Power Spectral Analysis of Photic Driving Elicited by Flickering Dot Pattern and Red Flicker Stimuli in Adult Psychiatric Outpatients — With Special Reference to Age and Gender

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Takahashi, T., Kataoka, K. and Tsukahara, Y. Power Spectral Analysis of Photic Driving Elicited by Flickering Dot Pattern and Red Flicker Stimuli in Adult Psychiatric Outpatients — With Special Reference to Age and Gender. Tohoku J. exp. Med., 1988, 156 (2), 165-173 — Power spectrum of photic driving elicited by 5/sec flickering dot pattern (FDP) and 5/sec red flicker (RF) stimuli was investigated in 137 psychiatric outpatients. They consisted of 61 adults (33 males and 28 females) from 20 to 44 years of age, 55 preseniles (25 males and 30 females) from 45 to 64 years and 21 seniles (9 males and 12 females) over 65 years of age. Powers of 5 and 10/sec photic driving elicited by FDP and RF stimuli were greater than those of the other higher harmonics and increased significantly with age. When such a finding was compared in relation to gender, significant increase of power with age was found for 5 and 10/sec photic driving elicited by both stimuli in females, whereas it was found only for 5/sec photic driving elicited by RF stimulation in males. Our findings suggest that the visual system of older female patients is very responsive not only to patterned stimuli but also to red flicker stimulation. —— photic driving; geometric pattern; red color; aging; gender

Within a span of four decades since the first report by Walter et al. (1946) appeared, intermittent photic stimulation by the use of stroboscopic white light (to be abbreviated as IPS, hereafter) has been the most common method for eliciting photic driving in a routine EEG examination. Studies dealing with the activation of photoconvulsive response have revealed that visual simuli of flickering geometric pattern (Jeavons et al. 1972; Engel 1974; Panayiotopoulos 1974; Takahashi and Tsukahara 1975) and red flicker (Carterette and Symmes 1952; Takahashi and Tsukahara 1976) were more effective in provoking photoconvulsive response than IPS. Application of flickering dot pattern and red flicker stimuli

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165
to eyes in their open state also gave rise to higher amplitude photic driving than that evoked by IPS when applied to eyes both closed and open (Takahashi and Tsukahara 1979; Takahashi et al. 1980, 1981); the stimuli used in those studies were of 5/sec flicker frequency with the maximal brightness of 20 cd/m², and as such far less intense than those resulting from an ordinary IPS.

In a previous study of photic driving experienced by 137 adult psychiatric outpatients, we found that the maximal amplitude of 5/sec fundamental photic driving elicited by 5/sec flickering dot pattern and red flicker stimuli increased significantly with age in females and in both males and females, respectively (Takahashi and Tsukahara 1988).

Since the amplitude measurement was carried out by visual inspection, the power spectrum of the photic driving of the same patients was analized in order to know whether the above findings were consistent not only in fundamental driving but also in the harmonic driving, particularly in cases which were unable to be accurately measured by visual inspection.

**Subjects and Methods**

One hundred thirty seven adult psychiatric outpatients over 20 years of age were chosen as subjects. In each case EEG was examined because of various reasons during the period of November 1984 to June 1986. The subjects were divided into three groups: adults from 20 to 44 years of age (30.6±6.8 years), preseniles from 45 to 64 years of age (55.3±5.4 years) and seniles over 65 years of age (70.0±6.1 years). In the adult group, there were 61 patients (33 males and 28 females) with neurosis (27), schizophrenia (11), syncope (9), headache (5) and other diseases (9); In the presenile group, there were 55 patients (25 males and 30 females) with neurosis (20), cerebral arteriosclerosis (12), depression (6) and other diseases (17); In the senile group, there were 21 patients (9 males and 12 females) with cerebral arteriosclerosis (18), neurosis (2) and parkinsonism (1). In this study, patients with epilepsy as well as patients having definite focal cerebral disorders, such as brain tumor or cerebral infarction, were not included because unusual photic drivings with very high amplitude and/or with marked asymmetry are not infrequently observed in those patients (Takahashi 1987); none of the patients had apparent visual disturbance, such as cataract, nor anomalous color sensation, both of which were considered to influence the appearance of photic driving.

With regard to routine EEG examination, abnormal findings were observed in 8 (13%) cases in adults, 12 (22%) cases in preseniles and 8 (38%) cases in seniles; none of them, however, showed continuous unilateral posterior abnormalities.

Visual stimuli of 5/sec flickering dot pattern (FDP) and 5/sec red flicker (RF) were obtained by the use of a visual stimulator (SLS-5100, Nihon Kohden, Tokyo) (Takahashi et al. 1980; Takahashi 1987). The subject, in a sitting position, looked at a tangent screen set 25 cm from the eyes, and the stimuli were projected on the screen measuring 25×25 cm (53'×53'). The maximal brightness of the ground of dot pattern (the visual angle of a single dot being 1.33 degrees) was 20 cd/m², whereas that of red light was 10 cd/m²; these stimuli were modulated sinusoidally at a frequency of 5/sec whereby yielding FDP and RF stimuli.

Prior to each stimulation, the subjects were instructed to look at the central part of the screen as much as possible without blinking. Then both FDP and RF stimuli, given in no specific order, were presented for 7 sec each with an interval of 20 to 30 sec. The subjects wearing glasses had the examination with their glasses on; those who were on medication
Electrodes for the EEG recording were attached to the scalp with paste, placed according to the International 10-20 system. The EEG was recorded from the left and right frontal-pole, frontal, central, parietal, occipital, anterior-temporal, mid-temporal and posterior-temporal regions by means of a 17-channel electroencephalograph (EEG-4217, Nihon Kohden); monopolar derivation with ipsilateral ear lobe reference was used; low cut and high cut filters were set at 0.1 sec and 60 Hz, respectively.

Activated EEGs were simultaneously recorded by a 12-channel tape recorder (UFR-61430, Sony, Tokyo). Power spectral analysis by a microcomputer (ATAC-450, Nihon Kohden) was made only on the EEGs obtained from both occipital areas (01 and 02), where the most apparent photic driving in response to FDP and RF stimuli was observed (Takahashi and Tsukahara 1988). Because the initial part of the recording was occasionally contaminated by artifacts, such as blinking, power spectral analysis was made on the record for 5 sec after the stimulation of 2 sec. Power spectrums were calculated based on the fast Fourier transform algorithm (Press et al. 1986). The root of each power was expressed as indicating amplitude for convenience.

Results

In a previous report (Takahashi and Tsukahara 1988), EEG changes in response to FDP and RF stimuli in a female patient with cerebral arteriosclerosis were demonstrated as an example of photic driving. In order to easily be understood the results of this study, the raw data of power spectral analysis of photic driving obtained from the same patient are shown as an example (Fig. 1). In this case, it became evident that FDP stimulation chiefly elicited fundamental photic driving, whereas RF stimulation elicited higher harmonic photic drivings at frequencies of 10 and 15/sec.

Each peak of the power spectra at the frequencies of 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 Hz were observed after the stimulation of 5/sec flickering dot pattern (FDP) and 5/sec red flicker (RF) in a 66-year-old female patient with cerebral arteriosclerosis. The vertical scale shows the root of power, indicating amplitude (μV) for convenience.

Fig. 1. An example of power spectral analysis of photic driving elicited by the stimuli of 5/sec flickering dot pattern and 5/sec red flicker in a 66-year-old female patient with cerebral arteriosclerosis. Tracings on the left and right indicate power spectra of photic driving recorded from the left and right occipital area, respectively. Vertical scale shows the root of power, indicating amplitude (μV) for convenience.
40, 45 and 50/sec was measured; this is carried out on that of both photic drivings elicited by FDP and RF stimuli in each patient, and the results were expressed as amplitude for convenience.

**Photic driving in relation to age**

Because the amplitude of the photic drivings at the frequencies of more than 30/sec was very minimal, the following analyses were made for that of 5, 10, 15, 20 and 25/sec. The results shown in Fig. 2 illustrate the mean amplitude of the left and right occipital photic driving evoked by both stimuli. The amplitudes of 5 and 10/sec photic driving elicited by both stimuli were apparently greater than the others. Therefore, further statistical analyses by use of the t-test were made on 5 and 10/sec photic driving evoked by both stimuli.

The following shows the mean amplitude (± S.D.) of the left and right occipital 5 and 10/sec photic driving evoked by both stimuli.

**5/sec photic driving evoked by FDP stimulation**
- Adults: 6.76 ± 3.96 µV; preseniles: 9.65 ± 7.25 µV; seniles: 13.71 ± 7.35 µV.

**10/sec photic driving evoked by FDP stimulation**
- Adults: 5.18 ± 2.77 µV; preseniles: 7.47 ± 4.30 µV; seniles: 10.50 ± 7.77 µV.

**5/sec photic driving evoked by RF stimulation**
- Adults: 5.02 ± 2.35 µV; preseniles: 6.08 ± 3.02 µV; seniles: 9.81 ± 6.81 µV.

![Power spectrum of photic driving evoked by 5/sec flickering dot pattern stimulation](image-url)

![Power spectrum of photic driving evoked by 5/sec red flicker stimulation](image-url)

Fig. 2. Averaged power spectrum of photic drivings elicited by the stimuli of 5/sec flickering dot pattern and 5/sec red flicker in a total of 137 psychiatric outpatients. Horizontal scale shows the root of power, indicating amplitude (µV) for convenience. *p < 0.05; **p < 0.01. senile, over 65 years; presenile, 45-64 years; adult, 20-44 years.
Fig. 3. Coefficient of correlation between age and power of 5/sec photic drivings elicited by the stimuli of 5/sec flickering dot pattern and 5/sec red flicker in male and female patients. Vertical scale shows the root of power, indicating amplitude (μV) for convenience.

Fig. 4. Coefficient of correlation between age and power of 10/sec photic drivings elicited by the stimuli of 5/sec flickering dot pattern and 5/sec red flicker in male and female patients. Vertical scale shows the root of power, indicating amplitude (μV) for convenience.
10/sec photic driving evoked by RF stimulation
Adults: $6.96 \pm 5.42 \mu V$; preseniles: $8.17 \pm 5.03 \mu V$; seniles: $10.33 \pm 5.91 \mu V$.

As shown in Fig. 2, the amplitude of photic driving elicited by both stimuli was greatest in seniles, followed by preseniles and adults; excepting 10/sec photic driving evoked by RF stimulation in adults and preseniles, the amplitude difference of the photic driving between adults and preseniles, preseniles and seniles, and adults and seniles was significantly different.

Photic driving in relation to age and gender
Concerning 5 and 10/sec photic driving elicited by both stimuli, the relationship of photic driving to age and gender was statistically analyzed by use of the z-test. As shown in Figs. 3 and 4, a significant increase of amplitude of 5 and 10/sec photic driving elicited by both stimuli was found in female patients, whereas it was found only for 5/sec photic driving elicited by RF stimulation in male patients.

DISCUSSION
The main results obtained in this study may be summarized as follows. 1. Powers of 5 and 10/sec photic driving elicited by FDP and RF stimuli were greater than those of the other higher harmonics and increased significantly with age. 2. When such a finding was compared in relation to gender, significant increase of power with age was found for 5 and 10/sec photic driving elicited by both stimuli in females, whereas it was found only for 5/sec photic driving elicited by RF stimulation in males. First of all, with regard to both fundamental drivings, results obtained by visual inspection as described earlier and those achieved by power spectral analysis are in accordance.

Hughes and Cayaffa (1977) reported that photic driving elicited by IPS slowly increased with age to reach a peak in the 40's and then rapidly diminished. According to Yoshida (1981), who studied photic driving in normal subjects over 60 years of age, photic driving significantly decreased with age. Because of the different method utilized in those studies, direct comparisons with our data are difficult to make. The visual stimuli of FDP and RF with the brightness of 10–20 cd/m² are far less intense as compared to that of IPS; for example, the brightness of IPS that we used in the previous study (Takahashi and Tsukahara 1988) was 5023 cd/m². Nevertheless, such FDP and RF stimuli applied to eyes in their open state usually elicit higher amplitude photic driving than that administered by IPS to eyes both in closed and open states (Takahashi 1987). It should also be mentioned that the patients having visual disturbances, such as cataract, were excluded in this study. Granted such a limitation, photic driving elicited by FDP and RF stimuli may give us useful information regarding aging and gender differences because in this study its amplitude increased significantly,
particularlly in aged female patients.

In a previous study (Takahashi et al. 1979) of photic driving evoked by FDP stimulation in normal subjects of the 20's as well as in adult psychiatric patients including epileptics, we found that the amplitude of 5/sec photic driving measured by visual inspection was significantly higher in females than in males. Such differences between the sexes in response to visual stimuli have already been known as Shagass (1955) reported that women showed higher-amplitude photic driving elicited by ordinary IPS. Concerning visually evoked potentials (VEPs) elicited by stroboscopic light stimulation, Rodin et al. (1965), Shagass and Schwartz (1965) and Buchsbaum et al. (1974) found higher amplitudes and shorter latencies in females than in males. By the use of dot pattern and grating, Aoki (1976) found that VEPs evoked by patterned stimuli were greater in females than in normal healthy male children and adults; a similar finding was observed for VEPs elicited by red color stimulation as well. As for pattern reversal evoked potential (PREP), La Marche et al. (1986) reported that PREP waves N70-P100 and P100-N150 from the older females aged 55-70 years were significantly greater than those from a male group of the same age and from younger females and males aged 25-35 years; as for the older women, unusually large potentials were also obtained for VEPs elicited by patterned flashes. On the other hand, it is a well-known fact that photoconvulsive response is more frequently observed in females than in males (Newmark and Penry 1979); with regard to photoconvulsive responses provoked by the stimuli of flickering pattern and red flicker, those of females were three times more frequent than those of males (Takahashi and Matsuoka 1981). All these evidences, together with the findings in this study, would indicate that the reactivity to the visual stimuli in the brain may be different in both sexes, females being more responsive than males.

The results obtained in this study suggest that age also plays an important role in the appearance of photic driving because in both sexes our data showed significant increase of powers with age. In males, however, it was observed only for 5/sec photic driving elicited by RF stimulation. Such an increased reactivity to the visual stimuli in aged subjects, therefore, appears to be related to the aging processes in the visual system including the striate and extrastriate cortices.

According to Niedermeyer (1963), a prominent enhancement of photic driving in response to IPS is a common finding in patients with vertebrobasilar artery insufficiency in association with a generally low voltage record. However, Niedermeyer (1987) states that the enhanced photic driving, as such, is nonspecific and probably caused by increased excitability of the mildly ischemic occipital cortex as suggested by Scheuler (1983).

In this study, the subjects were various psychiatric outpatients being treated with different drugs. The number of the patients with each disorder was also different in the three groups; for example, the percentage of the patients with cerebral arteriosclerosis in the adult, presenile and senile groups was 0%, 22% and
86%, respectively. In addition to the factors of age and gender discussed above, such a diversity in the patients examined and in the drugs used is thought to have played another important role influencing the appearance of the photic driving as well.

Meanwhile, we carried out a correlative study of clinical findings to photic driving elicited by FDP and RF stimuli in 206 psychiatric outpatients over 45 years of age (Takahashi 1988). When the patients were largely divided into 1. dementia of the Alzheimer type (11 cases), 2. cerebral arteriosclerosis (67 cases), 3. depression (46 cases) and 4. neurosis (82 cases), amplitudes of the fundamental driving measured by visual inspection were greatest in 1, followed by 2, 3 and 4. This result suggests that not only the aging processes but also some degenerative changes in the brain associated with dementia and/or amnesia may enhance the appearance of the photic driving with increased amplitude. As has been emphasized in the previous studies (Takahashi 1987; Takahashi and Tsukahara 1988; Takahashi et al. 1988) photic driving elicited by FDP and RF may be a useful diagnostic tool, particularly in elderly psychiatric patients such as described above. In such cases, analysis of photic driving by visual inspection as well as by power spectrum demonstrated in this study, may be needed. In order that it be used clinically, additional investigation of photic driving by FDP and RF stimuli, particularly in normal controls, remains to be done.

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References


