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Research Article

Phase-Frequency Channel of Alpha-Rhythm - New EEG Research Method

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Abstract

In the context of the search for a new paradigm of psychiatry, a new EEG method is proposed for determining the parameters of the phase-frequency channel of alpha rhythm. It is assumed that this characteristic of alpha rhythm is a marker of regulatory processes in the encoding of afferent information by the brain.

Key words: phase-frequency channel of alpha-rhythm; search for a new paradigm of psychiatry; diagnosis of mental illness

Abbreviations:

DAFCAR -dispersion of amplitude-frequency characteristics of alpha-rhythm; PFCAR - phase-frequency channel of alpha-rhythm NGNB - brain neural-glial network

Introduction

The information revolution currently taking place in the world was putting forward new challenges related to rethinking the mechanisms for the emergence of the Mind, objective methods for recording its manifestations and the closely related problem of mental illness among the population. The burden on the psyche of people with the introduction of new information technologies and attempts to influence the psyche in order to strengthen the ability to perceive information forces scientists in this area to look for new objective methods of research. With regard to psychiatry, it can be said that it should change its paradigm. The need for this is demonstrated in many scientific publications covering the state of modern psychological sciences [11, 13].

Unfortunately, the successes of modern science in this area are very modest - so far it has not been possible to link pathopsychological effects with organic disorders in the head office. The main reason for this is the simple fact that until now there were no objective methods of studies of the neural-glial network of the brain (NGNB), the data of which would correlate with the clinic of mental diseases [1].

Therefore, until now, psychiatry and psychology remain categorical sciences, despite attempts to present testing methods and the creation of expert assessment scales as methods of a dimensional approach to the diagnosis of mental diseases.

The more interesting is the appearance of each new method in neurophysiology, correlated with the manifestations of the human psyche. In a number of articles, the authors promoted a new research method - dispersion of amplitude-frequency characteristics of alpha rhythm - DAFCAR [1-3]. This technique made it possible to identify markers of the mechanism of encoding afferent information, its integrity and functional ability, linking these phenomena with various disorders of the psyche - psychopathology [5, 10], deviant behavior [6, 7], crime [8, 9]. However, this study completely did not cover the mechanisms of regulation of coding processes in NGNB. To some extent, this was said in terms of the dependence of cognitive processes on the frequency of alpha rhythm: activation of stress mechanisms and the release of neuro-humoral predictors of stress accelerates alpha rhythm. At the same time, another parameter of the oscillatory process remains completely unexplored - phase indicators. A large number of studies are devoted to this issue within the framework of determining the coherence of fluctuations between individual sections of the brain, but the polypositivity of the presented data and their variability, as well as the difficulties of imaging, allow many authors to argue that there is no

correlation between the coherence of fluctuations and psychopathology [12].

Purpose of the study - is to use new imaging methods and limiting the search for coherent-style alpha rhythm fluctuations in different leads relative to the occipital retraction of EEG (O1,O2) to identify the correlation of coherence with psychopathology.

Materials and methods

A standard technique for performing EEG was carried out with the arrangement of electrodes according to the international 10-20% system and ipsilateral ear electrodes on the «Telepat-106» electro-encephalograph. Spectrum parameters: according to the Fourier method, Hannah's window, with an epochs of 4 seconds, overlapping epochs of 50%. The hyperventilation test was carried out according to a standard method with a dispersion assessment of alpha-rhythm changes according to the method of Rosman SV (2017). PFCAR parameters were calculated using the Rosman SV method (2020) using Microsoft Excel and Statistica 10.0. To do this, after performing the EEG, a table of the distribution of the phase difference between frontal (O1; F3) and occipital (O2;F4) leads by leads and frequencies from 0 to 35 Hz.

For studies, young and middle-aged patients were selected to exclude the influence of age changes, with the minimum possibility of comorbidity and minimization of the alcohol and drug factor and a commission of psychiatrists recognized as mentally healthy - men - 146. (24.8 ± 1.2 years), women - 63 (34.5 ± 1.0 years).

The obtained data were compiled into a summary table, according to which the average and median values of the phase-frequency shift in leads relative to the occipital leads (O1, O2) were calculated. According to these data, a three-dimensional graph of the distribution of phase shift by frequencies and leads was built in the obtained table.

Results

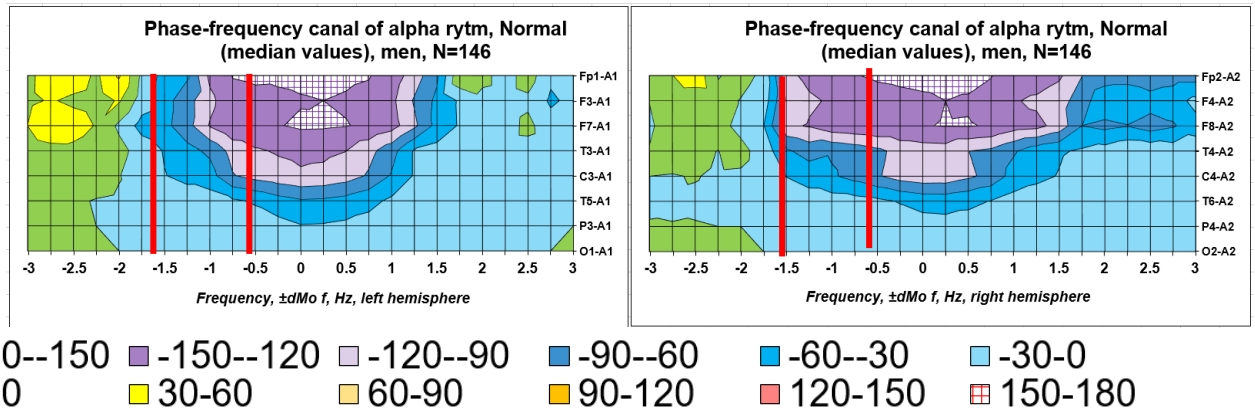

Figure 1 *Average cartogram of phase-frequency shifts of alpha-rhythm normal, men. Here on the left is the left hemisphere, on the right is the right hemisphere; along horizontal axis - difference of displacement relative to modal frequency (alpha-rhythm frequency at which its amplitude is maximum), Hz; along vertical axis - EEG retractions. Below is the scale of phase shift range from -180 deg. up to + 180 deg. The phase-frequency channel is conditionally limited by red lines.*

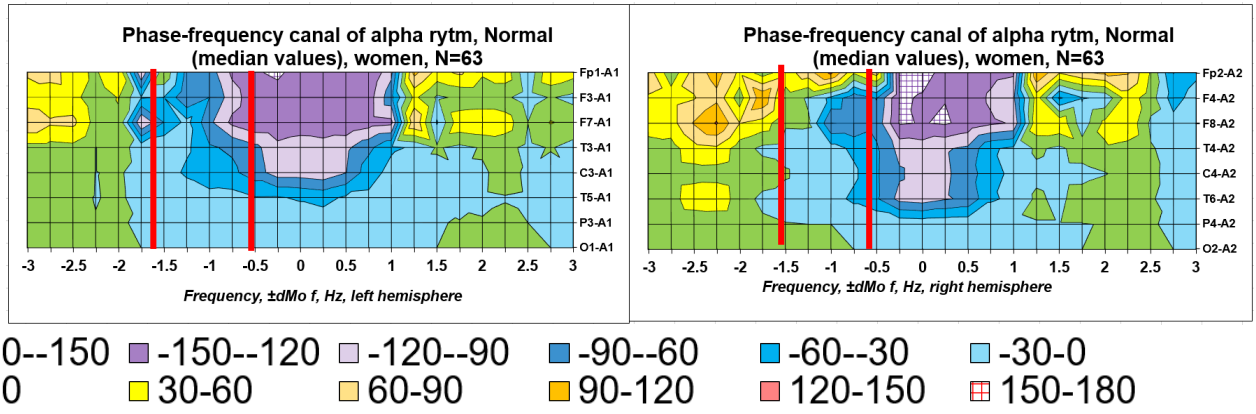

Figure 2 *Average cartogram of phase-frequency shifts of alpha-rhythm normal, women.*

Gender	Hemisphere	Индексы	Mean	Confidence -95%	Confidence +95%	Median	Standard deviation	Coefficient of Variation
men	Left	dΦ,град, Mo f -0.5	-92	-111	-73	-145	115	-125
		dΦ,град, Mo f -0.25	-116	-131	-101	-147	91	-78
		dΦ,град, Mo f	-138	-146	-130	-148	50	-36
		dΦ,град, Mo f +0.25	-141	-147	-135	-150	37	-26
		dΦ,град, Mo f +0.50	-137	-144	-129	-148	47	-34
	Right	dΦ,град, Mo f -0.5	-107	-123	-91	-143	96	-90

Gender	Hemisphere	Индексы	Mean	Confidence -95%	Confidence +95%	Median	Standard deviation	Coefficient of Variation
		dФ,град, Mo f -0.25	-123	-136	-110	-145	78	-64
		dФ,град, Mo f	-139	-146	-132	-147	43	-31
		dФ,град, Mo f +0.25	-143	-147	-139	-150	26	-18
		dФ,град, Mo f +0.50	-134	-143	-126	-148	54	-40
Women	Left	dФ,град, Mo f -0.5	-41	-80	-2	-141	154	-378
		dФ,град, Mo f -0.25	-37	-77	2	-138	156	-421
		dФ,град, Mo f	-44	-82	-5	-140	152	-348
		dФ,град, Mo f +0.25	-30	-69	8	-125	153	-506
		dФ,град, Mo f +0.50	-41	-78	-4	-136	148	-360
	Right	dФ,град, Mo f -0.5	-2	-42	37	-39	157	-6907
		dФ,град, Mo f -0.25	-51	-88	-13	-151	150	-298
		dФ,град, Mo f	-51	-88	-13	-150	149	-292
		dФ,град, Mo f +0.25	-56	-93	-19	-147	147	-264
		dФ,град, Mo f +0.50	-49	-86	-12	-138	147	-297

Table 1. *Statistical parameters of phase-frequency channel of alpha-rhythm.*

Индексы	Полушарие	Mean м	Mean ж	t-value	df	p
dPh,degr, Mo f -0.5	левое	-92	-41	-2.67	207	0.008218
dPh,degr, Mo f -0.25		-116	-37	-4.56	207	0.000009
dPh,degr, Mo f		-138	-44	-6.71	207	0.000000
dPh,degr, Mo f +0.25		-141	-30	-8.23	207	0.000000
dPh,degr, Mo f +0.50		-137	-41	-7.04	207	0.000000
dPh,degr, Mo f -0.5	правое	-107	-2	-5.90	207	0.000000
dPh,degr, Mo f -0.25		-123	-51	-4.56	207	0.000009
dPh,degr, Mo f		-139	-51	-6.53	207	0.000000
dPh,degr, Mo f +0.25		-143	-56	-6.93	207	0.000000
dPh,degr, Mo f +0.50		-134	-49	-6.11	207	0.000000

Table 2. *Table of gender differences in the parameters of the phase-frequency channel of the alpha rhythm according to Student's criterion.*

Note. 1. dPh,degr. - Displacement of alpha-rhythm oscillation phase in frontal retraction relative to occipital, in degrees at different values of modal frequency.

2. Statistically significant differences between the data are highlighted in red.

Variable	Gender	Mean Left hemisphere	Mean right hemisphere	t-value	df	p
dPh,degr, Mo f -0.5	men	0	0	0.64	290	0.520
dPh,degr, Mo f -0.25		-92	-107	1.18	290	0.237
dPh,degr, Mo f		-116	-123	0.72	290	0.469
dPh,degr, Mo f +0.25		-138	-139	0.16	290	0.874
dPh,degr, Mo f +0.50		-141	-143	0.62	290	0.537
dPh,degr, Mo f -0.5	women	-137	-134	-0.39	290	0.700
dPh,degr, Mo f -0.25		0	0	-0.12	124	0.907
dPh,degr, Mo f		-41	-2	-1.39	124	0.167
dPh,degr, Mo f +0.25		-37	-51	0.49	124	0.625
dPh,degr, Mo f +0.50		-44	-51	0.27	124	0.786

Table 3. *Table of inter-hemisphere differences of alpha-rhythm phase-frequency channel parameters according to Student's criterion.*

Discussion

The first thing that is striking when considering a cartogram is that it has an ordered character.

1. In the distribution zone of the modal frequency value (Mo f ± 0.5 Hz), a negative value of the deviation of the alpha-rhythm oscillation phase is observed. This range is considered as PFCAR.
2. There is a gradient of increasing the value of phase shift from frontal to occipital leads (the value approaches zero)
3. Within the limits (Mo f ± 0.25 Hz), that is, true oscillations of the modal frequency, there are maximum phase shift values that decrease towards the channel boundaries.
4. There are no significant differences between hemispheres in the values of phase shifts in either men or women (Table 3).
5. There are statistically significant differences between men and women. Here it should be noted that the reasons for these differences are reliably unknown (Table 2).
6. Outside the phase-frequency channel, phase shift oscillations are close to zero or are erratic.

The explanation of the presence of a phase-frequency shift between the frontal and occipital sections may lie in the plane of considering it as a regulator in the process of encoding afferent information. There are no statistically reliable studies on various nosological forms of mental illness, but the following observations are available.

The phase-frequency channel is inverted (takes positive values) in cases of affective disorders in the patient, when he is in an alarming voltage state.

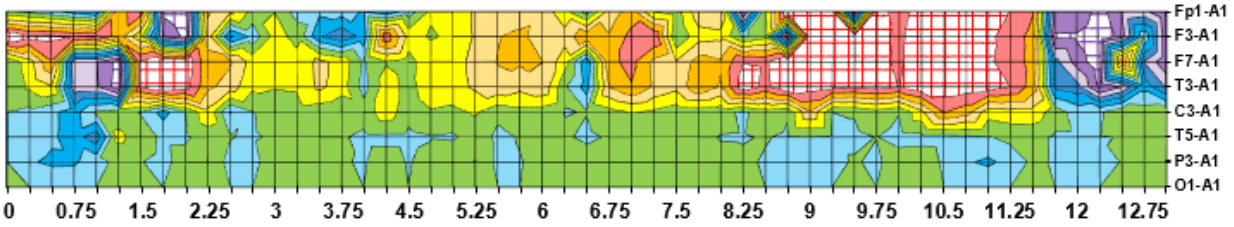

Figure 3. *Phase-frequency channel in the patient without psychopathology, but with pronounced affective experiences. Phase shift in frontal leads relative to occipital leads is in modal value + 170 deg.*

Normally, the phase frequency channel is always present at the location of the modal value of the alpha rhythm. However, in cases where the functional capacity of the brain is sharply reduced, no pronounced PFCAR is determined. This is observed after severe injuries and hemorrhages to the brain, as a result of prolonged toxic effects.

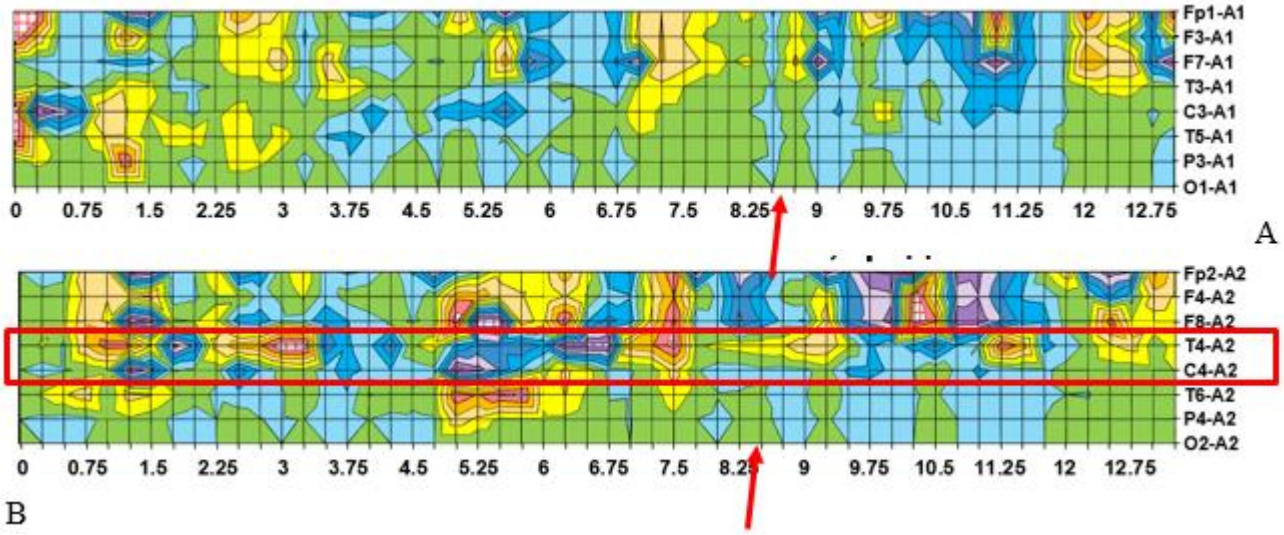

Figure 4 *Phase-frequency channels in a patient with multiple episodes of alcoholic delirium. A- left hemisphere, B - right hemisphere. Mo f = 8.5 Hz (red arrow). A reliably expressed PFCAR is not detected. Attention is drawn to the region stretched along the entire frequency range in the zone of temporal diversions of the right hemisphere in the form of elongated inverted phase shift zones - a frequent feature in degenerative processes.*

Perhaps the PFCAR technique will find use in the diagnosis of such a dangerous disease as schizophrenia. We give an example: a man, 28 years old, a university graduate, a mathematician. After graduation, he did not work, a psychotic state developed with a persecution mania. Diagnosis: "Schizophrenia, paranoid form." On the dispersion cartogram (Figure 5), the main features characteristic of schizophrenia are: the normal modal value of the alpha rhythm frequency 10 Hz (Figure 5, 1), the sharp deceleration of the alpha rhythm in the frontal lobes (Figure 5, 2), the presence of coarse splitting of the alpha rhythm spectrum with transition to the theta range and the appearance of the second modal zone in the range of 5.5-6.5 Hz (Figure 5, 3)

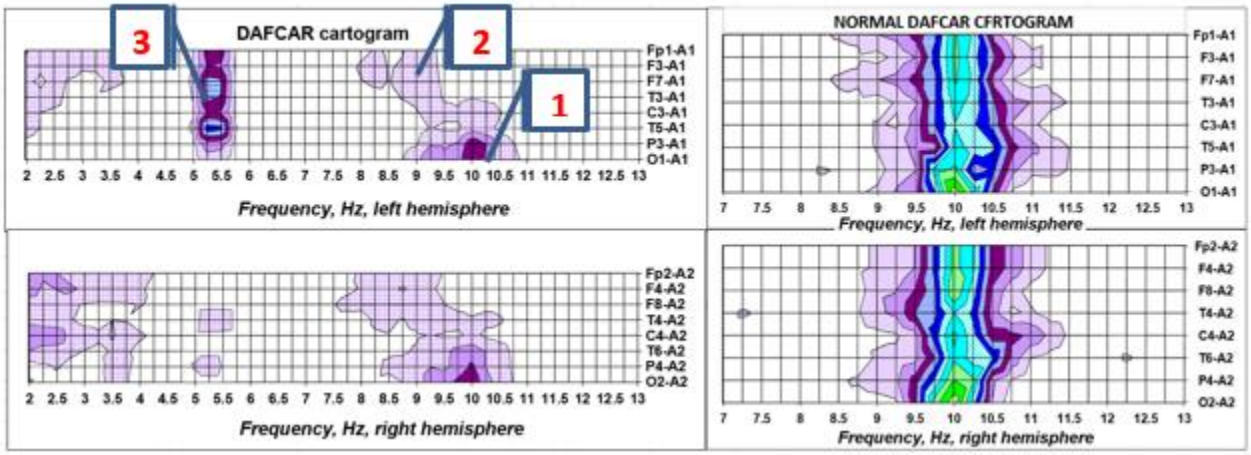

Figure 5. *Dispersion cartogram in schizophrenia.*

At the same time, on the PFCAR cartogram in the modal zone of alpha rhythm (Mo f ± 0.5 Hz = 9.5-10.5 Hz), channel "splitting" is observed: on the left, phase shift to the region of negative values, on the left, inversion, shift towards positive values (Fig. 6). In addition, rudimentary PFCAR (indicated by arrow) is observed in the 6 Hz region.

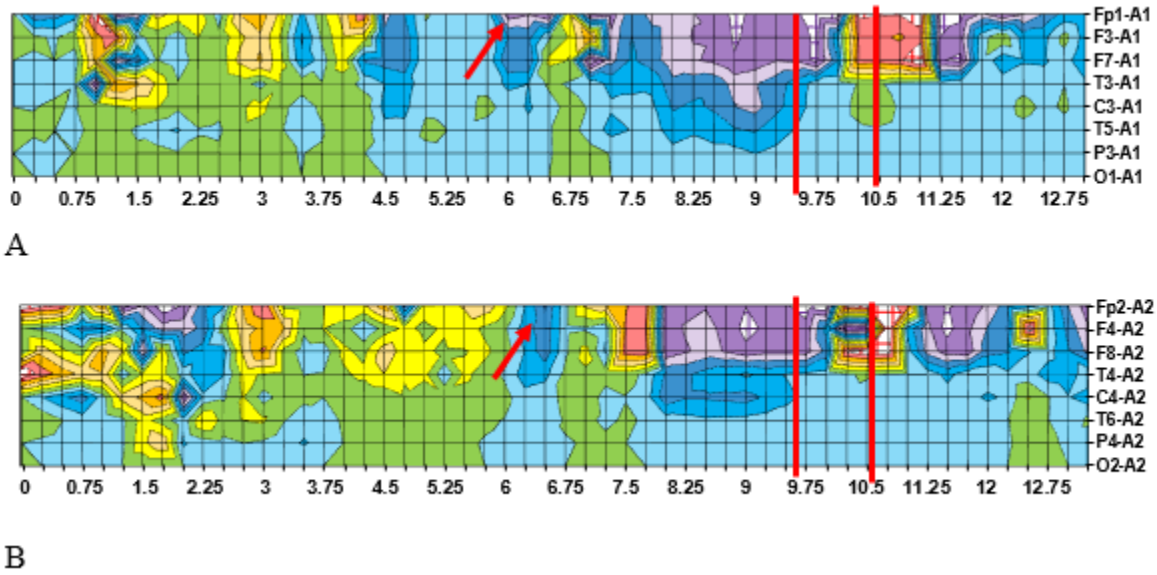

Figure 6. *Phase frequency channel splitting in schizophrenia. A- left hemisphere, B - right hemisphere.*

The study of neurophysiological parameters of brain activity, such as DACAR and PFCAR, allows us to bring psychiatry to the frontiers of a new paradigm, in which they understand the mechanisms for the formation of the human psyche and the treatment of patients is carried out not only according to abstract and vague psychiatric syndromes, but taking into account the nature of neurophysiological disorders.

Conclusion

1. A new way to visualize phase-frequency changes in the alpha rhythm of EEG is a fairly simple, fast and non-invasive way to study the regulatory mechanisms involved in the formation of the human psyche

2. Normally there is a shift of phase values in frontal leads relative to the occipital to negative values

3. Activation of the stress mechanism leads to an inversion of PFCAR and a shift in the phase shift of alpha oscillations to the positive side.

4. A sharp decrease in the functional capacity of the brain due to toxic, traumatic and vascular disorders leads to the disappearance of PFCAR.

5. Possibly PFCAR cleavage is one of the markers of schizophrenia

6. DAFCAR and PFCAR are objective methods for identifying markers of functional capacity of mechanisms involved in the formation of mental processes in the brain.

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