AN ELECTROENCEPHALOGRAPHIC STUDY OF THE RHYTHM ASSIMILATION REACTION ASSOCIATED WITH APPLICATION OF DOUBLE LIGHT STIMULI

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One of the most important problems in the physiology dealing with clinical electroencephalography is to evaluate the functional state of the brain on the basis of data from an electrophysiological examination. This problem is simplified by recording the electrical processes of the brain in response to afferent stimuli of measured intensity and timing.

Analysis of the rhythm assimilation phenomena associated with photostimulation has received wide circulation in the field of clinical electroencephalography. The works of a number of authors [1,2,4,5,7,10,12,13,14] have served to establish the range of flicker frequencies normally assimilated, the connection between the rhythm assimilation phenomenon and certain structures of the brain, the relationship of its arisal to the intensity of the light, the correlations between duration of the light stimuli and duration of the pauses between stimuli, etc.

Knowledge of the characteristics of the rhythm assimilation reaction under normal conditions has permitted its use as an indicator of the functional state of the brain during various forms of cerebral pathology, and as a diagnostic procedure as well [1,5,6,8,9,14]. However, despite the large number of projects on this subject, the nature of the rhythm assimilation phenomenon is still not adequately understood.

The purpose of this investigation lay in studying the significance of the extent of the time intervals between the light stimuli as it effects arisal of the rhythm assimilation reaction.

It should be noted that as early as 1940 M. N. Livanov [4] observed certain principles pertaining to the occurrence of the rhythm assimilation reaction in rabbits, where two light stimuli of identical intensity and rhythm were separated from one another by varying lengths of time.

EXPERIMENTAL METHOD

Rhythmic light stimulation was accomplished by means of an "Al'var" system photostimulator, providing a light flash of constant duration (50 millisec) and unvarying intensity (within a given frequency range), and thus, a determinable energy output of 0.3 joules for each light flash. The investigation was carried out on 30 essentially healthy human subjects (keeping their eyes open, and with a distance of 50 cm between the source of light and the eyes). Along with rhythmic series of single light stimuli we applied rhythmic series of double light stimuli (light complexes) at a frequency of from 3 to 9 flashes per second. The time intervals between the two stimuli of each light complex were equal to 50, 70, 90, 120, 130 and 150 milliseconds. The investigation always began by determining the range of assimilation frequencies with application of rhythmic single light stimuli. Thus, if the rhythm assimilation was seen at 10 and 12 light flashes per second, then the doubled light stimuli were applied in a rhythm of 5 and 6 per second. In that way, the same number of light flashes were presented in various ways: either with equal time intervals between all flashes (rhythmic series of single light stimuli, Fig. 1a), or with equal time intervals between serial pairs of light stimuli (rhythmic series of doubled light stimuli, Fig. 1b, c). Varying the time intervals between the pair of stimuli, it was possible voluntarily to make this series increasingly or decreasingly similar to the rhythmic series of single light stimuli.

EXPERIMENTAL RESULTS

Where we used the light stimulation in rhythmic doubled flashes (light complexes), the EEG of the healthy human subject showed assimilation either of the light complex frequency or of the doubling frequency, depending on the time interval between the two stimuli of the light complex. For example, if the doubled flashes were presented

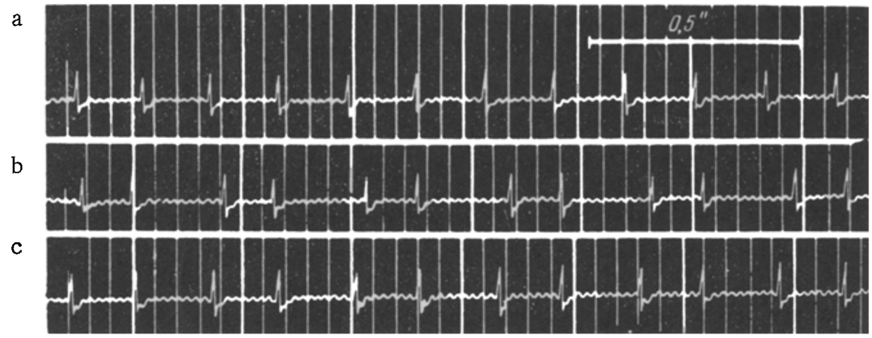

Fig. 1. Rhythmic series of single and doubled light stimuli. a) Single stimuli, in a rhythm of 6 flashes per second; b, c) doubled stimuli in a rhythm of 3 flashes per second.

in a rhythm of 4 per second, then at time intervals between the two stimuli of each pair equal to 50, 70, and 150 milliseconds it was possible to assimilate only the rhythm of the light complexes, i.e., 4 per second. However, if at the same rhythm of doubled flashes (4 per second) we used time intervals between the pair of stimuli equal to 90, 120 and 130 milliseconds, then assimilation was usually seen in the EEG for the doubling frequency of the light complexes, i.e., a rhythm of 8 per second (Fig. 2).

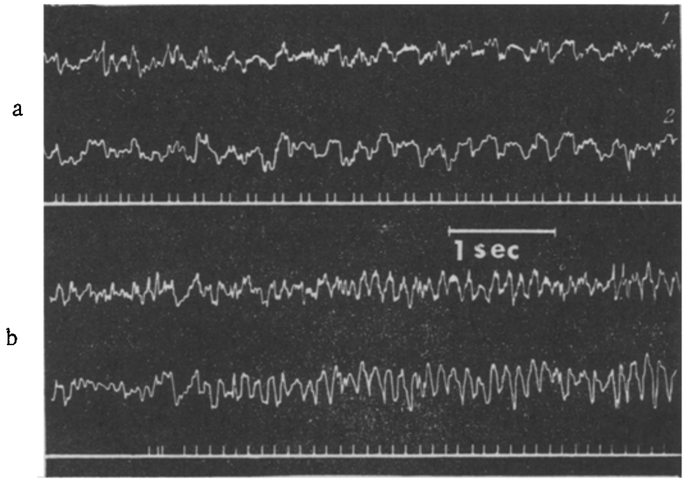

Fig. 2. EEG for the occipito-parietal regions. 1) Left hemisphere; 2) right hemisphere; a) rhythm assimilation of the light complexes (4 flashes per second), time interval between the stimuli of the complex equal to 70 milliseconds; b) assimilation of the doubling frequency of the light complexes (8 flashes per second). Time interval between the stimuli of the complex equal to 120 milliseconds.

Studying the phenomenon of rhythm assimilation using light complexes of varying frequency, it was easily noted that assimilation of both the light complex frequency and its doubling frequency are observed at different time intervals between the elements of the complex (Fig. 3).

With elevation of the light complex frequency, the time intervals between the elements of the complex decrease , so that assimilation of the doubling frequency of the complexes occurs, and, simultaneously with this, there is a change in the time intervals at which the frequency of the light complexes is assimilated. Detailed analysis of this fact showed that assimilation of both the light complex frequency and its doubling frequency is only observed at certain relationships between the time interval dividing the elements of the light complex and the time interval between the complexes themselves.

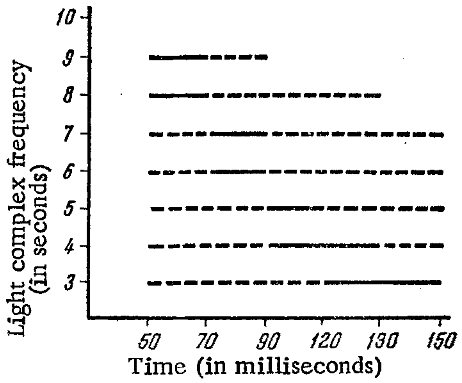

Fig. 3. Relationship of the character of rhythm assimilation to the magnitude of the time intervals between the two stimuli of the light complex. Continuous line denotes the time intervals at which assimilation of the doubling frequency of the light complexes was observed; the broken line indicates the time intervals at which the light complex frequency assimilated.

If the time interval between the elements of the complex is designated as a, and the time interval between the complexes themselves by b, then assimilation of the doubled frequency of the light complexes is only noted when the fraction a/b ranges within the bounds of 0.6 to 1.7. The optimal value of the a/b fraction, for genesis of this phenomenon, is 0.7–1.2. When a/b equals 0.7–0.9 it represents approximation of rhythmic series of single light stimuli, and a value of a/b equal to 1.2 characterizes a minimal distinction from the rhythmic series of single stimuli. A coefficient a/b equal to 1 is the expression of the rhythmic series of single light stimuli itself.

With all remaining values for the a/b fraction, below 0.6 or above 1.7, we observed only assimilation of the light complex frequencies.

The table shows the values for the fraction a/b for all light complex frequencies employed, and for all variations of the time intervals between the two stimuli of each light complex.

It should be noted that at certain frequencies of the doubled light stimuli in rhythmic series characterized by a coefficient a/b>1, the results were functionally identical or almost identical to a rhythmic series defined by a coefficient a/b<1. For example, the series of light complexes administered at a rhythm of 5 flashes per second with a time interval between the stimuli of the complex equal to 50 milliseconds was functionally identical to this series with an interval between the stimuli of the complex equal to 150 milliseconds. Thus, to simplify the investigation, in this case we could use any one of these intervals. However, it must be kept in mind that the two series will differ from one another in the action of their first two stimuli. In the first case, the first two stimuli will be separated by an interval of 50 milliseconds, while in the second case, this interval will be equal to 150 milliseconds. Evidence may be found in the literature indicating that the magnitude of the latent period for the reaction to the first stimulus (with exposure to a rhythmic series of single light stimuli) differs from the magnitude of the latent periods associated with the reaction of the brain waves to the subsequent stimuli [3]. If this fact is taken into consideration, then apparently one can never speak of strict functional identity between the aforementioned two series of rhythmic light flashes.

On the basis of our factual material and data in the literature pertaining to a study of the excitation cycle of cortical cells associated with application of isolated pairs of light stimuli [8], we came to the conclusion that the characteristics of the assimilation reaction during rhythmic stimulation with light complexes characterize, to a certain degree, the excitation cycle of the nerve cells, exactly reproducing the administered rhythm or transforming it into a doubled rhythm.

Whether the assimilation occurs with the frequency of the light complexes or with their doubling frequency apparently depends on which phase of the excitation cycle of the nerve cells is encountered by the second element of each pair of stimuli.

In the cases where the light complex frequency is assimilated, the second stimulus of each pair falls on the refractory phase following the action of the first stimulus. However, this second stimulus may still have an effect on the response to the first stimulus of the subsequent pair, acting as a facilitating factor and strengthening the effect of the following stimulation.

Thus, assimilation of a certain rhythm is not only possible with equal time intervals between the serial light stimuli, but also with deviation from this strict temporal stimulation series within given limits. In addition, the critical magnitude of this deviation (i.e., the maximum value, above which the character of the brain's reaction changes) emerges, in light of what has been presented, as a unique and important functional indicator.

Our investigations showed that with application of light complexes the character of the assimilation reaction in patients with various forms of cerebral pathology often differs from the characteristics of the analogous reaction in healthy individuals. This difference in the character of the reaction serves as evidence that the method of stimulating with double light flashes can be used in clinical practice as one of the auxiliary procedures of functional diagnostics.

Light complex frequency (in seconds)	Interval between the elements of the complexes (in milliseconds)					
	50	70	90	120	130	150
3	0,17	0,26	0,37	0,56	0,64	0,8
4	0,25	0,38	0,56	0,9	1	1,5
5	0,33	0,5	0,9	1,5	1,8	3
6	0,4	0,7	1,2	2,6	3,6	9
7	0,5	1	1,7	5	10	
8	0,6	1,2	3,6	24		
9	0,8	1,7	4,3			

Note. A heavy line encloses those values at which we always observed assimilation of the doubling frequency of the light complexes; the numbers in the light lined squares indicate that at this value for the fraction a/b the assimilation phenomenon was seen in some cases and absent in others. The values for the a/b coefficient that are not enclosed by lines indicate assimilation of the light complex frequency.

SUMMARY

A study was made of the cortical rhythm reconstruction processes (rhythm assimilation reaction) in 30 healthy individuals following application of a rhythmical series of paired light stimuli (light complexes). There were two types of reactions of cerebral rhythms to light depending upon the time interval between the pair of the stimuli constituting the light complex: assimilation of the light frequency complexes and assimilation of their double frequency. Variations of the light frequency complexes and of the time intervals between the pair of the stimuli have shown that the character of the cerebral rhythm reaction to light applied in the form of a rhythmical series of paired light stimuli depends on the interrelationship between the time interval between the light complex elements and the time interval between the complexes themselves.

LITERATURE CITED

1. N. N. Zislina, Zhurn. Vyssh. Nerv. Deyat. Im. I. P. Pavlova, Vol. 5, No. 5 (1955) p.676.
2. A. G. Kopylov, Collection "Theoretical and Practical Questions in Electroencephalography." (Leningrad, 1956) p.96.
3. E. Krigel' and V. Neshtianu, Zhurn. Vyssh. Nerv. Deyat. Im. I. P. Pavlova, Vol. 8, No. 4 (1958) p.570
4. M. N. Livanov, Fiziol. Zhurn. SSSR, Vol. 28, No. 2-3 (1940) p. 172; 183.
5. V. E. Maiorchik and B. G. Spirin, Voprosy Neirokhir., Vol. 15, No. 3 (1951) p. 3.
6. P. V. Mel'nichuk, Zhurn. Nevropatol. i Psikhiatr., Vol. 58, No. 1 (1958) p. 35.
7. Adrian E. D. Mathews, Brain, V. 57, (1934), p. 355.
8. H. Gastaut, J. Roger, A. Corriol, and R. Naquet, EEG a. Clin. Neurophysiol., Vol. 3, No. 4 (1951) p. 401.
9. K. A. Kooi, H. G. Eckman, and M. H. Thomas, EEG a. Clin. Neurophysiol., Vol. 9, No. 2 (1957) p. 239.
10. A. C. Mundy-Castle, EEG a. Clin. Neurophysiol., Vol. 5, No. 1 (1953) p. 1.
11. A. C. Mundy-Castle, EEG a. Clin. Neurophysiol., Vol. 5, No. 2 (1953) p. 187.
12. J. J. Toman, Neurophysiol., Vol. 4 (1941) p. 51.
13. W. G. Walter, V. J. Dovey, and H. Shipton, Nature, Vol. 158, No. 4016 (1946) p. 540.
14. V. I. Walter and W. G. Walter, EGG a. Clin. Neurophysiol., Vol. 1, No. 1 (1949) p. 57.