CEREBRAL ELECTRICAL RESPONSES OF HEALTHY PERSONS TO RHYTHMICAL LIGHT OR LIGHT AND SOUND STIMULI

L. G. Makarova

Institute of Neurology (Director – Active Member AMN SSSR Professor N. V. Konovalov), AMN SSSR, Moscow

(Presented by Active Member AMN SSSR A. V. Lebedinskii)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 54, No. 12, pp. 7-11, December, 1962
Original article submitted February 20, 1962

It is known that when sufficiently intense rhythmical light stimuli of a certain range of frequencies act on the eyes of healthy persons or intact animals the spontaneous potentials are altered so as to take up the rhythm [5, 8-11, 14, 19, 21, 22].

Wide use has been made of this phenomenon in clinical electroencephalography both for topical diagnosis and for assessment of function. Because in healthy persons there are individual differences, for an accurate assessment of a pathological condition it is important to know the incidence of high or low indices of this reaction.

We here give an analysis of the effect as observed during the first 5 seconds of the operation of the light stimulus at frequencies of 6, 8, 12, 14, 16, and 18 per second.

EXPERIMENTAL METHODS

The basis of the measurement was to calculate indices,* and to measure the latent period of reaction and the amplitude of the assimilated rhythms in the EEG of the central occipital region (bipolar leads). The assimilation of the photic flicker was studied in 45 healthy subjects aged 18-35 years. A constant sequence was maintained in changing from the low to the high frequencies. The time interval between successive frequencies was 30 seconds. The investigations were made with the eyes open and with them shut. In the first case the light was placed at a distance of 50 cm from the eyes, and in the second at 10 cm. We used an "ALVAR" combined light and sound stimulator. Most of the EEGs were recorded on a 15 channel inkwriting recorder made by the same firm.

The assimilation of the photic flicker was studied both with light alone, and with combined rhythmical light and sound stimuli.

EXPERIMENTAL RESULTS

Cerebral Electrical Response to Photic Flicker

Among 45 healthy subjects, none were found who failed to assimilate the light rhythm. There were some who failed at one or two photic flicker frequencies only. No appreciable differences in assimilation of the rhythm were found with the eyes opened or closed.

Latent period. The latent period for the uptake of different rhythms is very variable both from one person to another, and in the same person. Nevertheless, at frequencies below 16 per second, the latent period is usually comparatively short, and it may be taken as 100-265 mseconds. Most frequently such latent periods are found at light stimulus frequencies of 8, 12 and 14 per second. Probably the cortical cells become most rapidly reorganized to light stimulus frequencies which are nearest to the dominant rhythm of the initial activity. Flicker frequency at rates of 8, 12, and 14 per second represents just such frequencies, and are close to the predominating frequencies of the natural activity which occur at 9-12 per second. It would appear therefore that the low values of the latent periods are related to the ratio of the flicker frequency to the α-rhythm.

* The index represents the ratio of the number of waves recorded during light stimulation to the number of light pulses in unit time.

Moderate values of the latent period (300-430 mseconds) are found at flicker frequencies of 8, 12, and 14 per second much less often than low values; it is only at a flicker frequency of 16 per second that moderate values of the latent period are more common than lower values.

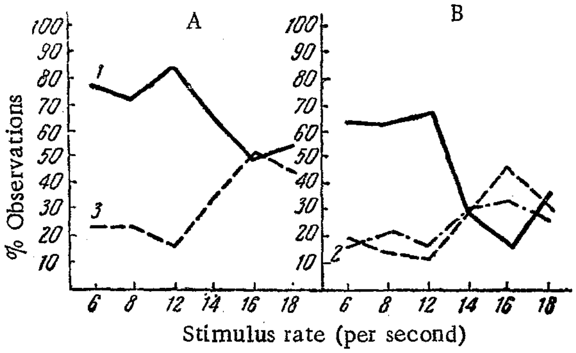

Fig. 1. High (1), medium (2), and low (3) indices (A) and amplitudes (B) of assimilation of the rhythm in healthy subjects.

Long latent periods (400-700 mseconds) are very rare at all flicker frequencies. The variations in the values of the latent periods of the response to successive photic stimulations appear to represent physiological variations in the excitability of the cerebral nerve cells. However, to explain the variability of the latent period in one person (during a single investigation), we must not fail to take into account figures giving the relationship between the stimulus and the phase of the oscillatory process, especially between the stimulus and the phase of the α-rhythm [1, 2, 7,-13, 15-18, 20].

The index of assimilation of the rhythms. To describe the extent to which the applied rhythms were taken up, we will arbitrarily consider values from 0.6 to 0.96 to be high and values from 0.2 to 0.5* to be low. As can be seen from Fig. 1A, for all the frequencies (apart from 16 per second) high indices were found in most of the subjects. However, the most frequent were found at photic flicker frequencies of 6, 8, and 12, and least often at 16 per second. Similarly, for stimulus frequencies of 6, 8, 12, and 14 per second, low values of the index were found much less often than high. When light stimuli were applied at a rate of 16 or 18 per second the number of low and high indices was approximately equal.

Amplitude of assimilated rhythms. The amplitude of the assimilated rhythms were divided arbitrarily into three categories: high – 25 μV or above, moderate – 21-24 μV, and low – up to 20 μv. High amplitudes prevailed at frequencies of 6, 8, and 12 per second (Fig. 1B). With increase of light stimulus frequency (14, 16, or 18 per second) many fewer subjects produced a high amplitude of the assimilated rhythm, and there was a corresponding increase in the number with low† or moderate amplitudes.

From a comparison of Fig. 1, A and B it is easy to see that the high indices and amplitudes of assimilation of the rhythm were more frequent at light stimulus frequencies of 6, 8, and 12 per second.

Cerebral Electrical Response to Combined Light and Sound Stimulation

In 25 out of the 45 subjects studied we investigated the assimilation of the rhythm in response not only to light, but to light and sound stimuli presented together. Only a few reports deal with the stimulation of the rhythm when two or more afferent stimuli are applied. In experiments on animals [9] and on healthy children [6] it was shown that the assimilation of the rhythm may be enhanced if a sound stimulus is applied at the same rate, with or without a tactile stimulus. Clinical electroencephalography has also provided information on the influence of additional stimulation on the course of the cerebral response to light stimulation [1, 3, 4, 6, 12].

We have applied coincident (isorhythmic) and non-coincident (heterorhythmic) sound and light stimuli. For the heterorhythmic stimuli we used chiefly sound signals at a frequency of 21 or 50 cycles.

For the isorhythmic light and sound stimulation, in 18 of 25 healthy adults we found an improved assimilation of the rhythm representing a positive interaction of two stimuli directed to different analyzers; this result is in line with results obtained on healthy children [6]. This improvement was shown as an increase in the amplitude or in the index of the assimilated rhythm, and in a greater regularity (Fig. 2A); it might occur at a particular rate, or at other rates, although exceptionally the addition of the sound impaired the assimilation of the rhythm.

With combined light and sound stimulation there was usually an increase of 5 μV in the amplitude of the assimilated rhythm over and above the amplitude of the rhythm when the light acted alone; less frequently the

* Normally indices of 0.2-0.3 are found only in isolated cases at comparatively high stimulus rates.

† Normally amplitudes of assimilated rhythm below 16 μV are found only at high stimulus rates of 16-18 per second.

increase was of 3-4 or 8-12 μV. The increase in the index was usually insignificant (usually of 0.2). Sometimes, addition of the sound reduced the uptake of the rhythm in the temporal EEG leads also, though here the deterioration was much less than was found in the central occipital regions.

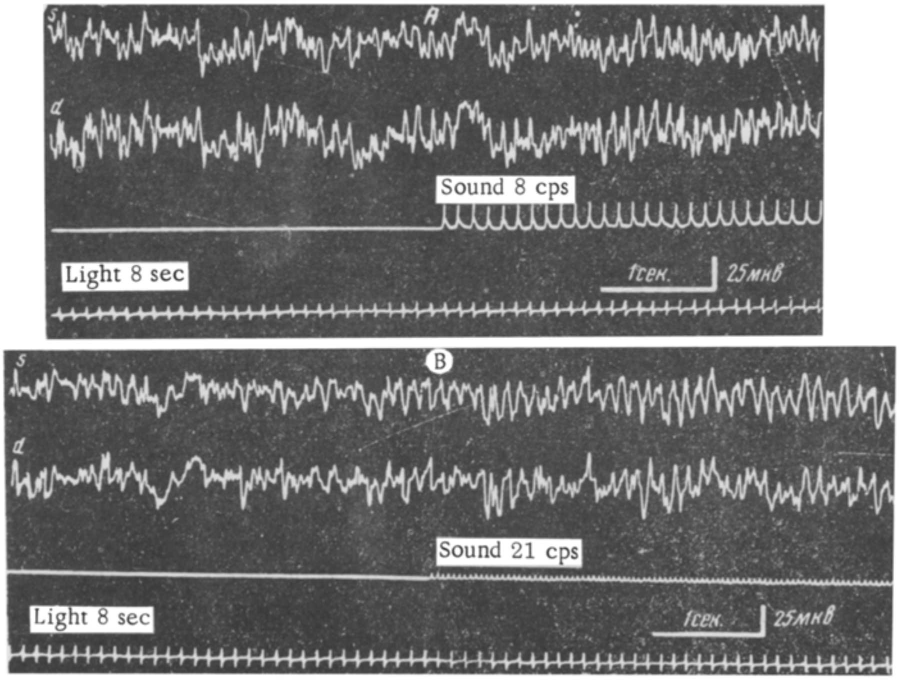

Fig. 2. EEG of the left (s) and the right (d) central occipital regions. Deterioration of the uptake of the flicker frequency after the addition of (A) an isorhythmic and (B) a heterorhythmic sound stimulus.

Vertical scale(s) in millivolts (мв) or microvolts (мкв); horizontal scale(s) in seconds (сек).

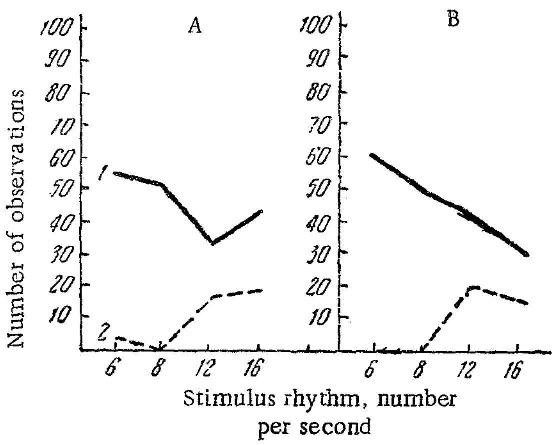

Fig. 3. Change of uptake of the rhythm with (A) isorhythmic and (B) heterorhythmic combined light and sound stimulation. 1) Deterioration; 2) improvement.

In 6 of the 25 subjects, addition of the isorhythmic sound stimulus caused no improvement but rather a deterioration of the extent to which the rhythm was assimilated; the interaction of the excitations developed in the different analyzers must therefore have had a negative effect. A graph of the changes in the uptake of the rhythm with isorythmic light and sound stimulation is shown in Fig. 3A. It is interesting that in 2 of the 6 subjects, reduction of the uptake of the rhythm caused by association of sound with the light coincided with a tremor; in one subject the tremor occurred at the first application of the additional sound stimulus. It may have been that in the remaining three subjects, the deterioration of the uptake of the rhythm was an indication of some kind of latent functional cerebral defect. However, we must also consider another possible explanation: although the light and sound stimuli were presented at the same rate, they were not always strictly synchronized, i.e., each sound stimulus did not coincide in time with the light flash. The extent of this phase difference in the stimuli might be such that the light stimulus fell during a refractory phase induced in certain nerve cells by the sound stimulus—at a time when the response to the light stimulus might be reduced.

With heterorhythmic light and sound stimulation the assimilated rhythm was always determined by the light and not the sound. It was interesting that in most of the subjects studied (Fig. 3B) the addition of the sound to the light heterorhythmically not only failed to impair synchronization already induced by the light, but quite frequently actually enhanced it, as was shown by an improved uptake of the rhythm (Fig. 2B).

Under the influence of combined sound and light the amplitude and the index of the assimilated rhythm sometimes changed simultaneously in the same direction; usually only one of the two indices changed. This last type of reaction is evidence that the amplitude change and the index of the assimilated rhythm are different functions.

The results reported indicate that to improve the extent to which the rhythm is assimilated it is not necessary for the sound and light stimuli to be coincident. Auditory stimulation appears to act rather as a nonspecific stimulus able to combine with other forms of afferent stimulation to enhance the excitability of the nerve cells of the visual analyzer, and so to increase the extent to which the rhythm is assimilated. We may postulate the presence of various mechanisms facilitating the action of the additional sound stimulus, mechanisms such as the spread of the excitation from the auditory into the visual analyzer (cortico-cortical influence), or the spread of excitatory influences to the visual analyzer along cortico-reticulo-cortical pathways.

SUMMARY

The reactions of 45 healthy persons aged 18-35 years to light flashes at 6, 8, 12, 14, 16, and 18 per second were studied. The index of assimilation of the rhythm, its amplitude, and latent period were measured. The incidence of high and low values of these indices varied according to the stimulus frequency.

In 25 out of the 45 persons, the assimilation of the rhythm was investigated when light was applied alone or together with sound (iso- and heterorhythmic stimuli).

In most cases the addition of sound facilitated assimilation of the rhythm.

LITERATURE CITED

1. N. P. Bekhtereva, "Biopotentials of the cerebral hemispheres of the brain in cases of supratentorial tumors." [in Russian] (Leningrad, 1960).
2. N. P. Bekhtereva and V. V. Zontov, Fiziol. zh. SSSR, No. 12 (1961), p. 1463.
3. N. A. Gavrilova, "An electroencephalographical investigation of the interaction of the visual and auditory analyzers in various psychic illnesses." Author's abstract of Candidate's Dissertation (Moscow, 1958).
4. Yu. G. Gaponova, Zh. nevropatol., No. 8 (1960), p. 965.
5. N. N. Zislina, Zh. vyssh. nervn. deyat., No. 5 (1955), p. 677.
6. N. N. Zislina, "Electrophysiological investigation of the functional condition of the brain of normal children and of oligophrenes by the method of rhythmic photic stimulation." Author's abstracts of Candidate's Dissertation (Moscow, 1957).
7. V. V. Zontova, Transactions of the 4th Combined Scientific Conference of Young Neurosurgeons (Leningrad, 1961), p. 156.
8. A. G. Kopylov, in book: Problems of the Theory and Practice of Electroencephalography [in Russian] (Leningrad, 1956), p. 96.
9. M. N. Livanov, Fiziol. zh. SSSR, Nos. 2-3 (1940), pp. 172, 183.
10. V. E. Maiorchik and V. G. Spirin, Vopr. neirokhir., No. 3 (1951), p. 3.
11. L. G. Makarova, Zh. nevropatol., Vol. 6 (1961), p. 807.
12. P. V. Mel'nichuk, Zh. nevropatol., Vol. 7 (1958), p. 823.
13. A. I. Roitbak, "Bioelectrical phenomena in the cortex of the cerebral hemisphere." [in Russian] (Tbilisi, 1955).
14. E. D. Adrian and B. H. C. Matthews, Brain, Vol. 57 (1934), p. 355.
15. S. H. Bartley, J. Exp. Psychol., Vol. 27 (1940), p. 624.
16. G. H. Bishop, Am. J. Physiol., Vol. 103 (1933), p. 213.
17. H. T. Chang, J. Neurophysiol., Vol. 14 (1951), p. 95.
18. R. W. Lansing, Electroenceph. clin. Neurophysiol. Vol. 9 (1957), p. 497.
19. A. C. Mundy-Castle, Electroenceph. clin. Neurophysiol., Vol. 5 (1953), p. 1.
20. J. Tiffin and F. L. Westhafer, J. Exp. Psychol., Vol. 27 (1940), p. 318.
21. J. Toman, J. Neurophysiol., Vol. 4 (1941), p. 51.
22. V. I. Walter and W. G. Walter, Electroenceph. clin. Neurophysiol., Vol. 1 (1949), p. 57.