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Abstract

Theta activity in EEG was found to be augmented in the frontal midline area in 5 young women while they played classical piano pieces and during related mental tasks. This activity was considered to be a frontal midline theta rhythm with the maximal amplitude mostly in Fz and of the frequency ranging from 5 to 7.5 Hz. This theta activity was observed to increase depending on the degree of the subjects' concentration on piano playing or related tasks. In bilateral parietal derivations, increases in the power value of alpha activity were observed in some subjects while they were listening to music, suggesting that alpha activity was involved in appreciation of music.

KEYWORDS: frontal midline theta rhythm, EEG, music, piano playing, mental concentration

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Electroencephalographic Changes During Piano Playing and Related Mental Tasks

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Theta activity in EEG was found to be augmented in the frontal midline area in 5 young women while they played classical piano pieces and during related mental tasks. This activity was considered to be a frontal midline theta rhythm with the maximal amplitude mostly in Fz and of the frequency ranging from 5 to 7.5 Hz. This theta activity was observed to increase depending on the degree of the subjects' concentration on piano playing or related tasks. In bilateral parietal derivations, increases in the power value of alpha activity were observed in some subjects while they were listening to music, suggesting that alpha activity was involved in appreciation of music.

Key words : **frontal midline theta rhythm, EEG, music, piano playing, mental concentration**

When a pianist plays exercises on a piano, various psychic phenomena including thought, judgement, speculation, will and sentiment must occur. While these occur, the pianist may read a musical score, understand the soul of the music and touch the keys as specified in the score. The pianist also listens to the music which he or she plays. This constitutes feedback, and is the mechanism by which the pianist is mentally affected by his or her music. By repetition of exercises, the pianists' skill may become an art. A physiological analysis of the mechanisms of such a psychomotor phenemenon as the performance of prolonged musical tasks would be expected to be difficult due to its complexity. Hess has extensively discussed the complexity of sensory and motor mechanisms operating in the process of training musical skills (1). When we listen to music, our will to listen must be exercised first, then we concentrate our attention on the music. In the case of playing a piano without making any mistakes, the degree of mental concentration would be much higher. A particular EEG activity, the frontal midline theta rhythm (Fmθ) is reported to be augmented during concentration on a mental task (2–6). We hypothesized that the Fmθ would be augmented during piano playing. The purpose of the present experiment is 1) to determine whether Fmθ is augmented during piano playing of an artistic composition and

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during related mental tasks, and 2) to determine whether there is an EEG pattern specific to piano playing.

Subjects and Methods

Five female subjects aged 18 to 27 were selected for the present experiment. Each had practiced playing the piano for more than 12 years. They had practiced the piano pieces prior to the EEG recording. EEG electrodes were attached to the scalp by a conventional method. The electrode placement was determined according to the international 10–20 systems. The subjects sat in a chair in front of a piano. EEG and sound from the piano were recorded with a 13 channel electroencephalograph and stored on electromagnetic tape via a 16 channel data recorder. In later experiments, EEG was recorded by telemetry (Telemeter type 514-1, Nihon-Koden Co., Ltd.).

EEG was recorded during activities under each of the 7 conditions, in the following order:

Table 1 EEG recording trials in each subject

Music	Subjects	Conditions A	B	C	D	E	F	G
Fleecy Clouds by F Mendelssohn								
	Y. S.	1	1	2	2	2	1	1
	S. H.	2	2	3	4	4	2	2
	Y. G.	1	1	2	2	2	1	1
	T. I.	2	2	3	3	3	2	2
Scherzo by F Chopin								
	Y. S.	0	0	1	1	1	1	0
	S. H.	0	0	1	1	1	1	0
	N. K.	0	0	1	1	1	1	0
Each of Nocturne and Impromptu by F Chopin								
	Y. S.	0	0	1	1	1	0	0
	S. H.	0	0	1	1	1	0	0
	N. K.	0	0	1	1	1	0	0
Jesu, joy of man's desiring by J S Bach								
	S. H.	1	1	1	1	1	1	1
	Y. S.	1	1	1	1	1	1	1

Figures in the Table show numbers of EEG recording trials in each subject under each condition. Conditions A ~ G are shown in the text.

A: Resting with eyes open for 3 min. B: Resting with eyes closed for 3 min. C: Listening to the music while watching its score as attentively as in a real performance. D: Listening to the music with the same mental state as in condition C above, but with eyes closed. E: Playing the music on a piano. F: Resting with eyes open for 3 min. G: Resting with eyes closed for 3 min.

The following music was used.

F. Mendelssohn: Songs Without Words, No. 20, "Fleecy Clouds", Op. 53, No. 2.; *F. Chopin:* a) Nocturne, No. 8 in D-flat major Op. 27, No. 2, b) Impromptu, No. 2 in F-sharp major Op. 36, c) Scherzo, No. 2 in B-flat minor Op. 31; *J. S. Bach:* Jesu, Joy of Man's Desiring, Chorale from Cantata No. 147 (piano solo arranged by Myra Hess).

The music listened to in conditions C and D above was tape recorded from performances by famous pianists.

The number of EEG recording trials in each subject under each condition are shown in Table 1. Most of the EEG records were analyzed manually. Theta activities lasting more than 1 sec. and dominant around Fz were counted and the total duration per unit time was compared between different conditions in each subject.

Part of the recorded EEG was filtered through a multi-channel 3rd order Butterworth low pass filter with a cut-off frequency of 20 Hz, and converted into 12 bit digtal data at 128 Hz. This system makes it possible to acquire simultaneously multi-channel waveform data.

For spectral analysis, a 256-point Fast Fourier Transform weighted by the Hanning window function was performed. The resolution of the frequency analysis was 0.5 Hz and the maximum frequency was 64 Hz. When the low pass filter was taken into consideration, the bandwidth was limited by 20 Hz. Our main interest was focused on frequencies from 4 to 10 Hz, but the analysis was extended to 30 Hz.

Results

Fig. 1A shows the EEG of subject Y. G. recorded by telemetry during piano playing (condition E). The composition was "Songs Without Words, No. 20" by F. Mendelssohn. Although the EEG record was interrupted by artifacts due to eye blinking, theta activity with a frequency of 6.5 Hz appeared at Fz for about 1 sec (arrow). Its amplitude was 60–80 μV in this case. This activity seemed to be an Fmθ. It appeared 37 sec after the beginning of the music. Simultaneously, theta activity with the same frequency and a smaller amplitude was observed at Pz. Also at the same time, theta activity with almost the same frequency and considerably greater amplitude appeared at Fp_1 and Fp_2.

Fig. 1B shows the EEG of the same subject, but in condition D. The music was the same as in Fig. 1A. No blinking artifact was recorded because the eyes were closed. The amplitude of the EEG was higher in this condition than in condition E, probably because the eyes were closed. Theta activities appeared in the EEG recorded at Fz and Pz for 2 sec, starting 2 sec after the beginning of the music. Its frequency was 6.5–7.0Hz. In the other derivations, relatively low amplitude activities in the range of theta or alpha appeared simultaneously with the theta rhythm in Fz and Pz. Afterward, theta activity with the same frequency appeared repeatedly around Fz during the music. In the 3 other subjects who played the same piece, Y. S., S. H. and T. I., theta waves were also augmented around Fz during performance and during related mental tasks.

In the 3 relatively experienced subjects S. H., N. K. and Y. S., EEGs were recorded while they played the 3 pieces by F. Chopin, and during related mental tasks. All of them were sufficiently skilled to play Chopin's pieces after considerable practice. S. H. and Y. S. practiced these 3 pieces for more than 8 weeks, but subject N. K. could only practice for 4 weeks, which was insufficient. In this experiment, the EEG was recorded not by telemetry but by the conventional method. Therefore we used a bipolar lead to minimize artifacts. The results are summarized in Table 2. As shown in the Table, the appearance of Fmθ-like activity differed between condi-

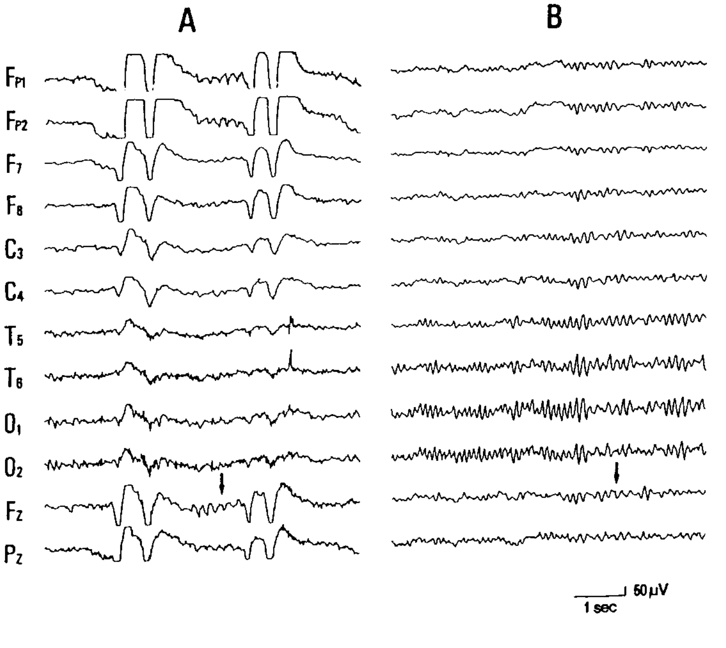

Fig. 1 EEG record of subject Y. G. **A**: during condition E by telemetry. Fmθ appeared at Fz (arrow) and continued for about 1 sec, starting 37 sec after the beginning of the performance. The music was "Fleecy Clouds" by F. Mendelssohn. **B**: while listening to the same music with the eyes closed (condition D). Appearance of an Fmθ is indicated by an arrow. It was 2–4 sec after the beginning of the music.

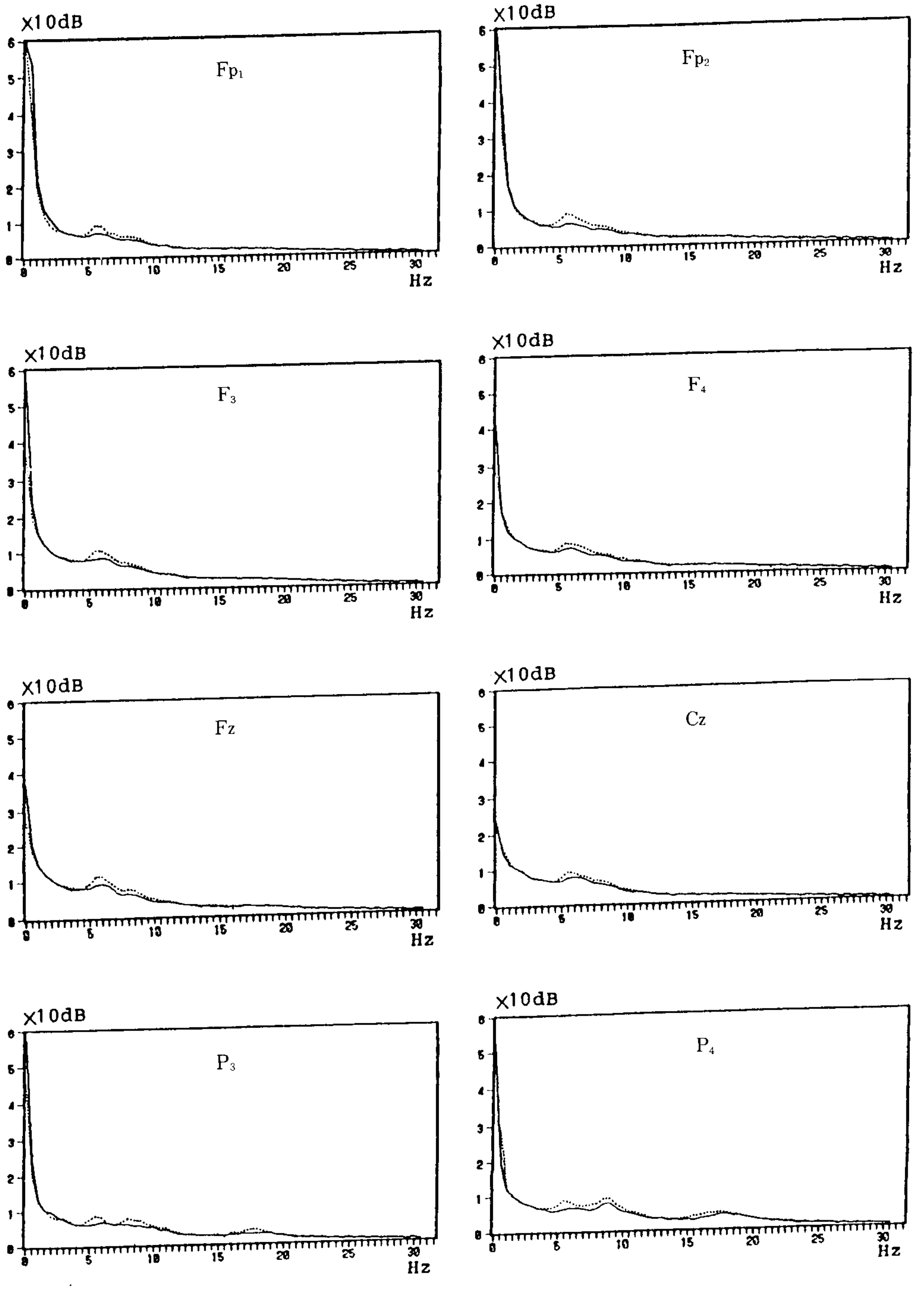

Fig. 2 Power-spectrogram of the total EEG record of condition B (solid line) and condition D (broken line) in subject S. H. Derivations are Fp_1, Fp_2, F_3, F_4, Fz, Cz, P_3 and P_4.

Table 2 Average duration (in sec) of Fmθ per minute while listening to and playing piano pieces by F. Chopin.

Subjects	Age	Career on piano (years)	Range of θ wave (Hz)	Nocturne(6'15") C	D	E	Impromptu(5'56") C	D	E	Scherzo(9'32") C	D	E	Rest F
S.H.	18	12	6.0–6.5	1.6	1.4	—*	0.5	1.9	—*	0.4	2.0	—*	0.6
N.K.	23	19	5.0–6.0	0.6	0.2	0.6 (6'27")	0	0.5	0.3 (5'48")	0.2	1.4	0.4 (11'53")	0
Y.S.	27	21	6.0–7.5	1.4	4.3	3.3 (6'58")	1.5	4.7	3.3 (6'04")	2.9	4.6	2.9 (9'59")	0

*Due to artifacts, EEG recording was impossible.
C: Condition C (listening with eyes open). D: Condition D (listening with eyes closed). E: Condition E (playing the piano). F: Condition F (resting with eyes open)
Numerals in parenthesis in the headings show the performance time on recordings by famous pianist.
The numerals in parenthesis in the lower part of the table show the performance times of each subject.

tions, compositions and subjects. It was more frequent during the musical tasks (conditions C, D and E) than while resting with the eyes open (condition F), but in subject S. H. it was less frequent while listening to the "Impromptu" or the "Scherzo" with the eyes open than while resting. Fmθ was highest in condition D with minimal exception. Its appearance differed between pieces. There was a tendency for it to appear most during the "Scherzo". The appearance of Fmθ-like activity during the tasks also differed among subjects. In N. K., Fmθ occurred less often than in the other 2 subjects. This may be related to the fact that she also made more mistakes in her performance than did the others.

A power-spectrum analysis was made of EEGs of 2 subjects, S. H. and Y. S, recorded while they played Bach's composition, "Jesu, Joy of Man's Desiring" and related mental tasks. The results from EEGs measured during condition B and condition D were compared in both subjects. The results from S. H. are shown in Fig. 2. Analysis time was 3 min and 40 sec which was equal to the duration of the piece. As shown in Fig. 2, the increase in power due to listening appeared in 2 frequency ranges, 5–6Hz and 8–9Hz. The former change was observed in all derivations of Fp_1, Fp_2, F_3, F_4, Fz, Cz, P_3 and P_4, with the maximal change in Fz. The latter was observable only in P_3 and P_4 as bilateral and almost symmetrical changes. At derivations O_1 and O_2, there was no increase in power in the alpha range such as that seen in P_3 and P_4 (data not shown). In subject Y. S., substantially the same results were obtained.

Discussion

When one listens to an acomplished performance by a famous pianist, many subjective phenomena occur. However, in the present experiment our analysis was focused only on the EEG changes due to listening to and playing music.

The Fmθ is a theta rhythm which is most dominant in the frontal midline area. Its frequency is usually 6–7 Hz and it is augmented by a mental task. It can appear during certain stages of sleep (7). The Fmθ is also reported to appear more frequently when subjects are concentrating on a mental task than when they are not (2–6, 8). The theta activities recorded in the present experiment are considered to be Fmθ. That is, the amplitude was maximal around Fz, and the frequency was generally 6–7 Hz, though it was 7.5 Hz in one subject. The theta activities recorded in the present experiment were also augmented by mental tasks. That is, they were augmented while listening to music and also while playing the piano.

Ramos and Corsi-Cabrera reported that theta relative power increased while listening to music in the bilateral central, temporal and parietal delivations (9). They did not record EEG from the midfrontal region.

The reasons for the 7 recording conditions were as follows. By comparing conditions A and C (eyes open) and conditions B and D (eyes closed) EEG changes due to listening to music would be easier to notice on the same EEG background. By comparing conditions C and D we hoped to determine which condition is more favorable to the appearance of Fmθ, desynchronized or synchronized EEG. We expected augmentation of Fmθ during condition E, since playing a piano is probably impossible without mental concentration. Conditions F and G are apparently the same as conditions A and B. However, in the conditions F and G, there may be after effects of listening to the music. If the fine motor control mechanisms are involved, this would be reflected in condition E. Furthermore, subjects were told to keep the same mental state in conditions C and D as in condition E. Therefore, a kind of rehearsal effect may have influenced the mental activity in the former 2 conditions.

We selected these pieces by F. Chopin, J. S. Bach and F. Mendelssohn, rather than pieces for beginners, because to play such artistic compositions without a mistake requires much more mental concentration than to play on a piece for beginners and, therefore, favors the appearance of an Fmθ. However, more Fmθ appeared in condition D than in condition E. In the latter condition, the mental load might have been too heavy, as the subject tried not to make any mistake while playing. However, in condition D, the mental load may have been less, because there was no need for performance. It has been shown that for the appearance of Fmθ, a certain degree of task difficulty is important (6, 8).

In the EEGs of the 3 subjects who played Chopin, the subject with the least Fmθ was N. K. This may indicate a lack of concentration on the performance. She made much more mistakes than the others and temporary changes in her appearance were observed every time she made a mistake. This indicates interruption of her mental concentration during playing, even if she was more alert than the others. In a previous study, Fmθ was augmented in 33.3% of subjects who listened to 3 classic violin pieces consecutively (10). In another report, the percentages of subjects with augmented Fmθ during various mental tasks ranged 32% to 73% (3). Musical tasks do not appear to be very different from other tasks in their ability to facilitate Fmθ. However, it has not yet been determined exactly which task most favors the augmentation of this EEG activity.

Conscious mental concentration is not only activity that facilitates Fmθ. Fmθ is augmented during certain periods of sleep (11). A lower level of wakefullness also favors the appearance of Fmθ which is consistent with the fact that Fmθ appeared more often in condition D than in condition C or E.

Earlier studies of the Fmθ discussed its relations to a kind of pleasant sensation (6, 8). Recently, only mental concentration is considered to be a facilitator of the Fmθ, probably because the Uchida-Kraepelin test is used to evoke the Fmθ in most experiments (2–7). In the present experiment some subjects reported their experience of a kind of pleasant feeling when they were satisfied that they had played the piano without making a mistake. However, mental concentration accompanying rather unpleasant feelings can also evoke the Fmθ. It was augmented in a subject with urinary urgency (12).

In addition to the results regarding Fmθ, we found an increase in the power value of the alpha frequency in derivations P_3 and P_4 while listening to music with the eyes closed (Fig. 2). Several authors have already studied the change in alpha activity as related to music. Though Bruya and Severtsen (13), Kohrman *et al.* (14) and Ramos and Corsi-Cabrera (9) reported no change in alpha activity while listening to music, others found some music-related changes in alpha activity. Duffy *et al.* (15) showed that music induced right temporal lobe activation (decrease in alpha activity), but Breitling *et al.* (16) reported an increase in alpha power value caused by a melody stimulus, in the right mid-temporal and right frontal region. Davidson and Schwartz (17) found no difference in EEG asymmetry between whistling the melody of a song and speaking the lyrics of a song in musically-trained subjects, but a significantly greater relative right hemisphere activation was found in non-musically trained subjects. Konovalov and Otmokhova (18) found that while listening to music the power of alpha activity decreased in the left and right occipital regions almost symmetrically. Our result is not consistent with any of these results and is difficult to interpret. Still, we may say that both alpha activity and the Fmθ are involved in musical tasks.

References

1. Hess WR: Memory and intellect; in Biology of Mind, W. R. Hess, English Translation, by GV. Bonin, The University of Chicago Press, Chicago and London (1964) pp 17-26.
2. Ishihara T and Yoshii N: Multivariate analytic study of EEG and mental activity in juvenile delinquents. Electroenceph Clin Neurophysiol (1972) **33**, 71-80.
3. Yamaguchi Y: Frontal midline theta activity; in Recent Advances in EEG and EMG Data Processing, Yamaguchi and Fujisawa eds, Elsevier/North Holland Biomedical Press, Amsterdam (1981) pp 391-396.
4. Mizuki Y, Tanaka M, Isozaki H, Nishijima H and Inanaga, K: Periodic appearance of theta rhythm in the frontal midline area during performance of a mental task. Electroenceph Clin Nurophysiol (1980) **49**, 345-351.
5. Matsumoto T: The relationship between reminiscence effect and the appearance of Fmθ. Clin Electroenceph (1980) **22**, 404-409 (in Japanese).
6. Tani K: Motivated performances and Fmθ. Clin Electroenceph (1978) **20**, 115-120 (in Japanese).
7. Yamaguchi Y: Frontal midline theta rhythm. III. Clin Electroenceph (1983) **25**, 425-431 (in Japanese).
8. Yamaguchi Y: Frontal midline theta rhythm. II. Clin Electroenceph (1983) **25**, 352-358 (in Japanese).
9. Romas J and Corsi-Cabrera M: Does brain electrical activity react to music ? Int J Neurosci (1989) **47**, 351-357.
10. Katayama S, Hori Y, Nanba R, Yanagihara M and Inokuchi S: Correlation between the variance in physiological functions caused by listening to music and divergence in the histories of musical training of university students. Neurosciences (1991) **17**, 341-347.
11. Hayashi H, Iijima S, Sugita Y, Teshima Y, Tashiro T, Matsuo R, Yasoshima A, Hishikawa Y and Ishihara T: Appearance of frontal mid-line theta rhythm during sleep and its relation to mental activity. Electroenceph Clin Neurophysiol (1987) **66**, 66-70.
12. Ishihara T: EEG and somatic sensation. Electroenceph Electromyogr (1986) **16**, 214. (in Japanese)
13. Bruya MA and Severtsen B: Evaluating the effects of music on electroencephalogram patterns of normal subjects. J Neurosurg Nurs (1984) **16**, 96-100.
14. Kohrman M, Sugioka C, Huttenlocher PR and Spire J: Inter-versus intra-subject variance in topographic mapping of the electroencephalogram. Clin Electroenceph (1989) **20**, 248-253.
15. Duffy FH, Bartels PH and Burchfiel JL: Significance probability mapping: An aid in the topographic analysis of brain electrical activity. Electroenceph Clin Neurophysiol (1981) **51**, 455-462.
16. Breitling D, Guenther W and Rondot P: Auditory perception of music measured by brain electrical activity mapping. Neuropsychologia (1987) **25**, 765-774.
17. Davidson RJ and Schwartz GE: The influence of musical training on patterns of EEG asymmetry during musical and nonmusical self-generation tasks. Psychophysiology (1977) **14**, 58-63.
18. Konovalov VF and Otmakhova NA: EEG manifestations of functional asymmetry of the human cerebral cortex during perception of words and music. Hum Physiol (1983) **9**, 250-255.

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