Psychophysiology

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Frequency specificity of gamma-rhythm oscillators

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In this article, there is analysis of gamma-rhythm's issue, which provides foundation for appearance and wide expansion of the binding conception of different networks into united system via mechanism of gamma-rhythm synchronization. Author research own issue of activity's synchronization with narrow band gamma oscillators, adjusted to a certain frequency under conditions which stimulate gamma-rhythm increase. New research technology of gamma-rhythm which gets more precise data about brain localization of gamma-rhythm dipoles because of their projection to individual brain homographic section.

Key words: *gamma-rhythm, synchronization, gamma oscillators, communicative function of gamma-rhythm, intercalated neurons.*

Gamma-rhythm is high frequency activity of human brain, registered by Electroencephalogram, attracts researchers' attention more and more. This interest is caused by the fact that different types of cognitive processes are accompanied by activity intensification in the range of gamma-rhythm, which is from 30 to 200 Hz, according to some data can be even 600 Hz [30].

Connection between gamma-rhythm and reception and recognition of stimulus, illusion appearance and gestalt formation is noticed. [5,8,13,34,38]. Gamma-rhythm increase was watched not only at work with sensory, but also semantic information [24,29].

Gamma-rhythm is connected with motion reactions performance. Gamma-rhythm flashes appear in human motor and pre-motor cortex, additional motor field and parietal cortex before the motion starts, then continue during performance and appear additionally when the motion ends.

The hypothesis about relation of gamma-rhythm and motion reaction to stimulus was expressed [26,28,31].

In experiments with delay periods, during which information about previously given incentive for the following its recognition should be kept, gamma-rhythm relation to processes of information keeping in short-term memory was shown. In the research [39] the proof of the relation between gamma-rhythm activity and efficient remembering of information was given. During delay period with information about visual stimulus kept in memory the researchers showed stable increase of gamma oscillations power (24-60 Hz) in visual cortex and beta oscillations (15-20 Hz) in front cortex. With delay period increase oscillations weakened which caused parallel decrease of incentive recognition results.

Inclusion of gamma-rhythm into different sensor, cognitive and performing processes, its existence not only in human, but also in animal brain, mammals in particular, allowed E. Basar [1,2] to consider gamma-rhythm as functional building blocks used in integration of brain activity and psychic functions.

Major step on the way to gamma-rhythm participation in information processing processes was discovery of gamma oscillations phase synchronization in the range of 35-85 Hz, appearing between distant parts of cat’s visual cortex [13]. Later this fact was proved by the existence of intercolumn synchronization of cat’s visual cortex neurons spike activity in the range of gamma oscillations, appearing at visual stimuli perception (Gray et al., 1989). Spatially distant neurons possessing similar detector features, selectively adjusted to react to a certain direction and with certain speed stripe movement, in response to this stimulation there were synchronous and with no delay discharges repeated at 40 Hz frequency of gamma-rhythm.

This and following works are the foundation for appearance and wide expansion of the binding conception of different neuron networks into a united system via mechanism of gamma rhythm synchronization. At first, it was said that coherent gamma oscillations reflect visual cortex mechanism, providing different object features integration for its image recreation, gestalt formation [11,22]. Later, oscillation activity synchronization was considered as more universal and major communication mechanism between neuron networks, which provided different kinds of interaction between sensor, performing and cognitive processes, memory included (E.Basar, 1999).

It should be noted that in many research works the conclusion about gamma oscillations synchronization as major connection mechanism was made on the basis of amplitude or gamma rhythm capacity measurements, without phase relations between gamma oscillations measurements. However, it is a mistake to refer capacity change to synchronization, as capacity and phase are two independent measurements of oscillatory activity. Synchronization deals with phase relations and has nothing to do with capacity. Phase synchronization of gamma oscillations can appear without any increase in capacity. Neuron discharge synchronization in the cat's visual cortex was observed without changes in discharge frequency [16,18].

Binding should be a quick process, and it is natural to expect it to use high frequency neuron networks activity. Characteristic feature of gamma oscillations which allows to consider it as the basis for binding is not appearance or increase of gamma oscillations, but rather the fact that oscillations in different neuron populations are frequency synchronized or phase bound [3,32,41].

Evaluation of gamma oscillations phase relations between different leads by coherency calculation on multi-channel EEG or MEG is one of the most successfully developed methods of gamma oscillations and brain processes binding and control interaction investigation. Another method is application of УВП calculations with further frequency filtration in the gamma-rhythm band [19,44]. Each of the mentioned above methods calculate different types of gamma activity synchronization.

Coherence calculation method measures phase synchronization appearing between different leads of brain electric activity, i.e. spatial synchronization. However, it ignores phase relations between gamma oscillations and stimulus.

With the GPC assistance gamma rhythm characterized by the phase relation to stimulus is investigated. According to classification of Galambos, it should be differentiated from inducted gamma-rhythm. The last in phase is not synchronized with the stimulus, as it is initiated by the other inner factors which do not coincide in time with presented outer stimuli [17]. GPC method evaluating gamma oscillations phase synchronization with the stimulus does not measure gamma rhythm synchronization in space.

These method shortcomings can be overcome in gamma-rhythm research with the dipole analysis method. Dipole analysis considers the fact of spatial gamma oscillations synchronization, as at finding the equivalent dipole for oscillations information from a number of electrodes is considered. The decision about dipole source existence is made on the basis of gamma oscillations synchronized appearance on a number of electrodes. Combination of dipole analysis with the Generated Potential Control (GPC) method allows considering special synchronization of gamma oscillations as well as their phase relation to stimulus.

Besides, dipole analysis allows defining localization of their point sources in three-dimensional brain volume for any form of brain activity gamma oscillations included. Localization algorithm is based on the hypothesis that there are point sources of electrical activity in the brain locally distributed among its structures. Electrical activity in every moment of time registered by many electrodes from the scalp is considered as a result of spatial summation of electrical field of these sources, passively distributed in the brain as some kind of conductor. The solution of the reverse problem lets find with some kind of trustworthy approximation spatial location of equivalent dipole sources for chosen form of brain electric activity.

Under high frequency of EEG readings dipole analysis exposes temporary dynamics of gamma oscillations in GPC with high time dissipation. All the above allows considering GPC method and dipole method combination as one of the most prospective trends for gamma oscillations functions in the integrated brain activity research [5-8].

With great interest of the researchers to gamma rhythm that can be reflected in annual increase of the number of publications devoted to its investigation, many questions are still to be answered. Neither mechanism of gamma oscillations generation nor ways with the help of which synchronized gamma rhythm is included in different brain operations is clear. The very fact of gamma oscillations appearance in different frequency requires explanation. There are few works focused on oscillation frequency connection to brain structures and functions.

Only in a number of works connection of brain structures to certain frequency gamma rhythm range is mentioned. In locust olfactory system oscillations sensitive to the smell appear within the range of 20-34 Hz [23,37,42]. With humans similar frequency smell selectivity is found in the range of 33-44 Hz, registered from olfactory bulb, which is clearly correlated with subjective smell perception [20].

In visual system of vertebrates oscillatory responses appear consequently in retina and visual cortex. Their comparison shows that for their generation in each structure different frequency ranges are used. Simple and complex neuron-detectors of 17 and 18 fields with cats and monkeys oscillations in the range of 20-80 Hz with the peak at 40 Hz appear as a response to exposition of optimally oriented light stripe. Higher frequencies of 50-100 Hz are recorded with the same animals from the primary visual cortex as a response to more complicated stimuli: moving stripes and grids [4,12,15]. With monkeys these oscillations are recorded in multi-cell spikes and in the focal potentials of striatic (V1) and extra-striatic (V2) cortex with the phase difference close to 0 (Frien et al., 1994).

Ganglia cells of retina and LCT neurons, also grids react to flashing or moving stripes with the oscillations appearance with frequency 60-120 Hz, higher than in the cortex [27].

Gamma rhythm frequency selectivity, its different frequency ranges connection to stages of motion skill formation is demonstrated in the works of Dumenko V.N. and the others [9,10]. Based on the research of high frequency electrocorticogramm components (30-200 Hz) in the process of instrumentsl skill formation with the dogs, they concluded that gamma rhythm is heterogeneous. Dividing frequency ranges into stripes 15 Hz wide, the authors wrote that the energy of separate bands changed independently. With the dogs successfully developing this skill, as a response to conventional sign gamma rhythm capacity increased within the range of 80-200 Hz with parallel decrease of activity at frequencies of 30-80 Hz. This connection of gamma rhythm frequency with function was absent with the animals with poorly developed skill.

Considered above publications do not give the answer to the question of how far frequency dependence of gamma oscillations will reach. To highlight this problem we researched activity synchronization with narrow band gamma oscillators, adjusted to a certain frequency under conditions which stimulate gamma rhythm increase. New research technology of gamma rhythm – GPC method connected with dipole analysis and anatomical magneto-resonance brain tomography – was used. The later allows getting more precise data about brain localization of gamma rhythm dipoles because of their projection to individual brain homographic section.

Gamma rhythm was researched in three experimental situations. In one of them the subject passively listened to sound clicks (indifferent series) and fulfilled sensor-motor reaction to switching off the sound (motor series). In other type of experiment the subject had to quickly multiply numbers, heard through ear-phones, pronounced by a woman’s voice. In the third experimental situation there were visual stimuli on the monitor, among which the subject had to recognize target stimuli (bright light square spot) and respond with the motion reaction.

In series with passive listening to sound clicks and motor reaction to switching them off 120 stimuli were presented, 130msec long, at the interval of 1.5 sec. In these experiments 5 subjects participated (3 women and 2 men) at the age of 18 -24. Experiments with numbers multiplication were carried out with 12 subjects (women at the age of 24-27). 100 pairs of two-digit numbers were read through the headphones with a female voice, average sound stimulus length was 2.3 sec. The interval between stimuli was 8 sec. In the series with visual stimuli the subject had to press the button after a target stimulus – the white square appearing in the right or left visual field. Differentiating stimulus was a gray square appearing simultaneously on the right and left. Stimuli length was 1 sec. Experiment was carried out with 10 subjects at the age of 18 – 23.

In all these experiments gamma rhythm was researched as a part of average sound and light GPC, id est. induced gamma rhythm which was phase synchronized with stimulus. For gamma rhythm extraction from GPC method of frequency filtration was used.

EEG registration was done with the help of computer system "Brainsys", produced by the company “Statokin” (Russia). 15-channel recording of EEG was done according to international system 10-20% with taking away at, O1, O2, P4, P3, C4, C3, CZ, T6, T5, T4, T3, F4, F3, F8, F7. As a referring ear electrode was used. EEG frequency was

400 Hz. Signal bandwidth was 0.3-8- Hz. Turnoff filter was used to cut out fluctuations of 50 Hz, connected to grid induction.

Narrow band gamma oscillations behavior with the frequency tuning of 1 Hz was researched. To do this GPC, received for each series were passed through narrow band filtration of 1 Hz width in two frequency bands of 30-45 and 55-57 Hz.

To determine three-dimensional localization of gamma oscillations in the brain dipole analysis method was connected with anatomical magnet-resonance tomography. Equivalent dipole current coordinate calculation for gamma oscillator is carried out under Brainloc program (model of one movable dipole). Under numeralization EEG frequency of 400 Hz, dipole source existence was done every 2.5 msec. Calculated according to 15-channel EEG coordinates of gamma oscillations sources were projected to images of axial tomography brain sections of certain subjects, received with the magnet-resonance tomography TOMIKON S50 (BRUKER) at Moscow State University.

For structural magnet-resonance subjects’ brain sections receiving the method of 3D-gradient echo was used, which allowed high spatial resolution of 1 mm in the whole volume of subjects’ brain. Gradient echo application is alternative to object layer scanning in other researches. Due to 3D method it is possible to create undistorted images for thin layers of 1mm, that is impossible with layer scanning because of the artifacts caused by signal imposition from neighboring layers. As a result we can get complete 3D brain image in very short time (approx. 30 min.).

The level of summary gamma oscillator activity, adjusted to a certain frequency, was judged by the number of its dipole sources, received in a certain time interval at the dipole coefficient (DC) equal to 0.95. Dipole number calculation was done according to the whole brain no matter in what structures of brain they were found.

In earlier works induced gamma rhythm was researched with the method of wide brand frequency filtration, with the band width of 15 Hz in the range of 30 to 45 Hz. In the series with sound clicks reception wide brand filtration of sound GPC, received for 120 sound stimuli, finds out the so-called sensor response with all the subjects – gamma oscillation flashes in the interval of 0-100msec after the stimulus - which occurs practically in all the EEG readings. Gamma rhythm sensor response can be seen both in indifferent and motor series [5,8]. Figure 1 presents gamma rhythm sensor response, received as a result of wide brand frequency filtration of one subject's sound GPC.

When using GPC filtration in the frequency narrow band the number of gamma oscillators dipole sources with sharp tuning in comparison with the results received under wide band filtration. Under narrowing filtration band from 15 to 1 Hz (frequency scale 30-45 Hz) all the subjects demonstrated number increase of actively working gamma oscillators both in indifferent and motor series. Figure 2 shows post-stimulus bar graphs (PSBG) as long as 1.5sec, characterizing distribution of brain localized number of narrow and wide band gamma oscillators in two series with one of the subjects. It is seen that the number of oscillators with sharp tuning is ten times more than the dipole number received under wide band filtration of average EEG. Meanwhile PSBG received by two methods shows significant similarity: activation and inactivation phases occur at the same time. Moreover, the activity phase of sharp tuning oscillators is more noticeable before the moment of stimulus application or anticipation reaction.

Research of 15 narrow band gamma oscillators behavior both as a part of a sensor response and during all GPC and even longer time for EEG of 1.5sec showed frequency selective gamma oscillators with sharp tuning activity.

Figure 3 shows GPC and the results of its wide band (in the range of 30-45 Hz) and narrow band filtration of 1 Hz within the same range. It is seen that narrow band gamma rhythm flashes have different amplitude.

Major contribution to the content of gamma rhythm sensor response is made by frequencies of 37, 38, 39 and 40 Hz. These frequencies oscillations appear before stimulus reflecting anticipation reaction that appears frequently under conditions of multiple sound repetitions with fixed inter-stimulus interval.

Frequency selective character of gamma oscillators' activity is seen not only on the primary part of GPC (0-100msec). It is present along all the averaged EEG as long as 1.5sec. Figure 4 shows typical bar graph of frequency-temporal distribution of narrow band oscillators in the structure of the averaged EEG received for series with indifferent sound clicks.

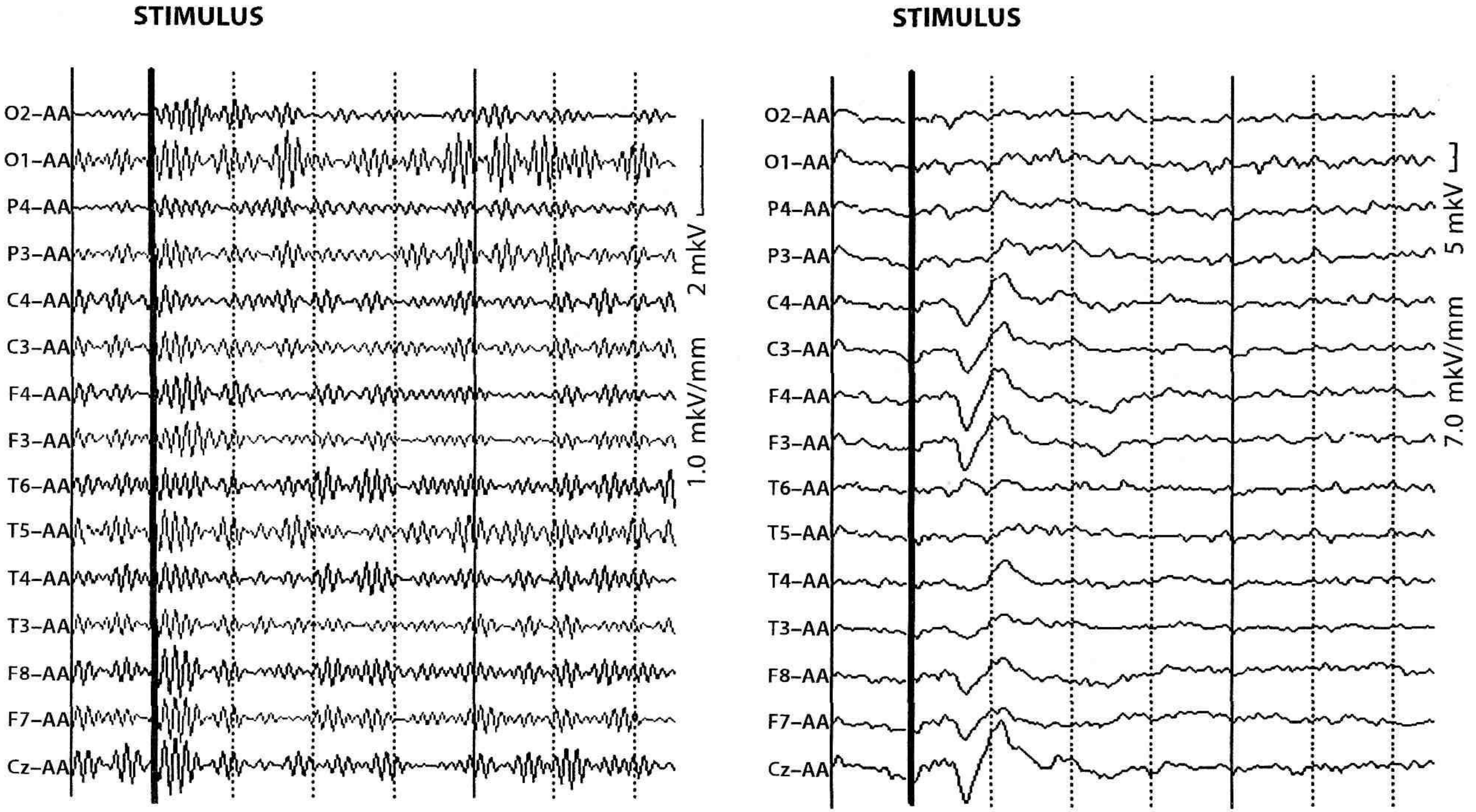

Fig. 1. Sound GPC using EEG 15 channels (left) and their wide band filtration in the gamma-frequency range from 30 to 45 Hz (right). Gamma-oscillation flashes are seen, the so-called sensor response emerging in the interval of 0–100 msec after the sound

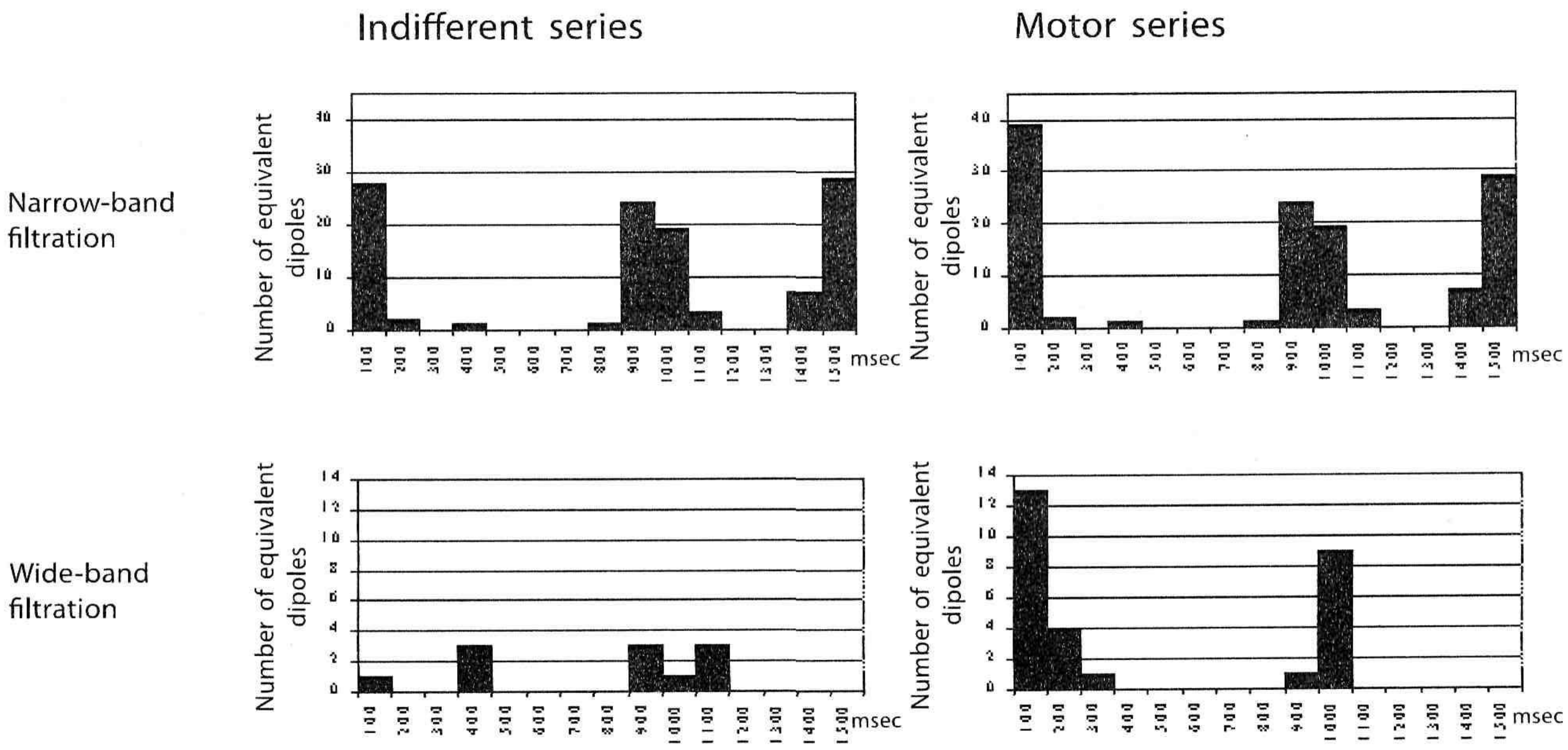

Fig. 2. Equivalent dipole gamma-oscillation sources number increase under narrowing GPC sound filtration band from 15 to 1 Hz within frequency range 30–45 Hz. Post-stimulus bar graph shows dependence of dipole sources number on time quant in structure of averaged EEG 1,5 sec long with subject M.S. The dipoles number is calculated for time quant of 100 msec.

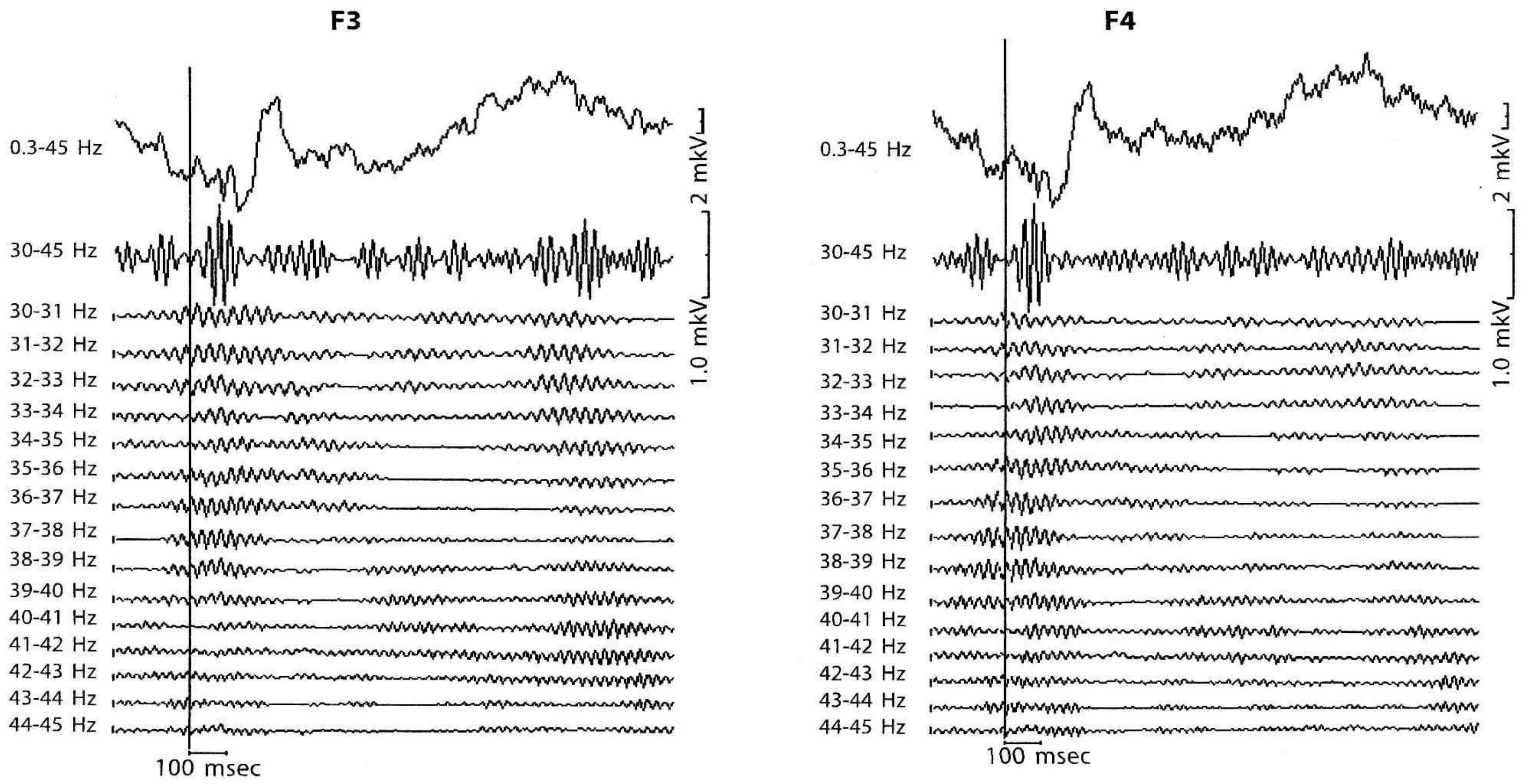

Fig. 3. GPC frontal leads left (F3) and right hemisphere leads (F4) received to 128 sound clicks presented. Below is the frequency filtration in wide band gamma-rhythm (30–45 Hz) and narrow band filtration 1 Hz wide at 15 different frequencies from 30 to 45 Hz. It is seen that gamma-rhythm flash maximum at the primary GPC section coincides with its earlier positive component. At separate frequencies gamma oscillation flashes are seen brighter. Sensor response reaction of gamma-rhythm in the right hemisphere surpasses the reaction in the left. Numbers in the left show GPC frequency filtration bands

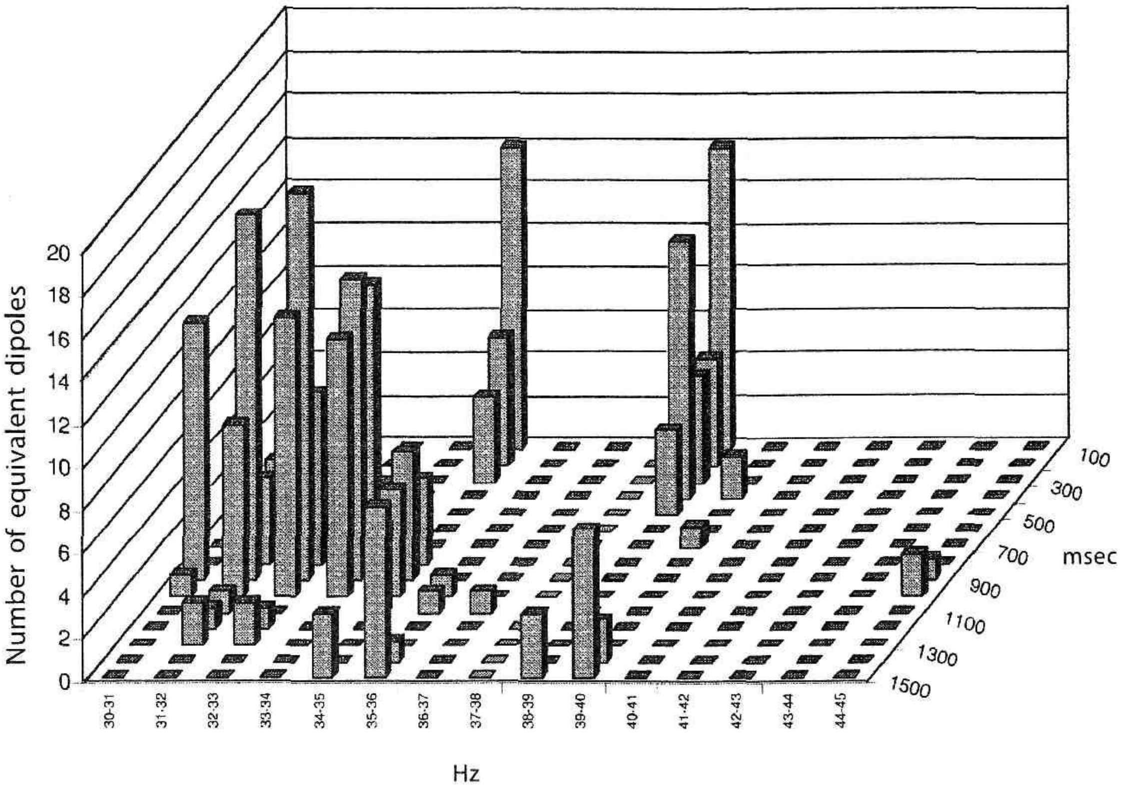

Fig. 4. Narrow band gamma-oscillator activity frequency-time distribution bar graph in the structure of averaged EEG in regard to sound click 1,5 msec long within frequency range from 30 to 45 Hz. Equivalent dipoles number is a measure of gamma-oscillator activity. It is defined for each time frame of 100 msec. Horizontal scale is narrow band oscillator frequency

Activity level of every narrow band gamma oscillator is measured by the summarized number of its dipole sources, calculated for each GPC time frame of 100msec with the dipole ratio of 0.09. Dipole calculation was done for the whole brain volume notwithstanding in which brain structures they were localized.

It is seen that on the primary section of sound GPC only two oscillators are activated working at frequencies of 38-39 and 34-35 Hz. At the same frequencies anticipation reaction is presented (in the time frame of 1400-1500msec). In the interval 800-100msec after the stimulus gamma oscillators of lower frequency are activated (from 30-31 to 33-34Hz). In every time frame only part of gamma oscillators tuned to certain frequencies work. With time frame change the structure of active gamma oscillators changes too. Thus, narrow band gamma oscillators' activity in the GPC structure depends on its frequency tuning and time frame after the stimulus. This allows considering gamma rhythm activity as frequency selective process.

Narrow band filtration method application to higher range of gamma rhythm (55-75Hz) allows detecting frequency selectivity with gamma oscillators tuned to higher frequencies. Figure 5 shows individual bar graphs of frequency-temporary distribution of narrow band gamma oscillators' activity in the structure of averaged EEG received after multiple presentations of number pairs for their multiplication via head-phones. Bar graphs are drawn for two frequency ranges: 30-45Hz (A) and 55-75 Hz (B). It is seen that earlier gamma rhythm sensor response is represented with two low frequency oscillators' activity, tuned to 34-35, 35-36 Hz, and two high frequency ones working at 58-59 and 64-65 Hz.

Activated gamma oscillators groups at other frequencies are connected to later time frames (600-100msec). Selective character of narrow band gamma oscillators' activity is revealed and in the structure of averaged EEG received to a visual stimulus (bright light square on the monitor) the reaction to which should be a punch on the computer keyboard (Fig.6). In both frequency zones sharp tuned gamma oscillators' activation has selective character and connected to certain time frames of averaged EEG.

Imposition of equivalent dipole sources of narrow band gamma oscillators calculated coordinates on brain structural magnet resonance tomograms allows revealing brain structures involved in the perception process with great accuracy.

Combination of dipole analysis with method of anatomical magnet resonance tomography shows that dipole sources of each frequency specific gamma oscillator activated within the structure of sensor response appears in one or several brain local zones. Their location on tomography sections depends on gamma oscillator frequency. Gamma oscillators with different frequencies activity is connected to different loci.

Under performance of sensor motor reaction to sound switching off dipole of active gamma oscillators are found in two local brain loci. With activated gamma oscillators working at different frequencies two zones loci on brain tomograms do not coincide.

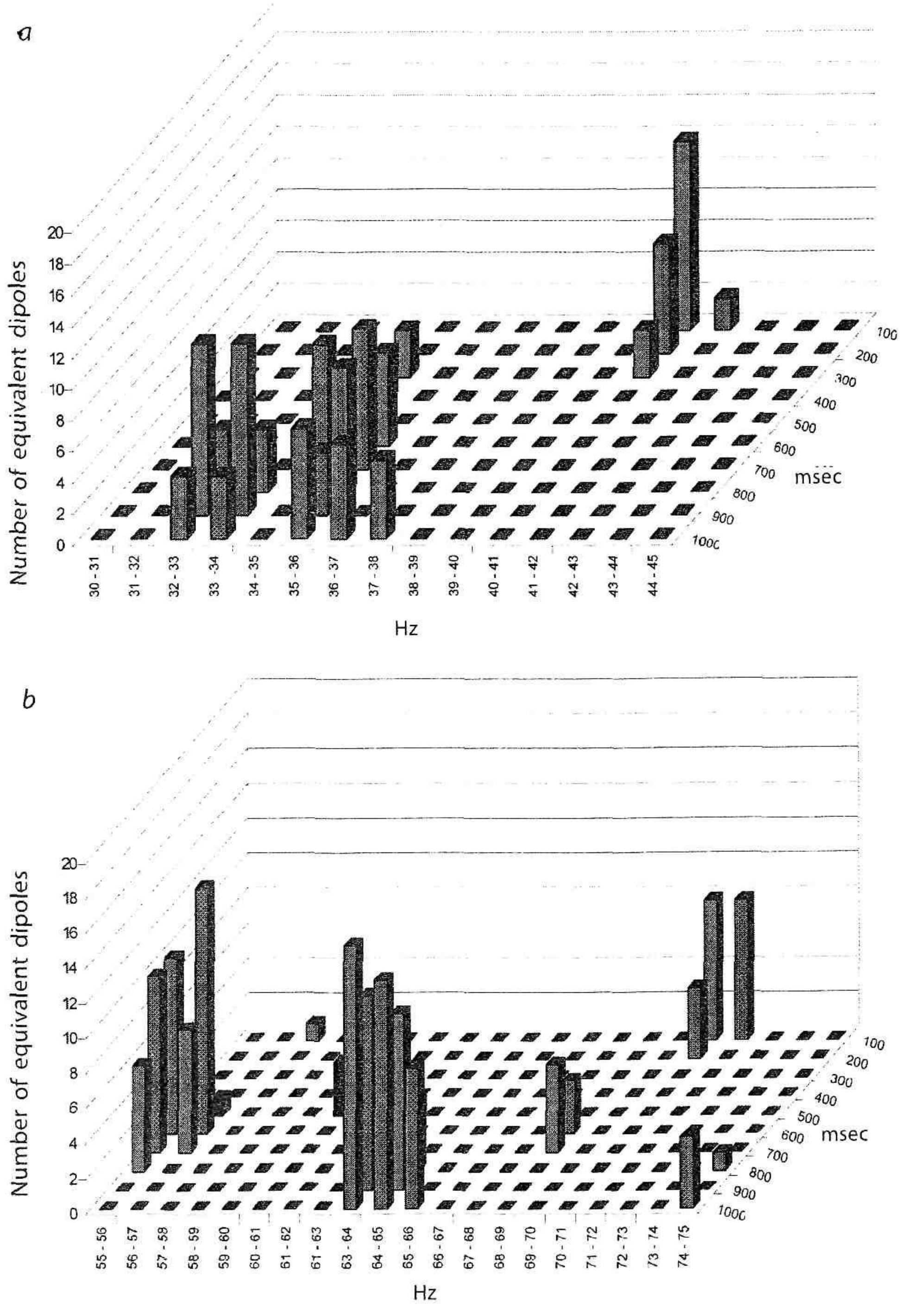

Fig. 5. Narrow band gamma-oscillator activity frequency-time distribution bar graph in the structure of averaged EEG as long as 1000 msec received to the multiple presentation via head-phones pairs of two-digit numbers for multiplication in two frequency ranges 3–45 Hz (*a*) and 55–75 Hz (*b*) (for the rest see Fig. 2)

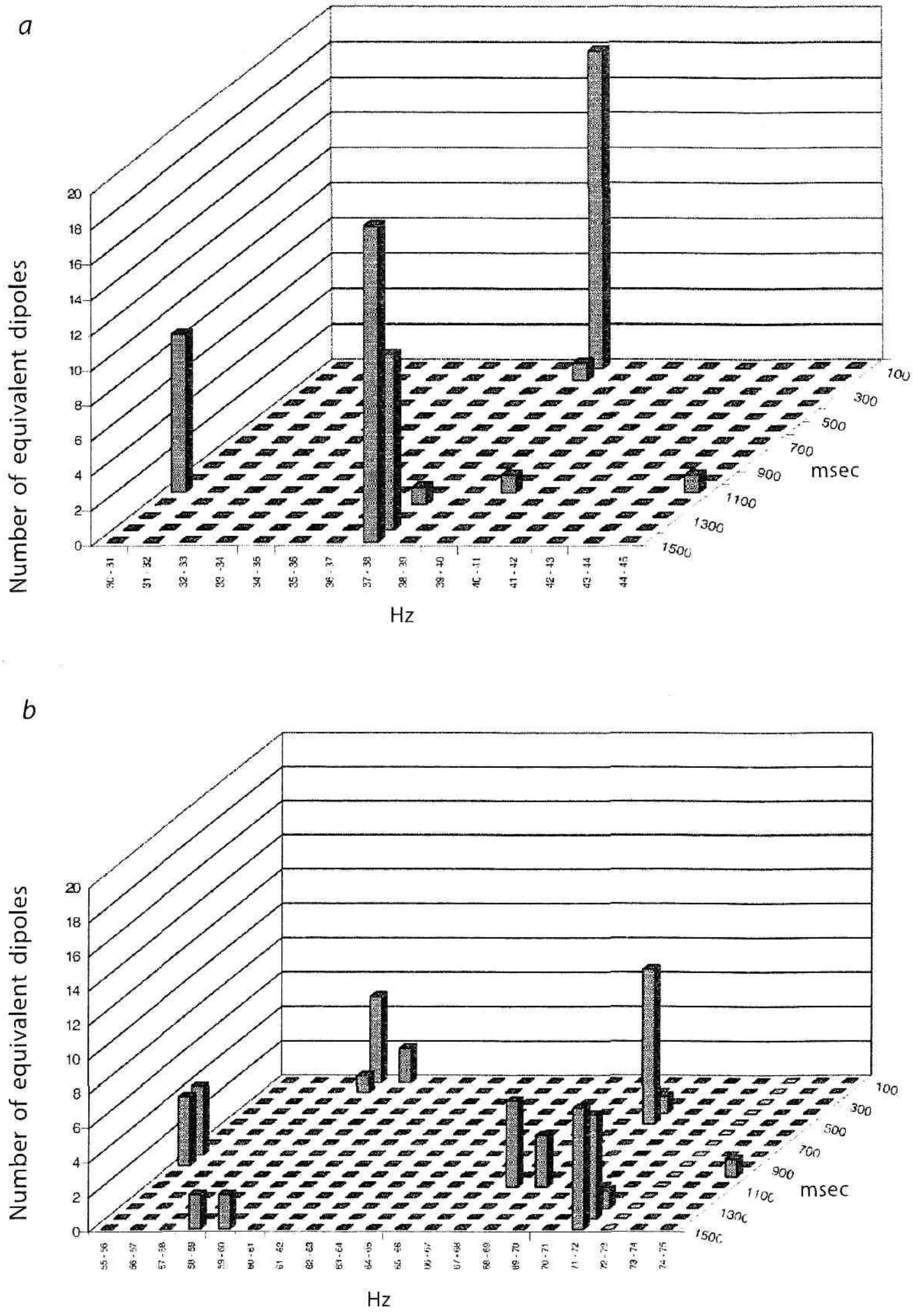

Fig. 6. Narrow band gamma-oscillator activity frequency-time distribution bar graph in the structure of averaged EEG as long as 1500 msec received to presentation of visual stimulus in two frequency ranges 30–45 Hz (*a*) and 55–75 Hz (*b*) (for the rest see Fig. 2)

Figure 7 represents dipole source localization of two gamma oscillators with frequencies of 34-35 Hz (A) and 33-34 Hz(B) on brain tomography. It is seen that positions of equivalent dipoles of two gamma oscillators are biased one toward another. Gamma oscillator sources with the frequency of 33-34Hz in great degree are represented in the left hemisphere, but in case of the oscillator with frequency of 34-35Hz they appear in the right temple and lower frontal cortex, closer to medial surface.

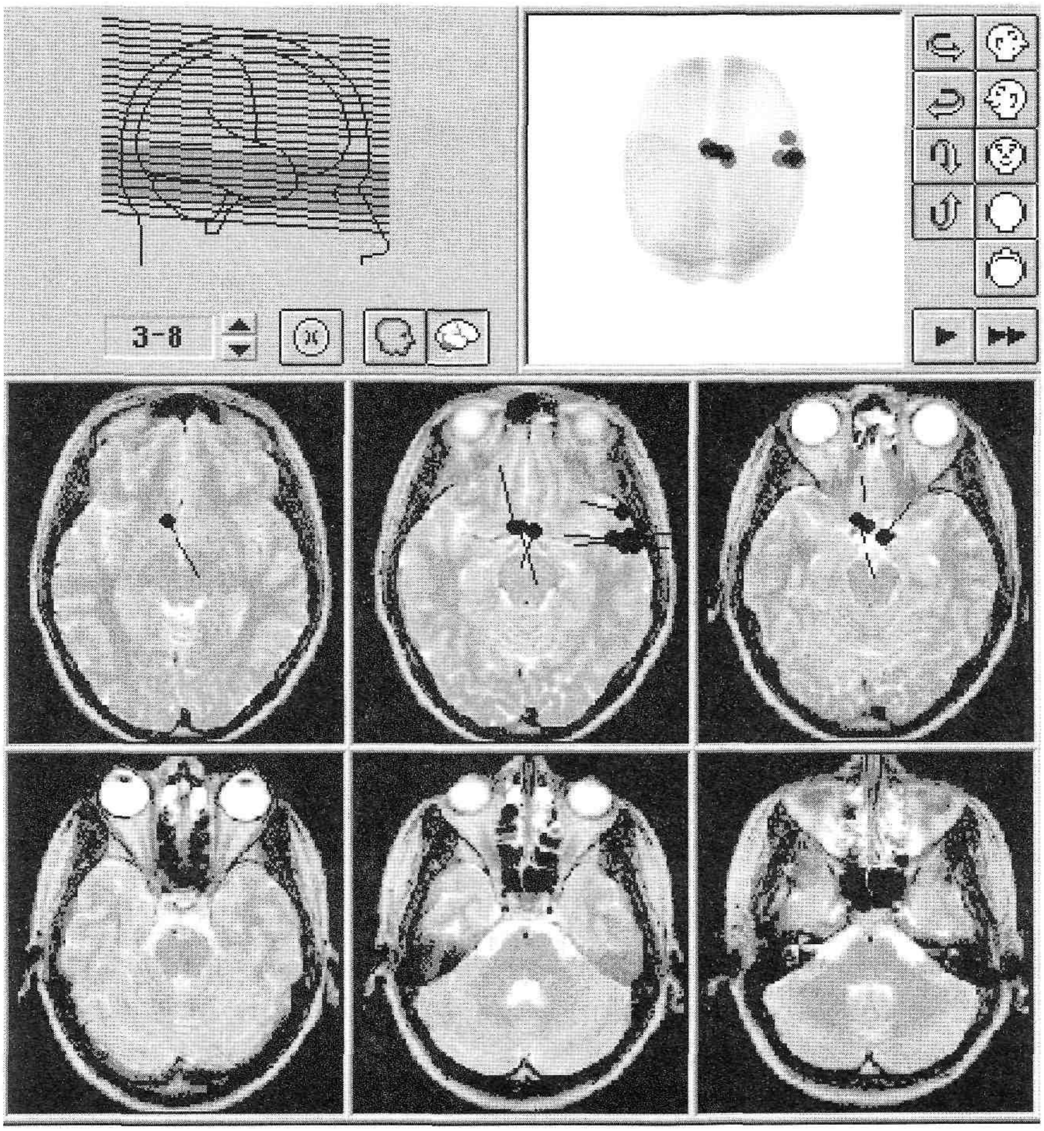

Fig. 7*a*. Localization of equivalent dipoles of two narrow band gamma oscillators on structural magnet resonance tomography images working at frequencies 34–35 Hz (*a*) and 33–34 Hz (*b*). Each of the two gamma oscillators with sharp tuning was activated on two spatially separated brain zones during 100 msec.

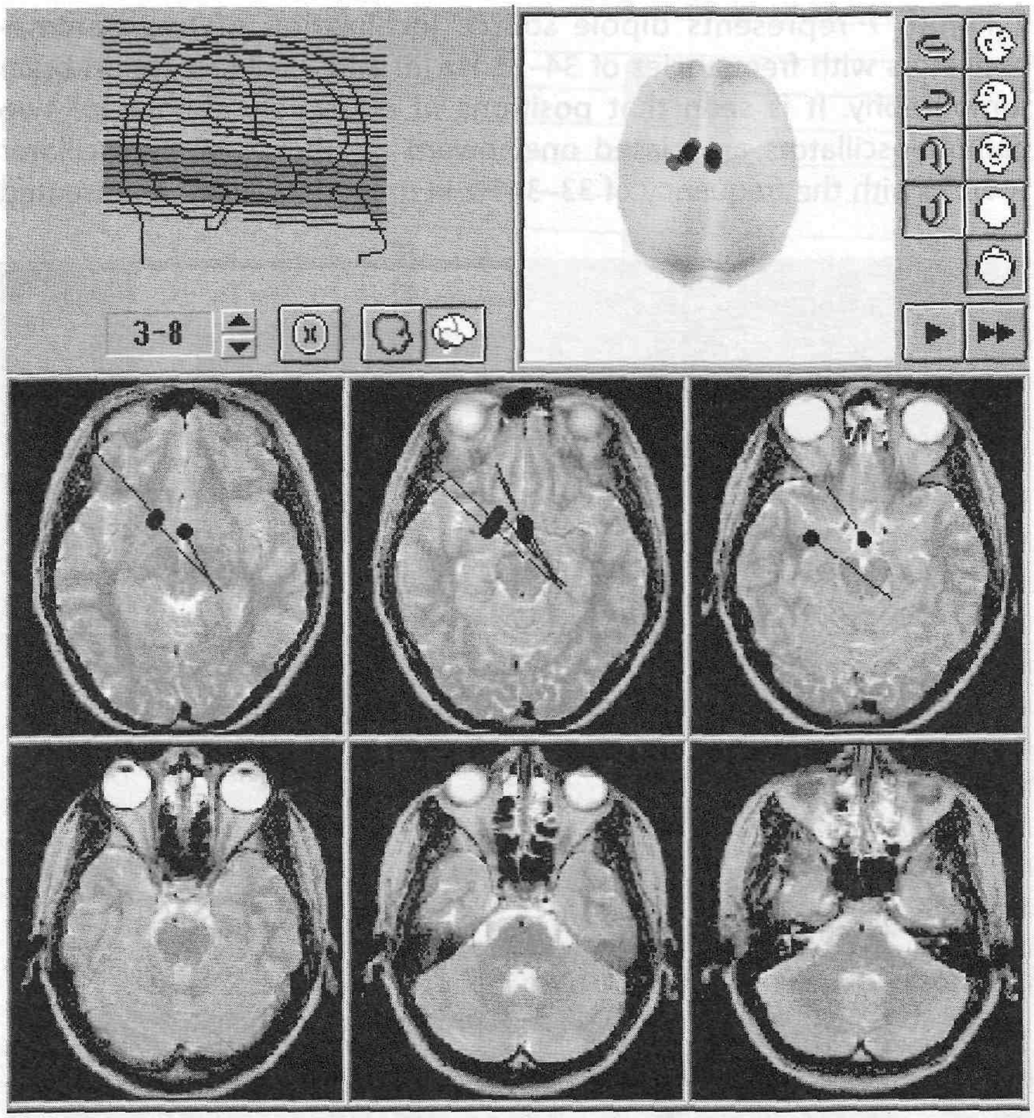

Fig. 7*b*

For various frequencies interrelation research of gamma oscillators their time dynamics at the primary GPC section was researched. All the subjects during the whole sensor response (in the interval of 0-100msec) were characterized by the gamma oscillators' activation periodicities, common for various frequency oscillators. Due to time synchronization of gamma oscillators flashes working at different frequencies, common rhythm of their mutual activity in the way of alternation periods of activation and inactivation. Figure 8 shows one subject’s periodical appearance of dipole sources in brain structures for each of actively working narrow band gamma oscillators at the primary section of sound GPC (0-100msec after the stimulus). Equal dipole existence is the index of gamma oscillator activity. It is seen that two gamma oscillators activated in a subject in indifferent series are stimulated periodically. Narrow band oscillators activity is time synchronized. In the interval of 0-100msec 8 flashes of gamma oscillators mutual activity appear creating rhythm at frequency about 120Hz. In motor series periodical synchronization of various frequency oscillations forms 6 periods of activity and pauses between them.

For the first time results supporting discrete character of gamma oscillators activity, tuned to very narrow frequency bands not more than 1Hz were received. Their activity discreteness was shown both in frequency scale and time. Data received about frequency specificity of gamma oscillators with sharp tuning as a whole agree with other researchers’ results, announcing about heterogeneity of gamma rhythm on the basis of gamma rhythm separate power specter sectors independent changes [9,20,42 et al.]. Thus present research results highlight the importance of rather narrow band gamma oscillators than wide band oscillators in realization of sensor and cognitive processes. Thus statement is proved by the fact that gamma oscillators discrete character is better expressed with narrow band rather than wide-band oscillators, and the number of activated gamma oscillators with sharp tuning (1Hz wide) ten times greater than the number of oscillators at frequency filtration band increasing up to 15Hz.

Given results about the narrow band gamma activity with the sound clicks operation, perception of pairs of two-digit numbers given for multiplication, and also target visual stimuli, shown their common feature. Narrow band gamma oscillators perform as frequency specific and independent systems. They find out their activity modulation in time, which appear in our research in a result of dipole analysis application as their activity discreetness during the whole GPC. Oscillators’ activity is present within some time frames and is absent in the others. Besides, frequency specific gamma oscillators’ activity is connected with different loci in brain structures working at different frequencies.

Indifferent series

Quants	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
34 Hz	■				■	■				■	■					■	■					■	■				■	■					■	■					■	
38 Hz	■	■				■	■					■					■						■	■				■	■				■	■				■	■	

Motor series

Quants	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
31 Hz								■													■						■							■						
33 Hz			■	■					■	■					■	■					■	■					■	■					■	■						
34 Hz		■	■	■	■				■	■	■				■	■	■				■	■						■												
36 Hz		■	■	■				■	■	■				■		■					■																			

Fig. 8. Periodicity of narrow band gamma-oscillator dipoles appearance during 100 msec after the stimulus in the structure of sound GPC in indifferent and motor experiment series. For each time quant in 2,5 msec presence or absence of dipole was defined at S.D. of 0,95. It is seen that gamma-oscillator group tuned to different frequencies is activated synchronously to each other and forms common activity rhythm. On the left frequencies to which gamma-oscillators are tuned are shown. Horizontally there is time scale in quantum. Black squares show time quantum for which presence of dipole source was found, showing gamma oscillators activity

Gamma oscillator dipole sources appearance selectively tuned to a certain frequency in two loci on tomography images can be considered as expression of two brain zones interaction, involved in common function via mechanism of synchronized gamma oscillations at the same frequency. As our results show, similar interaction process is present at the earliest stages of sound stimulus perception – in the interval 0-100msec after its presentation. Supposition can be made that narrow band gamma oscillators perform communicative function, providing memory participation and pre-frontal cortex function involvement on the sensor coding process [7,8]. They connect sensor processes with memory ones already in the structure of sensor response providing merging of two information flows "bottom-up" and "top-down".

Two forms of gamma rhythm communicative function are found: combining brain structures into a single functional system is done both with the help of gamma oscillators' common frequency activated in connected brain structures and via mechanism of time synchronization of various frequency narrow band gamma oscillators activity creating common rhythm of activation and inactivation periods alternation.

What is a mechanism defining frequency selectivity of gamma oscillators' tuning? The important step on the way to gamma rhythm generation study was intracellular registration of identified intercalated and pyramid neurons of hippocampus. Clusters of intercalated neurons were found generating synchronized high frequency commissures simulating condition of pyramid neuron, with which they are connected. Synchronized discharges of intercalated neurons coincided with focal potential fluctuations which are considered as summarized characteristic of local group of functionally interacting neurons condition [43].

As focal potential fluctuations frequency is relative to frequency range of gamma rhythm [33,34], we can suggest two models explaining narrow band gamma rhythm generation. According to one version, the signal coming to intercalated neurons puts into action their interaction process which in its turn creates resonance effect to a group of neurons involved in common function. Interacting intercalated neurons cluster frequency is defined by the potentials frequency of dominated intercalated neuron action. According to the other version, intercalated neurons have pace-making qualities. Signal coming to them switches them into pace-making activity mode simultaneously causing commissure discharge launching that provides a group of intercalated neurons activity synchronization effect which causes certain frequency gamma rhythm in local cellular ensemble [35].

Thus, frequency specific mechanism of information coding based on frequency selectivity of intercalated neurons pace-making activity causing binding of brain structures for brain functions realization seems to exist.

Different brain zones are characterized by different frequency of intercalated neurons pace-making potentials which can be separated from caused potential via frequency filtration method. Intercalated neurons pace-making localization in different brain zones is achieved by calculating frequency specific location of equivalent dipole.

Experimental research of human brain equivalent dipoles narrow band gamma oscillators activated in the GPC structure brought in a conclusion that oscillators’ frequency structure combines a discrete series, but not a solid specter. Equivalent dipole at a certain frequency appears consequently in time frames certain intervals apart from each other. In one and the same brain zone and within the same time frame different frequency dipoles can appear. We can suppose that every frequency selective dipole has a corresponding group of pace-making intercalated neurons giving a stimulus by their activation on a certain time line. One-stage appearance of several frequency selective dipoles in brain local zone proves that several groups of intercalated neurons function there. Dipole position bias means new brain structure involvement.

Combination of GPC method, dipole analysis and anatomical magnet- resonance tomography for narrow band gamma oscillators study allowed finding out two forms of communicative function performance caused by gamma rhythm. Brain structure connection into a single functional system is done because of the common frequency gamma oscillators are tuned to; they are activated in connected brain structures, also with the help of various frequency gamma oscillator group time synchronization mechanism, forming common rhythm of alternation of activation and inactivation periods.

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