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On the Average Time- and Frequency-Pattern of Photic Flicker Response in Relation to Intrinsic Alpha Activity Verified by a New Simple Method

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Delivering photic flicker stimulations from about 8 to 12 flashes per second for about 60 seconds continuously to relaxed normal adult human subject, the average properties of the driven EEG waves are obtained by applying a new practical crosscorrelation method to eliminate the irrelevant oscillations to the stimulation. The average time-pattern of the intrinsic alpha activity was carved in relief by a new simple autocorrelation method, which is originally demonstrated here. The EEGs are traced from the occipital, parietal, temporal and frontal regions by monopolar technique.

Even immediately after the initiation of flicker stimulation, the response wave of the stimulating frequency was driven and tended to build up gradually to the maximum average intensity in the course of contiunal stimulation, especially in the occipital region, showing some fluctuation in size.

The average distribution of the driven wave over the scalp was similar to those of the relaxed intrinsic alpha wave activity, in size and phase angle. From these evidences it would be assumed at least for the first approximation that the driven waves are produced from a generator essentially similar to what acts in relaxed state.

In the occipital region, the EEG response was easily driven more intensely the intrinsic alpha activity in the relaxed state by a photic flicker stimulation with a higher frequency than that of relaxed alpha activity, whereas weaker response tended to be driven by lower frequency of stimulation. In other regions, however, a reverse tendency was observed immediately after the initiation of the stimulation.

There have been reported many investigations (ADRIAN and MATTHEWS 1924[1)]; ADRIAN 1944[3)], 1947[5)]; TOMAN 1941[38)]; WALTER, DOVEY and SHIPTON

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1946[40]; WALTER and WALTER 1949[41,42]; MUNDY-CASTLE 1953[22,23]; ULETT 1938[39]; ILIANOK 1959[12]; GOLLA 1959[14]; KANEKO et al. 1961[15]) concerning the effect of photic flicker driving on the brain wave (EEG). However, so far as its effect analysed by crosscorrelation and power spectrum method is concerned, few evidences have been demonstrated on the time varying properties in relation to the intrinsic alpha activity from the point of view of the *transforming action* (SATO, MIMURA et al. 1957[33]; SATO 1959[26]) and the *activity* (SATO, OZAKI et al. 1961[34], Sato 1962[27])of the brain, which are recently defined as an extensive concept of the *excitability* of a living excitable cell and/or system.

In the present paper, some results on the above properties of photic flicker driven waves are demonstrated by applying a new simple practical method for obtaining the average time-pattern (SATO, HONDA et al. 1961[28], 1962[29,30,31]).

METHODS

Several subjects who produced good alpha activity were selected among many normal adults after numerous tests. In a dark and electromagnetically shielded room, the subjects were laid in the supine position with his eyes closed to produce good alpha activity in relaxed state. The EEG tracings were taken by monopolar technique from bilateral frontal, parietal and occipital leads and unilateral right temporal lead. The indifferent electrodes were put on both ear-lobes. Eight-channel inkwriting electroencephalograph (San'ei-Sokki Instrument Co.) was employed, and one of channels was used for recording the rhythmic photic stimulation by Buffington type photic stimulator through a photo-tube simultaneously with the brain waves. The flash lamp of the stimulator was placed facing the subject one meter distance from the subject's eyes.

In each series of the experiments, the EEG tracings were made continuously for 60 seconds during each rhythmic photic stimulation of 8 to 12 (8.3, 9.2, 10.2, 11.4 and 11.9) flashes per second, after the control EEG without stimulation had been traced for 20 seconds. Before each photic stimulation, the tracing was interrupted for 100 seconds without stimulation to avoid the after effect of the control recording.

In order to analyse the driven brain wave exclusively, the average response time-patterns to the rhythmic photic stimulation (the crosscorrelogram of the stimulations and brain wave recording) were computed by our simple practical digital analysis (SATO, HONDA et al. 1961[28], 1962 [29,30]), and furthermore the power spectra of them were derived by Kobayashi's multi-harmonic digital analysis (KOBAYASHI 1953[16], 1955[17]), wherein the average frequency-patterns of the driven waves can easily be obtained.

In the control tracing before initiation of the stimulation, its average time-pattern was obtained by our new method (SATO et al. 1962[31]), a modification of the above-noted new method for the average response time-patterns.

RESULTS AND DISCUSSION

As illustrated in Fig. 1, the average time-pattern (autocorrelogram) (Fig. 1, a) derived from the EEG tracing immediately before initiation of the rhythmic photic stimulation (Fig. 1, A) showed only regular periodic oscillation of intrinsic alpha activity, whereas the crosscorrelograms (Fig. 1, b-f) picked up selectively the waves relevant to the rhythmic stimulation, i.e., the driven waves themselves. In addition, the power spectra of the simple auto- and crosscorrelograms, as illustrated in Fig. 2, show the average intensity of the oscillations as ordinate and their frequencies as abscissa. Although the frequency of the intrinsic alpha waves in the control tracing was slightly lower than 11 cycles per second (c/sec), that of the driven wave was 11.4 c/sec, the same frequency of photic stimulation, and no wave of this frequency had appeared in the control. Thus the driven wave with the frequency of the flicker stimulation is the response of the brain wave generator evoked by the stimulation. The peak height in the power spectra of the driven wave shown in Fig. 2 and 3 are, therefore, the average intensity of the response, which was advocated by SATO, MIMURA et al. (1957)[33] and SATO (1959)[26] as indicating the *transforming action* and also by SATO, OZAKI et al. (1961)[34] and SATO (1962)[27] as the *activity* of the cerebral cortex in the neighbourhood of the leading electrode.

It is easier to recognize in the crosscorrelograms than in the EEG tracing themselves that the driven brain waves with the stimulating frequency are evoked even immediately after initiation of the stimulation (Fig. 1,b), when the alerting reaction or concentration of the subject's attention to the stimulation is not yet intense. When the rhythmic stimulation was continued, the driven waves were built up, as illustrated in Fig. 1, 2, and 3, more and more regularly and remarkably to a certain maximum average response, though with some fluctuation. The average intensity of the driven wave, which is shown by the peak height at the stimulation frequency in the power spectra (Fig. 2), was always the strongest in the occipital region, the second in the parietal and the weakest in the temporal region. This distribution modus over the scalp was essentially similar to that of the intrinsic alpha wave. Concerning the distribution over scalp of relaxed alpha wave amplitude, ADRIAN and YAMAGIWA (1935)[2] and many others observed only by visual inspection of EEG tracings and MOTOKAWA (1944)[19,20] by a simple but gross method, which is proved as two

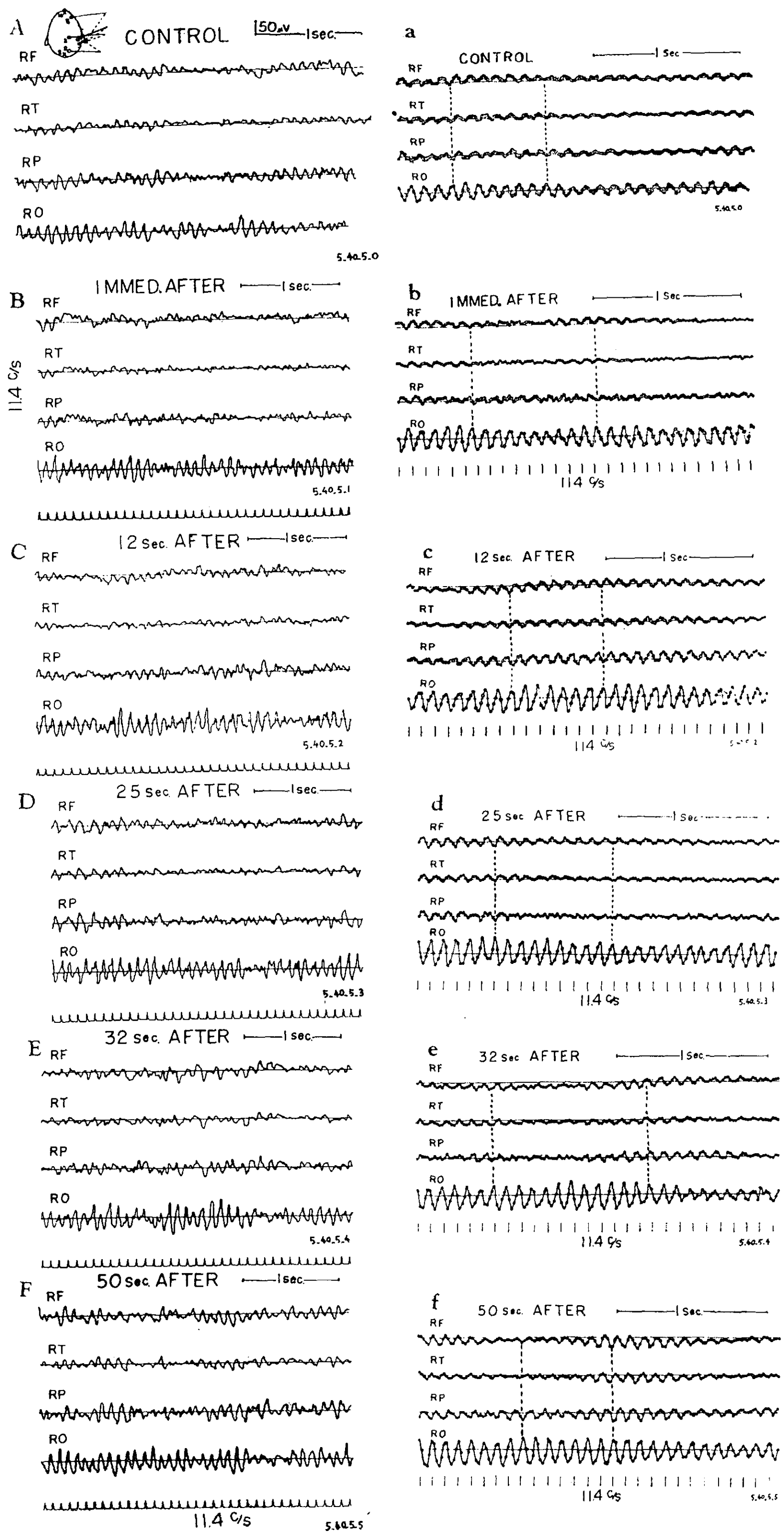
A CONTROL 50 μv 1 sec
RF
RT
RP
RO
5.40.5.0
a CONTROL 1 Sec
B IMMED. AFTER 1 sec
11.4 c/s
5.40.5.1
b IMMED. AFTER 1 Sec
11.4 c/s
C 12 Sec. AFTER 1 sec
5.40.5.2
c 12 Sec. AFTER 1 Sec
11.4 c/s
D 25 Sec. AFTER 1 sec
5.40.5.3
d 25 Sec. AFTER 1 Sec
11.4 c/s
E 32 Sec. AFTER 1 sec
5.40.5.4
e 32 Sec AFTER 1 Sec
11.4 c/s
F 50 Sec. AFTER 1 sec
11.4 c/s
5.40.5.5
f 50 Sec. AFTER 1 Sec
11.4 c/s

Fig. 1. EEG tracings before (A) and after (B-F) the initiation of photic flicker stimulation, simple autocorrelograms (a) and crosscorrelograms (b-f).

R,F,T,P and O show right, frontal, temporal, parietal and occipital respectively. B, C, D, E and F are tracings taken immediately after initiation of the flicker stimulation with frequency of 11.4 flashes per sec, 12 sec. 25 sec. 32 sec. and 50 sec. after it respectively. The stimulation is traced as a comb-like curve under the EEG tracings. "a" on the uppermost right shows the simple autocorrelograms of the tracings in "A" on the uppermost left. "b,c,d,e" and "f" show crosscorrelograms between the EEG tracings and the flicker stimulation in B, C, D, E and F respectively. Vertical lines under the crosscorrelograms are the signals of the flashes.

Dotted vertical lines in the crosscorrelograms show the phase reversal of the driven wave between occipital and other regions.

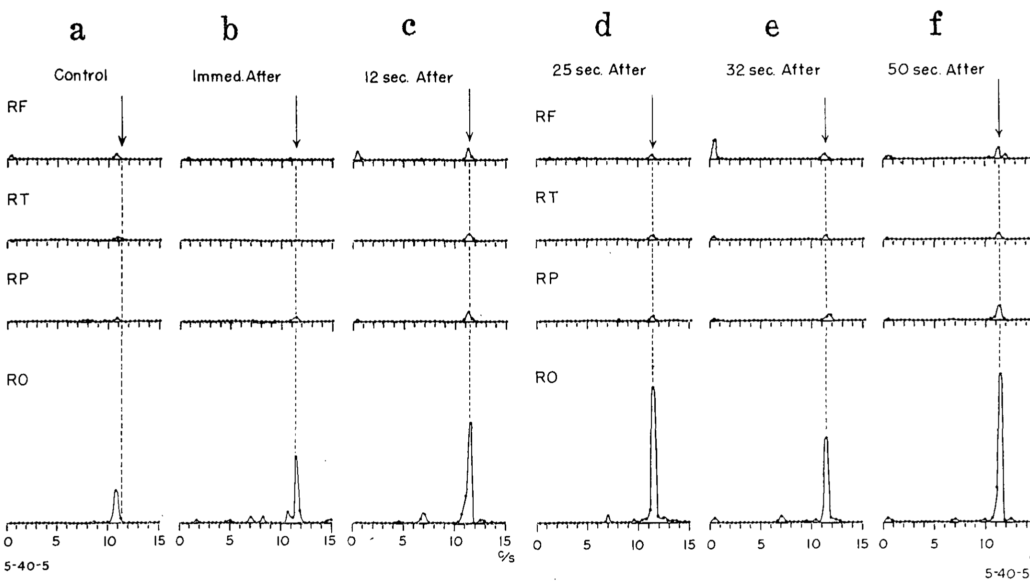

Fig. 2. Power spectra of the simple autocorrelograms (a) and the crosscorrelograms (b-f) in Fig. 1.

Abscissa· frequency per second (c/s). Ordinate: average intensity. Arrows and dotted lines perpendicular to abscissa show the frequency of photic flicker stimulation.

ordinates harmonic analysis by Sato (1954)[24]. The more exact evaluation on the average time- and frequency-pattern would be obtained without doubt from the autocorrelogram of EEG tracing during relaxed state and its power spectrum obtained by 72 or 120 ordinates harmonic analysis respectively than those by visual inspection and/or Motokawa's simple method.

It was easily recognized from the auto- (Fig. 1, a) and crosscorrelogram (Fig. 1, b-f) that there was a phase reversal of the intrinsic and the driven alpha activity between occipital and other regions except only in the later half crosscorrelograms of 32 sec. after initiation of the stimulation. The similar phase reversal in the relaxed alpha waves traced by monopolar technique was suggested also by MOTOKAWA (1944)[19, 20]. Consequently, the brain waves driven by the photic flicker stimulation with a certain frequency of alpha wave (8-13 c/sec) show the properties similar to the intrinsic alpha wave not only in the distribution of their average intensity over the hemisphere, but also in that of their phase angle, by which no essential difference would be considered in the brain wave generator activity in average during the relaxed and stimulated state, when the stimulation is moderately delivered.

By observing the resemblance between the frequency response of EEG activity in average to rhythmic photic stimulations and the power spectrum of relaxed EEG, SATO and MIMURA et al. (1957)[33] and SATO and OZAKI et al. (1961)[34] suggested that the relaxed intrinsic alpha wave may be caused by some afferent stimulation having the properties of a random stochastic process to the *brain wave generator* in the relaxed subject. And lately, BARLOW (1960)[6] verified the same average response as the relaxed alpha activity elicited by random flashing, whereas no such response was verified during sleep state. In addition, HONDA (1959)[11] demonstrated also in the frequency response of EEG activity in this state that very low peaks or no peaks appeared, in the frequency range of alpha activity but some of delta, theta activities and sleep spindles. Actually, even a relaxed subject in supine posture in a dark room cannot help getting various weak stimuli to his various extero-, intero-, and proprioceptors, every moment, and each of them may cause various regular or irregular trains of afferent impulses and form a random stochastic process as an ensemble when they flow into the brain to cause the relaxed state without concentrating subject's attention or provocating his alertness to a certain stimulus. It would not be unreasonable, therefore, to consider that the relaxed intrinsic alpha wave is also the response of the generator caused by some random *natural stimulation*[34] noted above, while the above noted driven wave is the one elicited by a rhythmic *experimental stimulation.* Thus, it would be noteworthy to note here that BARLOW (1960)[6] and MASUYA (1960)[18] obtained such an average rhythmic response by a flash stimulation that has quite similar properties to the intrinsic alpha activity in the relaxed state.

The average intensities of the driven waves with their frequencies and those of the relaxed alpha wave immediately before the initiation of the stimulation are illustrated in Fig. 3. In the occipital region, it is easily acknowledged that the driven waves with higher frequency than that of the relaxed alpha wave are elicited far more intensely than the relaxed alpha wave, while the former with lower frequency than that of relaxed alpha wave are evoked either with similar or less intensity than the latter.

In the three regions other than the occipital region, the similar

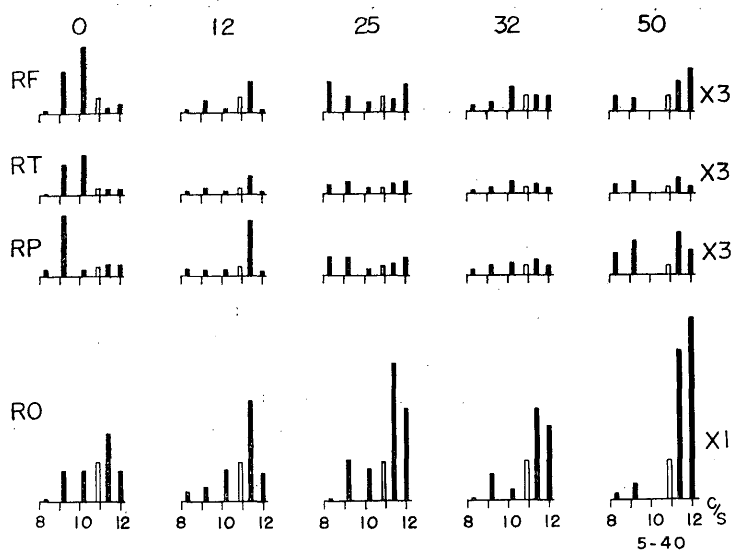

Fig. 3. Average intensities of EEGs caused by photic flicker stimulation with each of various frequencies.
Abscissa : Frequency of the driven EEG, i.e. of the stimulation.
Ordinate : Average intensity of the EEGs.

The height and the location of hollow columns show the average intensity and frequency of the relaxed alpha rhythm before the onset of the stimulation respectively. Those of the black columns indicate the average intensity and frequency of the driven EEGs. The numerals 0, 12, 25, 32 and 50 on the uppermost show immediately after, 12 sec. 25 sec. 32 sec. and 52 sec. after the onset of the stimulation respectively and the height of the columns with the numeral ×3 (RF, RT and RP) on their right are enlarged three times higher than those (RO) with the numeral ×1.

tendency to that of occipital region was produced 12 seconds after the onset of the stimulation, but a reverse phenomenon was observed immediately after the onset of the stimulation. In addition, a combined phenomenon of the above noted two tendencies seemed to appear 25, 32 and 50 seconds later.

REFERENCES

1) Adrian, E.D. and Matthews, B.H.C., *Brain* 57 : 355 (1934).
2) Adrian, E.D. and Yamagiwa, K., *Brain* 58 : 323 (1935).
3) Adrian, E.D., *Nature* 153 : 360 (1944).
4) Adrian, E.D., *The Physical Background of Perception*. Oxford : Clarendon Press (1947).
5) Barlow, J.S., IRE Trans. *Medical Electronics*, M.E-11 : 179 (1959).
6) Barlow, J.S., *Electroenceph. clin. Neurophysiol.* 12 : 317 (1960).
7) Barlow, J.S., Brazier, M.A.B. and Rosenblith, W.A., *Proc. 1st Nat. Bioph. Conf.*, 622 (1959).
8) Brazier, M.A.B. and Casby, J.U., *Electroenceph. clin. Neurophysiol.* 4 : 201 (1952).

9) Brazier, M.A.B. and Barlow, J.S., *Electroenceph. clin. Neurophysiol.* **7** : 463 (1955).
10) Brazier, M.A.B. and Barlow, J.S., *Electroenceph. clin. Neurophysiol.*, **8** : 325 (1956).
11) Honda, N., *Nô to Shinkei* **11** : 937 (1959). (Japanese).
12) Ilianok, V.A., *Dokl. Akad. Nauk. SSSR*, **129**:228 (1959).
13) Imahori, K. and Suhara, K. *Folia Psych. Neurol. Jap.*, 3:137 (1949).
14) Golla, F.L. and Winter, A.L., *Electroenceph. clin. Neurophysiol.*, **11** : 539 (1959).
15) Kaneko, Z., Hidaka, Y., Hishikawa, Y., Shimizu, A. and Miyazaki, K., *Folia Psych. Neurol. Jap.*, **15** : 206 (1961).
16) Kobayashi, T., *J. Met. Soc. Japan, Series II*, **31** : 370 (1953). (Japanese).
17) Kobayashi, T., *J. Met. Soc. Japan, Series II*, **33** : 68 (1955).
18) Masuya, S., *Nô to Shinkei* . **12** : 101 (1961). (Japanese).
19) Motokawa, K., *Tohoku Jour. Exp. Med.*, **46** : 382 (1944).
20) Motokawa, K. and Tuziguti, K., *Jap. Jour. Med. Sci. III, Biophy.* **10** : 23 (1944).
21) Motokawa, K. and Tuziguti, K., *Tohoku Jour. Exp. Med.*, **48** : 73 (1944).
22) Mundy-Castle, A.C., *Electroenceph. clin. Neurophysiol.*, **5** : 1 (1953).
23) Mundy-Castle, A.C., *Electroenceph. clin. Neurophysiol.*, **5**: 187 (1953).
24) Sato, K., *Folia Psych. Neurol. Jap.*, **8** : 232 (1954).
25) Sato, K., *Folia Psych. Neurol. Jap.*, **10** : 283 (1957).
26) Sato, K., *Jap. Jour. Physiol.*, **9** : 327 (1959).
27) Sato, K., *Kagaku (Science)*. **32** : 253 (1962). (Japanese).
28) Sato, K., Honda, N., Ozaki, T., Masuya, S., Awazu, T., Teramoto, S. and Kitajima, K., *Proc. XIth Ann. Meet. Japan EEG Soc. and XIVth Ann. Meet. Japan EMG Soc.* **99** (1961).
29) Sato, K., Honda, N., Mimura, K., Ozaki, T., Teramoto, S. and Kitajima, K., *Electroenceph. clin. Neurophysiol.* **14** : in press (1962).
30) Sato, K., Honda, N., Mimura, K., Ozaki, T., Masuya, S., Teramoto, S., and Kitajima, K.. *Electroenceph. clin. Neurophysiol.* **14** : in press (1962).
31) Sato, K., Honda, N., Mimura, K , Ozaki, T., Teramoto, S., Kitajima, K. and Masuya, S., *Electroenceph. clin. Neurophysiol.* **14** : in press (1962).
32) Sato, K. and Mimura, K., *Jap. Jour. Physiol.*, **6** : 206 (1956).
33) Sato, K., Mimura, K., Ozaki, T., Yamamoto, Y., Masuya, S. and Honda, N., *Jap. Jour. Physiol.*, **7**:181 (1957).
34) Sato, K., Ozaki, T., Mimura, K. Masuya, S., Honda, N., Nishikawa, T. and Sonoda, T., *Electroenceph. clin. Neurophysiol.*, **13** : 208 (1961).
35) Sato, K., Sonoda, T., Nishikawa, T. and Mimura, K., *Acta Med. Nagasaki.* **5** : 188 (1961).
36) Sonoda, T., *Nihon Shinkei-Shi* **62** : 925 (1960). (Japanese).
37) Suhara, K., *Folia Psych. Neurol. Jap.* **6** :1 (1952).
38) Toman, J., *Jour. Neurophysiol.*, **4** : 51 (1941).
39) Ulett, G.A. and Johnson, L.C., *Jour. Nerv. Ment. Dis.* **126** : 153 (1958).
40) Walter, W.G., Dovey, V.J. and Shipton, H., *Nature*, **158** : 540 (1946).
41) Walter, V.J. and Walter, W.G., *Extrait des Rapports du 2 Congrès de l'Éectroencencéphalographie.* Paris, (1949).
42) Walter, V.J. and Walter, W.G., *Electroenceph. clin. Neurophysiol.* **1** : 55 (1949).