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The Spectrum of Bio-electric Activity in Response to Taste Adjectives

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Abstract

Frequency spectra of the induced brain activity function in the range of 0.13 to 27 Hz of 16 female subjects aged 18–20 were studied. The activity was caused by reading of taste adjectives from the screen. The function significantly differs for different hemispheres in the studied frequency range. Frequency shifts ranges in the stimulation (maxima) and inhibition (minima) zones of the brain activity differential function were determined. ANOVA model implemented within the Statistica 10.0 software was used for statistical analysis of the measured data

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1. Introduction

The chief component of the neural networks are the connections used by their parts to exchange the information. Stimulation of any receptor is reflected in the induced potential within the respective cortex zones. The physiological processes, associated with these exchanges, can be objectively studied by registering and analyzing the brain activity while the cognitive processes are taking place [1–5], where of special interest is a sensory reactivation associated with adjectives [6] from a psycholinguistic vocabulary [5]. Language acquisition is based on our knowledge about the world and forms through multiple sensory-motor interactions with the environment. We link the properties of individual experience formed at different stages of ontogeny with the phased development of sensory modalities and with the acquisition of words describing the appropriate forms of sensitivity. To test whether early-formed experience related to skin sensations, olfaction and taste differs from later-formed experience related to vision and hearing, we asked Russian-speaking participants to categorize

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or to assess the pleasantness of experience mentally reactivated by sense-related adjectives found in common dictionaries. It was found that categorizing adjectives in relation to vision, hearing and skin sensations took longer than categorizing adjectives in relation to olfaction and taste [6].

While it is known that all oscillating elements if the brain core can generate broad frequency spectra, for many of the specialized sub-cortex structures it is possible to indicate their preferable frequency ranges, such as 3–6 Hz for hippocampus, 0.9–2 Hz for hypothalamus and 0.2–0.8 Hz for striatum, etc. [4, 7].

Slow brainwaves are generally taken to mean the bioelectric oscillations with the frequencies of 0.3–1 Hz. Their presence after the extensive thalamic damage indicates that they are generated within the cortex as opposed to the limbic system. In this work the slow waves are understood to include frequencies from 0,1 Hz to 1 Hz.

The goal of this work is to register and analyze the frequency spectra of the brain activity function, induced by the reading of the taste adjectives from the computer screen. It is based on and continues the research of the brain activity and the changes thereof associated with the certain psychical processes [2].

2. Methodology

The experiments were conducted in the neurocybernetic lab of the Fear Eastern Branch of the Russian Academy of Sciences “Arktika” research center, using the brain activity spectra monitor with PC MEGI-01 induction coil sensors. Low-noise (1–3 μV) UBP preamps were used with digital band filters (0.1–30 Hz) and 256 Hz sampling frequency [4, 7]. The analysis method was based on the procedure used for long-time hippocampus and neocortex EEG response in the pharmacological testing [8]. Fast Fourier transform with 0,06 Hz quantization frequency was used for spectral analysis. The spectra were divided into 840 bands with the width of 3% of the central frequency. All signals within each band were added and the resulting amplitude was ascribed to the central frequency. These intermediate spectra were normalized by the logarithmic method. Only repeating or stable oscillations were analyzed with the epoch of 160 s. The measurements were taken in series of 3 without cognitive load (background measurement) and then 3 sessions with the cognitive load of 20 taste adjectives displayed, each corresponding to the medium and strong sensation [6].

All tests were taken using the same adjectives in the same sequence. Each word was displayed in large-size font in the center of computer screen for 5 seconds, followed by the empty screen for 3 seconds. This method allowed for reliable registering of the global brain activity with the frequency range of 0.13–27 Hz [4, 7].

All sixteen subjects were willing young females aged 18–20.

ANOVA method implemented within Statistica 10.0 software was used for statistical analysis of the measured data.

3. Results

3.1. The amplitude and spectrum of bioelectric activity

3.1.1. Differential spectral brain activity function (BAF)

The acquisition software plots the dimensionless differential BAF against the measured frequency (Figure 1) with the left hemisphere data displayed as the dashed line and the right one as the solid line. The acquisition software plots the dimensionless differential BAF against the measured frequency (Figure 1) with the left hemisphere data displayed as the dashed line and the right one as the solid line. This allows for separation of the maximum and minimum amplitudes of spectral brain activity function.

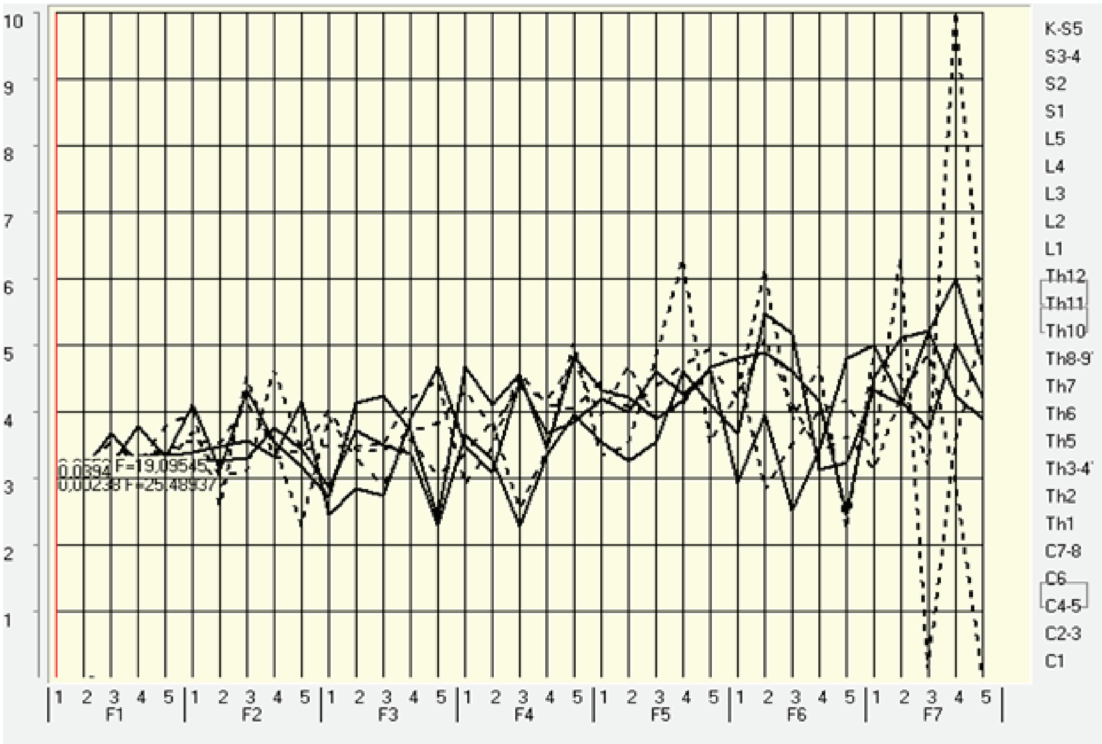

Figure 1: BAF amplitude plot, where the x-axis – frequency functions, dashed line – left hemisphere data, solid line – right hemisphere data.

The normalization of the data is performed by the software [4].

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3.1.2. Biorhythm sessional dynamics

The differential BAF of both the right and the left hemispheres are normally distributed according to the χ2 criterion, with the difference between the hemispheres being statistically relevant according to the Student criterion.

Figure 2 shows the accumulated data plot of differential BAF against the whole frequency range while the reading of the taste adjectives was taking place. It's evident that the greatest activity is observed in the left hemisphere in the delta- and slow-rhythm frequency ranges.

Detailed spectral measurements reveal the greatest activity in the slow-rhythm range, with the lowest activity in the delta- and theta-rhythm ranges for both hemispheres (Figure 2).

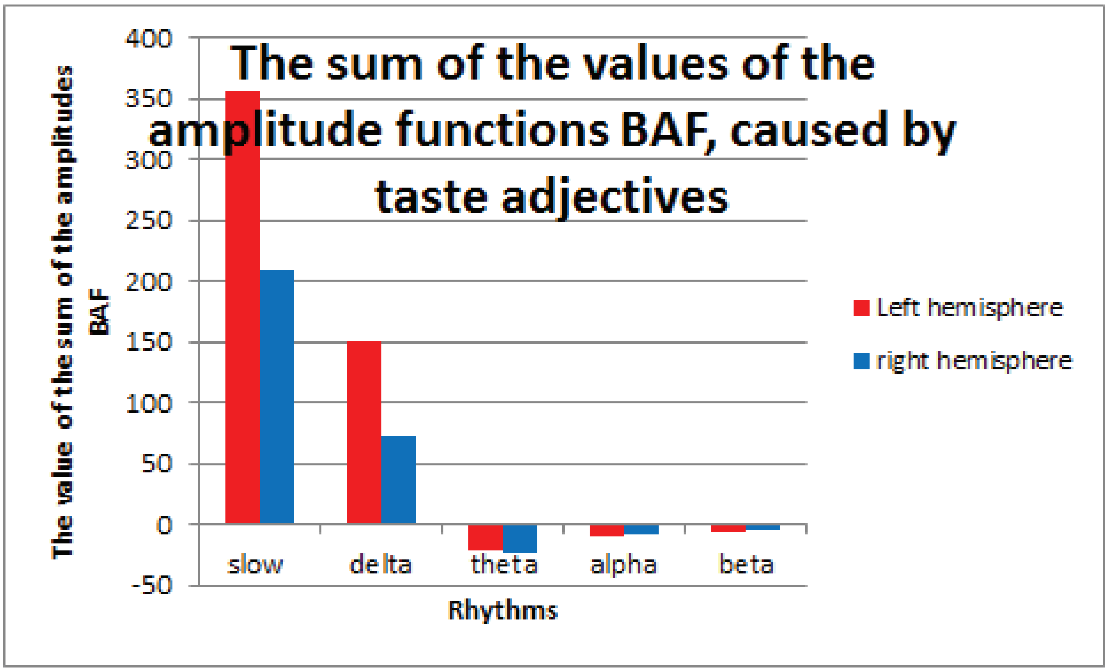

Figure 2: Accumulated differential BAF under cognitive load plotted against frequency range: solid – left hemisphere, dashed – right hemisphere.

As evident from Figures 2–4, the total value of the evoked bioelectrical function is negative for the faster (alpha, beta and theta) rhythms, and for the theta rhythm, the first session is prominent compared to the two others. This can be probably explained by the initial extraction of the test adjectives' meanings from the memory.

In the slower rhythms area the total BAF amplitude is positive. It increases from the first to the third session for the slow rhythm in the left hemisphere (Figure 2), but fluctuates in the right one, with the decrease of 30% in the second session (Figure 3).

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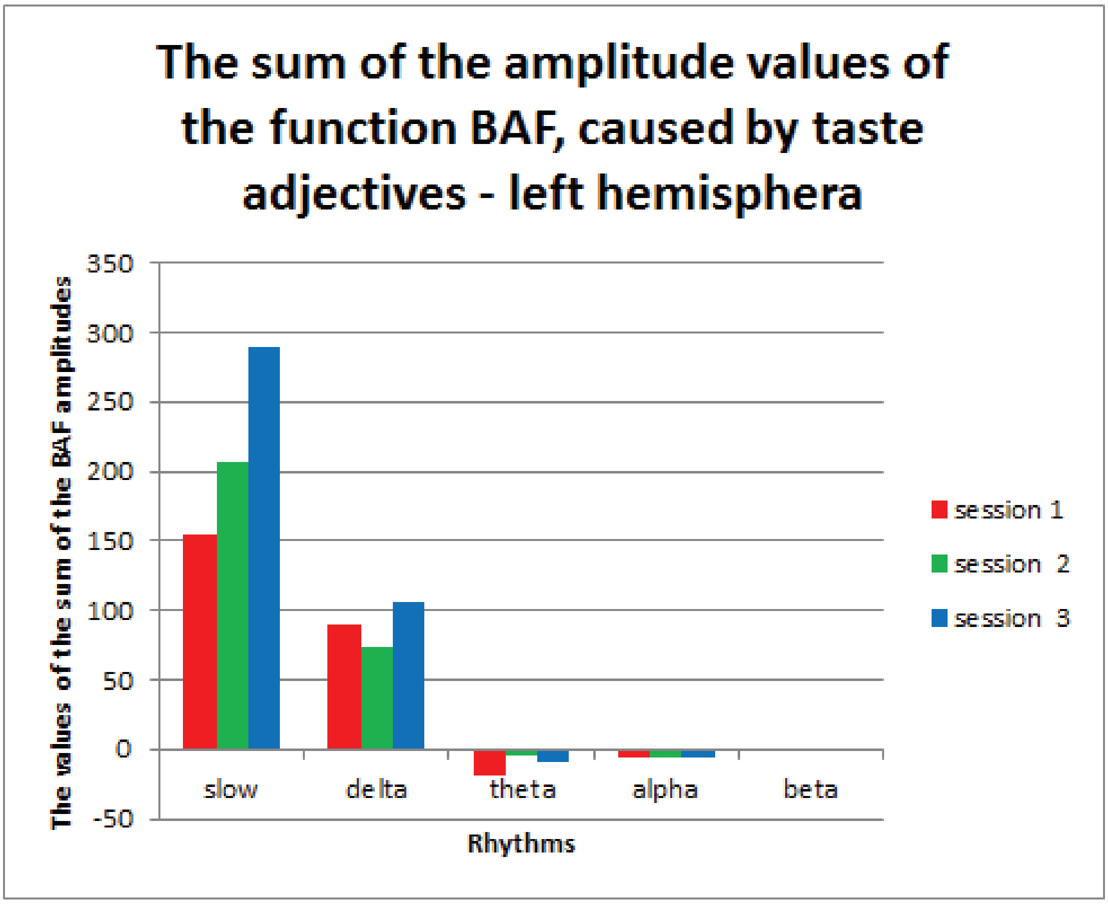

Figure 3: Accumulated differential BAF caused by taste adjectives in three sessions – left hemisphere.

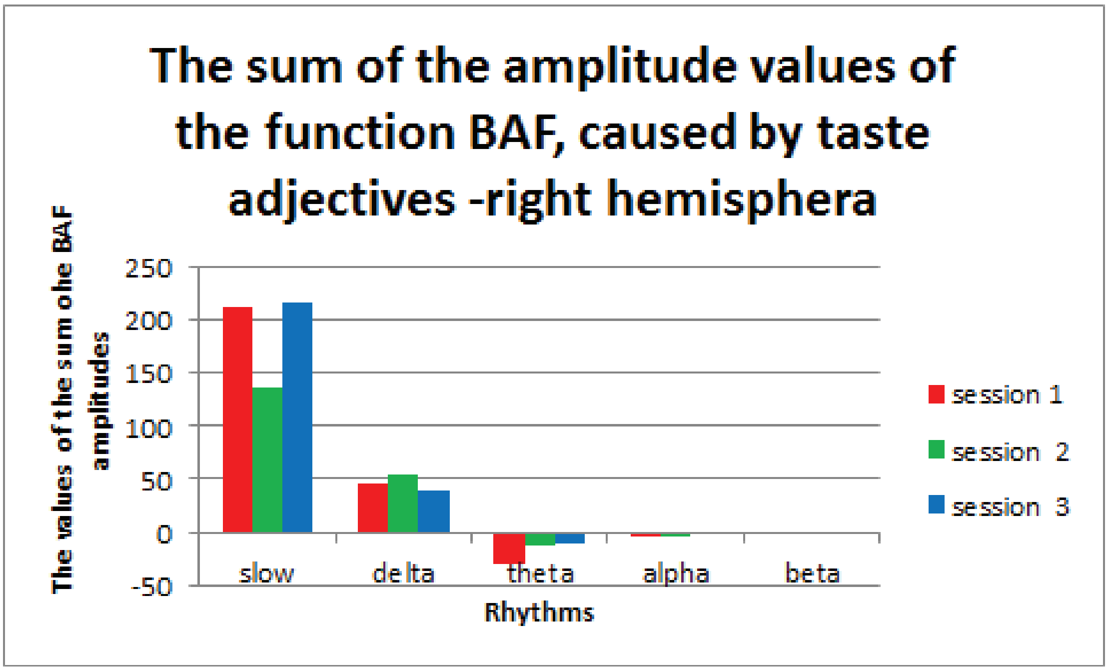

Figure 4: Accumulated differential BAF caused by taste adjectives in three sessions – right hemisphere.

For the delta rhythms the total amplitude changes little between the runs for both the left and right hemispheres (Figures 3–4).

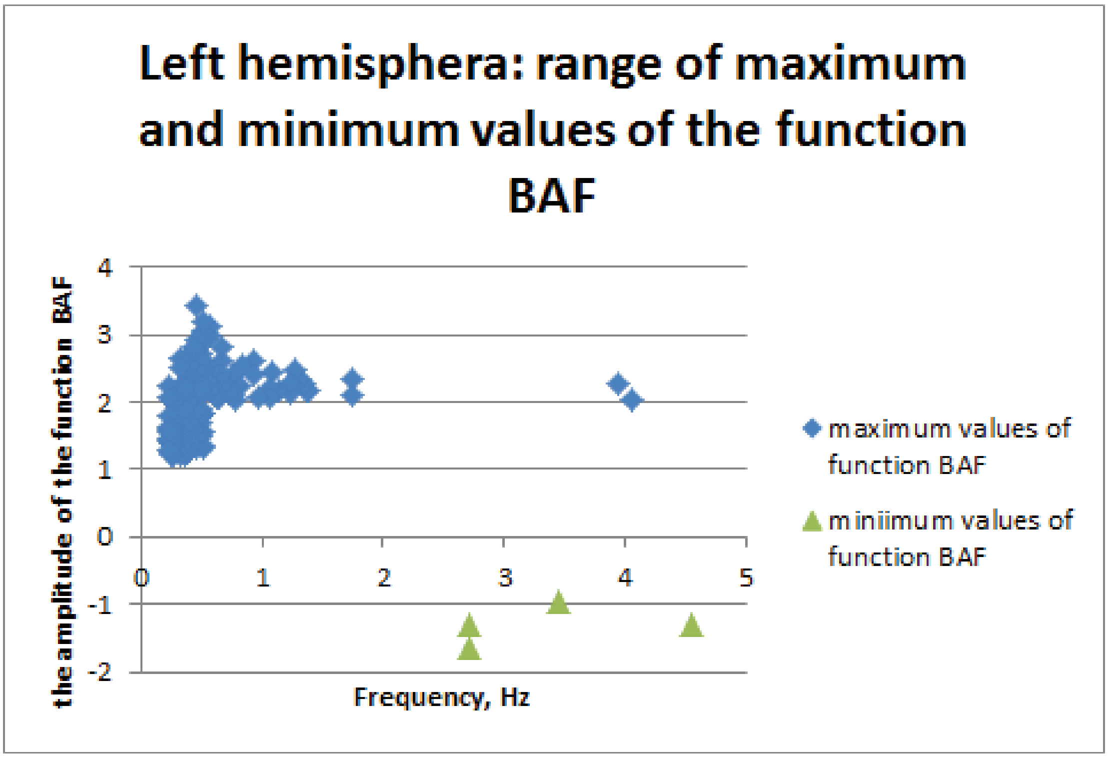

Figure 5: Minimum and maximum BAF amplitude spectra under cognitive load for the left hemisphere.

The amplitudes of the BAF peaks are smaller for the right hemisphere, and the frequency is limited by the 4.5 Hz number, while for the left hemisphere it reached 10 Hz (Figures 5–6).

The greatest amplitude in the left hemisphere is observed at the slow-rhythm frequency of 0.51–0.57 Hz; while the minimal amplitude is at 3.44–4.64 Hz, in the delta-rhythm zone.

In the right hemisphere the maximum amplitudes are seen at 1.07–3.94 Hz frequencies, however their values are ~1.5 times smaller than for the left one, and the minimum amplitudes also observed in the delta-rhythm range at 3.12 Hz.

3.2. Model and discussion

As noted in the introduction, the adjectives set used in this work are associated with the little differentiated behavior (tasting). These adjectives are included in the affective adjectives lists used to study emotional response and the subjects' mood [6]. Most taste properties (such as the taste itself, smell, gastrointestinal tract activation), and the positive or negative emotions linked with them, are part of the genetic inherited

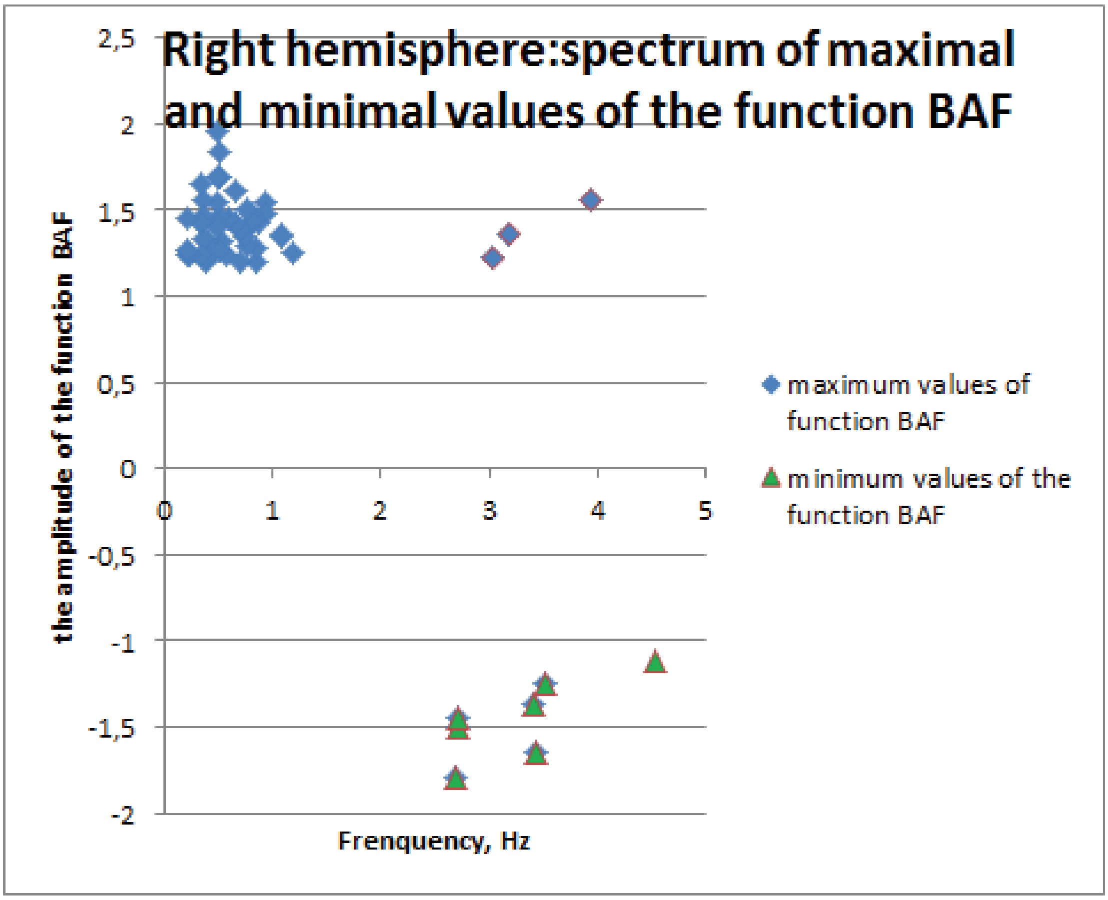

Figure 6: Minimum and maximum BAF amplitude spectra under cognitive load for the right hemisphere.

program, linked to the visceral reflexes. Apparently, with the development of the speech and word recognition system, the brain forced the association between the respective properties of the recognized words and the genetic program.

It is known [3] that word understanding and associating them with the deeper reflexes is processed in the left hemisphere, while the emotions are processed in the right one. If we assume that the BAF amplitude is linked to the emotional response, (Figure 4, slow rhythm), then the lack of positive reinforcement from the gastrointestinal system explains the stability of the response for the right hemisphere, as there is no connection with the taste analysis system.

Another hypothesis is that the increase of the slow rhythm range amplitude from session to session in the left hemisphere can be explained by assuming that the taste response (such as gastrointestinal tract receptors activation) is activated when reading each taste adjective, that is, every 8 seconds. A secondary evidence to that is that vegetative index [9] is increased toward the parasympathetic activity by the third session.

These assumptions are supported by the presence of maxima and minima in the metabolic (slow rhythm) and heartbeat (delta rhythm) within the BAF spectra (Figures 5–6). These frequency ranges point to the inhibition processes or excitation process: of either participation of inhibitory (GABA) or excitatory (Glu) neurotransmitters, which in general account for the 40% of all synaptic transmissions of the neural system. It is known that Glu is able to activate the 'Umami' taste receptors in the tongue [10], while GABA not only has a general inhibitory action (which improves the concentration while the word recognition takes place), but also stimulates the memory and cognitive processes. The attention system ('thalamic filter') and motor control (basal ganglia, cerebellum) are primarily regulated by the GABA [9].

4. Conclusions

In this work we obtained the spectrum, where the BAF amplitude, evoked by the reading the taste adjectives, is either minimal or maximal. The characteristic frequencies of this spectrum point to the activity of the either stimulating (Glu) of inhibitory (GABA) neurotransmitters.

The model explaining the inter-session dynamics of the BAF spectrum change is also proposed.

The increase of the left hemisphere BAF during the sense reactivation while reading the taste adjectives correlates well with the location of the verbal associative zones of the cortex' left hemisphere. (Luria, 2008) The experiments were conducted in the early afternoon (1 pm local time) around the lunchtime, and the subjects were somewhat hungry, so the increase in the slow rhythms connected to the digestive processes because of the cognitive stimuli connected to food (such as 'bouillon' of 'ham') is quite understandable.

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