjects who practice relaxation sessions.

The spectral analysis of the alpha-wave activity in Group II subjects as they were doing EC tests suggested that alpha-waves had the same power everywhere while being dominant in both occipital and fronto-central deflections, see Fig. 1 below. Alpha-wave activity was predominant in the occipital areas and in the left hemisphere deflections in the subjects who practiced no relaxation sessions (Group I).

Figure1: Alpha-wave power in frontal areas of the cortical hemispheres of subjects doing EC tests (The specter and the frequencies, M:2). The diagram on the left (A) – Group I; the diagram on the right (B) –Group II. Abbreviations used here: Fp1, Fp2 – frontal; C3,C4 – central; T3, T4 – temporal; and O1, O2 – occipital deflections



A B

The lengths of alpha-wave spindles was 20 to 35% longer on average, with spans between being much shorter in 2/3 of Group II subjects (the PPSR Group), in sharp contrast to those found in Group I subjects.

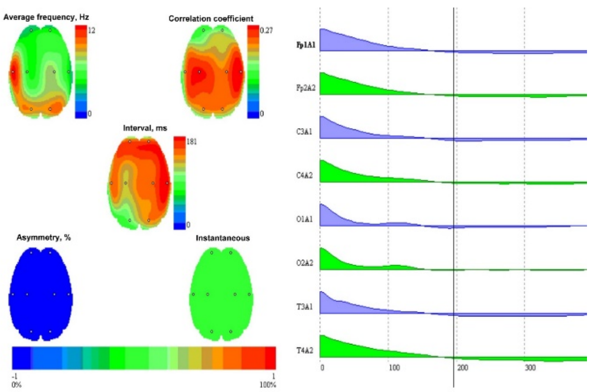
Thus, background records typically find alpha-wave activity with a high wave index in frontal deflections and a second slow-frequency peak within the alpha-wave spectrum in the subjects who practice relaxation as they are doing EO tests, in contrast to those who practice no relaxation sessions. Alpha-waves of Group II (the PPSR Group) subjects come in the shape of patterns of long spindles with short spans in between, in contrast to those of Group I subjects.

Spectral and correlation analysis of bioelectrical activity of the brain while doing mental subtraction cognitive tests also discovered that there were certain differences between the Group I and Group II subjects. E.g., there was no increase in the alpha-wave activity in a majority of Group I subjects, except for those who were first to solve the task proposed; on the contrary, a considerable increase in the alpha-wave activity was discovered in those successful subjects, its amplitude being increased in the centro-occipital deflections of the right hemisphere, while the centro-parietal areas of the left hemisphere were the dominant alpha-range deflections in the rest of Group I subjects.

On the contrary, a consistent increase in the alpha-wave activity in the fronto-central and temporal deflections of predominantly right hemispheres was discovered in Group II (the PPRS Group) subjects (those practicing regular relaxation sessions) as they were doing mental subtraction cognitive tests.

The correlation analysis findings suggest that a substantial increase in the alpha-wave activity was discovered in the fronto-central and temporal deflections of both hemispheres in Group II subjects (the PPRS Group), see Fig. 2 below, where the first alpha-wave peak was found within the range between 11 and 12 Hz, and the second one – within the range between 8 ± 0.6 Hz, whereas no increase in the alpha-wave activity was found in any of Group I subjects, their alpha-wave activity hovering around 10 to 11 Hz.

Figure 2: The alpha-wave values for mental subtraction tests done by Group II (the PPRS Group) 2018 sec, 196ms, M:2 (Autocorrelation function)



EEG coherent analysis suggest that Group I subjects (the PPRS Group) have significant interhemispheric brain connections within the frontal and central deflections as they are being engaged in cognitive activities, in contrast to Group I subjects who practice no PPRS. It is a fact of interest that a decrease in the coherence between interhemispheric brain connections is found in all EEG deflections in the high-frequency beta-wave range that is inherent to cognitive activities.

Of all Group I subjects, the increase in the beta-wave power was highest in high-frequency mode in those who were best at doing the tests – that is, were faster at doing mental subtractions than the Group average. In Group II, the high-frequency beta-wave values were indicative of an increased wave index in the fronto-temporal and occipital deflections in most of the subjects. Beta-waves, as well as alpha-waves, commonly predominated in the frontal deflections of the right hemisphere, and in the temporal and/or occipital deflectionsof the left one.

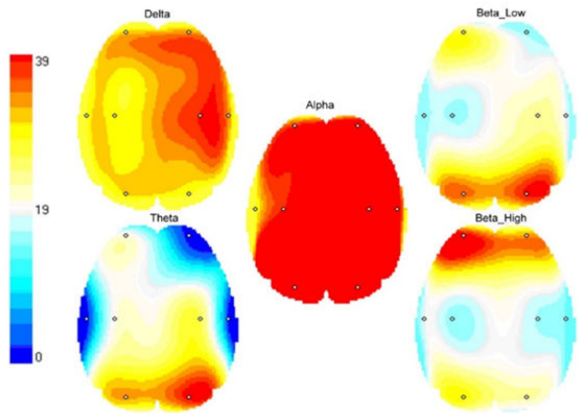
In is worth noting that the subjects having beta-wave dominant in their frontal areas of both of the brain hemispheres have proved the most efficient at doing cognitive tests. Most of Group II subjects (the PPRS Group) were 10 to 15% more efficient at doing the task than Group I subjects, with only one of them losing count, while four of Group I subjects produced wrong results.

These successful subjects have formed a hyper-neural network (Fig 4), which is characteristic of the subjects, namely, those who practice psychophysical exercises for concentration and relaxation with visualization of an educational nature.

Alpha-wave synchronization followed by its generalization (see Fig. 3 below) with its spectral power increased predominantly in deflections F1, F2, C3, C4, T4, O1, and O2 can be observed in all of the subjects as they are doing relaxation exercise that involve concentration on the backbone and the pineal gland.

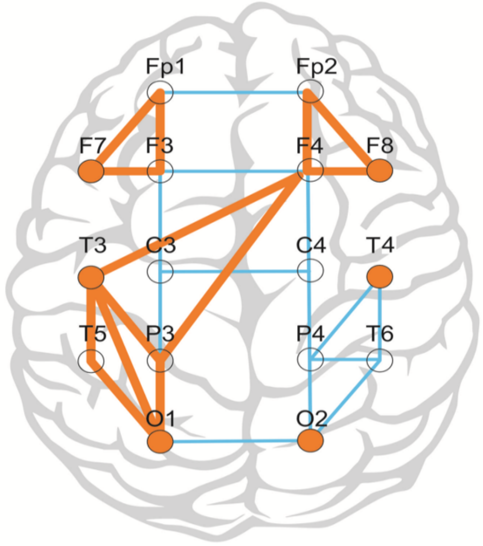
Analysis results mapping (Amplitude, µV).(T. Sh-ev, age 19, the PPRS Group)

Figure 3: Alpha-wave generalization during a PPRS.



A relaxation exercise session lasted for 10 to 12 minutes, with an increase in the spectral power of the medium-frequency alpha-wave detectible by EEG (9 to 10.5 Hz) in the tempo-occipital deflections of the right hemisphere in the first 2 or 3 minutes, and in the left-hemispheric fronto-temporal and right-hemispheric fronto-central deflections 3 to 7 minutes into a session. An increase in the slow-frequency alpha-wave (7 to 9 Hz), often accompanied by alpha-wave generalization, could be detected while at the final stage – 6 to 8 minutes into a session.

Figure 4: Ahyper-neuralnetwork for solving creative cognitive



Thus, our research indicate that alpha-wave synchronization can be observed by EEG when the subjects are either doing cognitive tests or relaxation sessions. The very nature of synchronization in the subjects who practice relaxation sessions differs from that of those who practice no relaxation; besides it also depends on the very essence of relaxation exercises being done.

DISCUSSION

Neurophysiology and neuropathology place a strong emphasis on the nature of alpha-wave activity, depending on various human body states. There exist inconclusive concepts of the very nature of alpha-waves and their functional essence. Some of the parameters of bioelectrical activity of the brain, which are found in the subjects practicing regular relaxation sessions, and which are related to alpha-wave synchronization, can be attributed to the relaxation technique using specific breathing patterns.

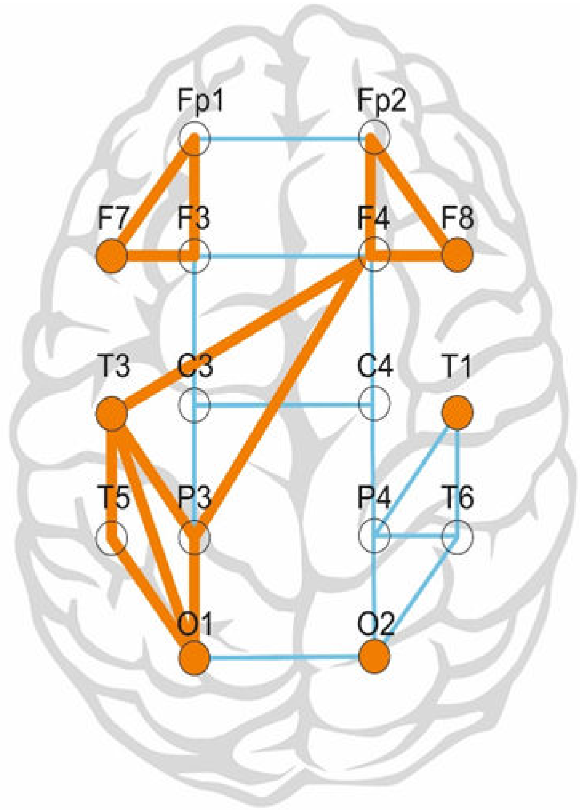
Our data of the essence of alpha-wave spindles in those practicing relaxation also corroborate an assertion (Soroko, S. I. et al., 1995) that the wave in question plays a major role in safeguarding a high level of plasticity of neurodynamic processes. When there is a malfunction in any of the mechanisms underlying control of sensory motor integration, alpha-wave spindle patterns on EEGs also become altered (Giesbrecht, T. et al., 2006; Middleton et al., 2004; Kaplan et al., 2005).

Alpha-wave analysis is used in estimation of the efficiency of psychomotor functioning by means of biofeedback (Bazanova, O.M. et al., 2013; Koryukalov Yu. I., 2014; Bazanova, O.M. et al., 2008).

Our research suggests that the very nature of alpha-wave synchronization in the subjects who regularly practice relaxation sessions (PPRS) differs from that found in those who practice no relaxation when both Groups are doing relaxation exercise or cognitive tests. It is noteworthy that the best cognitive activity efficiency was found in the PPRS Group subjects, a fact that we attribute to an enhanced ability of concentration in Group II subjects, with low-frequency alpha-wave observable in the PPRS subjects as a second alpha-wave activity peak. The researchers (Machinskaya,R.I., 2003; Schuher, F., 1995) also prove that it takes low-frequency alpha-waves within a range between 6.5 to 8 Hz to perform simple arithmetical operations.

The subjects who had the activity focuses in their fronto-central areas of both of the hemispheres and the temporo-parietal areas of the left hemispheres were the most efficient in doing the tests, see Fig. 4 below.

Figure 4: Pronounced coherent connections between alpha- and beta-waves of the right frontal areas and the temporo-occipital areas of the left hemisphere in the subjects who succeeded in completion of cognitive tests.



Thin line – coherence between 0.6 and 0.75; thick line – coherence > 0.75

Activation in the fronto-central and temporal areas of the brain cortex in subjects doing mental subtraction tests was observed by many researchers (Burbaud, P., 2000; Dehaene, S., 1999). Memory function also participates in cognitive activities, which involves, according to the data provided by (Haxby, J.V. et al., 2000; Bunge, S.A. et al., 2001), alongside frontal areas, the actuation of other cortical structures – e.g., parietal ones.

Our data concerning activity of various cortical areas when being engaged in cognitive activities (Koryukalov, Y.I., 2013) also indicate that alongside the frontal areas, the temporo-parietal areas of the hemisphere that dominates in information formation play a key role in retention of the information in question in short-term memory.

It is self-evident that cognitive activities and other mental functions are safeguarded by complex dynamical systems of neural ensembles. Based on the above facts, it is fair to assert that the very organization of those systems is founded on alpha-wave synchronization processes, which is why more profound research into synchronization may provide understanding of the mechanisms that underlie cognitive functions and contribute to the development of techniques for their correction.

We sought to find out how regular relaxation sessions impacted the nature of alpha-wave synchronization in subjects engaged in doing cognitive activities. We have discovered that relaxation sessions enhance the spectral power of alpha-wave both while at rest and when doing cognitive tests. Alpha-wave synchronization covers more extensive cortical areas, including frontal and central areas of both hemispheres in subjects that are being engaged in cognitive activities. The efficiency of cognitive activities is higher in those who practiced relaxation sessions than in those who do not.

We have identified the criteria for alpha-wave synchronization observed in the subjects that are being most efficient in solving cognitive tasks, namely Their EEG patterns have long spindles with short spans in between;two alpha-wave peaks are visible on their EEGs, the peak frequencies lying within the ranges between 11.4 ± 0.5 Hz and 8 ± 0.6 Hz respectively.

CONCLUSION

Beneficial effect of relaxation sessions on the psychophysical body state has been proved by many researchers (Garwin, A. W., 2001; Scheufele, P. M., 2000). Our add facts as to the impact of relaxation on the cognitive functions at the level of bioelectrical activity of neurons to the research in question. The synchronization that we have observed may improve the plasticity of neurons, contribute to the formation and activation of neural networks that unite a number of key areas to synchronous function, and ultimately enhance cognitive efficiency.

We believe that the criteria for synchronization, which we have identified, may be of both diagnostic and prognostic value in estimation of cognitive function. However, further comprehensive research is required, including that conducted on subjects as they are being engaged in various cognitive activities.

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