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Application of EEG-Interval-Spectrum-Analysis (EISA) to the Study of Photic Driving Responses

A Preliminary Report*

Takanori Fukushima

Neurochirurgische Universitätsklinik, Klinikum Steglitz
der Freien Universität Berlin (Direktor: Prof. Dr. W. Umbach)

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Summary. Photic driving responses were analyzed by means of Tönnies' EISA method in 65 normal subjects, 20 patients with brain tumor and 4 cases of severe head injury. The response patterns were classified into 5 types, incidence of which in normals were 1. all band-responsive type (38%), 2. θ-α type (8%), 3. α-β type (32%), 4. β type (8%) and 5. non-responsive type (14%). Each response pattern was compared with the resting EEG activities, however, no significant relationship was found between them. The responses of patients with brain tumor or severe head injury were considerably reduced. The reduction of the photic driving responses in brain tumor cases was not specific to the localization of the tumor. It seems to represent the diminution of the general cerebral reactivity corresponding to the severity of the brain damage. Our results have confirmed that EISA is a simple and practical method for the frequency analysis of long duration and suitable for routine clinical examination.

Key words: EEG — Visual Evoked Responses — Interval Spectrum Analysis — Photic Driving Response — Brain Tumor — Normal Man.

Zusammenfassung. Die Reaktionen auf rhythmische photische Stimulation wurden mit Hilfe eines EISA-Gerätes bei 65 gesunden Versuchspersonen, 20 Patienten mit Hirntumor und 4 Fällen schweren Schädelhirntraumas analysiert. Bei Gesunden konnten 5 Reaktionsmuster klassifiziert werden: 1. all band-responsive Typ, 2. θ-α Typ, 3. α-β Typ, 4. β Typ und 5. non-responsive Typ. Jedes Reaktionsmuster wurde mit dem Ruhe-EEG verglichen, es fand sich jedoch keine signifikante Korrelation. Die Reaktion der Patienten mit Hirntumor oder schwerem Schädeltrauma waren erheblich vermindert. Die Minderung der Reaktionen bei Hirntumor-Fällen war nicht abhängig von der Tumorlokalisation. Sie scheint die Herabsetzung der allgemeinen cerebralen Reaktivität, hervorgerufen durch das Ausmaß der Gehirnschädigung, widerzuspiegeln. Unsere Ergebnisse bestätigen, daß das EISA-Verfahren eine einfache und praktische Methode für die Langzeit-Frequenzanalyse ist und sich als klinische Routineuntersuchung eignet.

Schlüsselwörter: EEG — Licht evozierte Potentiale — Intervallspektrumanalyse — Photic driving — Hirntumor — Gesunde.

The examination of driving responses to rhythmic photic stimulation is now performed as a routine provocation in the most of clinical EEG laboratories. A number of publications have been issued concerning the normal response pattern [8, 9, 14] and their changes in pathological conditions [3, 4, 7, 10, 12, 13]. It has been emphasized that some automatic frequency analyzer is essential for the analysis of photic driving responses [9, 12, 14]. Various kinds of electronic analyzers have been

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reported [2]. The well-known Walter type wave-analyzer using band pass filters and integrators [1] is not reliable enough because of artifacts contamination. The spectral analyses with Fourier transformation [5] or other principles [6] are essentially periodic and need complicated computer works. Tönnies (1969) described a new simple method of EEG interval spectrum analysis (EISA) based on the principle of a digitized interval point coding which is suitable for a continuous aperiodic frequency anylsis [11]. The present report deals with its application to the analysis of photic driving responses.

Material and Method

The subjects examined were 65 normal adults, mean age 44 years, 20 patients with brain tumor, mean age 49 years and 4 cases of severe head injury with signs of decerebration and without peripheral optic nerve injury (positive VEP, no optic atrophy etc). All subjects were recumbent relaxed with their eyes closed in a shielded chamber. The EEGs were recorded bipolar on a conventional EEG apparatus (Schwarzer, model 1220) with the time constant of 0.3 sec and the upper frequency cut of 70 Hz. Disc electrodes were placed in Oz-Fz, O1-F3 and O2-F4 according to the international 10—20 system (Jasper, 1958). In several cases, electrode montage of Oz-Cz were also used. The photic stimulation was generated by a 15 W Xenon lamp stroboscope (Knott, type STRN) giving a blue-with flash of 10 μsec durationt at the flash energy of 0.725 Joule. Stimulus frequencies were varied continuously from 4 to 24 Hz, so that responses to 10—20 different frequencies were obtained. Duration of each stimulus were 15 to 20 sec. The flash lamp was placed about 25 cm away from the subject's eyes. EEG signals were stored in a magnetic type for an occasional later analysis and fed to an EISA apparatus (Tönnies, 1969). By this method each interval of EEG waves at the level of one third of the average amplitude is automatically measured, digitalized and displayed oscillographically as a point corresponding to the frequency bands of 1 to 30 Hz. The sweep speed of 1 min per division was selected (Figs. 1—4).

Results

Corresponding to the responsiveness at the fundamental frequencies of photic stimulation, the patterns of driving responses were classified into 5 types: 1) all band-responsive type, 2) θ-α type, 3) α-β type, 4) β type and 5) non (or minimal)-responsive type. They are summarized in Table 1. There was no case responding only at the θ band or at the α band. 86 % of the normal subjects responded more or less to some frequency bands of the photic stimulation and 14 % were non-responsive. Fig. 1 shows a case of all band-responsive type. Fundamental responses to every frequency of photic stimulation are clearly demonstrated as a diagonal band of white dots.

Fig. 2 shows other response patterns: θ-α type, α-β type and β type. Driving responses in α and β bands were commonly observed (78 %), whereas those in θ band (6,7 Hz) were noticed in 46 % of normal subjects (Table 1). Responses at the frequencies less than 5 Hz were rare. Subharmonic responses were noted in 84 % of responsive cases and harmonic responses in 72 %. Amplitudes of the responses increased usually more than the resting activities, however, 15 cases showed on the contrary some amplitude decrease with good driving. Table 2 indicates a relationship between the resting EEG activities and the response patterns. Resting activities were divided into 2 groups: 1) α dominant group and 2) β dominant or diffuse activity group. Response patterns were compared with the resting EEG activities, but no significant relationship was found.

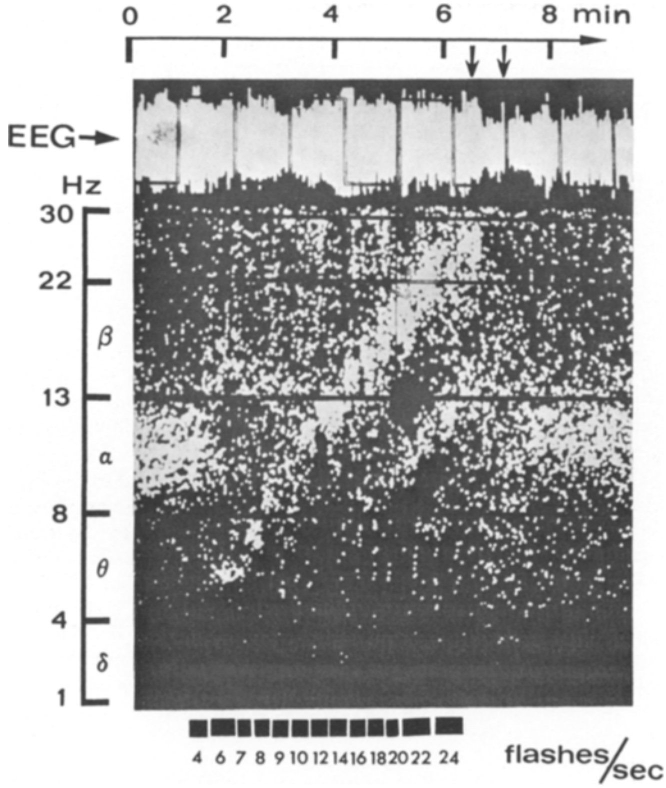

Fig. 1. A case of all band-responsive type (F. E. 26 y., female): The upper white band represent a condensed EEG showing amplitude increase during photic stimulation. A suppression period of some 40 sec was noted after the end of stimulation (double arrow, upper between 6 and 8). Fundamental responses to a series of flashes are clearly demonstrated as a diagonally shaped accumulation of the dots. Harmonics and subharmonics are also present. Note the rather better responses in θ and β than α band despite the α dominant resting activity. The ordinate on the left indicates the frequency bands (δ, θ, α, β) of EEG waves. Abscissa shows the EEG time course in minutes. The amount and duration of flashes are indicated below

As compared to the normal subjects, the responsiveness of patients with brain tumor was considerably reduced. Table 1 indicates that 40% were non-responsive type. Even the responsive cases showed far reduced driving responses, which were often much irregular and diffuse. There were only 2 cases, a case of convexity meningioma and a temporal astrocytoma, which had good driving responses. Although the reduction of responses was observed in all fundamental and harmonic frequencies, the responses at faster frequencies seemed to be reduced much more. Fig. 3 demonstrates poor driving responses of 2 brain tumor cases. The responses in 4 cases of severe head injury with decerebration (so-called apallic syndrome) were also considerably reduced. The averaged visual evoked potentials (VEP) in these cases were almost normal. Fig. 4 is an example of such case showing no driving response with normal VEP.

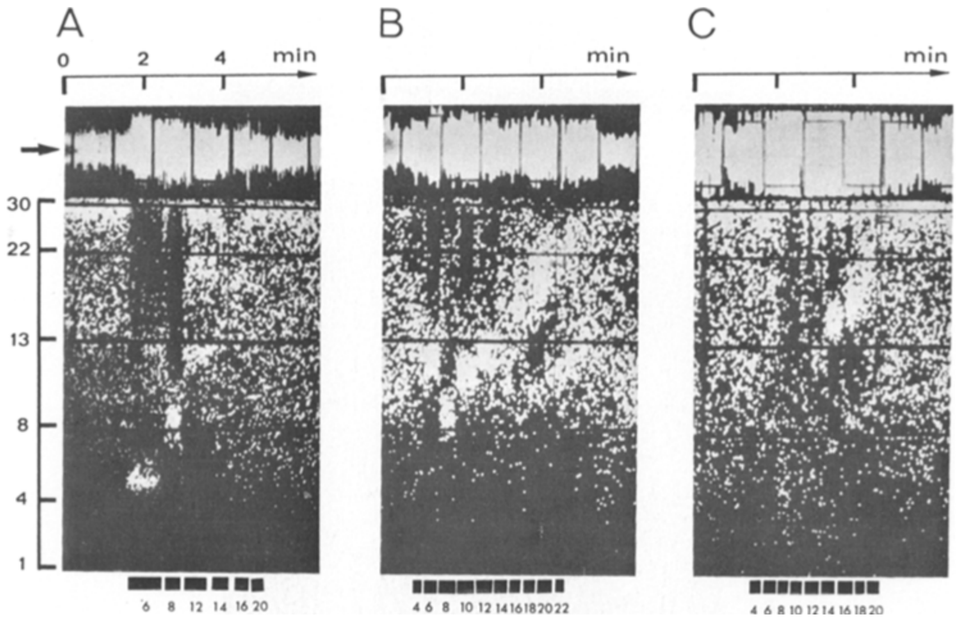

Fig. 2A—C. Examples of other response patterns: (A) θ-α type (B. H. 55 y., male). Note the remarkable fundamental driving at 6 flashes per second with amplitude increase; (B) α-β type (S. H. 48 y, male); (C) β type (K. H. 44 y., male). Ordinate and abscissa are the same as in Fig. 1

Table 1. Incidence of response patterns: The patterns of driving responses are classified into 5 types. 86% of normal subjects responded to one or more frequency bands of the photic stimulation. In the patients with brain tumor or severe head injury, non-responsive type was frequently observed and even the responsive cases showed far reduced driving responses

	All band-responsive type	θ-α type	α-β type	β type	non (or minimal)-responsive type
Normal subjects 65	25 (38%)	5 (8%)	21 (32%)	5 (8%)	9 (14%)
Patients with brain tumor 20	5	3	4	0	8 (40%)
Patients with severe head injury 4		1	1		2

Table 2. Resting EEG activities and response patterns: The resting EEG activities of normal subjects were divided into 2 groups, 1) α dominant and 2) β dominant or diffuse activity group. There is no significant relationship between the resting activities and response patterns

Resting EEG activity	All band-responsive type	θ-α type	α-β type	β type	Non (or minimal)-responsive type
α dominant 39	17	3	14	2	3
β dominant or diffuse activity 26	8	2	7	3	6

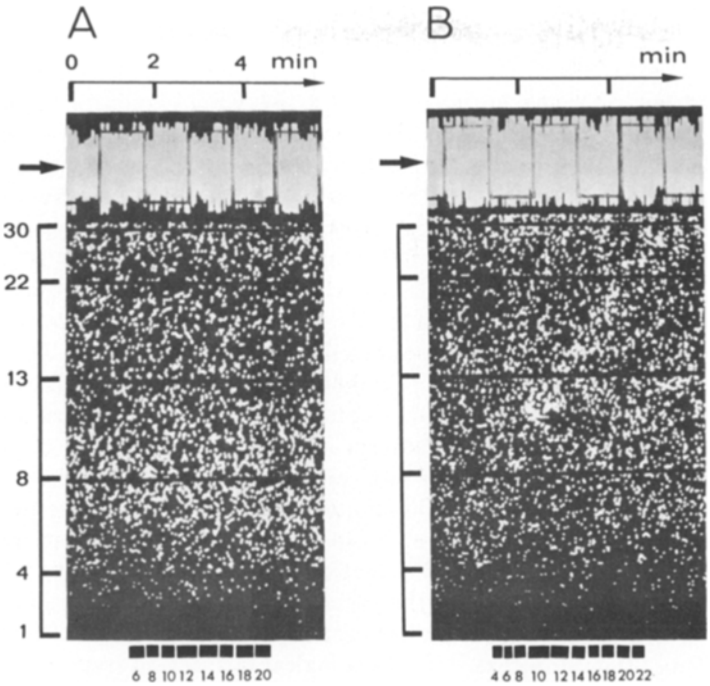

Fig. 3 A and B. Driving responses of patients with brain tumor: (A) Left occipital glioma (B. E. 30 y, female) showing non-responsive type. (B) Left frontal meningioma (W. W. 69 y., male) showing α-β type. The responses, however, are considerably reduced

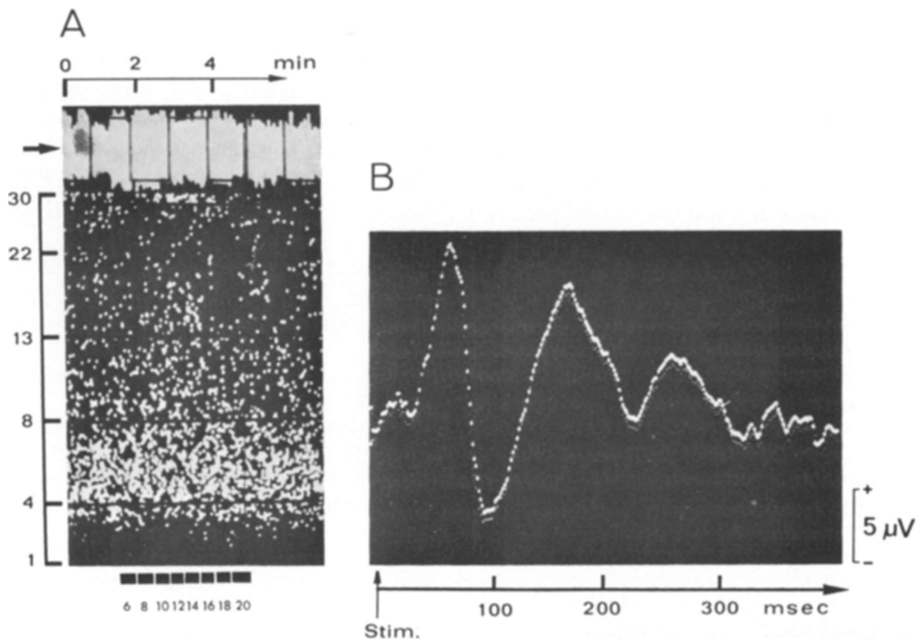

Fig. 4. (A) Driving responses of a patient (K. E. 46 y., female) with severe head injury. Resting EEG activities were irregular θ rhythm and almost no driving response was observed. (B) Averaged visual evoked potential (VEP) of the same patient showed normal response

Discussion

As pointed out by many investigators [8, 9, 14], EEG responses to rhythmic photic stimulation showed considerable individual differences. The author had arbitrarily classified these various response patterns into 5 types. Montagu [8] as well as other authors [7, 9] reported the close relationship between the dominant α resting activity and the driving responses at 8—12 Hz. They also noted the correlation between the dominant fast rhythms and the responses at 20—24 Hz. The present results revealed no significant relationship between the spontaneous rhythms and the response patterns. In some cases, the better responses at β and θ frequencies were found in spite of the prominent α background (Fig. 1). The data on the incidence of harmonics (72%) and subharmonics (84%) also disagree with those of Kooi [7] and Mundy-Castle [9]. One must be careful to diagnose abnormal driving responses, because normal subjects showed a wide variety of response patterns, and even 14% of them were non-responsive type. Nevertheless, patients with brain tumor responded to photic stimulation poorly. The reduction of the driving responses was not specific to the location of the tumor, but rather it seemed to represent, irrespective to the localisation, the diminution of the general cerebral reactivity corresponding to the severity of the brain damage or clinical neurological deficits. A similar finding has been reported by Kooi and Thomas [7]. Cantor and Ilbag [3] described recently paradoxical facilitation responses in cases of unilateral brain lesions, but no such facilitation was found in the present examination. It is interesting to note the discrepancy between the poor driving responses and the normal VEPs in the cases of severe head injury. Presumably, the more complicated cerebral integration may be necessary for the manifestation of the photic driving responses.

The present study has demonstrated the value of EISA for the examination of photic driving responses. This method is according to Tönnies [11] more accurate than the band pass filter and properly sensitive as compared with Fourier analysis. The most prominent feature is the continuous and aperiodic recording which is suitable for the frequency analysis of long duration. Although the present EISA apparatus is a qualitative one and not quantitative, it is simple, practical and useful for the routine clinical EEG examination.

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Dr. T. Fukushima
Neurochirurgische Universitätsklinik
Klinikum Steglitz
D-1000 Berlin 45
Hindenburgdamm 30