A STUDY OF PHOTOSENSITIVE EPILEPSY

WITH PARTICULAR REFERENCE TO OCCIPITAL SPIKES

INDUCED BY INTERMITTENT PHOTIC STIMULATION

A THESIS

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SUMMARY

This thesis is the result of an attempt to find means of diagnostic value and understand the underlying mechanisms of photosensitive epilepsy which is a variety of epilepsy where seizures are provoked by photic stimuli. A detailed review of the relative literature has been endeavoured.

The aspects dealt with were mainly concerned with electroencephalographic responses to intermittent photic stimulation.

It has been found that intermittent photic stimulation is more effective on "eye-closure" than in any other eye state and more abnormalities are induced when the eyes are open than when they are closed. The significance of light in the provocation of "eye-closure" induced discharges has been emphasized. The characteristics of the occipital spikes induced by intermittent photic stimulation have been studied.

The majority of photosensitive epileptic patients and those with epilepsy who are not clinically photosensitive but in whom E.E.G. abnormalities are provoked by intermittent photic stimulation, show occipital spikes alone or preceding photoconvulsive responses, during photic stimulation.

The occipital spikes were compared with the visual evoked responses of the same patients and of normal subjects.

This showed that there was no simple relation between occipital spikes and components of visual evoked responses.

The characteristics of the negative occipital spike show striking similarities to those of the recruiting response evoked by electrical stimulation of the non-specific thalamic nuclei as described by other authors. This may indicate that the non-specific thalamocortical system is responsible for the genesis of the "epileptogenic" occipital spikes and therefore implicated in the pathogenesis of photosensitive epilepsy. The intermittent photic stimulation showed an increased effectiveness when combined with patterns and this may be due to an increased susceptibility of the occipital cortex.

It is suggested that seizures in photosensitive epilepsy are the result of discharges arising from abnormally activated, by photic stimuli, non-specific thalamic system and impinging upon a hypersensitive occipital cortex.

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SECTION 1

LITERATURE SURVEY

1.10 GENERAL INTRODUCTION

Epileptic seizures can arise in a "spontaneous" unpredictable fashion without detectable precipitant factors, or they can be provoked by certain recognizable stimuli. The factors which contribute to the initiation of the seizures are so numerous, and their interaction so complex, that it is often impossible to define them and thus the seizures appear to arise of their own accord.

Stimuli which contribute towards the genesis of a fit can be provided by either the internal and/or the external environment of the subject. Hormones, level of electrolytes, state of consciousness and body temperature are some examples of internal factors which can alter the subject's convulsive threshold. External stimuli which may have a similar effect include electrical, biochemical, sensory, etc. stimuli.

The interaction between external and internal stimuli does, of course, exist and this explains why the effectiveness of a well-defined seizure-precipitating stimulus may vary. It also explains why one patient may experience both "spontaneous" and "induced" seizures.

Despite the difficulties in determining precipitating factors, a number of epileptic seizures can be attributed to specific stimuli. Terms used for seizures which fall into this group of epilepsy include: "reflex"; "evoked"; "precipitated"; "triggered"; and "stimulus-sensitive" epilepsy.

The photic (light) stimuli are the most common amongst the sensory stimuli that can initiate an epileptic attack, and it has been speculated (Bickford et al., 1969) that this might be related to the fact that in normal subjects, responses to photic stimulation occur more widely in the brain than those to any other sensory modality.

"Photo-sensitive" epilepsy is the most widely used term for this variety of epilepsy in which seizures are directly attributable to light stimuli. The term "photogenic epilepsy" has also been used, but this should be abandoned as the word "photogenic" is in many countries connected with a person whose features look well in a photograph (Gastaut et al., 1962). Photo-epilepsy has also been used (Bickford et al., 1969). Much confusion has arisen from the use of the terms "photogenic" and "photo-sensitive" by Doose et al., (1969)

for different groups of photo-sensitive epilepsy (see 1.31).

While a study of photo-sensitive epilepsy can be made on the basis of experiments with animals, data obtained in this manner is not always applicable to the human situation. For this reason a direct study of photo-sensitive epilepsy in human subjects is essential.

The specific nature of photo-sensitive epilepsy provides a very satisfactory situation in which to explore the condition, for the following reasons:

a. The subject's epileptogenic discharges can be readily provoked and studied under experimental conditions using intermittent photic stimulation (I.P.S.).

b. The precipitating stimulus can be controlled and measured.

c. The abnormal "output" of the patient can be recorded by electroencephalographic (E.E.G.) techniques, measured and compared with accompanying clinical manifestations and also with the responses of normal subjects under similar conditions of activation.

It should be noted that, with experience, experimental conditions can be controlled. Thus, seizure-precipitating factors can be regulated, so that sufficient data is obtained without the patient actually suffering a fit. In this manner it is hoped to collect data necessary to throw some light on the condition of photo-sensitive epilepsy.

1.20 HISTORICAL REVIEW

1.21 Light-induced Seizures

The book "On the Sacred Disease" - a collection of medical writings by Hippocrates is the first monograph on epilepsy.

In this Hippocrates considers epilepsy as being in no way different to other diseases, but believes that, "the cause lies in the brain - a brain overflowing with superfluity of phlegm. When the phlegm rushes into the blood vessels of the body it causes all the symptoms of an attack" (cf., Temkin, 1945). The sun is considered as a factor which changes the consistency of the brain and produces an epileptic attack. This was the first reference to the fact that a light source (the sun) is involved in epilepsy.

Whether Hippocrates in implicating the sun as a releasing factor of an epileptic attack was aware of photo-sensitive epilepsy is, however, open to doubt.

Many authors, (Mawdsley, 1961; Livingston et al., 1964; Lennox, 1950; Brausch et al., 1965; Troupin, 1966; Harley et al., 1967) attribute the first reference to photo-sensitive epilepsy to Apuleius in his book "Apologia" written around 125 AD.

This book is a record of a speech made by Apuleius defending himself against an accusation that he was practising magic on a young slave called Thallus. His accusers had seen the boy fall down in front of Apuleius and believed this to be sorcery. Apuleius pointed out that the boy suffered from epilepsy and said this was the cause of his collapse.

A study of the original translation of Apuleius's book shows no obvious referal to flickering light, thus:

> "Again the spinning of a potter's wheel
> will easily infect a man suffering from
> this disease with its own giddiness.

The sight of its rotations weakens his already feeble mind, and the potter is far more effective than the magician for casting epileptics into convulsions".

The above extract from the original translation (Apuleius) is obviously in contrast with statements made by some authors about "Apologia".

Mawdsley (1961) wrote: "Apuleius, a Roman contemporary of Galen, mentions in his "Apologia" that a seizure might be provoked when a potter's wheel was rotated before the eyes of a slave (Temkin, 1945). This ancient slave dealer's test for epilepsy is probably the earliest recorded association of fits with flickering light. In some the intermittent exclusion of the sunlight caused vertigo, and in some, occasionally, a seizure".

Brausch et al., (1965) wrote: "Many have been known to have a convulsion induced by light in various forms, the earliest recorded case being possibly an epileptic in ancient Greece who had a seizure when a potter's wheel was rotated in front of his eyes".

Troupin, (1966) wrote: "In clinical terms the fact that the individual can be stimulated to convulse following exposure to intermittent light stimulation has been recognized since ancient times. Apuleius in 125 AD. described the production of a flickering light stimulus by the rotation of a potter's wheel before the eyes of slaves in the market in order to determine which might have unreported epilepsy".

Harley et al., (1967) wrote: "A seizure might be provoked when a potter's wheel was rotated before the eyes. This means of distinguishing those potentially epileptic was used widely in Roman times as a slave-dealers' test and may well have been the earliest recorded association of convulsions with flickering light".

To obtain the "flickering light" or "intermittent exclusion of the sun-light" referred to by the above authors, a rotating spoked wheel would be necessary.

A communication from The British Museum confirms that there is no evidence that the potter's wheel referred to by Apuleius was spoked, and therefore could not produce flickering light when rotated.

"The passage in Apuleius seems to refer simply to the rotation of the turntable. I know of no evidence for spoked wheels in the mechanism of the potter's wheel in Roman times. The kick-wheel was certainly known (cf. Ecclesiastreus, 38, 32), but I imagine it was mounted on the same axis as the turntable and was itself also solid". (Cook, British Museum, 1970).

It should be noted that only one of our photo-sensitive epileptic patients noticed a feeling of nausea when watching the turntable of a rotating record-player.

It is therefore, only in extremely rare cases that nausea can be induced in photo-sensitive epileptic patients by watching rotating solid objects, in the absence of flickering light.

The oldest clear reference to photo-sensitive epilepsy, I know of, was made by Soranus of Ephesus (cf. Lennox et al., 1960) and it is as follows:

"The use of flame, or a very bright light obtained from flame has an agitating effect. In fact when a case of epilepsy is in its quiescent stage, the untimely use of light with its sharp penetrating action may cause the recurrence of an attack".

Gowers in 1881 presented the first scientific evidence of photo-sensitive epilepsy. In his authoritative treatise on epilepsy he reported:

"In very rare instances the influence of light seems to excite a fit. I have met with two examples of this. One was a girl of seventeen whose first attack occurred on going into bright sunshine for the first time, after an attack of typhoid fever. The immediate warning of an attack was giddiness and rotation to the left. At any time an attack could be produced by going out suddenly into bright sunshine. If there was no sunshine an attack did not occur.

The other case was that of a man, the warning of whose fits was the appearance before the eyes of "bright blue lights, like stars - always the same". The warning, and a fit, could be brought on at any time by looking at a bright light, even a bright fire. The relation is, in this case, intelligible, since the discharge apparently commenced in the visual centre".

In 1927 Gordon Holmes wrote that: "Some men subject to epileptiform attacks commencing with visual phenomena owing

to gunshot wounds of the occipital region, have told me that bright lights, cinema exhibitions and other strong retinal stimuli tend to bring on attacks".

He attributes the "reflex epilepsy" to an enhanced excitability of the cortex.

In 1932 Radovici et al., described a case of "reflex epilepsy provoked by optic excitation from rays of the sun". It concerned a man aged 20, who for ten years had suffered from a "tic". This consisted of rhythmical upward movements of the head with eyelid tremors when he looked towards the sun on bright days.

The following authors should also be mentioned as being amongst the first to report on patients showing photo-sensitive epilepsy: Catola, 1934; (cf. Robertson, 1954); Goodkind, 1936; Strauss, 1940 .

1.22 Experimentally Induced Seizures

Experimental provocation of fits in photo-sensitive epileptic patients by exposure to light sources was first detailed by Radovici et al., (1932), who were able to record by motion pictures two attacks evoked by sunlight.

Goodkind, (1936), described as follows his experimental

techniques of inducing epileptic attacks in photo-sensitive patients:

"The patient was placed on a bed in a darkened room in such a position that when the black window shade was raised her face only, was directed towards the early afternoon sunlight, which came through an ordinary wire window screen. On such exposure of the eyes to the sun, she responded within a few seconds with marked, diffuse, and apparently uncontrollable clonic jactitatory movements. The movements ceased the moment a blindfold was applied, or the black window shade was lowered. On repeated occasions during a period of three weeks the myoclonic response to various degrees of sunlight, (with exposure directly through a glass window or reflected by a head mirror) was constant, though it varied slightly in degree, apparently with the intensity of the sunlight and with the degree of the patient's irritability or "nervousness" at the time. She reacted definitely also when either eye was uncovered separately".

The patient was also exposed to ultra violet radiation from a quartz mercury vapour lamp, and to bright pocket

flash light, with little or no effect.

A small beam from a carbon arc lamp produced several rapid myoclonic jerks.

The introduction of Electroencephalographic (E.E.G.) techniques (Berger, 1929), presented opportunities for a more elaborate and detailed study of photo-sensitive epilepsy.

Adrian and Matthews, (1934) were the first to introduce Intermittent Photic Stimulation (I.P.S.) in the use of E.E.G. The subject was looking at an opal glass bowl which was illuminated from behind by a lamp, in front of which a disc with cut out sectors was rotated.

Strauss, (1940), is to my knowledge, the first scientist to use E.E.G. techniques to record epileptic seizures in human beings induced experimentally by photic stimulation.

His patient, a woman aged 33 years, had suffered right hemiparalysis and right Jacksonian fits from childhood. The epileptic attacks could be provoked by various sensory (tactile, auditory, visual etc.) stimuli.

Strauss described his techniques and E.E.G. recordings as follows:

"Flashing light into the right eye was associated with changes in the electroencephalogram. Three per second waves at high potential appeared, associated with twitching around the right corner of the mouth. The slow waves did not appear when the same stimulus was applied after cocainization of the right eye. The potentials, without a doubt, were true brain potentials, because they could not be reproduced by having the patient imitate the twitching activity. Moreover their appearance in the record from the left side makes it improbable that they represent muscle potentials from the muscles on the right side of the face".

He recommends that these stimuli should be noted not only by purely clinical observation, but also, if possible, by E.E.G. studies on the patient.

The real interest and detailed study of epilepsy by means of I.P.S. activation started in 1946, when Walter et al., (1946), using a high intensity lamp of strobotron light, found that I.P.S. could induce subjective and objective symptoms which correlated with specific E.E.G. patterns. The same authors were also able to record 3^{c}/s. spike and wave activity evoked by I.P.S. in an epileptic patient.

On this occasion the stroboscopic lamp was triggered by the patient's own electroencephalographic activity. This report was followed by the work of Gastaut and his colleagues (Gastaut, 1950; Gastaut et al., 1948 and 1949), and Walter et al., 1949 who established I.P.S. as an activating technique in E.E.G. recordings.

1.30 CLINICAL ASPECTS

1.31 Groups of Photosensitive Epilepsy.

Bickford et al., (1953) divided their photosensitive epileptic patients into the following groups:

a. A clinically sensitive group in which light of the intensity encountered in daily life is capable of inducing clinical attacks.

b. A less sensitive group in which clinical seizures can be induced only under conditions of high illumination intensity and a rapid flicker, which can be produced in the laboratory.

c. A group in which the only evidence of sensitivity is the occurrence of seizure discharge in relation to stimulation by light. A discharge is not accompanied by any detectable clinical evidence of seizure.

Doose et al., (1969a) divided the different groups of photosensitive epilepsy as follows:

" 1. "Photogenic epilepsy" in which seizures occur only under the influence of intermittent light stimulation.

2. Epilepsy in which both photogenic and spontaneous seizures occur.

3. "Photosensitive epilepsy". In such cases seizures occur independently of any detectable light stimuli. A photoconvulsive response can be revealed only by electroencephalography. In some patients, however, seizures can be triggered by very intense light stimulation under laboratory conditions."

Jeavons (1969b) divided his photosensitive epileptic patients into the six following groups:

A. Fits have occurred ONLY when watching television.

B. Fits have occurred whilst watching television, but also "spontaneously" at times when there was no evidence of flickering light as a precipitant.

C. Fits have occurred whilst watching television and also when the patient was exposed to flickering or bright light from other sources. No fit has occurred spontaneously.

D. Fits have occurred with television, with flickering light from other sources, and also spontaneously.

E. Fits have been evoked by bright or flickering light, but not by television.

F. The patient has spontaneous fits, but there is no clinical evidence of photosensitivity. All patients in this group show E.E.G. spike and wave discharges (photoconvulsive responses) during photic stimulation.

It is essential to differentiate between patients who have epileptic seizures precipitated by light and those patients who suffer from epilepsy and have E.E.G. abnormalities during I.P.S., but do not have a clinical history of photosensitivity.

1.32 Age and Sex of Photosensitive Epileptic Patients.

The reported ages of patients suffering from photosensitive epilepsy vary from five to fifty-two years and the disease occurs more often in patients under the age of twenty.

Gastaut et al., (1962) reported that the average age of 35 patients with T.V. epilepsy was 19.2 years. (53% in the age group 0-10 years; 18% in the group 11-20 years; 23% in the group 21-30 years; and 6% in the group 31-40 years).

There is also a clear predominance of females suffering from photosensitive epilepsy. (Melsen, 1959; Watson et al., 1962; Jeavons, 1966).

From 133 patients in the literature whose sex is given, 85 (i.e. 64%) were females.

A number of authors found in females a higher incidence of E.E.G. abnormalities provoked by I.P.S. (Herrlin, 1954; Melsen, 1959; Watson et al., 1962; Wadlington et al., 1965; Troupin, 1966; Doose et al., 1969a, b).

1.33 Light-Sources as Precipitant of Fits.

Many artificial or natural light sources can provoke epileptic attacks.

Examples of these are found in the following instances:-

1.33.1 Flickering Light.

I Rhythmically interrupted sunlight seen from a car passing by a row of trees, provoked repeated epileptic attacks in one patient with photosensitive epilepsy, first reported by Cobb, (1947). Gastaut, (1948); Walter et al., (1949); Livingston et al., (1964), have reported similar cases where while the subjects were cycling or driving along an avenue of trees through

which the sun was shining, fits were induced. In the case reported by Walter et al., (1949) the minor attack induced by the flickering sunlight made the cyclist stop pedalling; in so doing he automatically changed the frequency of the light stimulus, thus terminating the attack.

II The rhythmical interruption of light by the blades of the helicopter was demonstrated by Gastaut et al., (1966) to induce epileptic attacks in a helicopter pilot, who was involved in three accidents. Similar cases have been reported by Johnson, (1963).

III The flickering light of oscilloscopes is reported to have induced epileptic attacks (Gastaut et al., 1966).

IV Self-induction (hand waving). A small number of patients suffering from photosensitive epilepsy induce fits in themselves by staring at bright light sources or by waving their abducted fingers in front of their eyes so as to intermittently block out a light source, and thus induce flicker. Some other patients induce fits in themselves by blinking. This variety is known as self-induced photosensitive epilepsy.

The case reported by Radovici et al., (1932) is considered by Andermann et al., (1962) to be the first recorded reference to self-induced photosensitive epilepsy, because the patient had a compulsive tendency to look at the sun. Bickford et al., (1953) reported two cases of "hand waving" self-induced epilepsy. Robertson, (1954) described seven cases of photo-sensitive epilepsy in which attacks were precipitated by self-induced flickering light (eye-blinking or hand waving). Similar cases have been described by Andermann et al., (1962); Chao, (1962); Green, (1966). The condition is mainly found in young children, with a predominance in females, although cases of self-induced epilepsy in adult life have also been reported, (Green, 1966).

Those of the patients of this group who have a compul-sion to look at the sun and move their hands in front of their eyes are called "compulsive flickerers", (Livingston et al., 1964). The majority of this group of patients are of low intelligence, with psychiatric problems (mainly hyperkinetic children), (Robertson, 1954; Andermann et al., 1962; Chao, 1962; Green, 1966).

Janz, (1968) found addictive and masturbatory elements in self induced epilepsy. The patients appear to get satisfaction from the procedure (Robertson, 1954), or a relief from existing tension and pressure (Andermann et al., 1962; Green, 1966). The epileptic attacks induced in this way by patients, are mainly absences (including petit mal attacks) and myoclonic jerking. These might possibly proceed to a grand mal attack (Robertson, 1954; Andermann et al., 1962). The hand-waving or eye-blinking could be mistaken for habit until the true nature of the condition is found by E.E.G. and I.P.S. techniques. Livingston et al., (1964) reported the case of a 15 year old girl who was not cognizant of moving her hand in front of her eyes during hand-waving. The authors suggested that hand-waving is some cases is a manifestation of the seizure itself and not a compulsive or voluntary movement. One patient reported by Davidson et al., (1956) could prevent the epileptic attacks by willed inhibition of blinking.

V The cinema has, very rarely, been reported as being associated with the induction of fits (Holmes, 1927;

Jeavons, 1969b). The case reported by Holmes might be explained as being due to the screen flicker, characteristic of early cinema. Modern commercial cinema has a flicker frequency of 48 or 72 flashes per second which is above the critical flash frequencies in the majority of photosensitive epileptic patients (Troupin, 1966).

VI Fluorescent lights have also been known to cause epileptic fits. Car drivers passing through road underpasses have been affected by the "flickering" effect received when driving at speed past underpass lighting. Another example is found in supermarkets, where fluorescent lighting has been reported to produce epileptic attacks (Brausch et al., 1965; Jeavons, 1969b).

VII Television. The first reference to epilepsy induced by watching television (television epilepsy), was made by Livingston, (1952). He reported the separate cases of three children who had their first convulsive seizures whilst watching television shows. It was postulated that the seizures were provoked by television sets which were defective and flickered frequently, or in which the vertical hold was faulty, allowing the picture to roll.

A substantial number of reports of television epilepsy have since been published (Ismay, 1958; Klapatek, 1959; Whitty, 1960; Gastaut et al., 1960, 1961 and 1962; Lagergren et al., 1960; Mawdsley, 1961; Pallis et al., 1961; Fischer-Williams, 1961; Pantelakis et al., 1962; Jeavons et al., 1966). In the majority of these cases attacks occurred when the patient was either watching a faulty (i.e. flickering) television set, or was very near to a normal functioning set. Cases of patients suffering an attack while watching a correctly functioning set from a normal distance have also been reported (Pantelakis et al., 1962). Although a substantial number of these patients also had spontaneous attacks, some of them had fits only when watching television (Gastaut et al., 1962; Pantelakis et al., 1962; Jeavons et al., 1969b).

Gastaut et al., (1966) defined the following characteristics of the television induced seizures on the basis of the data collected from 52 patients who had fits exclusively or principally while watching television:

"a: These seizures arise essentially, but not exclusively in children.

"b: They assume almost exclusively the characteristics of generalized tonic-clonic crises (Grand Mal) sometimes preceded by myoclonic jerks.

"c: Such patients almost always present photosensitivity, expressed by E.E.G. generalized discharges of spike and waves, or multiple spikes and waves during I.P.S.

Various types of fits have been induced by watching television; Grand mal attacks, petit mal attacks, myoclonic jerking, confusional episodes, psychomotor attacks, subjective sensations, and focal fits have all been reported. The majority of fits appear to have been grand mal attacks. Gastaut et al., (1962) reported on the following types of epileptic attacks occurring in 35 photosensitive television epileptic patients; two Jacksonian attacks; one psychomotor attack; three violent myoclonic jerks; 12 grand mal attacks (in five of which jerking preceded the seizure); six cases of loss of consciousness (without convulsions or tonic spasms); and eleven unknown attacks, when it seemed that a tonic element was present. Grand Mal fits were also predominant in the series of photosensitive patients reported by Ganglberger et al., (1956) and Wadlington et al., (1965).

Another interesting clinical manifestation of photosensitive epilepsy is compulsive attraction towards the television set. Harley (1967) reported on one case and Jeavons (1969b) presented nine patients who appeared to be compulsively attracted towards the television screen. When they reached a certain nearness to the screen they had a fit. The parents of these children described them as "being drawn like a magnet" towards the set (Harley et al., 1967; Jeavons, 1969b).

Gastaut et al., (1962) failed to induce fits or E.E.G. abnormalities in photosensitive television epileptic patients when they placed them in front of a television set, although the background illumination was reduced and the patients were very close to the set. I.P.S. induced photoconvulsive discharges in the same patients. The authors noted that flickering of the television screen increased the brain excitability of patients to such an extent that after a few hours of viewing, stimuli which were otherwise without effect, became epileptogenic.

Gastaut et al., (1966) suggested that the epileptic fits in television sensitive patients are not

induced by the usual frequency of images on the set, but by the slower, accidental and exceptional frequencies seen by the subject when he is very close to the set in a dimly lit room.

Bickford et al., (1962) suggested that the causation of television induced seizures is convulsive sensitivity to the viewing of geometric patterns.

Pantelakis et al., (1962) put forward three reasons for the occurrence of television epilepsy when patients are near to a television set:

1. That a larger area of retina is stimulated.
2. That stimulus is more likely to fall on the periphery of the retina which is particularly sensitive to flicker perception.
3. The television scanning frequency of 25 fl/s. is only likely to be noted - and therefore effective - when the patient is near enough to the screen to distinguish between this and the 50 fl/s. scanning frequency.

Television epilepsy is rare in the United States in comparison with Europe (cf. Troupin, 1966). This is attributable to the difference in the frequency at the

mains AC supply (cf. Troupin, 1966). The two half scans of the horizontal display will alternate at a frequency of 25 c/s. in Europe and 30 c/s. in the United States. The 25 c/s. in European television is closer to the peak of frequency photosensitivity of the epileptic patients than the 30 c/s. of the U.S. television.

1.33.2 Reflecting or Continuous Light.

The first reports of photosensitive epilepsy were concerned with patients who had seizures when in bright sunlight. (Radovici et al., 1932; Goodkind, 1936).

Epileptic attacks have also been reported to occur when patients are suddenly exposed to bright light (Penfield et al., 1954; Livingston et al., 1964) and in some instances after patients have been exposed to bright lights for a period of time (Livingston et al., 1964). Bickford et al., (1969) stated that fluctuation of light stimulus appears necessary to induce an epileptic attack, and that any claims of observing seizure induction by continuous light can probably be discounted as due to interruptions of the light by flutter of eyelids.

Reflected light from waves of the sea (Gastaut et al., 1966); from the snow (Bickford et al., 1953; Gastaut et al., 1966); from bright hazes (Brausch et al., 1965); from blades of a mechanical saw (Brausch et al., 1965); from window glass (Hishikawa et al., 1967) have all been reported as provoking epileptic fits. Car headlights and lightning are also known as precipitating factors in photosensitive epilepsy (Hishikawa et al., 1967).

It is obvious that in some cases (e.g. reflected light from waves of the sea) the epileptic attack is not induced by the one single factor of reflected light, but from a combination of this factor with other factors such as patterns, flickering light etc.

1.34 Photic and Pattern Sensitive Epilepsy - Reading Epilepsy.

Some of the photosensitive epileptic patients have also been found to be sensitive to patterns. Keith et al., (1952) reported a case where clinical attacks and E.E.G. abnormalities were induced by visual stimulation with fine mesh patterns. In this case the sensitivity

to the fine mesh pattern was specific since floral designs did not produce epileptic symptoms or E.E.G. abnormalities.

Extreme sensitivity of patients to fine copper mesh patterns was also demonstrated by Bickford et al., (1953) in photosensitive patients. Bickford et al., (1962) studied 10 patients who were sensitive to visual patterns and to I.P.S. Six of these patients had epileptic attacks while watching television. The above authors speculated that patterns are also a factor in the causation of television epilepsy.

Epileptic seizures can also be induced by patterns in non-photosensitive patients. Gastaut et al., (1966) reported the case of a patient who was not sensitive to simple patterns or I.P.S., but was sensitive to complex and colour contours. Chatrian et al., (1970) presented an interesting study of pattern-sensitive epilepsy and their findings are detailed in 1.43.5.

Cases of epileptic attacks induced by other types of visual stimuli (e.g. reading) have also been reported at length (Bickford et al., 1956; Critchley et al., 1960; Gastaut et al., 1966), but this is beyond the purpose of this thesis.

1.40 ELECTROENCEPHALOGRAPHIC RESPONSES INDUCED BY INTERMITTENT PHOTIC STIMULATION.

1.41 Classification.

Jeavons (1969a) divided the E.E.G. responses to I.P.S. into three main groups on the basis of their distribution.

Group 1:

Responses seen only in anterior frontal regions (photomyoclonic response)*.

Group 11:

Responses seen only in the posterior regions:-

1. Photic driving (or photic following).
2. Responses to single flashes or to repetitive flashes at rates slower than 4 s^{-1} (visual evoked responses).
3. Occipital spikes or occipital pseudo-spike and wave at the same rate as the flash.

Group 111:

Photoconvulsive responses which are widespread, bilateral, and involve anterior and posterior regions.

For the purpose of this thesis I will detail only some of the responses induced by I.P.S.

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*Abnormalities of cerebral origin confined or starting from the Fronto-Rolandic regions have also been described and are discussed below.

1.41.1 Photomyoclonic Responses.

Gastaut (1950)* described in normal subjects undergoing metrazol-activation, the so-called "myoclonic" response. The characteristics of the response as given by Gastaut (1950) are as follows:

a. Precentral and frontal large amplitude spikes appear in the E.E.G. during I.P.S. They are bilateral and synchronous and of the same frequency as the flash.

b. They appear when the eyes are closed and are called "Polyspike" or "Polyspike and Wave" (depending on their form).

c. The response is associated with muscular jerking.

The same author described in patients suffering from various cerebral non-epileptic conditions, the "myoclonic response by recruitment". This response is provoked by flash rates of 10-20 s^{-1}, occupies the fronto-central regions and consists of diphasic spikes with an initial spike of positive polarity. The spikes show the phenomenon of "recruitment", i.e. the amplitude of the spikes progressively increases with continuous I.P.S.

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* The first description of muscular responses to I.P.S. in the frontal regions was made by Gastaut et al., (1949b).

The response is seen when the eyes are closed, and is inhibited when the eyes are open. It always ends in a generalized fit if the stimulation is continued and the eyes of the subject are kept closed.

Photomyoclonic response was the term used for the frontal responses of "myogenic" origin by Bickford et al., (1952 and 1953b), who differentiated the photomyoclonic from the photoconvulsive response (Table 1.41.1.1 gives the characteristics of the two responses).

Bickford et al., (1952) established the myogenic origin of the photomyoclonic response and considered it as a normal response to high intensity photic stimulation. It was found in half of the normal population that they examined. Predominent jerking of the facial muscles, especially around the eyes was found to be associated with the photomyoclonic response, and was called photomyoclonus (Bickford et al., 1952, 1953b, 1969).

The phenomenon of "recruitment" in the photomyoclonic response which was compared by Gastaut, (1950) to the non-

specific thalamic recruiting response described by Morison et al., 1942, was considered by Bickford et al., (1952) "to be the effect of changing facilitation (central excitatory state) at the motor neurone synapse".

The latency (50-60 ms.) of the photomyoclonic response within the range of 1-12 fl/s. is found to be independent of the flash frequency (Bickford et al., 1952).

Shagass (1954) found the photomyoclonic response in 20% of patients suffering from mental disorders. Gastaut et al., (1958) found the photomyoclonic response in 0.3% of a normal population, in 3% of epileptic patients, in 13% of patients with brain stem lesions and in 17% of psychiatric patients. Both Shagass (1954) and Gastaut et al., (1958) concluded that despite the high incidence of the photomyoclonic response in psychiatric patients, the response did not help in the differential diagnosis of mental diseases.

Kooi et al., (1957) found photomyoclonic responses in only 4 of 100 patients with a variety of organic cerebral diseases, and none in normal subjects.

Table 1.41.1.1 (from Bickford et al., 1952).

Comparison of Photomyoclonic and Photoconvulsive Responses.

	Photomyoclonic Response.	Photoconvulsive Response.
Effective Stimulus Frequency	8 to 20	3 to 20
Eyelids, position for maximal effect.	Closed	Closed (and open)
Clinical accompaniments.	Fluttering of Eyelids.	Eyes turning, Speech arrest.
Consciousness	Maintained	Often disturbed
Distribution of electrical changes.	Face, Frontal areas.	Diffuse over scalp.
Electrographic response, type.	Myoclonic spikes (polyspike).	Spike wave or atypical spike wave.
Recruitment	Marked	Less frequent.
After-discharge.	Nil	Frequent
Age group.	Adult	All ages.
Variability of threshold	Marked	Slight
Muscle tension	Increases	No effect.
Nervous tension	Increases	No effect.
Occurrence	Normals frequent.	Normals rare.

The difference in the results obtained from the different authors, seems to lie in the particular technique of I.P.S., as pointed out by Kooi et al., (1960), who found photomyoclonic responses to be significantly associated to convulsive disorders.

According to the same authors, photomyoclonic responses were not significantly associated with unidentified spells, psychiatric diagnosis or alcoholism.

1.41.2 Photoconvulsive Responses.

Photoconvulsive responses are E.E.G. abnormalities occurring during I.P.S. They are synchronous, involve all cerebral areas and may vary from patient to patient and for the same patient from time to time. The characteristics of the photoconvulsive responses are given in Table 1.41.1.1.

In the E.E.G. they appear as:-

a. Bursts of theta waves with some tiny or large spikes mixed with them.
b. Bursts of theta and delta waves without spikes.
c. Bursts of typical 3 c/s. spike and slow wave.
d. Bursts of atypical 3 c/s. spike and slow wave activity.
e. Bursts of poly spikes and slow waves.

f. Bursts of spikes at the same rate as the flash (Jeavons, 1969a).

The photoconvulsive responses may persist for a few seconds after the cessation of the I.P.S. or may terminate synchronously with the train of photic stimuli. The photoconvulsive response may be associated with clinical manifestations, which are related to the type of presenting E.E.G. abnormality, i.e. 3 c/s. atypical spike and wave activity with a clinical Petit-Mal attack, polyspike and slow wave activity with myoclonic jerking, etc.

Grand-Mal attacks, confusional episodes, minor attacks, have also been reported as induced by I.P.S. and associated with photoconvulsive responses. Bickford et al., (1953) found that myoclonic jerking was closely related to the appearance of spike discharges in the E.E.G. and arrest of speech was invariably in relationship to the appearance of spike discharges. The same authors also reported that turning of head and eyes was inconstant and might change from one direction to another.

Bickford et al., (1969) stated that in the majority of cases diffuse paroxysmal spike-wave discharge induced by

I.P.S. is associated with a Petit-Mal attack. According to the same authors Grand-Mal attacks are very rarely induced by I.P.S., but may follow a period of induction of Petit-Mal attacks or focal seizures.

1.41.3 Abnormalities Confined or Starting from the Posterior or Anterior Cerebral Regions - Occipital Spikes.

There is nearly a universal agreement that the abnormalities induced by I.P.S. are synchronous and generalized and consist of multiple spike and wave complexes, or typical 3 c/s. spike-slow wave discharges, or slow waves with some spikes, or typical spike and waves complexes, (Penfield et al., 1954; Rao et al., 1955; Watson et al., 1962; Gastaut et al., 1962; Pallis et al., 1961; Pantelakis et al., 1962; Capron, 1966; Bickford et al., 1953 and 1969; Jeavons, 1969a).

Abnormalities confined, or starting from the posterio-cerebral regions and induced by I.P.S., have also been reported, but to a much lesser extent than the photoconvulsive responses (Gastaut et al., 1948; Lloyd-Smith et al., 1951; Robertson, 1954; Davidson et al., 1956; Naquet et al., 1960;

Kooi et al., 1960; Forster et al., 1964; Hishikawa et al., 1967; Jeavons, 1969a; Panayiotopoulos et al., 1970 a and b). Our results (Panayiotopoulos et al., 1970 a and b) are included and discussed in this thesis. Apart from us (Panayiotopoulos et al., 1970 a and b), only Hishikawa et al., 1967 found that abnormalities induced by I.P.S. and appearing first in the occipital regions were more often seen (53.3%) than the generalized discharges.

It has also been reported that in a few cases occipital foci can be driven or activated by I.P.S. (Lloyd-Smith et al., 1951; Penfield et al., 1954; Rodin et al., 1955; Kiloh et al., 1966; Bickford et al., 1969).

E.E.G. abnormalities of cerebral origin induced by I.P.S. and starting from the fronto-Rolandic areas before spreading to the whole cortex, are more commonly seen in Photosensitive baboons Papio-Papio (Fischer-Williams et al., 1968). This is not usually found in man, but it has been reported in a few cases (Gastaut, 1951 Subirana et al., 1951; Penfield et al., 1954; Hishikawa et al., 1967).

Naquet et al., (1960) described seizure discharges provoked by I.P.S. and localized in the posterior cerebral regions (parietal, temporal and occipital) in 12 patients, some of whom were not epileptic. The I.P.S. was given in long or short trains and was continued even when paroxysmal discharges appeared in the E.E.G. The localized discharges might involve all posterio-Rolandic regions simultaneously, or remain localized to one area, or might spread to the other cortex. In one case the discharges appeared alternately to one or the other hemisphere.

The above authors suggested that the arrival of specific afferents and cortical hyperexcitability, play an important role in the precipitation of these seizures which they consider as an example of "reflex epilepsy".

Capron (1966) found that photoconvulsive responses involving all regions were more commonly seen in photo-sensitive patients, but she also reported that spike and spike wave complexes confined to the occipital regions, or spreading by recruitment to the Rolandic and Frontal regions were observed.

Bickford et al., (1969) stated that only occasionally

the spike and wave discharges built up by recruitment from the occipital regions.

Chatrian et al., (1970) reported in pattern and T.V. sensitive epileptic patients that E.E.G. abnormalities occurring spontaneously or induced by pattern stimulation had exclusively or predominantly posterior distribution. On the basis of this finding and on the experimental evidence that line patterns are more effective they postulated that increased convulsive susceptibility of the neurons of the visual cortex is responsible for the genesis of "epileptogenic" discharges in pattern sensitive patients.

Hishikawa et al., (1967) reported their findings on 15 epileptic patients with E.E.G. abnormalities during I.P.S. In four of these patients the precipitant factor was unknown and in the remaining 11 there was evidence of clinical photosensitivity. The I.P.S. was given while the patients kept their eyes closed. In 8 of the above 15 patients (i.e. 53.3%), occipital spikes preceded the photoconvulsive responses. In three of these 8 patients the earliest spike discharges occurred in response to the first flash and occipital spikes of 70-200μV were often induced by a single flash. The occipital spike was biphasic or triphasic.

The latency of the positive component of the spike (50-55ms.) was reported by the authors as corresponding to the latency of P_3 V.E.R. component of normal subjects (P_3 = 73 $\pm$ 12.6 ms.).

The latency of the negative component of the spike was not given, but it was reported to correspond to the latency of N_3 component of V.E.R. of normal subjects (N_3 = 88 $\pm$ 17.4 ms.). The spikes evoked by the subsequent flashes had a latency about 5 ms. longer.

In one of the above three cases the occipital spike in response to the second flash was preceded by a smaller biphasic spike with latencies of 30-35 ms. (positive peak) and 45-55 ms. (negative peak). These latencies were thought to correspond to those of P_2 and N_2 V.E.R. components of normal subjects (P_2 = 36 $\pm$ 5.2 ms. and N_2 = 45 $\pm$ 7.3 ms.).

In another three photosensitive patients the occipital spikes were evoked by the 2nd or 3rd flash of I.P.S. (10-16 fl/s. was the usual frequency used). In these cases the peak latency of the initial positive phase of the earliest occipital spike was 35-40 ms., which corresponded to the latency of component P_2 of the response to single flashes.

Similarly, the following negative and the second positive phases of the spike (which are not given by the

authors) had latencies analogous to that of N_2 and P_3 respectively.

In the remaining 2 cases with occipital spikes in their E.E.G. during I.P.S., the initial occipital spike occurred after a greater and variable number of flashes and had a variable latency from the preceding flash.

On the basis of the above findings the authors interpreted the earliest occipital spikes as unusually augmented components of the V.E.R., and they suggested that in some patients the augmentation took place at the cortical level (4 cases with occipital abnormalities in the E.E.G.) and in others the augmentation took place at the level of the lateral geniculate body (4 cases with occipital spikes during I.P.S., but no occipital abnormalities in the resting record).

1.42 Evaluation.

It should be emphasized from the beginning that comparative results should not be expected from the different laboratories since the technique of I.P.S., the parameters of photic stimulus and the evaluation of the E.E.G. patterns, vary widely in the different laboratories.

Another difficulty arises from the fact that some authors do not specify the abnormalities, neither do they illustrate them. It is, therefore, in some way arbitrary to draw conclusions from the current literature, to the "clinical" significance of "abnormal" responses during I.P.S., but an attempt will be made to include in this section the results from the different laboratories.

1.42.1 E.E.G. Abnormalities Induced by I.P.S. in Normal Subjects.

Clinical epileptic seizures have been induced by I.P.S. in healthy, mainly young subjects, with no personal or family history of epilepsy (Bickford, 1949; Ulett, 1953; Mundy-Castle, 1953a).

Bickford (1949) found that I.P.S. induced paroxysmal synchronous discharges in 14% of 50 normal subjects. In two of them clinical seizures were induced by sectored light. The same author noted that in 14% of the normal subjects examined, the resting E.E.G. was abnormal. Walter et al., (1951) stated that paroxysmal responses to I.P.S. occur in 2% of normal population.

Mundy-Castle (1953a) reported "definite" E.E.G. abnormalities induced by I.P.S. in 3.9% of young normal population and 2.5% of the old group. The same author found 3.25% of the young group and 2.5% of the old group showed questionable, but not definite abnormalities and reported that clinical epileptic manifestations (mainly myoclonic jerking without impairment of consciousness) were observed. One of the "normal" subjects examined had fainted whilst watching a programme on the effect of I.P.S., and this was the reason for his E.E.G. examination.

Herrlin (1954) found paroxysmal responses in only 1 out of 70 young normal children (1.4%). This "normal" 8 year old boy suffered from "slight heamophelia". Ulett et al., (1958) found "paroxysmal activation" in 4.4% of young normal adults.

Kooi et al., (1960) reported that 3 of 90 normal subjects showed photoconvulsive responses during I.P.S. and two showed photomyoclonic responses.

Brandt et al., (1961) found "paroxysmal E.E.G. responses" in 26% of normal children (14% of them showed generalized spike and wave discharges). The duration of each train of I.P.S. was as long as six minutes.

Petersen et al., (1968) found "paroxysmal abnormality" in 5% of 75 normal children, but in less than 1% (7 children only) was there a 3 c/s. spike and wave abnormality.

1.42.2 E.E.G. Abnormalities in Clinical Conditions and in Relatives of Photosensitive Epileptic Patients.

Gastaut et al., (1948) used the I.P.S. with E.E.G. in 100 cases of epilepsy. They stated that in 4% of their patients who had frank epilepsy and in 75% who had Petit-mal, there was a possibility of provoking seizures. Gastaut (1949) found that I.P.S. evoked E.E.G. abnormalities in 10-20% of the epileptic patients.

Walter et al., (1951) found that in E.E.G., of 2000 patients complaining of fits, 15% were normal, 20% doubtful and 65% abnormal. In 28% the abnormalities were specific and 37% non-specific for epilepsy. 12% of the non-specific resting E.E.G. records would become specific because of abnormalities induced by I.P.S. In 3% of the specific records the abnormalities were augmented by I.P.S.

Turton (1952) found that I.P.S. revealed specific E.E.G. abnormalities in only 15 of 120 epileptic patients. The number was increased to 26 patients when an electronic trigger circuit was used.

Buchthal et al., (1953) reported that 15% of epileptic patients showed paroxysmal abnormalities during I.P.S.

Mundy-Castle (1953b) found abnormal responses to I.P.S. in 13-25% of patients suffering from "probable epilepsy and allied disorders". Photomyoclonic responses were included in the abnormalities. The incidence of abnormalities was higher amongst those suffering from minor than major or other types of seizures.

Herrlin (1954) found 23.5 $\pm$ 2.2% abnormalities induced by I.P.S. in 362 children (under the age of 15) with definite epilepsy, 23% of the abnormalities were evoked in those suffering Grand-Mal epilepsy, 30% of Petit-Mal, 13% of Petit-Mal and Grand-Mal and 37% of Psychomotor attacks (19% of those with unilateral fits). He did not find any difference in the incidence of abnormalities induced by I.P.S. amongst those with normal or abnormal resting record. The incidence of a pathological response was more than twice as high in children over 5 years old, than in those under this age. Abnormalities were seen more often in the 10-15 years age group than in the younger ones.

The latter findings are in accordance with those of Gastaut et al., (1948), who reported that nine of 13 epileptic patients who had clinical or sub-clinical attacks during I.P.S. were between the age of 5-15 years, Gastaut et al., (1958) stated that I.P.S. did not induce spike and slow wave abnormalities (irradiating response of the fronto-central spike and wave pattern) in the normal population. These abnormalities were found in 15% of all epileptic patients, 25% of epileptics suffering from "centrencephalic" epilepsy (20% of the Grand-Mal type and 40% of the Petit-Mal type). They stress the high incidence of abnormalities induced by I.P.S. in patients suffering from generalized epilepsy (85%) in comparison to those who suffer from other types of epilepsy. In non-epileptic conditions I.P.S. induced spike and wave discharges in 3% of patients with brain stem lesions, 0.8% of patients with mental disorders, 0.5% with endocrine syndromes and 0.3% with head injuries.

Melsen (1959) reported that I.P.S. is most effective in relatively young patients (under 16), but paroxysmal activity is most frequent in patients with abnormal than normal E.E.G. He also confirmed previous observations

(Herrlin, 1954) that there was a higher percentage of abnormalities induced by I.P.S. amongst female than male patients.

Kooi et al., (1960) reported that amongst the patients who showed abnormalities during I.P.S., there was a high incidence of photoconvulsive responses alone, or in association with photomyoclonic response in those patients who suffered from epilepsy, than in the non-epileptic group of patients. Photoconvulsive responses were not significantly associated with unidentified spells, psychiatric diagnosis or alcoholism.

Jeavons (1966) reported that from 14.141 referred subjects for E.E.G., only 402 (i.e. 2.8%) showed abnormalities induced by I.P.S. From these 402 cases 57% showed 3^{c}/s. spike and wave or polyspike and wave induced by I.P.S., 16% showed spike and theta wave and 2% showed spikes only. Other types of abnormalities were present in 20% of cases and in 5% the abnormalities seen in the resting E.E.G. were not definitely increased by I.P.S. 3^{c}/s. spike and wave discharges evoked by I.P.S. were more commonly associated with the diagnosis of epilepsy than with other conditions. The same author stated that myoclonic jerking during I.P.S. was

significantly related to epilepsy. From 117 patients with myoclonic jerks during I.P.S. only 19 gave a clinical history of myoclonic epilepsy.

Abnormalities induced by I.P.S. have been reported in nearly all cases of photosensitive epilepsy with a few exceptions (Livingston, 1952; Klapetek, 1959; Chartlon et al., 1964).

Davidson et al., (1956) examined 16 families with history of photosensitive epilepsy (including non-clinically photosensitive patients), and found that light sensitivity can be detected in relatives of photosensitive patients by means of I.P.S. and E.E.G. recording. Such persons might also experience minor or major epileptic attacks for the first time in their life when exposed to photic stimulation.

Watson et al., (1962) reported that I.P.S. induced abnormalities in 6.8 $\pm$ 0.7% of 1.256 consecutive patients with no history of seizures. In a group of 372 epileptic patients I.P.S. induced abnormalities in less than 1% of patients under the age of six years, in 51.7 $\pm$ 9.3% of patients between 11-15 years of age (62.5 $\pm$ 12% of them were females) and in 15.5 $\pm$ 3.4% of patients between

21-60 years of age. The incidence of abnormalities induced in patients suffering from symptomatic seizures did not exceed that for the general population (4.5% and 5% respectively). A high percentage of abnormalities was found in symptoms free relatives of 60 propositi with "photogenic" cerebral electrical abnormalities (50% mothers, 17% fathers, 45% siblings, 32% offsprings).

A hereditary predisposition in photosensitive epilepsy was also found by Doose et al., (1969a and b)"on clinical and E.E.G. grounds" The above authors found that 26.2% of the siblings of patients suffering from photosensitive epilepsy exhibited a photoconvulsive response during I.P.S. as opposed to only 6.7% of the control group. It should be noted that from a large number of children examined by the above authors (Doose et al., 1969 a and b) only 4 presented with some form of clinical photosensitive epilepsy. The remaining (some non-epileptics) were selected because of E.E.G. abnormalities during I.P.S.

Chatrian et al., (1970) did not find any E.E.G. abnormalities in the parents of two brothers of T.V. and pattern sensitive patients during pattern or I.P. stimulation, but they suggested that in some cases the "defect" may be genetically determined.

1.43. Factors Altering the Effectiveness of I.P.S.

The effectiveness of I.P.S. in provoking E.E.G. abnormalities depends on a large number of internal and external factors.

Anticonvulsant drugs, menstrual cycle, hormones and electrolytes are some of the internal factors which alter the photoconvulsive threshold of the subject. The role of "internal" factors in altering the convulsive "threshold" of the brain and thus determining the effectiveness of the "external" stimuli was demonstrated by Bickford et al., (1969) in the following experiment:

A photosensitive patient was subjected to identical trains of I.P.S. under constant experimental conditions over a period of several minutes. The E.E.G. responses varied considerably from no detectable abnormality to self-sustained spike-wave discharge of 10 s. duration. Cyclical changes were observed when the length of spike-wave discharge was plotted over the time period. Similar results were found by Chatrian et al., (1970) in pattern and T.V. sensitive patients during pattern and I.P. Stimulation. The abnormal discharges to constant stimulation varied in latency and duration with successive presentation.

Frequency of I.P.S., intensity of light, position of eyelids and distance from the light source are some of the external factors which alter the effectiveness of I.P.S. and are described below:

1.43.1 Flash Frequency.

In a number of investigations it has been established that the photoconvulsive effectiveness of I.P.S. is closely related to the flash frequency. The most effective frequencies have been found to be between 10-25 fl/s. with a peak in the neighbourhood of 15 fl/s. (Walter et al., 1949; Gastaut et al., 1950; Carterette et al., 1952; Bickford et al., 1953; Melsen, 1959; Kooi, 1960; Gastaut et al., 1962; Johnson-Laverne, 1963).

Jeavons et al., (1966) found that 20 fl/s. induced E.E.G. abnormalities in all but one of the 17 patients examined by them. On the basis of this finding 20 fl/s. is proposed by the same author (Jeavons, 1969a), as an initial screening flash rate.

The flash frequency evoking E.E.G. abnormalities can be as low as 1 fl/s. (Bickford et al., 1953). The same authors

stated that the maximum effective frequency was 35 fl/s., and Gastaut et al., (1962) reported that photoconvulsive response could be evoked with flash frequencies as high as 40 fl/s.

Walter et al., (1946) reported that on the E.E.G. of an epileptic patient "seizure discharges" induced by I.P.S. when the flash was synchronized via an electronic trigger circuit with E.E.G. components at 16 and 8 c/s. alternately. On the basis of this finding, they suggested that certain types of seizures are due to exact synchronization of cerebral rhythms previously slightly out of step. Marshall et al., (1953) speculated that a cumulative or hypersynchronic inter locking of the spontaneous (alpha rhythm) and induced (by I.P.S.) responses occur and this explains why the frequencies of the alpha rhythm range and its harmonics are particularly effective.

1.43.2 Intensity of Light and Background Illumination.

Adrian et al., (1934) reported of the importance of the intensity in normal photic driving.

Buskirk et al., (1952) found that E.E.G. abnormalities induced by I.P.S. with Metrazol (pentylenetetrazol) activation had a definitely lower threshold when the intensity

of light was decreased (reducing, for example, the intensity of the light from 80.000 candle power abolishes the photo-convulsive responses and an increase of intensity to 800.000 candle power increases the threshold two-fold). The same authors commented on the effect of background illumination on the E.E.G. abnormalities induced by I.P.S.

By increasing the intensity of photic stimuli or decreasing background illumination the effectiveness of I.P.S. is greater (Marshall et al., 1953; Gastaut et al., 1961 and 1962; Pallis et al., 1962).

1.43.3. Colour of Light.

It has been reported that red light enhances the E.E.G. abnormalities induced by I.P.S., as compared to the white light and other colours (Walter et al., 1949; Livingston, 1952; Buskirk et al., 1952; Carterette et al., 1952; Bickford et al., 1953; Pantelakis et al., 1962; Brausch et al., 1965; Capron, 1966).

Carterette et al., (1952) found that there was a greater incidence and shorter latency of abnormal E.E.G. responses induced by red light I.P.S., than with blue, green, or white. The same authors reported that in one of their patients red light was least effective and they suggested that individual

differences might be important.

Brausch et al., (1965) also reported that red light was the most potent stimulus in photosensitive patients and their relatives, as compared with white, green, and blue light.

The same authors have found a substantial decrease in photoconvulsive threshold when the eyes were closed while using red light I.P.S. as compared with eyes-open state. On the basis of this latter finding they concluded that factors other than spectral filtering are responsible for the increased incidence of abnormalities during eyes-closed state.

They considered the photosensitive patients as the opposite extreme of the red-green colour blind individuals, the former being unusually sensitive to red light, the latter being unusually insensitive and they suggested that the abnormalities in photosensitive epilepsy may not be exclusively cortical or subcortical, but may in fact exist at a retinal level.

Capron (1966) reported that 41 from 66 photosensitive patients showed an increased sensitivity to red than to neutral light on at least one occasion, and that patients

with myoclonic epilepsy are more sensitive to red light than patients suffering from other types of epilepsy (i.e. Grand mal, absences). Marshall et al., (1953) speculated that the increased sensitivity to the red light in photo-sensitive epilepsy is due to the integration of the red carrying neuronal elements, probably at the geniculate body and the cortex level.

The use of coloured glasses in which the red light was filtered out was found by some authors to be beneficial for patients who showed increased sensitivity to red light (Carterette et al., 1952).

Chatrian et al., (1970) reported that in pattern and T.V. sensitive epileptic patients presentation of coloured vertical stripes would provoke E.E.G. abnormalities which were more prominent with black, red, green and blue and less prominent with orange stripes. The yellow stripes were proved completely ineffective. The difference was attributed by the same authors to the different degrees of contrast between the coloured stripes and the background. This was demonstrated by the fact that the duration and amplitude of E.E.G. abnormalities induced by patterns was diminished as the

degree of contrast between the stripes and the background was diminished.

1.43.4 Diffusion Screen.

The effect of a diffusion screen placed between the eyes of the subject and the stroboscope was described by Walter et al., (1949). The subject was a boy 7 years of age with a personal and family history of epilepsy. 5c/s. waves and frequent small spikes were seen in the resting record. The effect of a white diffusing screen was an augmentation of the amplitude of the responses evoked by I.P.S. and an increase of second harmonic "the change being seen in the primary trace as transformation from asymmetrical, square or saw-tooth waves into monophasic spikes". When the diffusion screen was removed the record immediately returned to its original character. Closing the eyes did not produce any similar effect.

The increase in E.E.G. abnormalities on I.P.S. when a diffusing screen was added, was confirmed by Davidson et al., (1956) and Brausch et al., (1965).

Pantelakis et al., (1962 b) and Troupin (1966) found that the effect of the I.P.S. with the eyes closed was similar to the effect of a diffusion screen.

1.43.5 Pattern Stimulation and Combination of Pattern and I.P. Stimulation.

It has been reported (Keith et al., 1952) that in some patients clinical attacks and E.E.G. abnormalities occurred with visual stimulation by fine mesh patterns. In the case that they reported the sensitivity to fine mesh patterns was specific in that floral or large designs did not induce symptoms or E.E.G. abnormalities.

Bickford et al., (1953) reported also the extreme sensitivity of patients to fine copper mesh.

Bickford et al., (1962) examined the effect of pattern presentation in ten epileptic patients. These patients were selected because they showed E.E.G. abnormalities during I.P.S. and also during pattern presentation (they also have spontaneous abnormalities). Six of them were T.V. sensitive and the other four might have Petit Mal attacks during T.V. viewing. Their findings are summarized as follows:

1. In the majority of cases simple geometric pattern of line (parallel lines and so on) is most effective, whereas low contrast and soft-toned patterns are less effective.

2. Fine and more detailed patterns were more effective

than large bold patterns.

3. Patterns with a crisp image were much more effective than those with a confused image.

4. The effectiveness of the pattern tended to increase when it was moved back and forth rhythmically than when it was stationary.

5. Fixation of the gaze on a part of the presented pattern tended to render the pattern ineffective, and conversely, when the subject looked around the pattern.

6. Monocular viewing was effective, but only with increased threshold.

On the basis of the above findings they concluded that a convulsive sensitivity to the viewing of geometric pattern is an additional factor in the causation of T.V. induced seizures.

Chatrian et al., (1970) in an extensive study of four patients suffering from pattern sensitive epilepsy (three of them were also T.V. sensitive) reached the following conclusions:

1. The most effective of the patterns were the geometric ones (quadrilled patterns of thin lines were more effective than similar patterns consisting of thick lines), whilst the complex non-geometric patterns which are optional for eliciting lamda waves were ineffective.
2. Quadrilled patterns were more effective than those consisting of parallel lines.
3. In some patients vertical lines were more effective than horizontal lines.
4. Increased luminance of the pattern increased the effectiveness of stimulation.
5. Sharp boundaries of the pattern play a significant role in eliciting epileptogenic discharges.
6. Monocular stimulation was less effective than binocular stimulation.
7. When the degree of contrast between the pattern and the background of the pattern was decreased the epileptogenic discharges diminished.
8. Oscillatory movement of the patterns resulted in an attenuation of the abnormal discharges.

9. Macular stimulation is more effective than stimulation of the periphery of the retina.

10. The photoconvulsive range of the patients was increased when pattern and I.P.S. were combined.*

1.43.6 "Eyes-Open", "Eyes-Closed", "Eye-Closure" States.

It has been demonstrated from the very early days of E.E.G. (Berger, 1929; Matthews et al., 1934,1935) that the recorded brain activity differs when the eyes are closed ("eyes-closed" state) and when the eyes are open ("eyes-open" state).

The above authors found that the alpha rhythm is attenuated by visual activity, and it is also dimished or abolished when the eyes are open.

Cruikshank, (1937) observed that the frequency of the alpha rhythm as it recovers from being blocked by light stimulus is higher than the prestimulation frequency (if one uses as a measure of post-stimulation frequency the first 5 alpha waves which appear). This effect is more noticeable when the intensity of light is high and decreases with decreasing intensity.

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* The pattern was illuminated by I.P.S.

It has also been observed (Durrup et al., 1935) and shown by E.E.G. spectrographic methods (Storm Van Leeuwen et al., 1958) that in a number of people the alpha rhythm is of increased frequency immediately after they closed their eyes ("eye-closure" state). In other words the alpha rhythm does not start at its dominant frequency, but at a higher frequency. This lasts for half to one second immediately after eye-closure. Walter called this phenomenon "squeak" phenomenon in analogy to frequency changes in sound (cf. Storm Van Leeuwen et al., 1958).

It is also known that a number of epileptic patients show generalized atypical spike and wave discharges following eye-closure (Lloyd-Smith et al., 1951; Atzev, 1962; Green, 1966 and 1968) and that eye blinking would initiate an epileptic attack in rare cases (Robertson, 1954; Gastaut et al., 1966; Green 1966 and 1968).

Atzev (1962) reported the "effect" of closing and opening the eyes upon epileptic activity of the brain. In 29 out of 1,000 epileptic patients examined, E.E.G. abnormalities (spikes, sharp waves, complexes) were provoked by closing the eyes, and in several patients Petit Mal attacks were induced.

Walter et al., (1949) stated that in some patients I.P.S. is effective only at the moment of closing the eyes.

Jeavons, (1966) reported that from 402 patients suffering from various deseases and who had E.E.G. abnormalities provoked by I.P.S. 7% showed spontaneous spike and wave discharges immediately following the closing of the eyes ("eye-closure" state).

It is clear from the above data, obtained from both normal subjects and patients, that the three states ("eyes-open", "eye-closure" and "eyes-closed") should be regarded as separate conditions. It is apparent from current literature that the majority of authors do not take this separate "eye-closure" state into account. It is also apparent that some authors use the terms "eyes-closed" and "eye-closure" indiscriminately.

It is nearly universal agreement between authors who have a prominent interest in photosensitive epilepsy that more abnormalities occurred when the subjects kept their eyes closed during I.P.S. (Bickford et al., 1953; Robertson, 1954; Pallis et al., 1961; Pantelakis et al., 1962 a and b; Troupin 1966; Bickford et al., 1969).

A number of theories were proposed in an attempt to explain the apparent increased sensitivity to I.P.S. during the "eyes-closed" state.

Some authors attributed the enhancement of photic activation during "eyes-closed" state to the eyelid behaving as a red filter (cf. Troupin, 1966). Pallis et al., (1961) also suggested that the eyelids act as a differential light filter although they found this incompatible with experimental evidence produced by Bickford et al., (1953) that, "the convulsive effect of light is not confined to any small segment of the visual spectrum, and seizures may be produced with pure red, green, or blue light".*

Troupin also excluded this theory by comparing the abnormalities induced by I.P.S. on "eyes-closed" and "eyes-open plus red filter" states. In 10 out of 12 patients the amount of activation during "eyes-open plus red filter" stimulation was clearly less than that during "eyes-closed" I.P.S.

Pantelakis et al., (1962 b) suggested that "the provocative effect of "eye-closure" is in some way concerned with loss of visual attention". They supported this argument by finding that light frequencies which evoked abnormalities when

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* In the same publication Bickford et al., (1953) stated that "the red end of the spectrum may be relatively more effective".

the eyes were closed had the same effect when transmitted to the open eyes via an illuminated screen.

The findings of the above authors were similar to the findings of Davidson et al., (1956) who reported that the interposition of a diffusing screen between the stroboscope and the open eyes produced E.E.G. abnormalities at frequencies which had hitherto evoked them only when the eyes were closed. Brausch et al., (1965) also rejected that spectro-filtering of the eyelids was responsible for the increased instance of abnormalities observed during the "eyes-closed" state compared with the "eyes-open" state. They supported their argument with their findings that a substantial decrease in photoconvulsive threshold was seen when the eyes were closed while using red light I.P.S., as compared with the "eyes-open" state. They postulated that "the mechanism of eye closing in augmenting the photoconvulsive response is one of diffusing the light source and thereby illuminating a greater area of retina". This was in accordance with their suggestion that the abnormalities in photosensitive epilepsy "may not be exclusively cortical or subcortical disfunction, but may in fact exist at a retinal level".

Bickford et al., (1969) also stated that seizures are more easily induced with eyes-closed as compared with eyes-open and they suggested that this is partly due to diffuser effect and "in addition a factor of lower convulsive threshold is produced by reduction in visual pattern input".

Pallis et al., (1961) suggested that the "variations in susceptibility to flicker (according to whether the eyes are open or closed)", might be related to the blocking of the alpha rhythm. However, they could not find any specific effect on E.E.G. abnormalities induced by I.P.S. when other alpha blocking stimuli (noise, visual imagery, calculation) were employed. In order to explain these findings they suggested that, "the eye opening may be the most potent of all attention, provoking stimuli, but might also imply the operation of two separate mechanisms, one for alpha-blocking and the other for spike-blocking".

Very few authors have found more abnormalities when the eyes are open during I.P.S. (Mawdsley, 1961; Jeavons et al., 1966).

As will be shown in the discussion, discrepancies between the results obtained by different authors seem to lie

in the fact that the three states (eyes-open, eye-closure, eyes-closed) were not examined separately.

It is, for example, the practice of some authors (Pantelakis et al., 1962b) to start I.P.S. when the patient's eyes are open and ask the patient to close his eyes while I.P.S. continues. Thus,the condition which they consider as "eyes-closed" state, is in fact a combination of "eye-closure" and "eyes-closed". It is also common practice in E.E.G. departments of this country to ask the patient to close his eyes immediately the stroboscope starts, and to regard the subsequent E.E.G. responses as occurring during the state of "eyes-closed". (quoted by Jeavons, 1969b).

Unawareness of the existence of this state of "eye-closure" is also shown by the fact that Kooi et al., (1960) did not mention the eye condition states in the standard technique of I.P.S. presentation they proposed. They emphasized that the difference in the results obtained by I.P.S. in various laboratories could be due to the "difference in the criteria of abnormality, characteristics of the light source, and methods of presenting the photic stimulus". In their

proposed standard technique the light source, the distance of the stroboscope from the face, the duration of photic stimulation for each frequency, and the interval between light presentations, were determined.

Jeavons et al., (1966) examined the effect of I.P.S. when the eyes were open and closed, the "eye-closure" state being excluded. They found more abnormalities during "eyes-open" state, in 17 patients with consistent generalized abnormalities during I.P.S.

Jeavons, (1969a) is, to the best of my knowledge, the only author who emphasizes the difference between the three eye states and he proposes that these stages should be examined separately.

It seems likely that the higher rate of abnormalities, found by some authors during I.P.S. in the "eye-closed" state, was due to "eye-closure" epileptogenic potentiation.

1.43.7 Occlusion of One Eye.

A number of authors have studied the effect of I.P.S. when only one eye is stimulated (the other eye being occluded by a patch or the palm of the patient).

Nearly all of them reported a reduction or inhibition

of E.E.G. abnormalities induced by I.P.S. during monocular stimulation. Bickford et al., (1952) reported that although the photoconvulsive response is frequently observed during monocular I.P.S., the photomyoclonic response is inhibited. They attributed the inhibition of the photomyoclonic responses to the reduction of the total illumination, occasioned by the occlusion of one eye. In accordance with this were the results of Marshall et al., (1953) who found that the intensity of the light had to be doubled in order that I.P.S. should reach photoconvulsive threshold during monocular stimulation.

Robertson (1954) found that E.E.G. abnormalities induced by I.P.S. were diminished or abolished in patients with self-induced epilepsy if the one eye was occluded.

Reduction of abnormalities on monocular I.P.S. was also reported by Davidson et al., (1956); Forster et al., (1964); Brausch et al., (1965); Green et al., (1966); Hishikawa et al., (1967); Jeavons et al., (1970). Forster et al., (1964) on the basis of the above findings used monocular stimulation as a method of conditioning in photosensitive epilepsy. Green et al., (1966) used eye-patch for therapeutic purposes and Jeavons et al., (1970) advised their patients who suffered from T.V. epilepsy to cover with their palm the one

eye when they approached the T.V. set.

Chatrian et al., (1970) also reported inhibition or attenuation of abnormal discharges induced by pattern stimulation in pattern sensitive epileptic patients when the one eye was occluded. In one of their subjects stimulation of the right eye was less effective than that of the left eye. Chatrian et al., (1970) postulated that the lesser effect of monocular as compared to binocular stimulation may be the result of a critical decrease of input to neurons of the visual cortex.

Comment.

The above detailed factors are some of the external parameters which change the effectiveness of I.P.S. It must be emphasized that other factors such as number of stimulated cones or rods, macular or peripheral retina stimulation, distance of light source etc., are also important in order to determine the effectiveness of I.P.S.

SECTION 2

TECHNIQUES

2.10 GENERAL INTRODUCTION.

The research included in this thesis was carried out in two departments. The first one (E.E.G. Department - Dudley Road Hospital - Birmingham) is a clinical E.E.G. department while the second one (Neuropsychology Unit - Aston University - Birmingham) is a research department with a prominent interest in the evaluation of E.E.G. and V.E.R. in clinical practice with the aid of computer facilities.

All examined patients were at first referred to the E.E.G. department in which a routine E.E.G. and the following investigations were carried out:

a. Range of flash rates to which patients are sensitive (photoconvulsive range).

b. E.E.G. responses to "eyes-open", "eyes-closed" and "monocular" I.P.S.

c. Spatial distribution of occipital spikes and cortical origin of photoconvulsive responses.

All the normal subjects and a number of patients were also examined at the Neuropsychology Unit where the following investigations were carried out:

a. Relation of occipital spikes and V.E.R.

b. "Eye-closure" E.E.G. responses in darkness and in normal room illumination.

c. Evaluation of stroboscopic factors in the provocation of E.E.G. abnormalities with particular reference to pattern stimulation.

2.11 Recording Techniques.

Scalp silver-silver chloride disc "stick-on" electrodes were placed according to the international 10/20 system (Jasper, 1958). The method of application of the electrodes on the scalp was identical to the one used by Harding, (1969). Additional electrodes were used in a few cases for the investigation of the spatial distribution of the occipital spikes (Fig. 4.21.1.1).

A routine resting E.E.G. was taken on all subjects on each occasion. Unless otherwise stated bipolar recording was used. The procedure was explained to the subject as far as possible. Surprise played no part in the presentation of stimuli. The subject reclined comfortably on a couch.

2.20 PROCEDURES USED IN CLINICAL E.E.G. DEPARTMENT

(Dudley Road Hospital)

2.21 Techniques of E.E.G. Recording - E.E.G. Montages.

Most of the E.E.G. records were taken on a 16 Channel Elema Schonander Mingograph machine.

For the routine resting E.E.G. parasagittal, temporal and transverse montages were used. Hyperventilation was performed for between $2\frac{1}{2}$ min. and 3 min. A parasagittal and a special V.E.R. montage were used during I.P.S. (Fig. 4.21.2).

The V.E.R. montage is used as a routine V.E.R. technique in the Neuropsychology Unit. A paper describing the technique and its advantages was published in 1969 and is included in appendix

Since in the 10/20 system the left occipital electrode (O_1) is midway between T_5 and O_2, in a simplified model, we may assume, that any signal arising under the O_1 electrode will be equipotential, in a bipolar recording for the T_5 - O_2 derivation. Thus, the O_2 - T_5 E.E.G. trace will not produce any deflection of the pen. The same signal (arising under the O_1 electrode) will show phase reversals to the O_1 electrode in the T_6 - O_1 and O_1 - T_3 derivations. It is

easily understood that signals arising from sources under electrodes other than the occipital ones will be clearly identified.

Since we were concerned with the localization of the "occipital" spikes we used this montage in the routine E.E.G. investigation during I.P.S.

High paper speed (6,15,30 cm/s.) and increased gain (50,30,20 μV/cm.) were used. This technique allowed us to detect the presence and location of any cortical precursors of the photoconvulsive responses, especially in those cases in whom only one or two small amplitude spikes immediately preceded a generalized discharge, evoked at relatively fast rates of stimulation, i.e. 20 fl/s.

The latency of occipital spikes and components of augmented V.E.R. may also be measured using this technique. In only one of the subjects (No. 52) referred to in this thesis was the measurement of latency carried out by this technique, (Fig. 4.42.1) although its relative accuracy can be seen in Fig. 2.21.1. The technique is recommended for use in clinical E.E.G. departments without averaging facilities.

The allining of the pens at the used high speeds is understandably essential and this must obsessionally and frequently be carried out.

Fig. 2.21.1 E.E.G. Recording of V.E.R.

The upper trace is the average V.E.R. at 1 fl/s.

The lower trace is a reproduction of the E.E.G. trace (E.E.G. taken at 20 μV/cm. and 30cm/s.).

The V.E.R. components (N_1, P_1, N_2, P_2, N_3) can be seen and measured with relative accuracy from the E.E.G. trace.

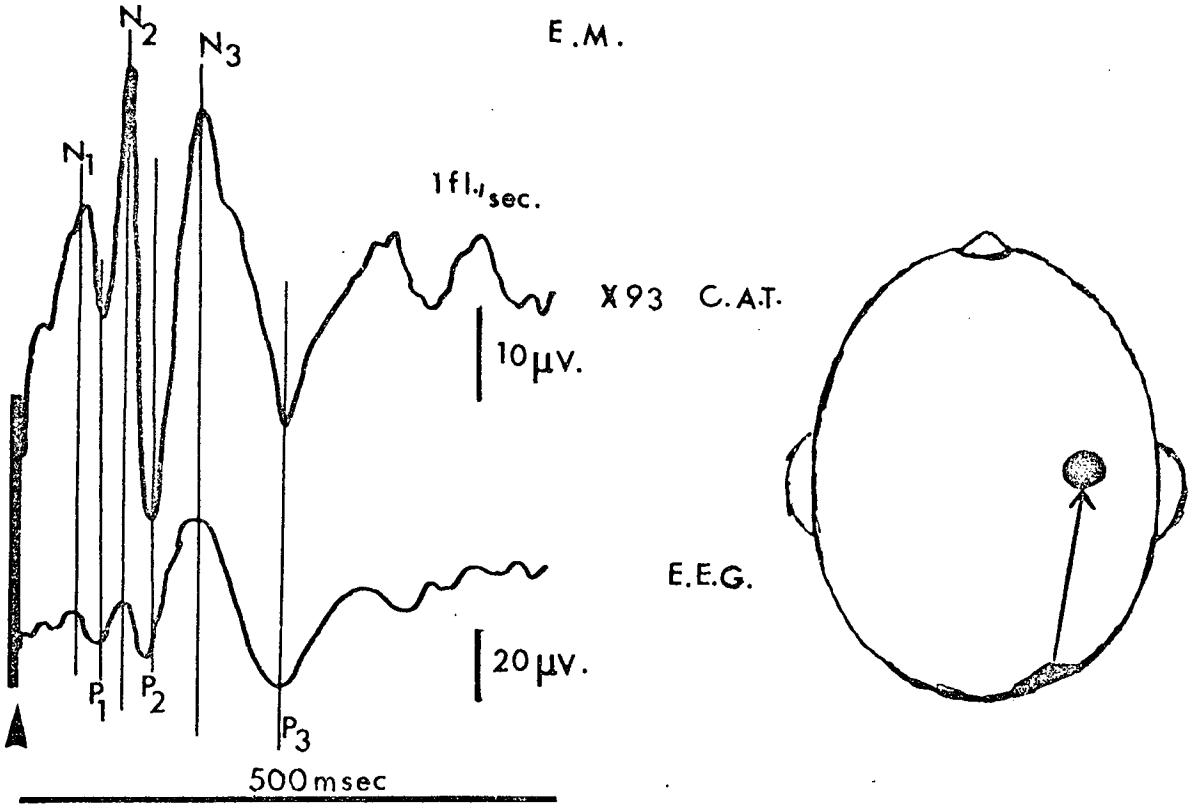


Fig. 2.21.1

In all recordingsa photocell was placed alongside the subject's head and the out-put of the photocell was recorded in one of the E.E.G. channels.

2.22 Presentation of I.P.S.

The lamp was placed 30 cm. directly in front of the subject's eyes, the subject being instructed to look at the centre of the lamp. The distance was measured from the eyes of the subject to the glass face of the stroboscope on a line perpendicular to the glass.

The screening method of testing the effect of I.P.S. was the same as described by Jeavons (1969). The subject kept his eyes open and 20 fl/s. were used as an initial flash screening. If no abnormality occurred after 5s. of I.P.S. the subject was asked to close his eyes and the photic stimulation was continued for another 5s. If no abnormality occurred the same procedure was used for subsequent flash rates (24, 16, 12, 10, 8 s^{-1}) which were the flash rates most likely to provoke E.E.G. abnormalities.

This technique was applied in all normal subjects, but only in a few patients, where photosensitivity was not suspected. Patients with known clinical photosensitive epilepsy

or E.E.G. abnormalities provoked by I.P.S. were tested with the method stated in 2.23 and 2.24.

The duration of a train of stimuli used for the patients was 2s. unless otherwise stated. Long trains of stimuli were used at flash rates which did not provoke E.E.G. abnormalities. In order to minimize the risk of inducing an epileptic fit during testing, the I.P.S. was immediately interrupted as soon as a photoconvulsive response lasting 1s. or longer was provoked.

The V.E.R. were obtained using long trains of I.P.S. If E.E.G. abnormalities (evoked or spontaneous) appeared during I.P.S. the V.E.R. were disregarded except in the case of patient No. 17 (Fig. 4.41.7).

2.23 Photoconvulsive Range.

In order to establish the range of flash frequencies which provoke photoconvulsive responses the patient was first exposed to low frequency I.P.S. (1, 2, 3, 4, 5 fl/s. etc.) at a rate increased in steps of 1 fl/s. until a flash frequency was reached which constantly provoked a photoconvulsive response within 2s. of I.P.S. . The I.P.S. was then given at high frequencies starting from 80 fl/s. and descending in

order of 2-5 fl/s. steps until a flash frequency was reached which again constantly induced a photoconvulsive response. In this way the upper and lower limits of the photoconvulsive range were established.

This procedure was followed for testing the photoconvulsive range for both eyes-closed and eyes-open conditions.

In a number of cases flash rates intermediate to the upper and lower limits of the photoconvulsive range were given, but it was soon discovered that this was not a safe procedure for the patient as these intermediate flash frequencies are potentially dangerous and may provoke an epileptic attack. For this reason very little testing was carried out within the photoconvulsive range.

2.24 Procedure for Testing the Responses to "Eyes-Open", "Eyes-Closed" and "Monocular" I.P.S.

2.24.1 "Eyes-Open", "Eyes-Closed" I.P.S. Testing.

In order to investigate the effect of I.P.S. during eyes-open and eyes-closed state, the I.P.S. was presented in a random sequence either with the patient's eyes open or closed, i.e. the patient was asked to have his eyes open,

then I.P.S. was given and terminated whilst the patient's eyes were still open. In a similar way the "eyes-closed" state was tested, i.e. the patient was asked to close his eyes and I.P.S. was started and terminated in the same eye condition.

2.24.2 "Eye-Closure".

In a few patients the effect of I.P.S. during "eye-closure" state was tested. A low flash frequency which did not provoke E.E.G. abnormalities on either "eyes-open" or "eyes-closed" states was chosen as a testing frequency. I.P.S. was given in this flash rate for 1-2s. with the patient's eyes open. The patient then was asked to close his eyes whilst the I.P.S. continued for another 2s. If abnormality did not occur, the flash frequency was increased in steps of two and the above procedure was repeated.

2.24.3 Monocular I.P.S.

In order to test the effect of monocular I.P.S. the patient was asked to press the palm of the hand firmly over the orbit of one eye making sure that the hand was closely applied to the edge of the nose so that no light could reach the occluded eye.

The patient was then exposed to a flash frequency which invariably provoked E.E.G. abnormalities in binocular I.P.S. The duration of I.P.S. and the intensity of the flash were increased if abnormality was not induced.

Each eye was tested in at least three I.P.S. presenta - tions and the effect of I.P.S. was again retested on binocular stimulation in order to make sure that no habituation or conditioning had occurred.

2.25 Methods for Detection of Spatial Distribution of Occipital Spikes.

Additional electrodes were applied midway between the standard 10/20 post-Rolandic electrode locations. Sub-occipital electrodes were also applied to complete the chain (Fig. 4.21.1.1) using the same distance as was used for the midway electrodes, i.e. 10% of the nasion-inion distance.

Bipolar and common reference recordings were used.

2.26 Tape Recording.

In nine of the photosensitive patients (Nos. 1-9) an F.M. tape recording was made from either the right or left occipito-central derivations ($O_2 - C_4$ or $O_1 - C_3$) and the flashes were recorded on the second channel of the tape

Fig. 2.22.1 Oscilloscopic traces of the occipital spikes.

Negativity: upwards deflection.

Flash stimuli are shown by vertical bars below the trace.

Horizontal bar: 20 ms.

Vertical bar: 100 uV.

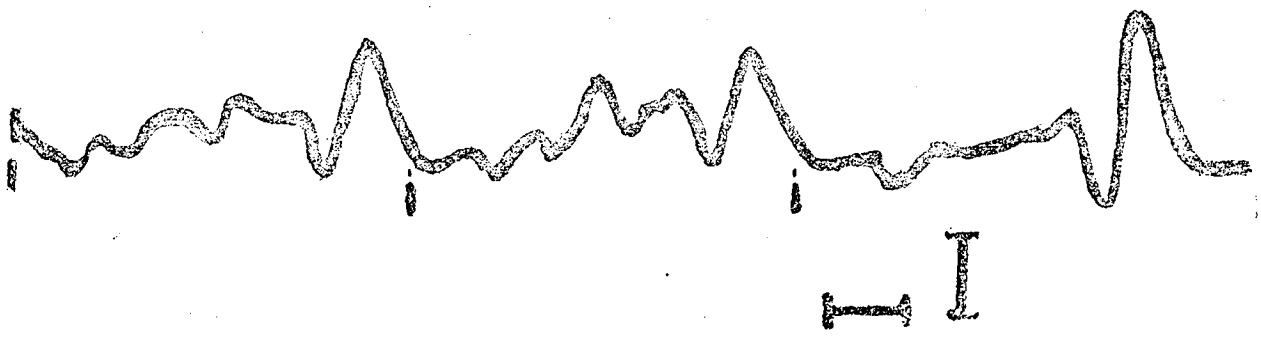


Fig. 2.22.1

recorder. Simultaneous play-back was used during the recording in order to check that there was accurate reproduction.

The magnetic tapes were subsequently replayed through an E.E.G. machine to the C.A.T. at the Neuropsychology Unit. Visual evoked responses (V.E.R.) and occipital spikes were obtained from the data in a way similar to that used for the on-line experiments (2.32). In a few initial cases the latency of the occipital spikes was measured by replaying the tape recording through a two channel oscilloscope (Fig. 2.22.1) but this method was subsequently abandoned as it was more laborious and the results obtained were not superior to the technique described in 2.32.

2.27 Evaluation of E.E.G. Abnormalities.

The E.E.G. were reported by Dr. P. M. Jeavons and myself. All records were re-examined by me without knowing the previous report. Any discrepancy which occurred was discussed with Dr. P. M. Jeavons and Dr. G. F. A. Harding in order to reach a final decision.

2.30 PROCEDURES USED IN RESEARCH E.E.G. DEPARTMENT

(Neuropsychology Department - Aston University)

2.31. Techniques for E.E.G. Recording-Montages.

The E.E.G. records were taken on an 8 channel S.L.E. machine. In a few initial cases an 8 channel Elther E.E.G. machine was used. During the recordings the subject reclined on a couch in a sound damped room with closed circuit television monitoring.

A standard parasagittal montage was used during the initial routine E.E.G. recording and during investigations of all I.P.S. factors other than those of V.E.R. and occipital spikes. For these latter investigations a special V.E.R. montage (see 2.21) was used.

2.32 On-Line Experiments.

The E.E.G. machine was connected via a four channel selector to a Technical Measurement Corporation Computer of Average Transients 400 C. (C.A.T.). This is a special purpose digital computer which allows differentiation of a small electrical signal, which has fixed phase and latency relations to the stimulus, from the background random activity.

Each sampling cycle (or analysis sweep) is triggered by a pulse (internally or externally) which has a fixed time relation to the specific signal under investigation.

The analogue sample is converted into a discrete number of digital counts proportional to the amplitude of the signal. These counts are stored in an address of the C.A.T. With each successive sweep the counts entered in each address are added algebrically to those previously stored in that address. In this way the signals which are time-locked to the trigger-pulse are added and are enhanced, whereas random noise, artifacts or spontaneous activity decay. The C.A.T. is not a true averager since it algebrically sums the repetitive samples and does not divide the stored signals by the number of sweeps or samples.

The C.A.T. contains 400 addresses which may be divided according to the number of channels being averaged (1-4). There are 400,200 and 100 addresses to each channel on 1, 2 or 4 channels of analysis respectively. The complete analysis time, that is the length of time allocated for each complete sweep (or series of samples),was 500 ms. On four channel analysis therefore, each store sampled a period of 5 ms.

Four channels of the C.A.T. were used for our on-line investigation, the first two channels recording the right and left occipito-central derivations ($O_2 - C_4$, $O_1 - C_3$) respectively.

The third channel monitored eye movement artifact using the right Centro-Frontal Pole derivation ($C_4 - F_{p2}$). This was found more satisfactory than monitoring from an eyelid-Frontal Pole derivation since the potential difference produced by eye movement between these two latter electrodes is much less than that produced between $F_{p2} - C_4$. In addition, by using C_4 as an active electrode of the monitoring channel, it was possible to determine whether there were any signals arising at or near the Rolandic regions and affecting both Occipito-Central and Centro-Frontal derivations. Any such signal would be easily recognized as, of course, it would have shown phase reversal to the central electrode.

In addition, potentials arising near the frontal electrode (i.e. eye movement artifact) would show higher amplitude in the Central-Frontal Pole than in the Occipito-Central derivation and they would be in phase in the two derivations. Such signals were easily recognized and Records of V.E.R. or occipital spikes contaminated by them were disregarded.

The remaining fourth channel of the C.A.T. was used to record the output of the photocell which was also used as a triggering pulse for the C.A.T. through an amplitude discriminator.

The number of repetitive sweeps on each V.E.R. investigation varied between 20-200 depending on the amplitude of the V.E.R. and the amount of artifact.

The C.A.T. was also used as a storage oscilloscope for displaying a single sample of the occipital spikes i.e. only a single sweep was used. This technique was found more satisfactory than using another oscilloscope. As we were concerned with the latency relation between occipital spikes and components of the V.E.R., it was felt essential that identical apparatus should be used. Obviously, since the critical latency relations are in milliseconds, no variation must occur in the time latency between stimulus and the sampling sweep time and the use of only one type of apparatus guaranteed that no such temporal difference could exist.

The output of the C.A.T. was fed to an X - Y plotter (Hewlett-Packard) and the stored results plotted as a permanent trace.

2.33 Effect of Illumination on Spontaneous Abnormalities Induced by "Eye-Closure".

The effect of illumination was investigated in patients who showed frequent spontaneous abnormal discharges on eye-closure. The patients were asked to open and close their eyes at random intervals between 5-30s. in conditions of either normal room illumination (130 Lux) or in total darkness. The periods of investigation under illumination and darkness were interspersed always starting and terminating the series with the illumination condition.

2.34 Comparison of Stroboscopic Factors.

Combination of pattern and I.P.S.

2.34.1 Parameters of the Stroboscopes.

The Grass P.S.2. and the Kaiser stroboscope were used.

Details of the stroboscopes are as follows:

a. Kaiser Stroboscope.

The glass face has a diameter of 15 cm. The lamp contains a protective metal grid with a 2 mm. mesh which is placed between a diffused glass and the light source. The electrical energy discharged across the gas tube is 0.1 or

0.2 or 0.6 joule with a total duration of approximately 150 micros., 200 micros. and 300 micros. respectively. 0.2 joule at 1 fl/s. corresponds to 4 megalux (approx.) (according to the curves given by the manufacturers) at a distance of 5 cm. from the lamp. Intensity declines with frequency increase.

b. Grass P.S.2. Stroboscope.

The glass face has a diameter of 13 cm. The glass is not diffused and there is no protective grid in front of the lamp. The lamp housing is aluminium and has a highly polished parabolic reflector. The instantaneous peak intensity at maximum setting (step 16, see below) measured on the axis of the parabola at a distance of 2 feet from the glass face plate is approximately 1.500.000 horizontal candle power.

The intensity can be altered in steps of 1, 2, 4, 8 and 16 which means that when the intensity switch is set to position 4, the brightness of the flash is 4 times that obtained when the switch is set to position 1. The duration of the flash is 10 micros.

In addition, the glass used in the tubes of the two stroboscopes is different which means that the colour of the

produced flash is also different.

2.34.2 Patterns.

A grid identical to the Kaiser grid and also a diffuser were made for fitting to the Grass stroboscope. In addition, the following series of patterns were made:

a. "Small squares" patterns with fine black lines ($\frac{1}{3}$mm. approx.) set at the same aperture spacing as the grid (2mm. x 2mm.).

b. Horizontal black lines (1mm. thick) spaced at intervals 1.3 - 2mm. apart.

c. The above pattern was also used as a "vertical lines" pattern.

d. "Large squares" with thick black lines (3mm. thick) placed 2.5 - 3mm. apart.(Fig. 2.34.2.1)

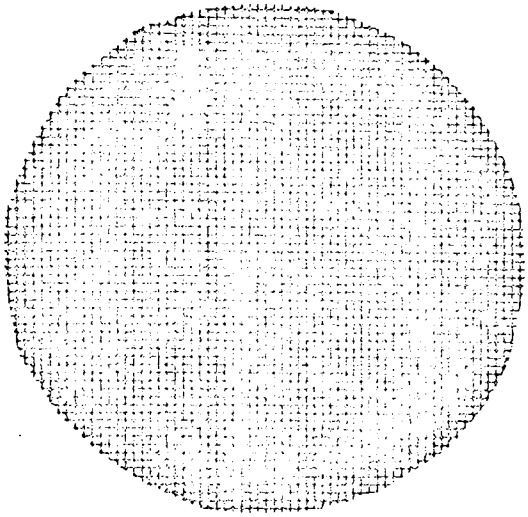
All the above patterns were on a slightly opaque background which has a diffusing effect.

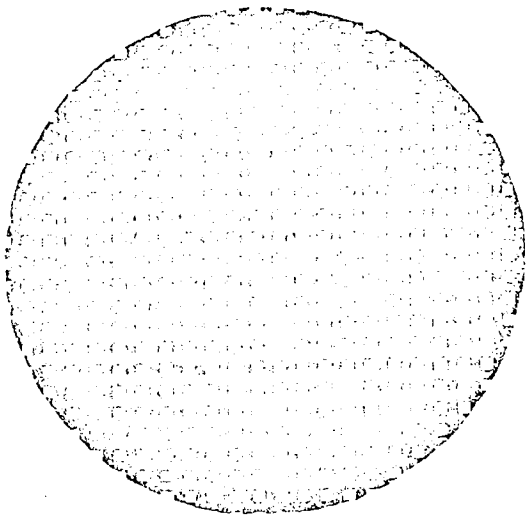
2.34.3 Comparison of the I.P.S. Effectiveness of the Two Stroboscopes.

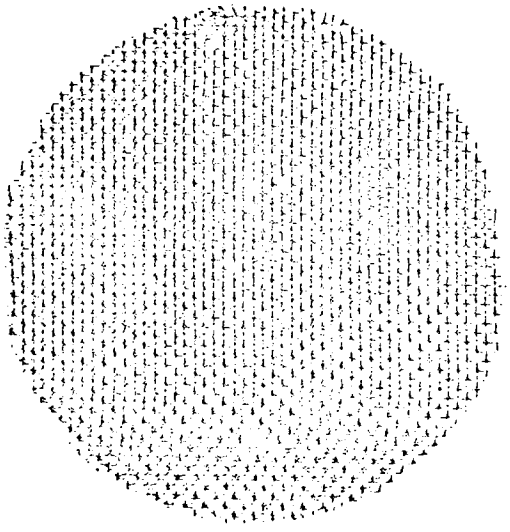
The various patterns or the grid were placed behind the plain glass of the Grass strososcope, but the diffuser was substituted for the glass.

Fig. 2.34.2.1 Patterns Used.

At the top "small squares" (left) and "large squares". At the bottom the grid (left) and the pattern used as "horizontal" and "vertical lines" are shown.







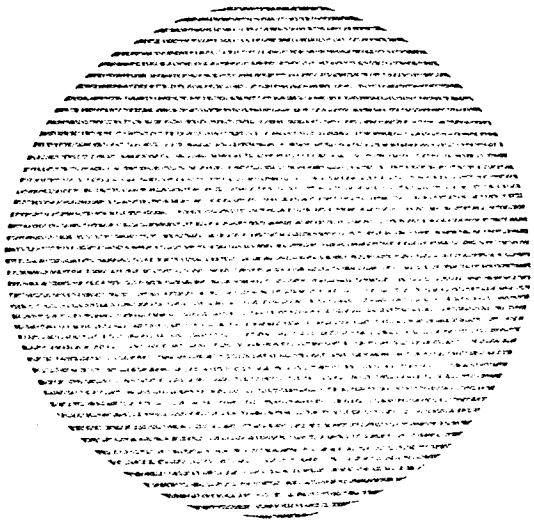


Fig. 2.34.2.1

From the comparison of the two stroboscopes given in 2.34.1 it is obvious that they differ on most factors, and the interpretation of their different effectiveness in provoking E.E.G. abnormalities is extremely difficult, if not impossible.

We decided, therefore, to use the following procedure in order to evaluate which of the factors of the two stroboscopes is more potent in the provocation of E.E.G. abnormalities.

A low flash frequency (using the Kaiser stroboscope at 0.1. J.) provoking clear and constant E.E.G. abnormality was established. This flash frequency was then used as a standard testing frequency using the Grass stroboscope.

Testing was carried out under the following stroboscopic conditions presented in a random order:

1. Diffusion screen.
2. Plain glass.
3. Large squares.
4. Horizontal lines.
5. Vertical lines.
6. Grid.
7. Small squares.

If abnormalities occurred using the small squares, but not with the Grid, a further condition, namely Grid and Diffusion, was tested.

Initially intensity 1 of the Grass stroboscope was used and if no abnormality was provoked,further testing was carried out with increasing intensity (in steps 2-4-8-16) until abnormality occurred or the maximum intensity was reached.

SECTION 3

MATERIAL

NORMAL SUBJECTS AND PATIENTS

3.10 GENERAL INTRODUCTION

Ninety two subjects were studied. There were seventy patients suffering from epilepsy. Fifty of these patients suffered from photosensitive epilepsy. The remaining twenty epileptic patients had no clinical history of fits precipitated by lights, but were selected because of E.E.G. abnormalities provoked by I.P.S. Twenty two normal subjects were also studied.

All subjects have been allotted a code number by which they will be subsequently recognized.

Numbers 1-50 have been given to patients with clinical photosensitive epilepsy, 51-70 to patients with epilepsy and E.E.G. abnormalities evoked by I.P.S. and 71-92 to normal subjects.

3.20 NORMAL SUBJECTS (Nos. 71-92).

These were normal students or staff employed by the University. Their mean age (18 years) was matched to that of the patients (Nos. 1-21). The latter were selected in order to study the relation of occipital spikes to V.E.R. There was a preponderance of males in the normal group (14 females and 8 males) in comparison to the patients group

(19 females and 2 males).

The past and family history of all subjects were carefully taken by the author. All subjects examined were free of epilepsy, migraine, ophthalmological disorders, intoxications, subjective sensitivity to light or any diseases which are known to affect the responses to I.P.S.

3.30 CLINICAL PHOTOSENSITIVE PATIENTS (Nos. 1-50).

These were patients referred by medical doctors to the E.E.G. Department of Dudley Road Hospital or Birmingham Childrens Hospital for E.E.G. examination. In some of these patients clinical photosensitivity was revealed after further questioning in the E.E.G. department. Clinical details of this group of patients are given in Table 3.30.1. The patients were divided into the following groups according to the clinical history:-

(A) Fits have occurred only when watching T.V. (21 patients)

(B) Fits have occurred whilst watching T.V., but also "spontaneously" at times when there was no evidence of flickering light as a convulsive precipitant. (19 patients)

Table 3.30.1: Clinical Details

of Patients with Photosensitive Epilepsy.

P.N. - Patient's Code Number

F - Female

M - Male

A, B, C, D, E - Groups of Photosensitive Epilepsy as given in 3.30.

Table 3.30.1 Clinical Photosensitive Patients.

P.N.	Sex	Age	Clinical Information	Group
1	M	16	Grand Mal attacks while watching T.V. from close distance. Compulsively attracted to T.V. set.	A
2	F	18	One Grand Mal attack whilst watching T.V.	A
3	M	12	One Grand Mal attack and one minor epileptic attack with right-hand movements whilst watching T.V. from close distance.	A
4	F	44	Two Grand Mal attacks whilst adjusting T.V. set.	A
5	F	14	Grand Mal and minor attacks precipitated by T.V. viewing.	A
6	F	27	Grand Mal attacks spontaneously and precipitated by T.V. viewing. Gets "vague" before the attacks.	B
7	F	25	Myoclonic jerking in the morning. Spontaneous Grand Mal attacks. T.V. and windscreen wipers give her an unpleasant feeling of discomfort.	D
8	F	13	One Grand Mal attack precipitated by reflecting lights. Grand Mal attacks spontaneously.	E
9	F	19	T.V. viewing makes her feel "funny". Spontaneous epigastric aura followed by temporal lobe epileptic attacks (being out of touch with surroundings and having auditory hallucinations). Family history of epilepsy.	B
10	F	15	"Dizzy spells" precipitated by reflecting and flickering sunlight (sea, snow, trees), and also by fluorescent lights.	E

Table 3.30.1 Clinical Photosensitive Patients.

P.N.	Sex	Age	Clinical Information	Group
11	F	12	Two epileptic attacks whilst watching T.V. (she could not see her fingers properly) - visual disturbances - cloudiness of consciousness and finally loss of consciousness. Her mother complains of attacks of visual disturbances when watching T.V.	A
12	F	11	Attacks during which she feels "far away", then her eyes roll up and she loses consciousness. Some attacks were spontaneous, others precipitated by T.V., flickering light and railings.	D
13	F	13	Compulsively attracted to T.V. set. Grand Mal attacks precipitated by T.V. viewing. (Long aura of "giddiness" and dizziness followed by left Jacksonian fit and terminated to a Grand Mal attack).	A
14	F	18	"Blackouts" precipitated by T.V., sunlight, moving patterns and pop-patterns.	C
15	F	15	Two Grand Mal attacks whilst watching T.V. from close distance.	A
16	F	12	Grand Mal attacks and myoclonic jerking precipitated by viewing T.V. from close distance. Spontaneous Grand Mal attacks. Compulsively attracted to T.V. set.	B
17	F	17	One Grand Mal attack precipitated by T.V. viewing.	A
18	F	12	Goes pale and feels "sick" whilst watching T.V. from close distance. Feeling of nausea precipitated by rotation of the turntable of record players and also moving stainless steel escalators.	C
19	F	14	One Grand Mal attack precipitated by T.V. viewing.	A
20	F	16	Myoclonic jerking in the morning. One Grand Mal attack when she approached the T.V. set to switch it off.	B

Table 3.30.1 Clinical Photosensitive Patients.

P.N.	Sex	Age	Clinical Information	Group
21	F	12	Grand Mal attacks precipitated by T.V. viewing.	A
22	M	9	Two Grand Mal attacks precipitated by T.V. viewing.	A
23	M	12	Spontaneous Grand Mal attacks and also precipitated by T.V. viewing. Stomach pain and vomiting preceded the attacks.	B
24	F	16	Spontaneous Grand Mal attacks and also precipitated by T.V. viewing.	B
25	F	18	Epilepsy since childhood. Spontaneous epileptic attacks and also precipitated by T.V. viewing. Compulsively attracted to T.V. set. Brother and mother also suffer from epilepsy with clinical photo-sensitivity. Sister suffers from epilepsy. Grandmother also suffered from epilepsy.	B
26	F	40	One attack of loss of consciousness whilst adjusting T.V. set.	A
27	M	9	One Grand Mal attack precipitated by T.V. viewing. Compulsively attracted to T.V. set. Mother and grandmother suffer from epilepsy.	A
28	F	14	Two Grand Mal attacks whilst adjusting T.V. set.	A
29	M	11	Two Grand Mal attacks precipitated by T.V. viewing. Compulsively attracted to T.V. set.	A
30	M	8	One Grand Mal attack whilst watching T.V. from close distance. Mother suffers from epilepsy (Grand Mal) with E.E.G. abnormalities during I.P.S.	A
31	F	13	One Grand Mal attack whilst switching on a T.V. set. Compulsively attracted to T.V. set. One sister has abnormal E.E.G. during I.P.S. and another sister gets "giddy" in discotheques.	A

Table 3.30.1 Clinical Photosensitive Patients.

P.N.	Sex	Age	Clinical Information	Group
32	F	13	Two Grand Mal attacks whilst adjusting T.V. set.	A
33	F	16	One Grand Mal attack precipitated by T.V. viewing and another one without precipitating factors.	B
34	F	19	One Grand Mal attack precipitated by fluorescent lights. Feels "funny" with flickering lights (sun, cars, railings and trees).	E
35	M	12	One Grand Mal attack precipitated by T.V. viewing.	A
36	M	16	Grand Mal attacks precipitated by T.V. viewing and one during sleep.	B
37	F	18	Spontaneous minor epileptic attacks. One Grand Mal attack whilst adjusting T.V. set. Mother and paternal grandfather suffer from epilepsy.	B
38	F	13	"Funny" feeling in her stomach precipitated by T.V. viewing. Two spontaneous attacks of focal epilepsy, (bats eyelids, twists mouth and right arm twitches). Feels sick afterwards. Father suffers from "fainting" (?) attacks.	B
39	M	21	One Grand Mal attack whilst viewing T.V. and another one possibly precipitated by flickering lights.	C
40	M	5	Grand Mal and Petit Mal attacks spontaneously and also precipitated by T.V. viewing. Brother of Patient No. 24.	B
41	F	16	One abortive Grand Mal attack precipitated by T.V. viewing from close distance. Grand Mal and Petit Mal attacks without obvious precipitating factors.	B

Table 3.30.1 Clinical Photosensitive Patients.

P.N.	Sex	Age	Clinical Information	Group
42	F	17	Two attacks of loss of consciousness (Grand Mal ?) whilst watching T.V. from close distance. Intermittent abdominal pain. Mother suffers from "blackouts".	B
43	F	10	Grand Mal attacks spontaneous and precipitated by T.V. viewing.	B
44	M	8	Myoclonic jerking spontaneous and precipitated by T.V. viewing. Compulsively attracted to T.V. set.	B
45	M	9	Minor and Grand Mal attacks precipitated by T.V. viewing. Compulsively attracted to T.V. set. Maternal uncle suffers from epilepsy.	A
46	F	39	Petit Mal and Grand Mal attacks spontaneous (not for 20 years). Sensitivity to flickering lights.	E
47	M	20	One Grand Mal attack precipitated by T.V. viewing and another one precipitated by reflected sunlight.	D
48	F	13	Two Grand Mal attacks when she switched on T.V. set. Myoclonic jerking in the morning.	B
49	F	18	Grand Mal attacks spontaneously and also precipitated by T.V. viewing or adjusting T.V. set.	B
50	F	17	Three Grand Mal attacks whilst asleep. "She does not like" flickering sunlight or flashing lights in discotheques. Mother, maternal grandmother and maternal aunt do not like flickering lights.	E

(C) Fits have occurred whilst watching T.V., but also when the patient was exposed to flickering or bright light from other sources. No fit has occurred "spontaneously".

(2 patients)

(D) Fits have occurred with T.V. and with flickering light and "spontaneously".

(3 patients)

(E) Fits have been evoked by flickering or bright light but not by T.V. (5 patients)

3.31 Sex and Age of Clinical Photosensitive Patients.

The age range of the 50 clinical photosensitive patients was from 5-44 years (Table 3.30.1) and the majority of patients (74%) were between 10-20 years of age (Fig. 3.31.1). As the age of onset of photosensitivity was not known a shift towards the youngest group is expected.

72% of the patients were females (Fig. 3.31.1).

3.32 Types of Epileptic Attacks in Clinical Photosensitive Epilepsy.

Although it is beyond the purpose of this thesis the following points should be made on the history of patients

Fig. 3.31.1 Sex and Age of Clinical Photosensitive Patients.

F - Female

M - Male

a: Percentage of patients who are younger than 20 years of age.

b: Percentage of patients who are older than 20 years of age.

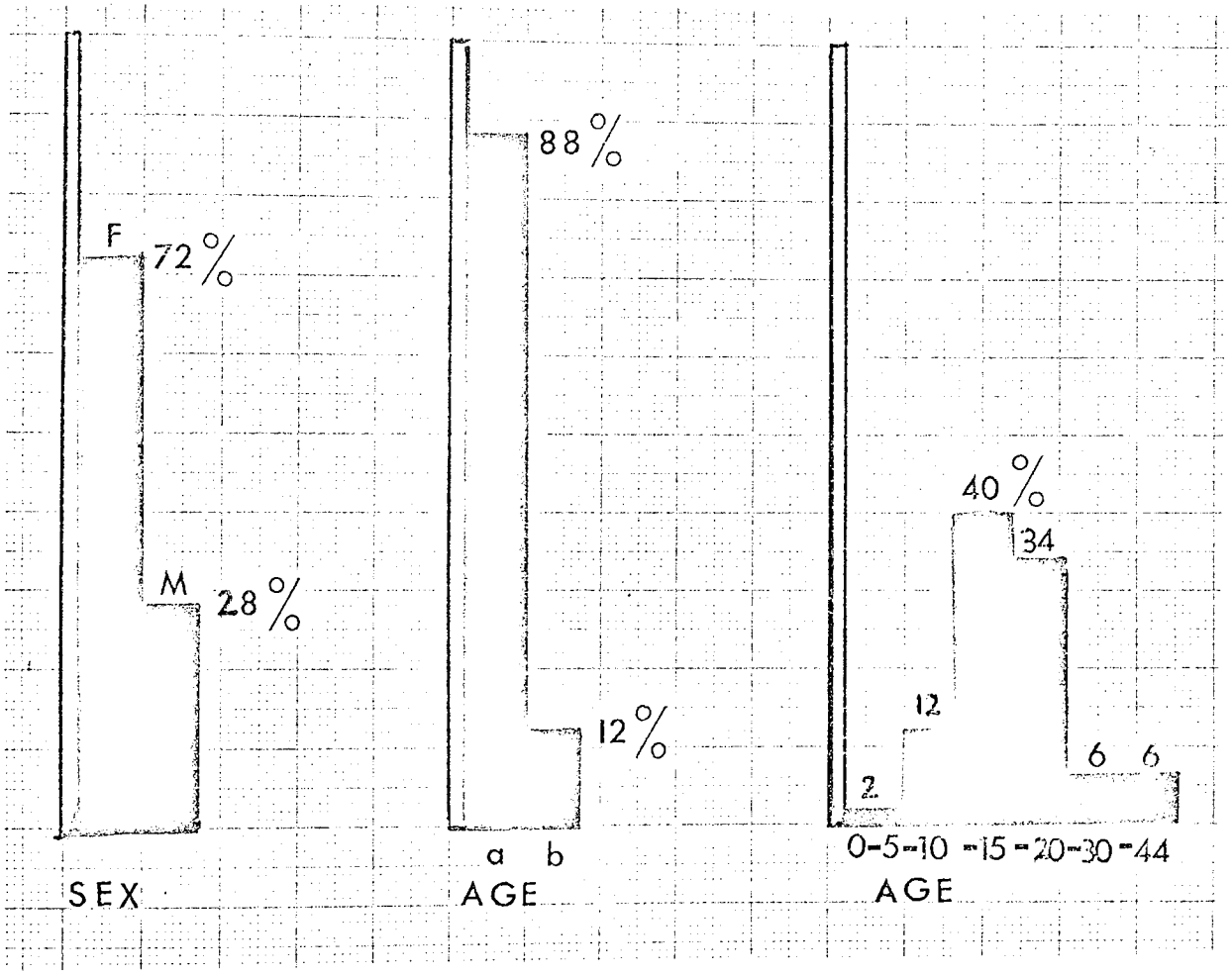


Fig. 3.31.1

with clinical photosensitive epilepsy:-

a. Grand Mal attacks only, occurred in 50% of the patients, i.e. in 16 patients of group A, 5 patients of group B, 1 patient of group C, 1 patient of group D and 2 patients of group E.

b. Grand Mal attacks were precipitated by T.V. in some patients (i.e. Nos. 20 and 48) although only myoclonic jerking occurred spontaneously.

c. Ten patients out of 45 (who suffered from T.V. epilepsy) were compulsively attracted to T.V. set.

3.40 EPILEPSY WITHOUT CLINICAL PHOTOSENSITIVITY. (Nos.51-70).

20 patients referred for E.E.G. examination because of clinical history of epilepsy were tested. There was no history of fits precipitated by flickering light. They were all selected because they had E.E.G. abnormalities during I.P.S. Clinical details are given in Table 3.40.1.

3.41 Sex and Age of Patients with Epilepsy and E.E.G. Abnormalities During I.P.S.

The age range of 20 patients of the above group was between 2 and 30 years (Table 3.40.1) and most of the patients (75%) were between 10-20 years of age (Fig. 3.41.1).

90% of the patients were females (Fig. 3.41.1).

Table 3.40.1 Clinical Details of Patients with Epilepsy and E.E.G. Abnormalities During I.P.S.

P.N. - Patient's code number.

M - Male

F - Female

Table 3.40.1 Patients with Epilepsy and E.E.G. Abnormalities

Provoked by I.P.S.

P.N.	Sex	Age	Clinical Information
51	M	18	Single Grand Mal attack.
52	F	30	Grand Mal Epilepsy. She has been free of attacks for the last eight years. Mother of patient No. 30.
53	F	13	Attacks of loss of consciousness. During the attacks she shouts, twitches and sees coloured lights. Incontinent sometimes.
54	F	12	Attacks described as Grand Mal. She has been free of them for the last three years.
55	F	19	Myoclonic jerking of right hand which sometimes proceeds to a Grand Mal attack. These occur usually early in the morning.
56	F	10	Grand Mal attacks and absences. Sister of patients No. 24 and 40.
57	F	14	Generalized convulsions since babyhood.
58	F	16	Two Grand Mal attacks shortly after waking up.
59	F	8	Petit Mal attacks.
60	F	3	Attacks of loss of consciousness.
61	F	5	Major epileptic attacks (febrile ?).

Table 3.40.1 Patients with Epilepsy and E.E.G. Abnormalities

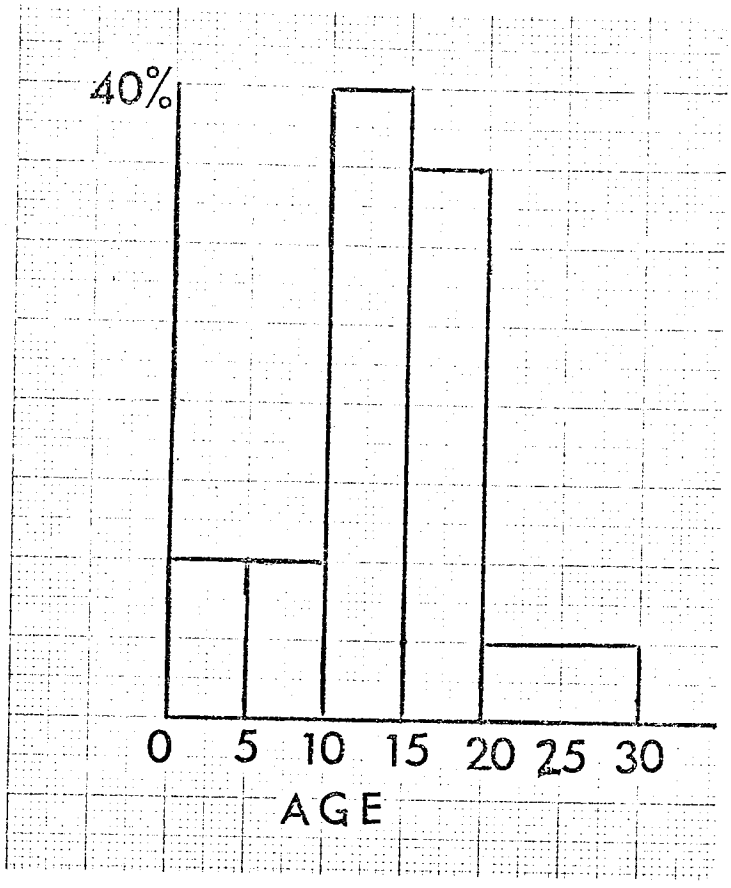
Provoked by I.P.S.

P.N.	Sex	Age	Clinical Information
62	M	14	Two Grand Mal attacks and also one attack described as temporal lobe automatism.
63	F	18	Epileptic attacks of loss of consciousness. They occur usually early in the morning and are associated with her menstrual cycle.
64	F	12	Grand Mal attacks. She has been free of attacks for the last six years.
65	F	17	Recurrent abdominal pain. Temporal lobe epilepsy.
66	F	16	Twitching of the right side of the body followed by loss of consciousness.
67	F	16	Recurrent epigastric pain followed by tinnitus and loss of consciousness.
68	F	14	Myoclonic jerking before going to sleep or in the morning after waking up. Grand Mal attacks during sleep.
69	F	14	Twin sister of patient No. 68. Myoclonic jerking before going to sleep and also nocturnal Grand Mal attacks.
70	F	2	Two epileptic attacks with right sided twitching.

Fig. 3.41.1 Sex and Age of Patients with Epilepsy and E.E.G. Abnormalities During I.P.S.

F - Female

M - Male



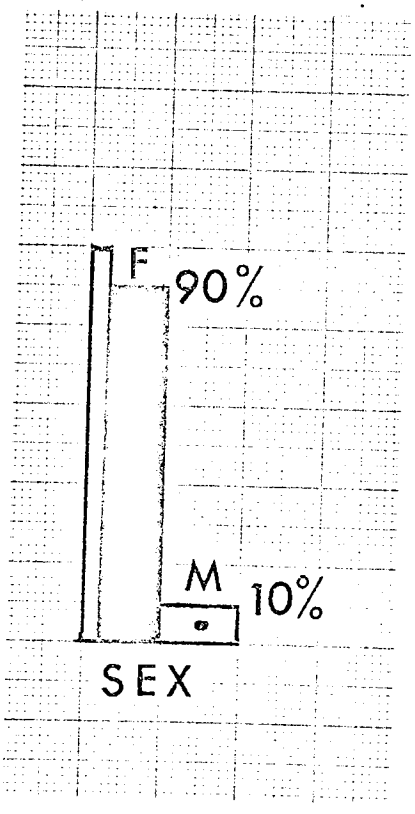


Fig. 3.41.1

SECTION 4

RESULTS

4.10 ELECTROENCEPHALOGRAPHIC FINDINGS.

(I.P.S. not induced)

4.11 Normal Subjects.

The resting E.E.G. of the 22 subjects were normal.

4.12 Clinical Photosensitive Patients.

Details of the E.E.G. findings in the 50 photosensitive patients are given in Table 4.12.1. Normal E.E.G. were found in 20 patients (i.e. 40%). In Fig. 4.12.1 the normal and abnormal E.E.G. are classified according to the five photosensitive groups. It can be seen that there is a clear difference between group A and group B. Ten out of 21 patients (i.e. 47.6%) of group A had a normal resting E.E.G. while only 3 (i.e. 15.78%) out of 19 patients of group B did not show abnormalities in their resting E.E.G. The number of patients of the remaining groups is too small for comparison and conclusions.

Generalized discharges immediately following eye-closure * were found in 8 (i.e. 16%) of the examined photosensitive patients. In four of these patients this was the only detectable abnormality in the resting E.E.G.

Unilateral abnormalities were found in nine of the 30 abnormal E.E.G.

Abnormalities confined to the posterior Rolandic regions were found in only two (i.e. 4%) of the 50 patients.

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* These abnormalities occur immediately or within 1-2 s. after eye-closure. The most common type of abnormality is spike and theta wave generalized discharge of maximum amplitude in the post-Rolandic regions (Fig. 4.14.1). Occasionally the abnormality is confined to the occipital or post-Rolandic regions. Its duration is usually 0.5-2 s. but it can sometimes last as long as 10 s.

Table 4.12.1 E.E.G. Findings on Clinical Photosensitive Epilepsy.

P.N.	Patient's Code Number
O.S.	Lowest frequency rate (flashes/s.) provoking occipital spikes during eyes-open.
P.C.R.	Photoconvulsive range (flashes/s.) on "eyes-open" state.
-	Means that no abnormalities occur during I.P.S.
+	Five + have been granted for abnormalities provoked by I.P.S. on "eyes-open" state.*
N.T.	Not Tested.
Gr.	Photosensitive Group.

* The + have been granted on an arbitrary basis. This was done to give only a gross idea on how much responses differ on "eyes-open", "eyes-closed" and monocular I.P.S.

Table 4.12.1 Clinical Photosensitive Epilepsy

E.E.G. Abnormalities.

P.N.	Gr.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
1	A	Normal	6	10-50	-	-
2	A	Normal	7	9-50	N.T.	N.T.
3	A	Bursts of atypical spike and theta wave complexes.	5	6-68	N.T.	-
4	A	Normal	6	10-50	++	N.T.
5	A	Bursts of atypical spike and slow wave complexes.	5	13-30	+	N.T.
6	B	Theta waves in the right temporal regions.	5	6-26	++	N.T.
7	D	Normal	6	14-N.T.	N.T.	++++
8	E	Excess of theta activity. Spike and theta wave discharges.	6	9-60	N.T.	N.T.
9	B	Theta activity in the right temporal regions.	6	10-50	+	+
10	E	Normal	7	7-60	+	-
11	A	Left sided small spikes. Discharges induced by eye closure.	4.5	8-59	+	++

Table 4.12.1 Clinical Photosensitive Epilepsy

E.E.G. Abnormalities.

P.N.	Gr.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
12	D	Normal	5	5-70	N.T.	-
13	A	Normal	6	9-60	N.T.	-
14	C	Normal	7	14-24	-	-
15	A	Bursts of 14 c/s. sharp waves on eye closure and hyperventilation.	6	12-30	++	-
16	B	Brief generalized discharges of spikes and theta waves.	6	8-66	N.T.	-
17	A	Scattered occipital spikes. Generalized discharges precipitated by eye closure.	5	6-70	-	+++++
18	C	Generalized discharges precipitated by eye closure.	5	7-50	-	-
19	A	Normal	10	10-68	-	-
20	B	Spike and theta waves precipitated by eye closure.	7	10-50	++	++
21	A	Normal	6	9-24	-	+
22	A	Discharges of polyspike and theta wave. Some precipitated by eye closure.	0	1-70	-	+++++

Table 4.12.1 Clinical Photosensitive Epilepsy

E.E.G. Abnormalities.

P.N.	Gr.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
23	B	Slower on the left. Discharges of atypical spike and slow wave.	0	10-30	-	-
24	B	Normal	6	9-60	++	++
25	B	Excess of diffuse theta activity. Spike and slow wave complexes more abundant on the right anterior regions.	8	9-36	++	-
26	A	Bursts of spike and theta waves precipitated by eye closure.	5	17-70	N.T.	N.T.
27	A	Independent right and left temporal lobe epileptogenic foci (spike and slow wave).	0	1-60	-	+++
28	A	Normal	0	12-24*	+++++ +++++	+++**

* The P.C.R. of Patient No. 28 corresponds to "eyes-closed" state. No abnormality was seen on "eyes-open" state.

** In comparison with the abnormalities seen on "eyes-closed" state. No abnormalities were observed when the eyes were open.

Table 4.12.1 Clinical Photosensitive Epilepsy

E.E.G. Abnormalities.

P.N.	Gr.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
29	A	Slow waves in the right temporal regions. Asymmetric alpha to the right.	7	10-50	-	-
30	A	Bursts of spike and theta waves during hyperventilation.	8	8-60	N.T.	N.T.
31	A	Normal	5	6-17	+	-
32	A	Normal	10	10-60	+	+
33	B	Generalized discharges of atypical spike and slow wave discharges.	10	0	N.T.	N.T.
34	E	Spikes in the right frontoparietal region.	6	10-60	N.T.	-
35	A	Normal	10	15-22	-	+
36	B	Bursts of spike and theta waves precipitated by eye closure.	11	12-55	++	-
37	B	Generalized discharges of spike and theta waves.	0	7-60	N.T.	N.T.
38	B	Normal	5	6-80	-	-

Table 4.12.1 Clinical Photosensitive Epilepsy

E.E.G. Abnormalities.

P.N.	Gr.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
39	B	Bursts of theta waves during hyperventilation.	6	6-64	+++++	-
40	B	Generalized spike and wave discharges.	0	5-30	N.T.	N.T.
41	B	Generalized discharges of atypical spike and wave activity.	6	6-62	++	+*
42	B	Excess of posterior rolandic diffuse theta activity.	7	7-72	++	-
43	B	Normal	15	16-62	++	-
44	B	Generalized discharges of polyspike and slow waves activity	7	7-66	-	-
45	A	Spike and theta wave complexes in the left parasaggital regions.	20	35-55	-	-
46	E	Normal	6	16-50	-	N.T.
47	D	Normal	0	20-26	+++	N.T.
48	B	Bilateral bursts of atypical spike and slow wave often precipitated by "eye-closure".	6	6-64	N.T.	-
49	B	Brief discharges of atypical spike and wave.	6	6-62	+++	+
50	E	Normal	0	20-58	-	-

* Only when left eye was open. When right eye was open no abnormality occurred.

Fig. 4.12.1 Comparison of Abnormal and Normal Resting E.E.G. in the Five Different Groups of Photosensitive Patients.

Indicates number of patients belonging to each particular group.

Normal resting E.E.G.

Abnormal resting E.E.G.

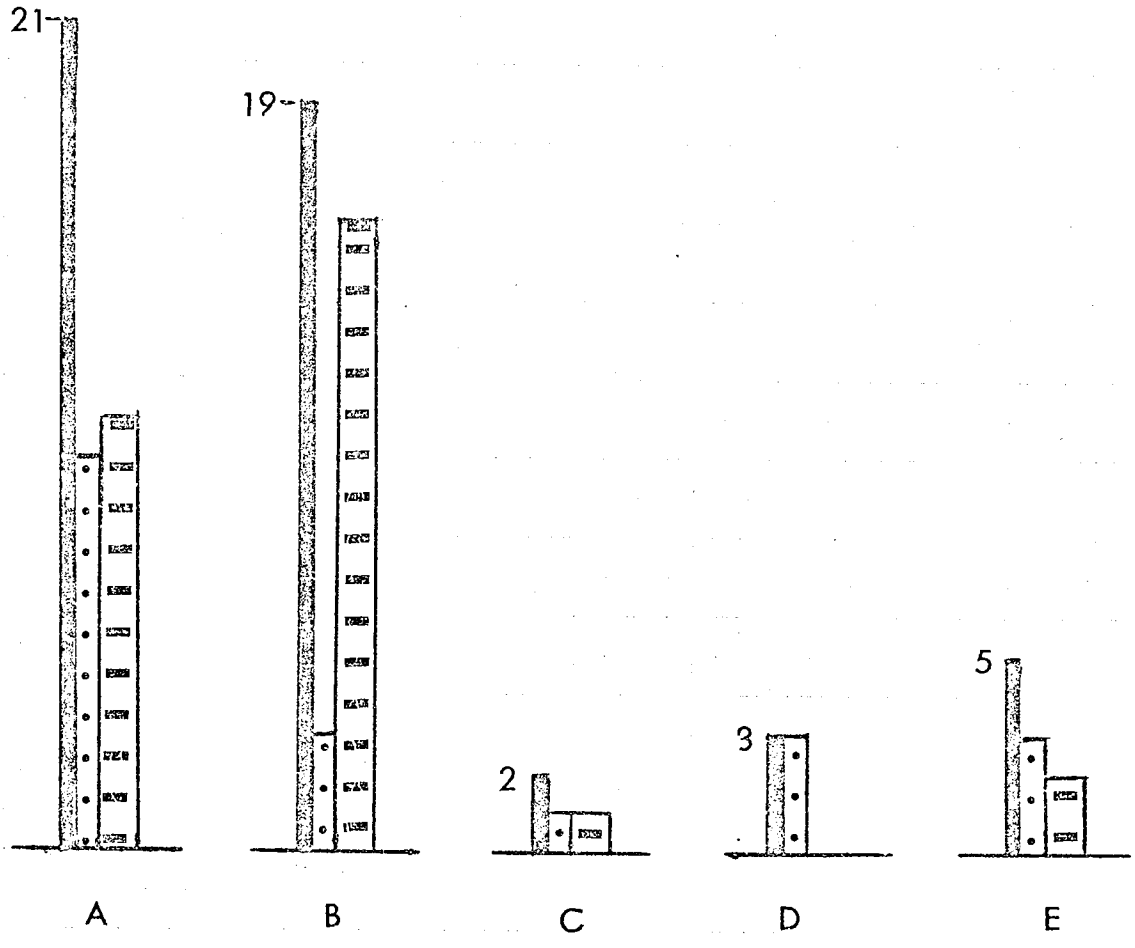


Fig. 4.12.1

4.13 Patients Suffering from Epilepsy.

Table 4.13.1 gives details of the E.E.G. findings in the group of patients suffering from epilepsy with E.E.G. abnormalities during I.P.S.

70% of the resting E.E.G. were abnormal.

Five patients (Nos. 53, 54, 55, 66, 67) showed abnormalities immediately after eye-closure. In two of these five patients this was the only detectable abnormality.

Table 4.13.1 E.E.G. Findings on Epilepsy with Abnormalities Provoked by I.P.S.

P.N.	Patient's code number.
O.S.	Lowest flash frequency (per s.). provoking occipital spikes.
P.C.R.	Photoconvulsive range (flashes/s.) on "eyes-open" state.
-	Means that no abnormality occurred during I.P.S.
+	Five + have been granted for abnormalities provoked during "eyes-open" I.P.S.
N.T.	Not tested.

* See comment in Table 4.12.1.

Table 4.13.1 Patients with Epilepsy and E.E.G. Abnormalities Provoked by I.P.S.

- E.E.G. Findings -

P.N.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
51	Bursts of spike and 5-3/s. waves.	6	12-55	N.T.	-
52	Bursts of spike and 5/s. waves of higher amplitude in the anterior regions.	6-12	-	N.T.	N.T.
53	Right sided occipital spikes associated with eye-blinking.	5.5	9-60	N.T.	+*
54	Generalized atypical spike and slow wave discharges on eye-closure. Tiny spikes in the left occipital regions.	8	10-60	-	-
55	Intermittent and diffuse theta activity. One burst of theta and delta waves in the anterior regions. Occipital spikes and generalized theta waves on eye-closure.	5	9-22	+++	+++

* No abnormality occurred when the right eye was open, but some right sided occipital spikes appeared when the left eye was open.

Table 4.13.1 Patients with Epilepsy and E.E.G. Abnormalities

Provoked by I.P.S.

- E.E.G. Findings -

P.N.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
56	Right frontal spike focus. Generalized discharges of atypical spike and slow wave activity starting from the right frontal regions.	0	7-62	+++	-
57	Generalized discharges of atypical spike and 4-6 c/s. slow wave. Bursts of polyspike and slow wave activity. Independent right and left sited sharp and theta waves.	10	10-20	+++	N.T.
58	Normal	5	8-20	-	+++*
59	Discharges of 3 c/s. spike and slow wave activity.	8	8-20	-	-
60	Normal	14	14-54	-	-
61	Normal	5	10-20	-	-

* There was no abnormality when the right eye was open, but P.C.R. occurred when the left eye was open.

Table 4.13.1 Patients with Epilepsy and E.E.G. Abnormalities Provoked by I.P.S.

- E.E.G. Findings -

P.N.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
62	Generalized discharges of 3/s. spike and wave activity. Some of these discharges started from the right frontal regions.	8	8-55	N.T.	N.T.
63	Normal	9	10-50	++	++*
64	Excess of diffuse theta and delta activity.	7	12-18	+++	-
65	Discharges of atypical spike and slow wave activity accentuated by hyperventilation. Some of these discharges started from the left temporal regions.	8	9-54	N.T.	-
66	Paroxysmal discharges of theta and delta waves of higher amplitude on the right. Discharges of theta waves on eye-closure. Excess of continuous theta activity in the occipital regions.	*	*	*	N.T.

* There was no abnormality when the left eye was open. Some abnormality appeared when the right eye was open.
*** The responses were very inconstant and they were mainly associated with eye-closure, although abnormalities occurred on eyes-open and on eyes-closed. The type of abnormalities also varied from occipital spikes to slow waves following and involving all regions.

Table 4.13.1 Patients with Epilepsy and E.E.G. Abnormalities

Provoked by I.P.S.

- E.E.G. Findings -

P.N.	Resting E.E.G.	O.S.	P.C.R.	Eyes Closed	Monocular
67	Bursts of theta waves following eye-blink.	7-9	-	N.T.	+++++
68	Normal	8	8-28	-	-
69	Spike and theta wave discharges appeared during drowsiness and light sleep.	7	7-50	-	-
70	Normal	4-15	-	N.T.	N.T.

4.14. Eye-closure in Darkness.

Five patients (Nos. 17, 18, 22, 54, 55) with frequent or constant abnormalities immediately after eye-closure were tested in order to evaluate the significance of light in the provocation of these abnormalities.

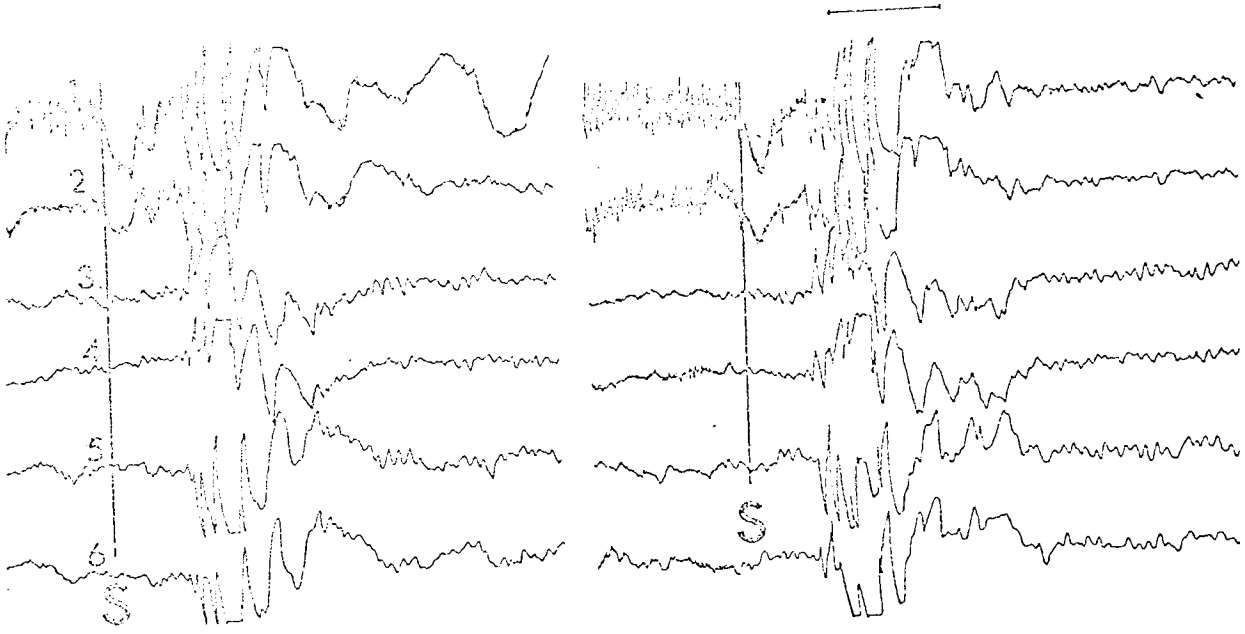
In none of the above patients abnormalities occurred on eye-closure in darkness (Fig. 4.14.1). It is also of interest that in two of the above five patients (Nos. 17 and 18) a squeak phenomenon was seen on a few occasions with normal room illumination. When the patients were tested in darkness the alpha thythm did not show any increase in frequency immediately after eye-closure.

Passive eye-lid closure was also tried in one patient (No. 17) in normal room illumination. It was noted that when the passive eye-closure was slow, no or little abnormality occurred, but constant abnormalities were seen when passive eye-closure was very fast.

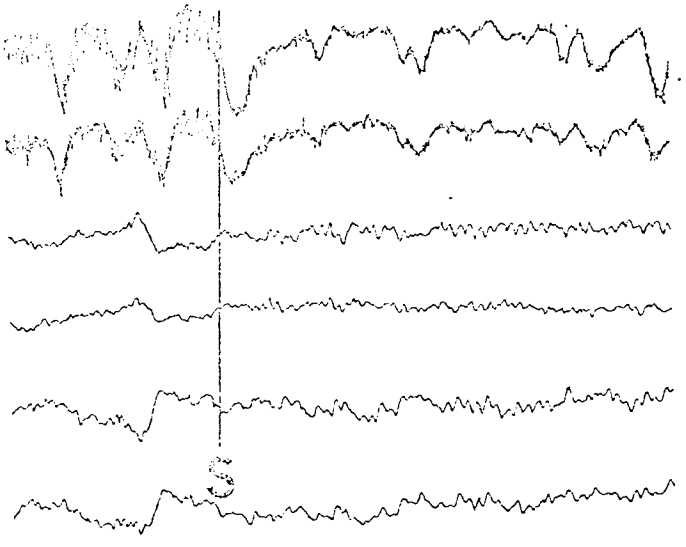
Fig. 4.14.1 E.E.G. Generalized Discharges Precipitated by Eye-Closure in Normal Room Illumination.

Complete darkness inhibits the abnormalities.

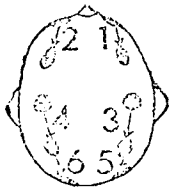
The top traces were taken before (left) and after (right) testing the effect of darkness.



light on



in dark



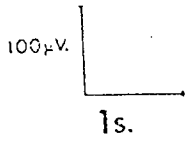


Fig. 4.14.1

4.20 ELECTROENCEPHALOGRAPHIC FINDINGS DURING I.P.S.

4.21 Description of Abnormalities.

The abnormalities provoked by I.P.S. were either occipital spikes alone (Figs. 4.21.1 and 4.21.2) or photo-convulsive responses preceded (Fig. 4.21.3) or not (Fig. 4.21.4) by occipital spikes. Other types of abnormalities, as for example on and off responses, to I.P.S. were seen but not studied in this thesis.

4.21.1 Occipital Spikes.

The occipital spike has a main component which is negative to the occipital electrode (O_1 or O_2). In addition there is a smaller positive component which precedes the main negative deflection and there is a further positive deflection following the negative component (Figs. 4.21.1 and 4.21.1.1).

Although the occipital spike is probably a complex, it is treated here with particular reference to its main negative component (negative occipital spike).

The polarity and relative localization of the occipital spikes were determined using a special V.E.R. montage (see techniques) and also by recording through additional scalp

and suboccipital electrodes.

As can be seen in Fig. 4.21.1.1 the maximum amplitude of the spike is obtained from the occipital electrode in the common reference recording. This indicates that the generators of the spike are under the occipital electrode. Electrodes 9 and 11 are less influenced and no spike is obtained from 7, 8, 12 and 13 electrodes, which indicates that these electrodes are further away from the spike-source.

The same conclusions are reached when the bipolar recording is studied. The occipital spikes show phase reversals to the O_1 electrode. The polarity of the components of the spikes are easily understood when simple E.E.G. recording knowledge is used. In the bipolar recording for example, there is an upward deflection of the pen in derivation 4 (i.e. the electrode O_1 connected to the black lead has become negative to the electrode 11 connected to the white lead). In the same way there is a downward deflection in the derivation 3 which means that the electrode 9 (connected to the black lead) has become positive in relation to electrode O_1 (connected to the white lead) or in other wards electrode O_1 has become relatively negative to electrode 9.

Similar conclusions about the polarity of the occipital spikes can be drawn by the study of the common reference recording.

The occipital spike first appeared between 0.2 and 3.0s. after the onset of a train of stimuli, but never appeared after the first flash. At increasing flash frequency it tended to appear earlier (Fig. 4.21.1.2). It was characterized in most cases by a successive increase in amplitude which reached a maximum after 3-9 successive flashes (Figs. 4.21.1 and 4.21.2). If the flash stimulus was continued the occipital spike might progressively decline in amplitude (Figs. 4.21.1.3 and 4.21.1.4) and then occur again, or it might terminate in a photoconvulsive discharge (Fig. 4.21.1.5). The waxing and waning of the occipital spike was most likely to occur at slower flash rates (5-7 fl/s.) whilst termination in a generalized discharge usually occurred at faster flash rates. In all patients the spike frequency was fundamentally related to the flash rate (Fig. 4.21.2), although in a few cases the spikes induced by slow flash rates (4.5-6 fl/s.) were intermittent.

In a few cases the occipital spikes started first or were of higher amplitude in the one hemisphere than in the other (Fig. 4.21.1).

The latencies of the initial positive and negative occipital spike are given in Table 4.41.1 for 21 clinically photosensitive patients and in Table 4.42.1 for 5 patients of the epilepsy group.

The initial positive wave had a latency of a range of 76-99 ms. (mean value 88.95 ms.) for the photosensitive group and 77-94 ms. (mean value 85.8 ms.) for the epileptics.

The latency of this positive component was, for most patients, constant for the same patient at different flash frequencies. The amplitude of this component was usually 30-60 microvolts, but in some cases reached a maximum of 100 microvolts.

The latency of the negative occipital spike was between 94-118 ms. (mean value 103.24 ms.) for the photosensitive patients and 97-104 ms. (mean value 101.8 ms.) for the epileptics. This latency was constant for the same patient irrespective of the flash frequency over a

range of 4.5-10 fl/s. (Fig. 4.41.7) although a progressive increase in latency (from 3-15 ms.) was sometimes seen with a pronounced augmentation of amplitude of the negative occipital spike (Fig. 4.21.1.6).

In a few cases the latency of the negative spike remained unchanged even when the interval between the flashes was shorter than the latency of the negative wave (Figs. 4.41.5 and 4.42.1).

The amplitude of the negative occipital spike was usually between 60-100 microvolts, occasionally reaching a maximum of 150-200 microvolts.

The positive wave which followed the negative occipital spike did not show a constant latency at different flash rates particularly with stimulation at fast flash frequencies.

4.21.2 Photoconvulsive Responses.

The photoconvulsive responses induced by I.P.S. were similar to those described in 1.41.2.

They were generalized involving all cerebral areas. The majority of them were of higher amplitude in the anterior regions.

Fig. 4.21.1 E.E.G. Responses to I.P.S. in Patient No. 34.

The occipital spikes are of higher amplitude on the left than on the right and show recruitment. Note that the occipital spikes show phase reversals to O_1 electrode (i.e. between channels 13 and 14). High paper speed (15 cm/s.) and high gain (50μV/cm. for channels 11-16) were used for the E.E.G. recording.

Upper vertical bar (ch. 1-8): 100μV.

Lower vertical bar: 100μV (ch. 11-16) and 70μV (ch. 10).

Time Marker: 1 s.

Channel 9 records photocell output.

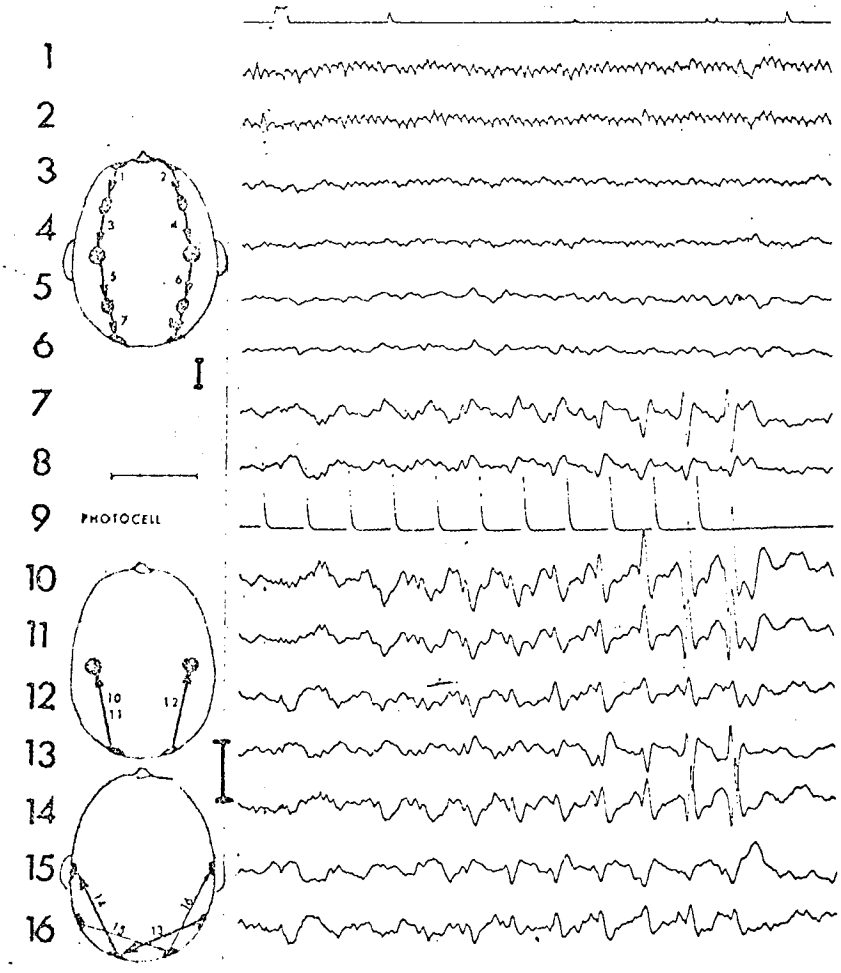


Fig. 4.21.1

Fig. 4.21.2 E.E.G. Responses in Patient No. 24.

A standard parasagittal (1-8) and a V.E.R. (10-16) montage are used. Routine E.E.G. paper speed (3 cm/s.) and gain (100μV/cm.).

The occipital spikes are frequency related to the flash and also their amplitude is successively increasing.

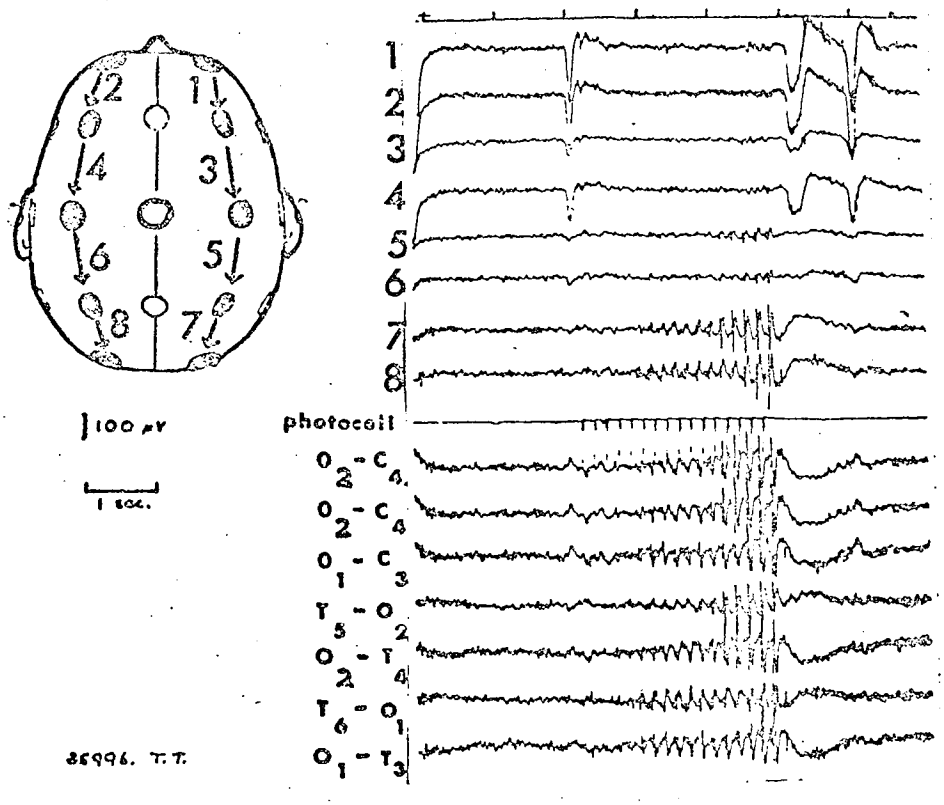

1
2
3
4
5
6
7
8
100 μV
1 sec.
photocell
O2 - C4
O2 - C4
O1 - C3
T5 - O2
O2 - T4
T6 - O1
O1 - T3

Fig. 4.21.2

Fig. 4.21.3 Responses to 8 fl/s. I.P.S. in Patient No. 34.

Occipital spikes precede a photoconvulsive response which is continuous long after cessation of stimulation. Fast E.E.G. paper speed (15 cm/s.) and high gain were used.

Squares: 1 cm.

Channels 1-8 and 11-16: 100μV/cm.

Channel 10: 70μV/cm.

Time Marker: 1 s.

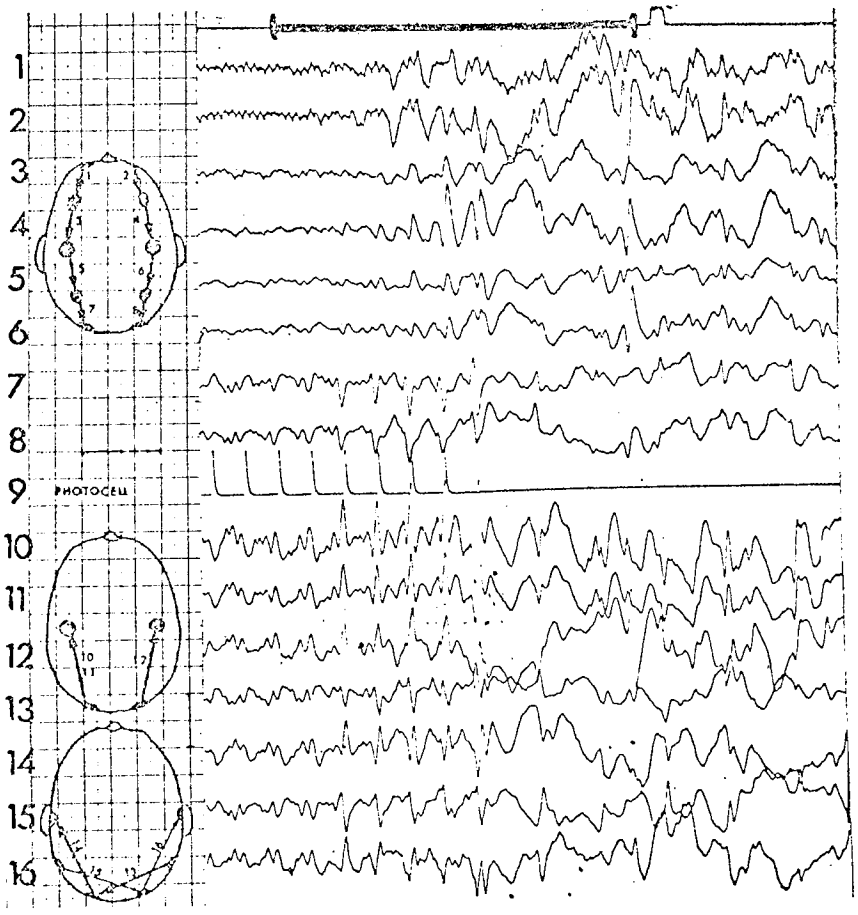


Fig. 4.21.3

Fig. 4.21.4 Photoconvulsive Response to 7 fl/s. I.P.S.

in Patient No. 37.

Despite the use of E.E.G. fast paper speed (15 cm/s.) and high gain (50μV/cm.) no occipital precursors can be seen.

Note that the photoconvulsive response does not terminate with the cessation of I.P.S. and that the early spikes of the response are frequency related to the flash.

Time Marker: 1 s.

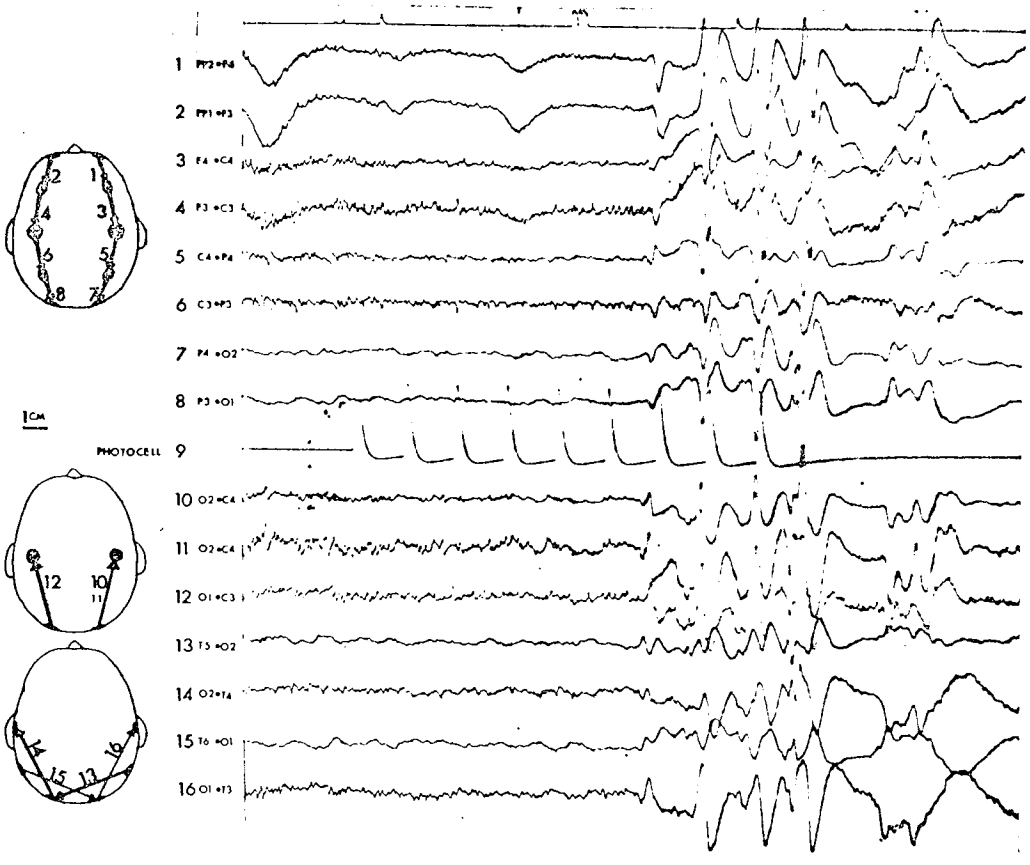

1 FP2-P4
2 FP1-P3
3 F4-C4
4 P3-C3
5 C4-P4
6 C3-P3
7 P4-O2
8 P3-O1
1CM
PHOTOCELL 9
10 O2-C4
11 O2-C4
12 O1-C3
13 T5-O2
14 O2-T4
15 T6-O1
16 O1-T3

Fig. 4.21.4

Fig. 4.21.1.1 Spatial Distribution of Occipital Spikes.

Electrodes 7 and 9 are placed midway between C_3 and P_3, P_3 and O_1, electrode positions respectively. Electrodes 11 and 12 (N) are placed at a 10% and 20% of the nasion-inion distance from O_1 (10) electrode respectively.

Electrodes 8, 10 and 13 correspond to P_3, O_1 and T_5 position in the 10/20 international system.

Electrode 14 is placed midway between T_5 and O_1. In the common reference recording (channels 7-14) the maximum amplitude of the occipital spike is obtained at O_1 (10) electrode. In the bipolar recording (channels 1-6 and channel 15) the occipital spikes show phase reversals to O_1 electrode (for further discussion see 4.21.1).

The vertical broken line between the thick arrows crosses the negative occipital spike. Photocell at channel 16.

Vertical bar: 100μV.

Horizontal bar: 100 ms.

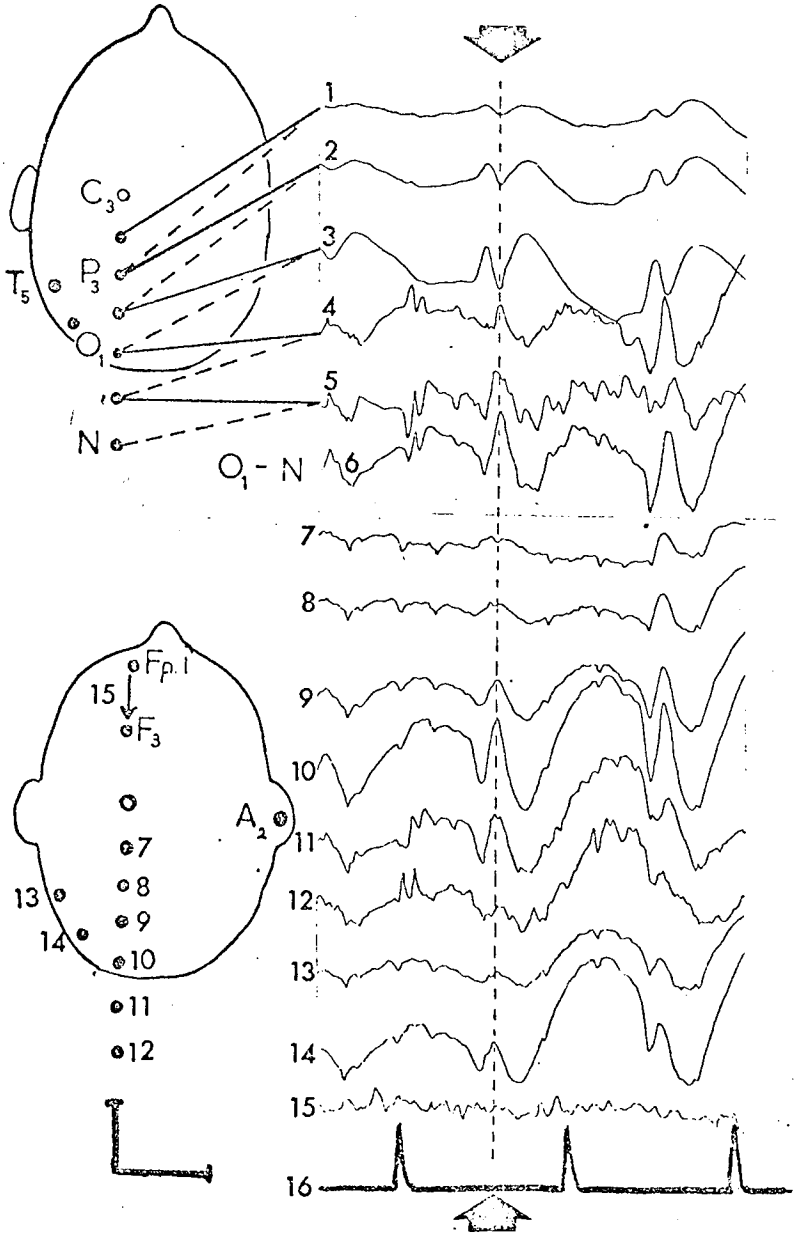


Fig. 4.21.1.1

Fig. 4.21.1.2 Occipital Spikes of a Photosensitive Patient.

At increasing flash frequency they tend to appear earlier. The numbers below the photocell-output traces denote flash frequency.

The long horizontal bars below the photocell-output traces denote time between onset of I.P.S. and the first occipital spike.

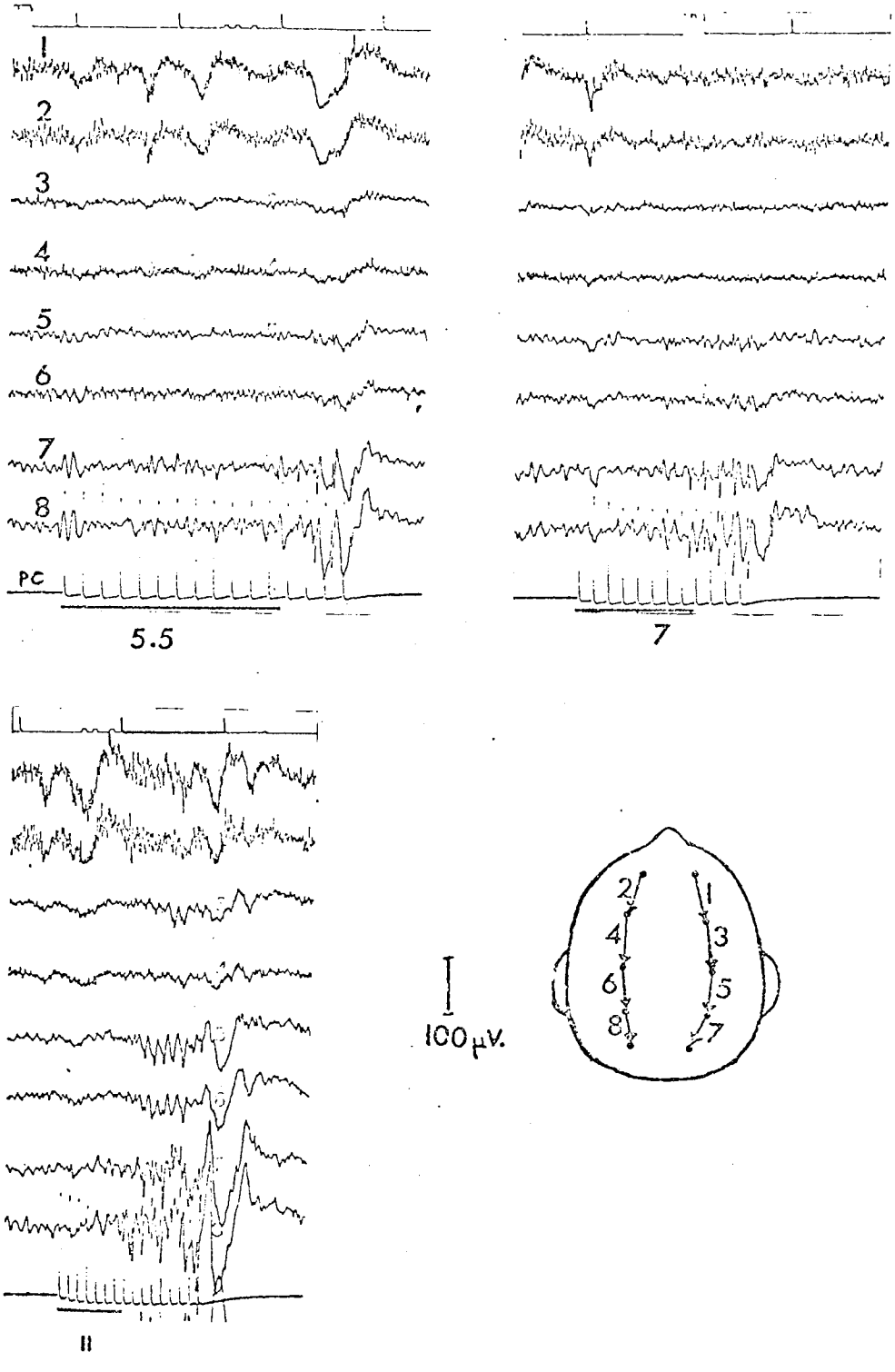


Fig. 4.21.1.2

Fig. 4.21.1.3 Waxing and Waning of the Occipital Spikes in Response to 5.5 fl/s. I.P.S.

Time Marker: 1 s.

Vertical bar: 30 μV.

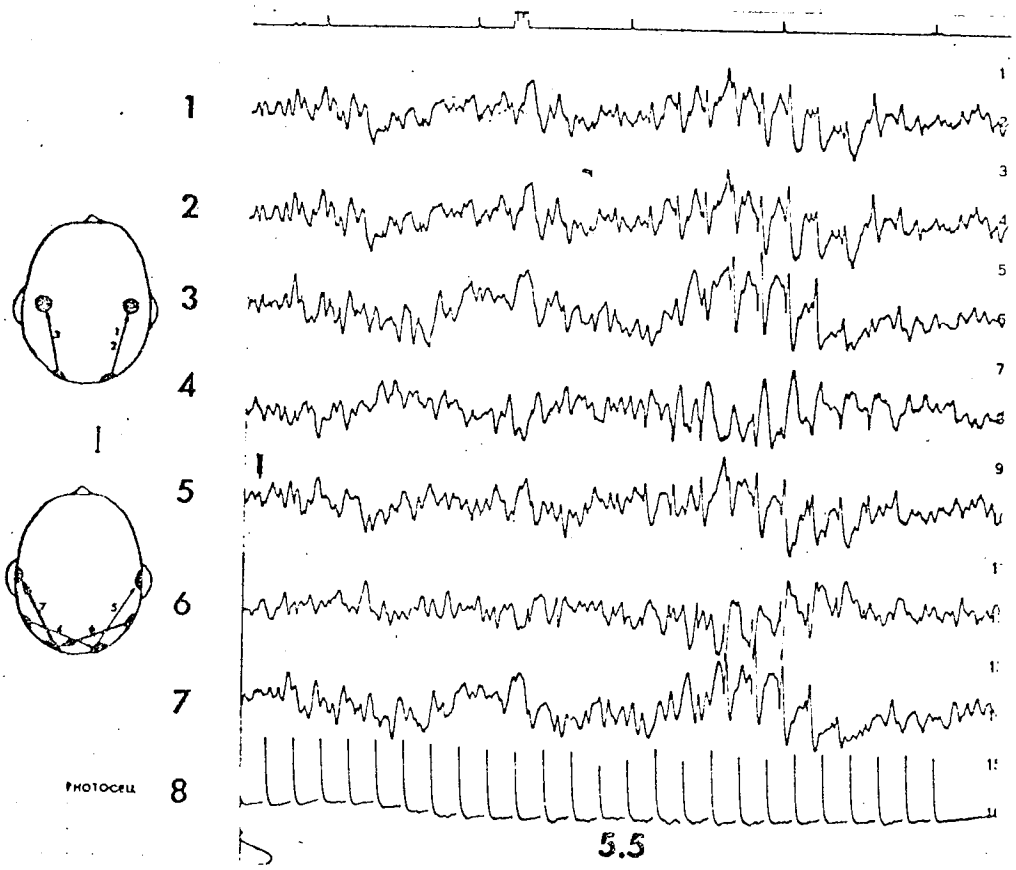
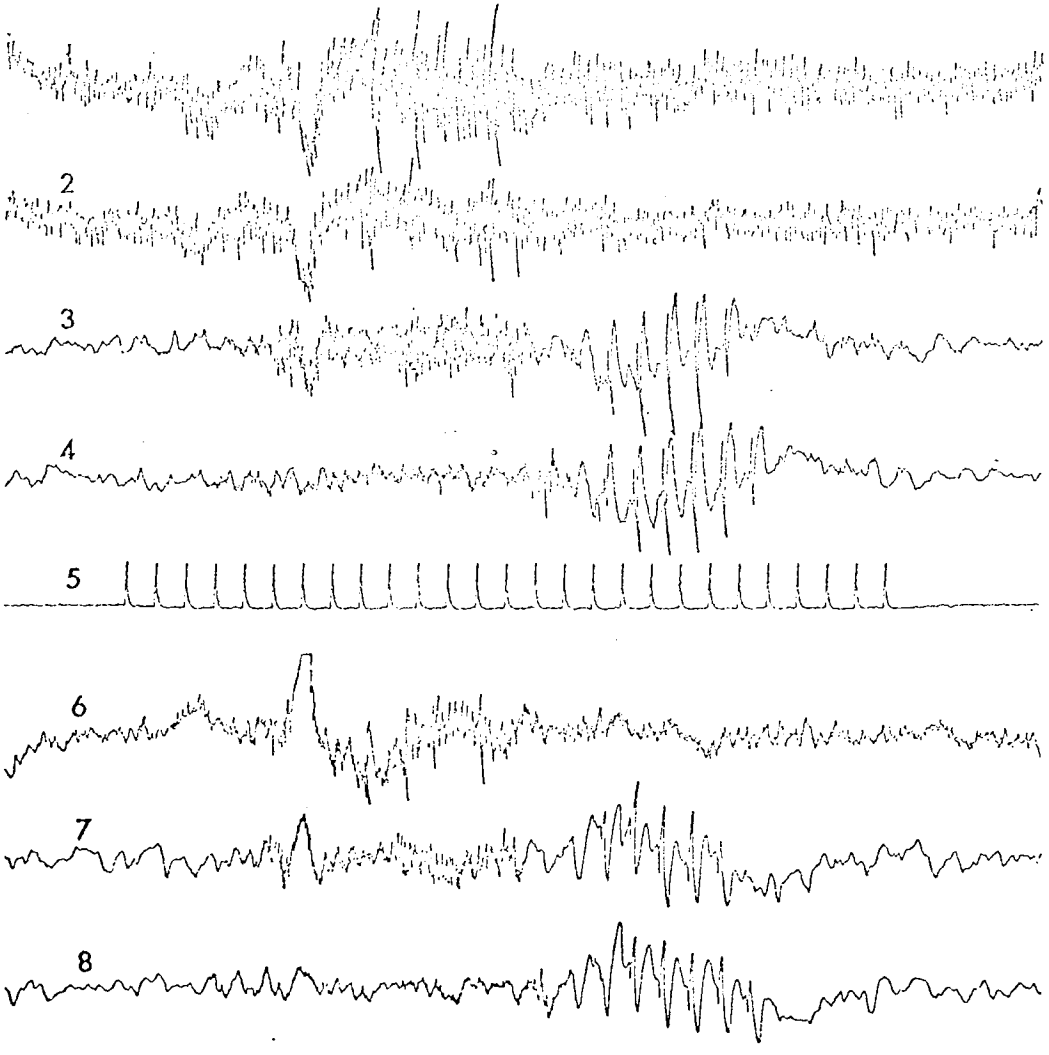


Fig. 4.21.1.3

Fig. 4.21.1.4 Occipital Spikes Showing Waxing and Waning at Low Flash Frequency (5.5 fl/s.) Stimulation.



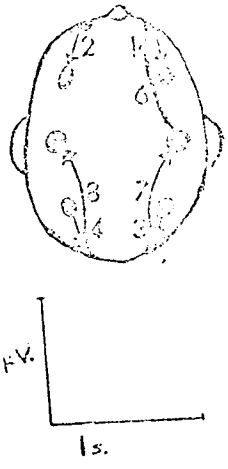


Fig. 4.21.1.4

Fig. 4.21.1.5 Occipital Spikes Preceding a Photoconvulsive Response.

Note the recruitment of the occipital spikes before the generalized discharge.

E.E.G. Paper Speed: 15 cm/s.

Time Marker: 1 s.

Gain: 100 μV/cm. (channels 1-8) and 50 μV/cm (channels 10-16).

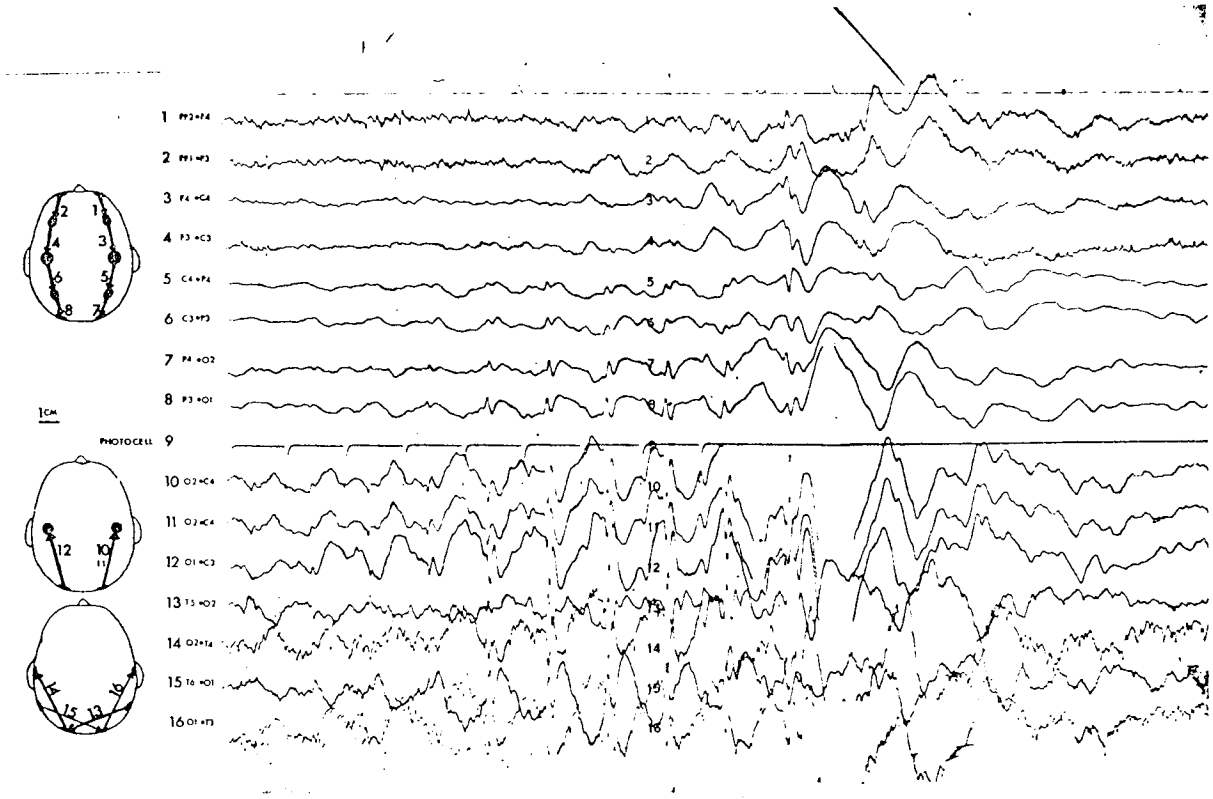

1 FP2-F4
2 FP1-F3
3 F4-C4
4 F3-C3
5 C4-P4
6 C3-P3
7 P4-O2
8 P3-O1
1CM
PHOTOCELL 9
10 O2-C4
11 O2-C4
12 O1-C3
13 T5-O2
14 O2-T6
15 T6-O1
16 O1-T5

Fig. 4.21.1.5

Fig. 4.21.1.6 Five Successive Occipital Spikes in Response to Five Photic Stimuli at Constant Flash Rate.

There is an increase latency of the negative occipital spike with increase amplitude.

Note the different amplitude between the occipital spikes illustrated on the top and bottom trace. Sequence of responses from top to bottom.

Arrows indicate flash instant.

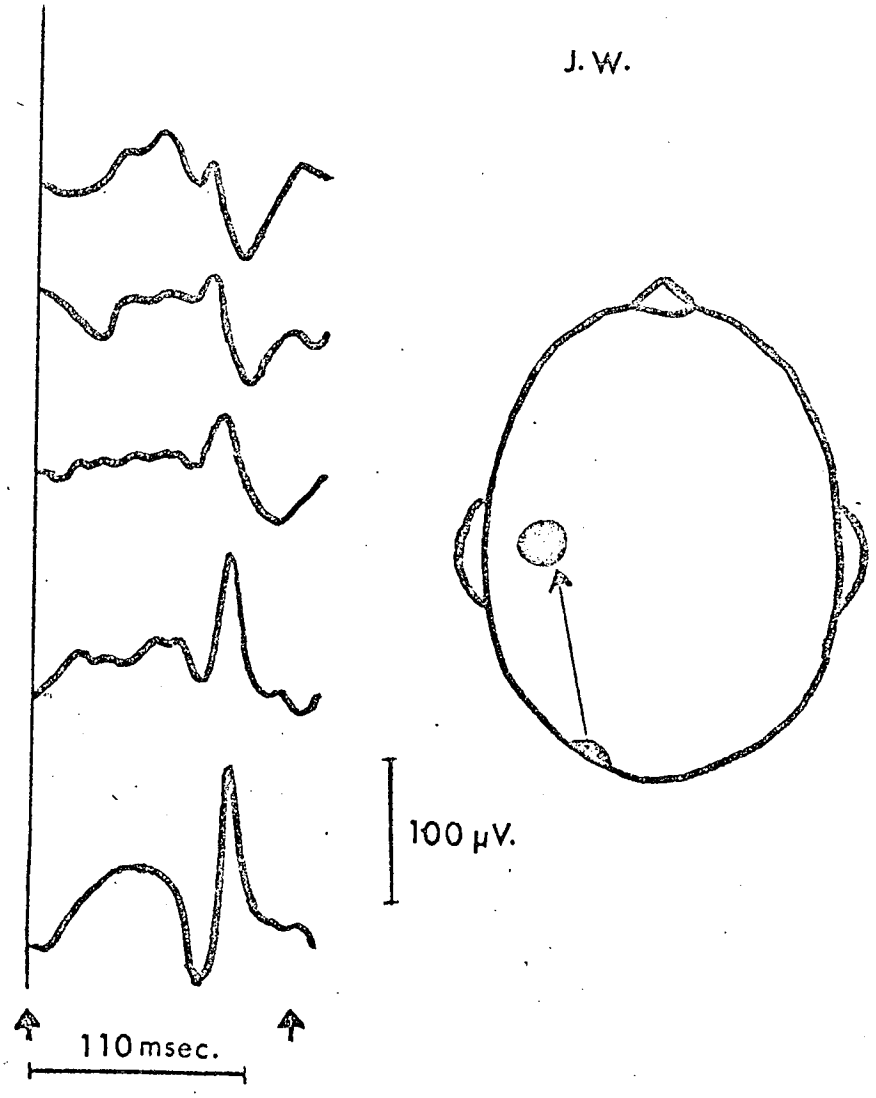


Fig. 4.21.1.6

The most common types of photoconvulsive responses occurring in the examined patients were:

a. Discharges of spike and 3-6 c/s. (mainly 5-6 c/s.) slow waves.

b. Discharges of 3-6 c/s. (mainly 5-6 c/s.) slow waves with tiny spikes.

c. Discharges of polyspikes and slow waves.

d. Discharges of slow waves.

e. Discharges of 3 c/s. spike-wave.

On a few occasions the frequency of the spike and slow wave discharges was at the same rate as the flash (Fig. 4.21.4).

The photoconvulsive responses usually terminated with the cessation of I.P.S., but in some cases persisted after the termination of I.P.S.

4.22. E.E.G. Findings in Normal Subjects.

In none of the normal subjects I.P.S. induced occipital spikes or photoconvulsive responses.

4.23. E.E.G. Findings in Photosensitive Epilepsy During I.P.S.

Forty nine (i.e. 98%) of the 50 patients of this group showed photoconvulsive responses, (Table 4.12.1).

In the remaining one (No. 33: Table 4.12.1) I.P.S. provoked occipital spikes only.

The E.E.G. of 42 patients (i.e. 84%) showed occipital spikes alone or preceding photoconvulsive responses. In 39 of these 42 patients the occipital spikes first appeared at flash rates slower than 11 s^{-1}. Table 4.12.1 gives details of the slower flash rates inducing occipital spikes and also the photoconvulsive range of the examined patients. It must be emphasized that a train of stimuli not exceeding 2 s. was applied. It is probable that lower frequencies would have evoked photoconvulsive responses if longer trains of stimuli had been used.

Flash rates provoking photoconvulsive responses were as low as 1 s^{-1} and as high as 80 s^{-1}.

Patient No. 38 showed the greatest photoconvulsive range (6-80 fl/s.) and patient No. 47 showed the smallest one (20-26 fl/s.) (Table 4.12.1).

In forty five patients photoconvulsive responses were induced at flash rates slower than 16 s^{-1} (1-5 fl/s. for four patients, 5-10 fl/s. for thirty four patients, 10-16 fl/s. for seven patients).

In only four patients flash rates higher than 16 s^{-1} were required in order to provoke photoconvulsive responses. 35 fl/s. was the lowest limit of the photoconvulsive range in patient No. 45.

In twenty one patients the lowest limit of the photoconvulsive range was between 8-12 fl/s. which is the frequency of the alpha rhythm.

In eight patients the lowest limit was below 8 fl/s. and in another ten patients above 12 fl/s.

In 12 patients the highest limit of the photoconvulsive range was more than 60 fl/s. which is the critical flicker frequency.

4.24 E.E.G. Findings in Epilepsy During I.P.S.

Table 4.13.1 gives details of the I.P.S. responses of these patients.

Seventeen patients (i.e. 85%) of the 20 showed photoconvulsive responses. The remaining three patients did not show photoconvulsive responses, but occipital spikes only were provoked by I.P.S.

Eighteen patients (i.e. 90%) showed occipital spikes alone or preceding photoconvulsive responses.

In only one patient (No.56) there were photoconvulsive responses without occipital spikes. The remaining one patient(No. 66) showed variable responses, that is the same flash frequencies would provoke either occipital spikes or photoconvulsive responses without preceding occipital spikes.

The limit of photoconvulsive range was as low as 7 fl/s. and as high as 62 fl/s. In all sixteen patients who showed constant photoconvulsive responses, E.E.G. abnormalities were induced at flash rates slower than 15 s^{-1}.

The largest photoconvulsive range was 7-62 fl/s. and the smallest 10-20 fl/s.

4.30 FACTORS CHANGING THE EFFECTIVENESS OF I.P.S.

4.31 Comparison of Responses on Eyes-Open, Eyes-Closed and Monocular I.P.S.

4.31.1 Photosensitive Patients.

Fig. 4.31.1.1 combines the results obtained in 31 photosensitive patients whose responses to I.P.S. were examined in three eye-states, namely eyes-open, eyes-closed and monocular. Table 4.12.1 gives details of the E.E.G. abnormalities obtained on "eyes-open", "eyes-closed" and monocular I.P.S.

Twenty nine (i.e. 93.54%) of the examined patients showed no abnormality or less abnormality on eyes-closed than on eyes-open. From these 29 patients 15 (i.e. 48.38%) showed no abnormality to I.P.S. when the eyes were closed whilst the remaining 14 had abnormal responses to I.P.S. on eyes-closed, but less than on eyes-open state.

In one patient (i.e. 3.23%) I.P.S. provoked the same amount of abnormalities whether the eyes were open or closed.

In the remaining one patient (No. 28) there was no abnormality on eyes-open, but photoconvulsive responses

Fig. 4.31.1.1 Comparison of Abnormalities Induced on "Eyes-Open", "Eyes-Closed", and Monocular I.P.S. in 31 Patients.

No abnormality occurred.

Less abnormalities were induced than on "eyes-open".

The amount of abnormality was equal with the abnormality induced on "eyes-open".

More abnormality was provoked than on "eyes-open".

E.C. Eyes-closed.

M Monocular.

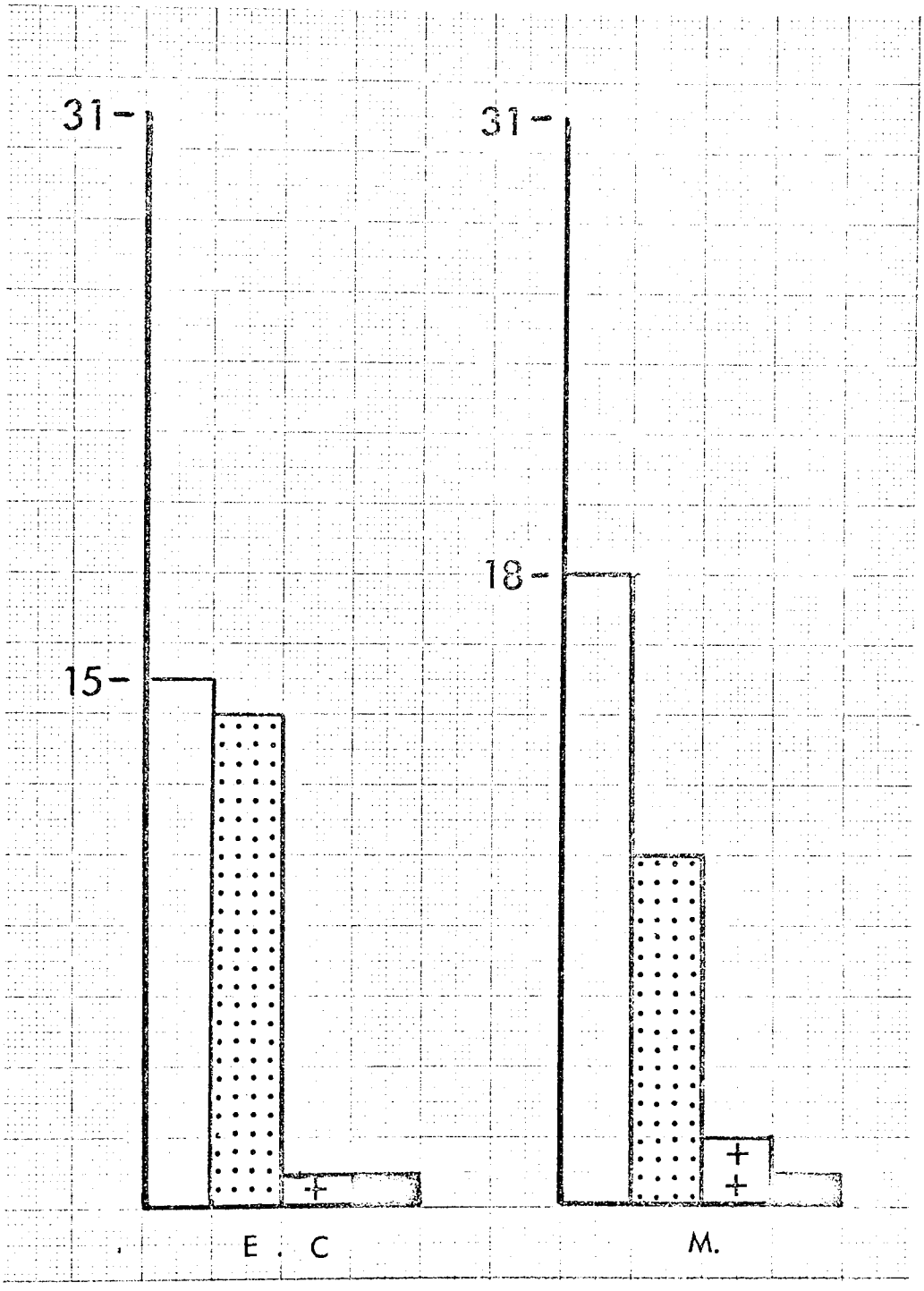


Fig. 4.31.1.1

were provoked when I.P.S. was applied when the eyes were closed.

Twenty eight (i.e. 90.3%) of the 31 patients showed no abnormality (18 patients, i.e. 58.07%) or less abnormality (10 patients, i.e. 32.23%) on monocular than on eyes-open I.P.S.

In two patients (i.e. 6.47%) the abnormalities provoked on eyes-open were the same as on monocular I.P.S.

In the remaining patient (No. 28) there was no abnormality on eyes-open, but photoconvulsive responses were seen on monocular I.P.S. This is the same patient who showed no abnormalities on eyes-open, but photoconvulsive responses occurred on eyes-closed.

One patient (No. 41) did not show abnormalities when I.P.S. was applied to the right eye, but photoconvulsive responses occurred when the left eye was stimulated.

Ten patients (i.e. 32.23%) who showed considerable abnormalities on eyes-open did not show any abnormality on eyes-closed and monocular I.P.S.

Four patients (i.e. 12.9%) in whom more abnormalities were evoked on eyes-open than in the other two eye-states showed equal amounts of abnormality on eyes-closed and monocular I.P.S.

Eleven patients (i.e. 35.48%) showed more abnormalities on eyes-closed compared to the abnormalities seen on monocular I.P.S. (seven of these eleven patients did not show abnormalities on monocular stimulation).

In six patients (i.e. 19.36%) there were more abnormalities on monocular than on eyes-closed I.P.S. and in fact five of these six patients showed no abnormalities on eyes-closed.

In general the following conditions were seen:-

1. Abnormalities on eyes-open, but no abnormalities on monocular I.P.S. (58.07%).
2. More abnormalities on eyes-open than on monocular I.P.S. (32.23%). One patient showed abnormalities when the one eye was stimulated, but no abnormalities occurred when I.P.S. was applied to the other eye.
3. Equal abnormalities on eyes-open and monocular I.P.S. (6.47%).
4. Abnormalities on eyes-open, but no abnormalities on eyes-closed (48.38%).
5. More abnormalities on eyes-open than on eyes-closed (45.16%).

6. Equal abnormalities on eyes-open and eyes-closed (3.23%).
7. Abnormalities on eyes-closed and monocular I.P.S., but no abnormalities on eyes-open (3.23%, only one patient).
8. Abnormalities on eyes-open, but no abnormalities either on eyes-closed or on monocular I.P.S. (32.23%).
9. More abnormalities on eyes-open than on eyes-closed and monocular I.P.S., but equal abnormalities in the two latter eye-states (12.9%).
10. More abnormalities on eyes-open than on eyes-closed and no abnormality on monocular I.P.S. (22.58%).
11. More abnormalities on eyes-open than on eyes-closed, but less abnormality on monocular than on eyes-closed I.P.S. (12.9%).
12. More abnormalities on eyes-open than on monocular, but no abnormality on eyes-closed (16.13%).
13. More abnormalities on eyes-open than on monocular, but less abnormality on eyes-closed than on monocular I.P.S. (3.23%).

14. More abnormalities on eyes-open than on eyes-closed with no abnormality when the one eye was stimulated and less abnormality on monocular I.P.S. of the other eye than on eyes-closed (3.23%).

4.31.2 Epilepsy with Abnormalities During Photic Stimulation.

Table 4.13.1 gives details of results obtained in 11 patients who suffer from epilepsy and showed E.E.G. abnormalities during photic stimulation. The following conditions were seen:-

1. Abnormalities on eyes-open, but no abnormalities on monocular I.P.S. (8 patients, i.e. 72%).
2. More abnormalities on eyes-open than on monocular I.P.S. (3 patients, i.e. 27.28%). It should be noted that two (Nos. 58, 63) of the above three patients showed no abnormalities when the I.P.S. was applied to the one eye, but photoconvulsive responses occurred when the other eye was stimulated.
3. Abnormalities on eyes-open, but no abnormalities on eyes-closed (7 patients, i.e. 63.64%).
4. More abnormalities on eyes-open than on eyes-closed (4 patients, i.e. 35.36%).
5. Abnormalities on eyes-open, but no abnormalities either on eyes-closed or on monocular I.P.S. (6 patients, i.e. 54.57%).

6. More abnormalities on eyes-open than on eyes-closed or monocular I.P.S., but equal abnormalities in the two latter eye states (1 patient).
7. More abnormalities on eyes-open than on eyes-closed, but no abnormality on monocular I.P.S. (2 patients).
8. More abnormalities on eyes-open than on stimulating the one eye, but no abnormality on eyes-closed or stimulating the other eye (1 patient).
9. More abnormalities on eyes-open than on eyes-closed or stimulating the one eye, but no abnormalities when the other eye was stimulated (1 patient). This patient showed equal amount of abnormalities on eyes-closed and monocular I.P.S. on the one eye.

Although the number of examined patients is small to draw conclusions about the percentage at the different conditions mentioned above it seems significant that all patients had more abnormalities on eyes-open than on eyes-closed and monocular I.P.S.

4.32 Eye-Closure During I.P.S.

In five unselected patients * (3 clinical photosensitive and two epileptics with E.E.G. abnormalities induced by I.P.S.) the effect of eye-closure was studied. It was found that in all examined patients the photoconvulsive range was invariably wider during eye-closure than in any other eye-state. In two of these patients no abnormality was evoked on monocular or eyes-closed I.P.S., although photoconvulsive responses appeared immediately after eye-closure at flash rates below or above the photoconvulsive range established for the eyes-open state.

Fig. 4.32.1 illustrates the responses of one of the above two patients and it can be seen that a photoconvulsive response is induced at 11 fl/s. immediately after eye-closure which was done within 2 s. of I.P.S. The lowest limit of the photoconvulsive range was 14 fl/s. for the eyes-open state, whilst eyes-closed I.P.S. was not effective.

---

* These patients were examined whilst the writing of this thesis was in progress and are not included in the patients given in section 3.

Fig. 4.32.1 Responses of a Photosensitive Patient to I.P.S. During Eyes-Open, Eye-Closure and Eyes-Closed.

Photoconvulsive responses occurred immediately after eye-closure at 11 fl/s. The same flash frequency is not effective in inducing photoconvulsive responses when the eyes are open. The lowest limits for the photoconvulsive range on eyes-open are 14 fl/s. I.P.S. is ineffective when the eyes are closed.

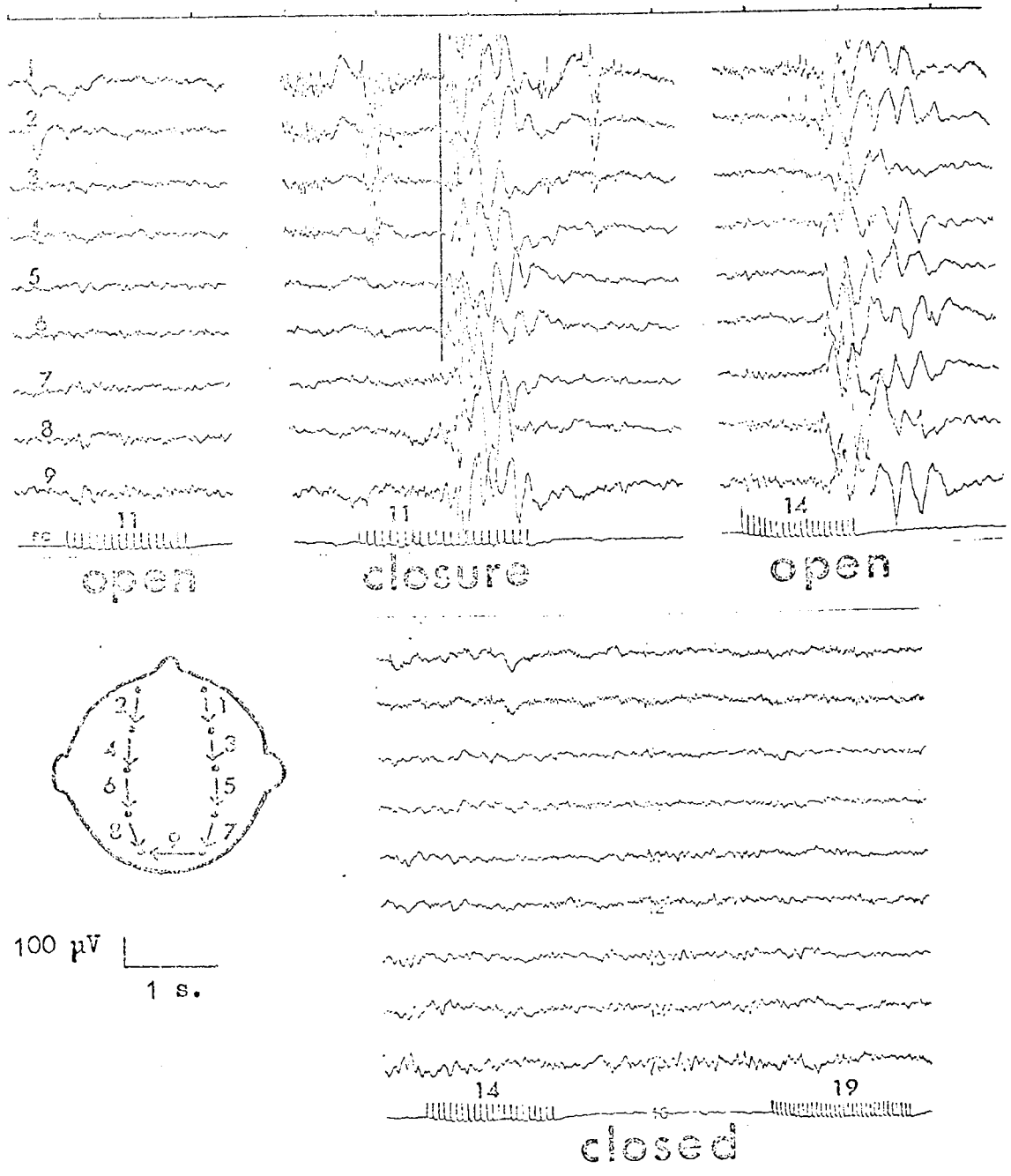

1
2
3
4
5
6
7
8
9
11
sec
open
11
closure
14
open
2
11
4
13
6
15
8
9
7
100 μV
1 s.
14
19
sec
closed

Fig. 4.32.1

4.33 Combination of Patterns with I.P.S.

4.33.1 Pilot Study.

During routine E.E.G. investigations of patients with photosensitive epilepsy and of patients with abnormalities induced by I.P.S., it was noted that flash frequencies which induced occipital spikes and/or photoconvulsive responses using the Kaiser stroboscope were less or not effective when using the Grass stroboscope.

Although it is known that several factors (detailed in section 1.43) affect the responses to I.P.S. and a combination of these factors might account for the different effect of the two stroboscopes, it seemed desirable to establish which particular factor was most important.

In a pilot study, four patients (Nos. 17, 18, 42 and 52) were studied. In all of these patients I.P.S. given by the Kaiser stroboscope evoked E.E.G. abnormalities.

The effect of I.P.S. given by the Grass stroboscope at intensity 1 was similar to that of the Kaiser stroboscope (at 0.1 Joule) only when the metal grid was fitted to the Grass lamp. The Grass stroboscope without the grid was not effective even when high intensity (16) was used (Fig. 4.33.1.1).

Fig. 4.33.1.1 Responses of a Photosensitive Patient to I.P.S. Given by a Kaiser Stroboscope (1) and a Grass Stroboscope (2, 3, 4, 5).

Occipital spikes were provoked only when the I.P.S. was combined with a grid (1, 2, 3). Despite a high increase of intensity no occipital spikes were obtained when I.P.S. was given by a Grass stroboscope through a diffuser (4) or a plain glass (5), although longer train of stimuli were applied.

Note that in this case the addition of a diffuser to the grid condition resulted to a less effective stimulus.

Abbreviations.

K	Kaiser Stroboscope.
Gr.	Grass Stroboscope.
Dif.	Diffuser (one sheet of white paper).
Plain	Plain glass.
P.C.	Photocell

Numbers below each E.E.G. denote intensity of flash.

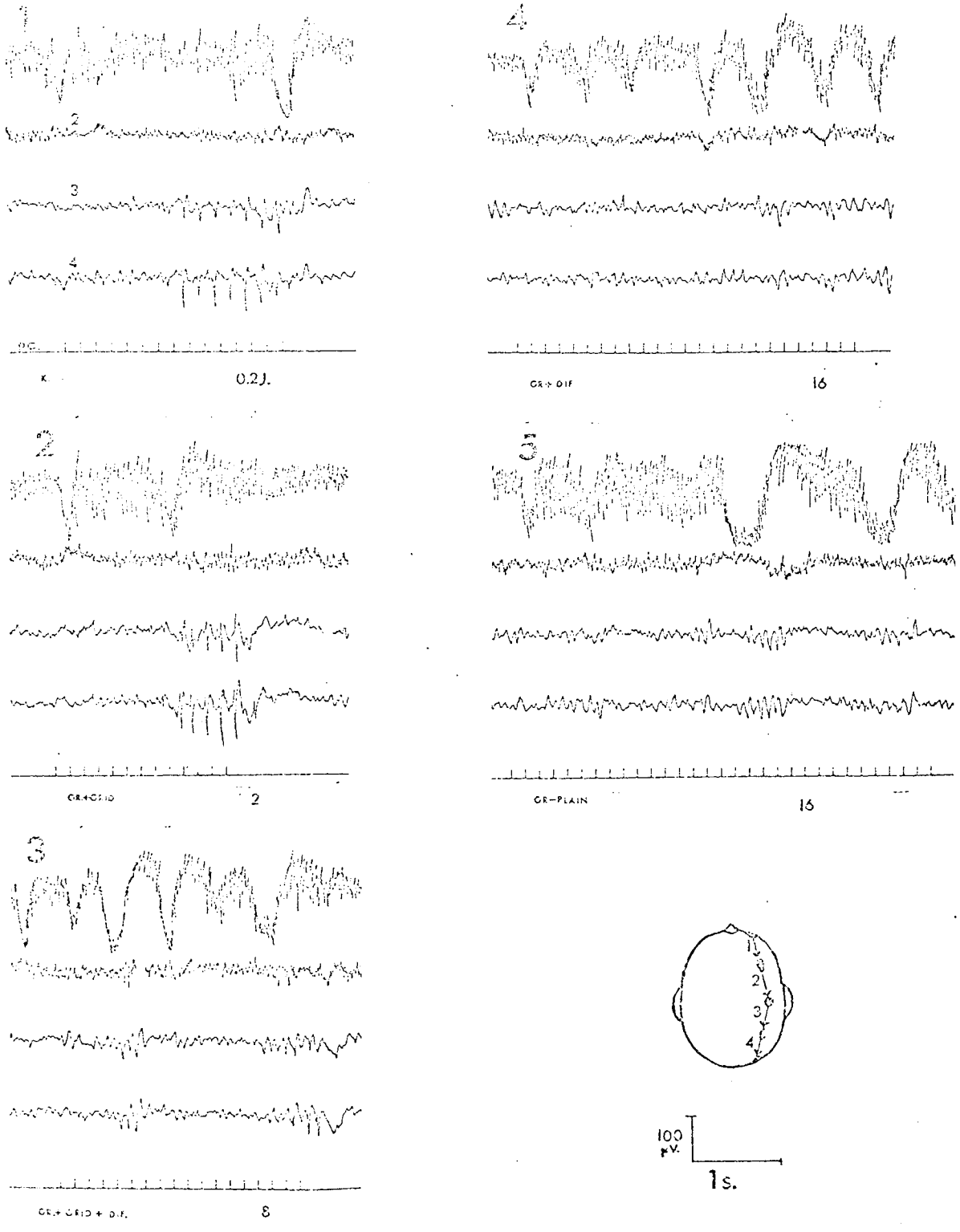


Fig. 4.33.1.1

4.33.2 Detailed Study.

The individual responses of ten examined patients to seven stroboscopic conditions are shown in Table 4.33.2.1.* The combined results are shown in Fig. 4.33.2.1 and Fig. 4.33.2.2. It can be seen that using the Grass stroboscope at intensity one no patient showed a photoconvulsive response with the diffuser or plain glass and only one showed a photoconvulsive response when the "large squares" were used. Horizontal and vertical lines, however, induced a spike and wave discharge in 5 and 6 patients respectively.

---

* Patient 50A was added in the series whilst the writing of this thesis was in progress. This is a boy, 9 years of age, who has had major and minor epileptic attacks precipitated by T.V. and also by flickering sunlight (group C). He is compulsively attracted to a T.V. set. His resting E.E.G. showed atypical spike and wave discharges which were sometimes induced by eye-closure. The photoconvulsive range was 7-64 fl/s. with eyes-open. The photoconvulsive responses were not precipitated by occipital spikes. Monocular I.P.S. inhibited the abnormalities and eyes-closed resulted in an attenuation of abnormalities (+++).

Table 4.33.2.1 Comparison of Stroboscopic Factors.

The E.E.G. responses to I.P.S. of 10 patients under different stroboscopic conditions.

Abbreviations.

D.	Diffuser.
P.	Plain Glass.
L.S.	Large Squares.
H.L.	Horizontal Lines.
V.L.	Vertical Lines.
G.	Grid.
S.S.	Small Squares.
P.N.	Patient's Code Number.
R.	Photoconvulsive Response*.
S.	Occipital Spikes Only.
-	No Abnormality Occurred.

* In all patients but one.(No. 50A) the photoconvulsive responses were preceded by occipital spikes.

Table 4.33.2.1 Comparison of Stroboscopic Factors.

Int.	1	2	4	8	16
D.	-	-	-	-	-
P.	-	-	-	-	-
L.S.	-	-	-	R	
H.L.	R				
V.L.	R				
G.	R				
S.S.	R				

P.N. 21

Int.	1	2	4	8	16
D.	-	S	S	S	S
P.	-	-	-	-	S
L.S.	-	-	-	R	
H.L.	R				
V.L.	R				
G.	R				
S.S.	R				

P.N. 38

Int.	1	2	4	8	16
D.	-	-	-	-	-
P.	-	-	-	-	-
L.S.	-	-	-	R	
H.L.	R				
V.L.	R				
G.	R				
S.S.	R				

P.N. 39

D.	-	-	-	-	-
P.	-	-	-	-	-
L.S.	-	-	-	R	
H.L.	-	-	R		
V.L.	-	R			
G.	R				
S.S.	R				

P.N. 41

D.	-	-	-	-	-
P.	-	-	-	-	-
L.S.	-	-	-	-	-
H.L.	-	R			
V.L.	-	R			
G.	R				
S.S.	R				

P.N. 48

D.	-	-	-	-	-
P.	-	-	-	-	-
L.S.	R				
H.L.	-	R			
V.L.	-	-	R		
G.	R				
S.S.	R				

P.N. 49

D.	-	-	-	-	-
P.	-	-	-	R	
L.S.	-	-	-	R	
H.L.	R				
V.L.	R				
G.	R				
S.S.	R				

P.N. 50A

D.	-	-	-	-	-
P.	-	-	-	-	-
L.S.	-	-	-	-	R
H.L.	R				
V.L.	R				
G.	R				
S.S.	R				

P.N. 54

D.	-	R			
P.	-	-	-	R	
L.S.	-	-	-	-	R
H.L.	-	-	-	-	R
V.L.	R				
G.	R				
S.S.	R				

P.N. 68

D.	-	R			
P.	-	-	R		
L.S.	-	-	-	-	R
H.L.	-	-	R		
V.L.	-	R			
G.	-	-	-	-	R
G.D.	R				
S.S.	R				

P.N. 69

Nine patients showed a photoconvulsive response when the Kaiser grid was added to the Grass stroboscope. The small squares which provoked a photoconvulsive response in all ten patients were the most effective.

Fig. 4.33.2.3 shows the responses of patient No.50A to various stroboscopic conditions.

Fig. 4.33.2.2 compares the effectiveness of the various factors in provoking a photoconvulsive response at any tested intensity. The figures show the number of patients in whom the factor denoted in the left-hand column was more effective than the factor shown in the top line, i.e. the Grass stroboscope with plain glass was more effective than with a diffuser in the case of one patient, whereas the large squares were more effective than the diffuser in 7 patients.

Increased intensity of flash increases the effectiveness of I.P.S. and thus, the difference between the various factors in inducing E.E.G. abnormalities becomes less obvious. Despite this, in more than half of the patients I.P.S. combined with patterns was more effective in evoking a

photoconvulsive response than I.P.S. given through a plain or a diffused glass.*

In the same Fig., 4.33.2.2 as well as in Table 4.32.2.1, individual variations can be seen, for example the diffuser was more effective than the large squares in two patients and the grid was less effective than the diffuser in one patient.

Despite these variations the potentiating effect of patterns in I.P.S. is outstanding as can also be seen in Table 4.33.2.1. The lowest percentage of patients who showed photoconvulsive responses to I.P.S. when combined with patterns was 90%, whilst the highest percentage of patients who showed abnormalities when I.P.S. was given through a diffuser or plain glass was 30% and 40% respectively. These latter percentages include patients in whom only occipital spikes were provoked.

---

* The comparison between the plain glass and diffuser is difficult because the diffuser attenuates the intensity of light. Despite this, the diffuser was more effective than the plain glass in 3 patients, and less effective only in one patient.

Fig. 4.33.2.1.

Figures show the number of patients who showed photoconvulsive responses to a certain stroboscopic condition and flash intensity using the Grass stroboscope. Figures in brackets denote the number of patients in whom occipital spikes only occurred without a photoconvulsive response. The last column on the right (inten. 1), gives the percentage of patients who showed photoconvulsive responses at intensity 1. The next column (under Total) gives the total percentage of patients who showed E.E.G. abnormalities at any of the tested intensities. It should be noted that patients who showed only occipital spikes are included.

Abbreviations.

D.	Diffuser.
P.	Plain Glass.
L.S.	Large Squares.
H.L.	Horizontal Lines.
V.L.	Vertical Lines.
G.	Grid.
S.S.	Small Squares.

Fig. 4.33.2.1 Stroboscopic Factors - Combined Results.

	INTENSITY					ABNORM. %	
	1	2	4	8	16	Total	Inten. 1
D.		2 (1)				30	0
P.			1	2	(1)	40	0
L.S.	1			5	3	90	10
H.L.	5	2	2		1	100	50
V.L.	6	3	1			100	60
G.	9				1	100	90
S.S.	10					100	100

Fig. 4.33.2.2 Comparison of Stroboscopic Factors in 10 Patients.

The figure of each block denotes the number of patients in whom the stroboscopic factor of the lefthand column was more potent than the stroboscopic factor shown in the top line.

One factor, i.e. small squares is considered more effective than another one, i.e. large squares only if, combined with I.P.S.*, can induce E.E.G. abnormalities at flash intensities in which the second factor is not effective for the same patient.

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* When comparing the effect of two factors the parameters of I.P.S. (except intensity) were as standard as possible.

Fig. 4.33.2.2 Comparison of Stroboscopic Factors.

	Diffuser	Plain Glass	Large Squares	Horizontal Lines	Vertical Lines	Grid	Small Squares
Diffuser		3	2	2	0	1	0
Plain Glass	1		2	1	0	1	0
Large Squares	7	6		1	1	0	0
Horizontal Lines	8	8	8		1	1	0
Vertical Lines	9	10	9	3		1	0
Grid	9	9	8	4	3		0
Small Squares	10	10	9	5	4	1	

Fig. 4.33.2.3 Photoconvulsive Responses of Patient No. 50A to Different Stroboscopic Conditions.

No abnormal response occurred when I.P.S. was given through a plain glass, although high intensity flash was used.

K Means that Kaiser stroboscope was used.

G Means that Grass stroboscope was used.

int: Intensity.

plain: Plain glass.

Vertical line: 100μV. Horizontal line: 1s.

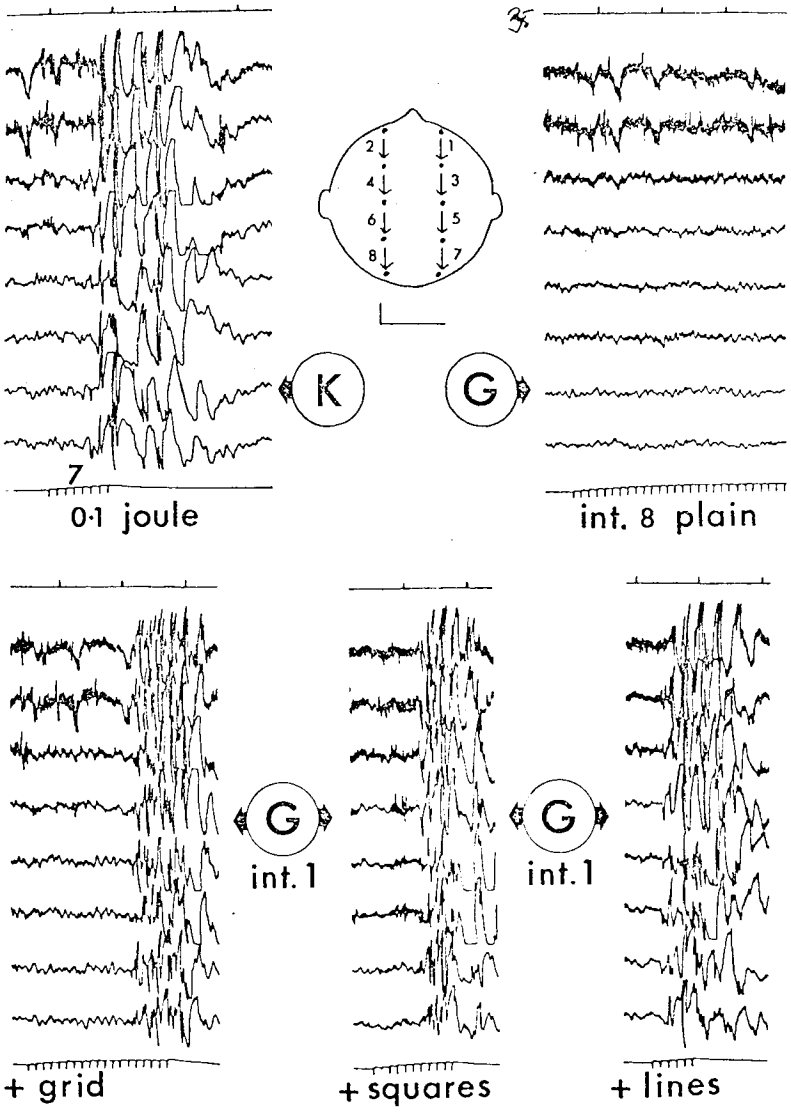
2
4
6
8
1
3
5
7
K
G
0·1 joule
int. 8 plain
G
int. 1
G
int. 1
+ grid
+ squares
+ lines

Fig. 4.33.2.3

4.40 RELATION OF OCCIPITAL SPIKES AND V.E.R.

4.41. Occipital Spikes and V.E.R. in Clinical Photosensitive Epilepsy.

The latencies of the occipital spikes of each of the 21 examined patients were compared with the latency of various components (P_1, N_2, P_2, N_3)* of the V.E.R. obtained in response to I.P.S. at 1-4 fl/s. The comparison was made with the V.E.R. of each individual patient and both occipital spikes and V.E.R. were obtained at the same session and using the same technique. Table 4.41.1 gives the latencies of occipital spikes and V.E.R. in clinical photosensitive patients.

In nineteen of the 21 photosensitive patients there was no simple relation between the negative occipital spike and negative components of the V.E.R.

---

* For latency of V.E.R. components in normal subjects see Table 4.43.1. These components were selected for comparison with the occipital spikes because their latency was within the latency limits of the occipital spikes.

Table 4.41.1 Clinical Photosensitive Epilepsy

Occipital Spikes and V.E.R.

Abbreviations.

L.F.F. (fl/s.)	Lowest flash frequency (flashes/s.).
P. Occ. S.	Positive occipital spike.
N. Occ. S.	Negative occipital spike.
Pho. Con. Range	Photoconvulsive range (eyes-open).
Pts. No.	Patient's code number.
P	Positive
N	Negative

Table 4.41.1 CLINICAL PHOTOSENSITIVE GROUP.

Pts. no.	OCCIPITAL SPIKES.			V.E.R. (1-4 fl/s)				Pho.Con. Range. (eyes open)
	L.F.F. (fl/s)	Latency in ms.		Latency in ms.				
		P.Occ.S.	N.Occ.S.	P_1	N_2	P_2	N_3	
1	6	88	102	-	78	100	140	10-50
2	7	80	102	70	-	-	120	9-50
3	5	91	103	78	85	105	160	6-68
4	6	76	94	75	85	125	150	10-50
5	5	95	108	50	60	P. N. P. 96-112-122 Triphasic	185	13-30
6	5	93	105	53	68	93-105-120. Triphasic	160	6-26
7	6	87	101	55	85	125	160	14-
8	6	90	108	83	102	129	170	9-60
9	6	88	100	62	77	104	150	10-50
10	7	89	100	-	-	100	166	7-60
11	4.5	97	118	65	71	119	161	8-59
12	5	92	105	48	76	106	140	5-70
13	6	83	100	-	-	89	127	9-60
14	7	88	98	67	83	89	124	14-24
15	7	84	96	66	76	100	166	
16	6	99	108	74	98	134	183	8-66
17	5	97	109	67	90	110	166	6-70
18	5	85	100	73	81	103	183	7-50
19	10	93	107	78	84	127	173	10-68
20	6	93	106	60	84	123	176	10-50
21	6	80	96	67	73	95	150	9-24.
Mean value:		88.95	103.24	66.17	80.89	110.00	157.62	

In only two patients (Nos. 5 and 6 in Table 4.41.1) the latency of the negative occipital spike appeared to be related to the latency of the negative wave of a triphasic P_2 V.E.R. component. (This negative V.E.R. wave has been named $\overline{V}_b$ component by Gastaut et al., 1964). In one patient (No. 6) the positive and negative waves of the triphasic P_2 component showed the same latencies with the positive and negative phases of the occipital spike and also the $\overline{V}_b$ component appeared to increase in amplitude with increasing flash rate, finally becoming the negative occipital spike (Fig. 4.41.1).

In ten patients (Nos. 1, 3, 9, 10, 11, 12, 15, 17, 18 and 21 in Table 4.41.1) there was some relation between the latency of the Negative occipital spike and the Positive P_2 component of the V.E.R. (Fig. 4.41.2).

In some patients (for example Nos. 2, 3, 7 and 13, Table 4.41.1) there was a remarkable similarity between the latency of the occipital spikes despite a noticeable difference in latency of V.E.R. components (Fig. 4.41.3).

In four patients (Nos. 13, 15, 19 and 20) V.E.R. were also obtained at flash rates faster than $4s^{-1}$, thus a comparison was allowed between occipital spikes and V.E.R.

Fig. 4.41.1 V.E.R. and Occipital Spikes in Patient No. 6.

The three upper traces show the average V.E.R. responses to 2, 3.5 and 4 fl/s. The occipital spike evoked by 7 and 8 fl/s. is shown in the two lower traces. The vertical line crosses the negative occipital spike and the V_b component of the V.E.R. to show the latency relationship.

The flash stimulus is shown by a thick arrow. The horizontal line indicates time in ms.

The C.A.T. write-out for the three upper traces is the average at 28, 20 and 21 sweeps respectively.

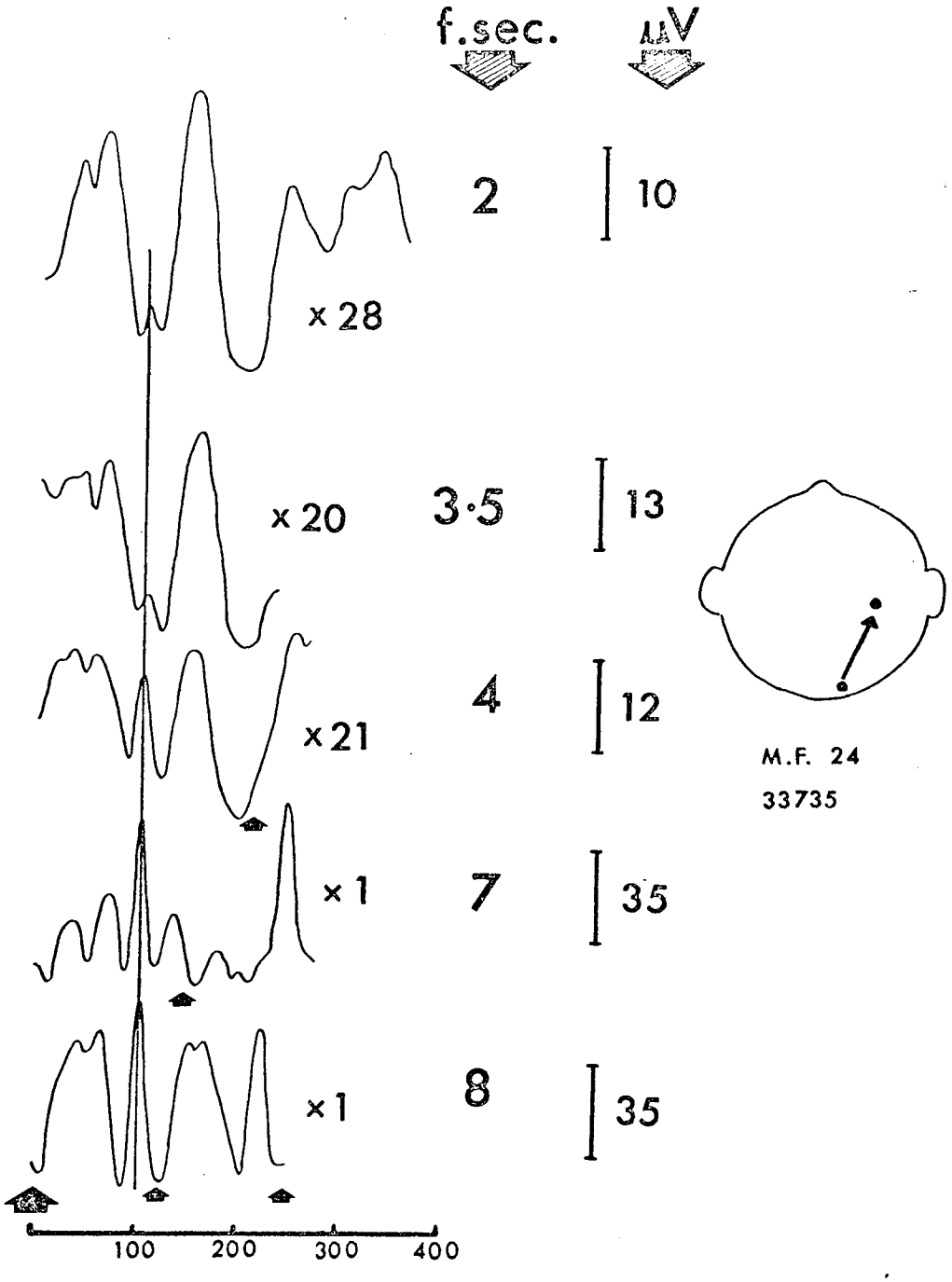
f.sec.
μV
2
10
x 28
x 20
3·5
13
4
12
x 21
x 1
7
35
x 1
8
35
100
200
300
400
M.F. 24
33735

Fig. 4.41.1

Fig. 4.41.2 Responses to photic Stimulation in Patient No. 9.

On the left are the V.E.R. to 1, 2 and 2.7 fl/s. On the right are the responses (occipital spikes) to 6, 8 and 9 fl/s. The vertical lines cross the P_2 component of the V.E.R. (right) and the negative occipital spike (left). The positive P_2 V.E.R. component is the only V.E.R. component which is of similar latency with the negative occipital spike. It should be noted that the latency of the occipital spike remains constant irrespective of the flash frequency. Flash stimuli are indicated by arrows. The C.A.T. write-out is the average response at 55 sweeps.

The horizontal line indicates time in ms.

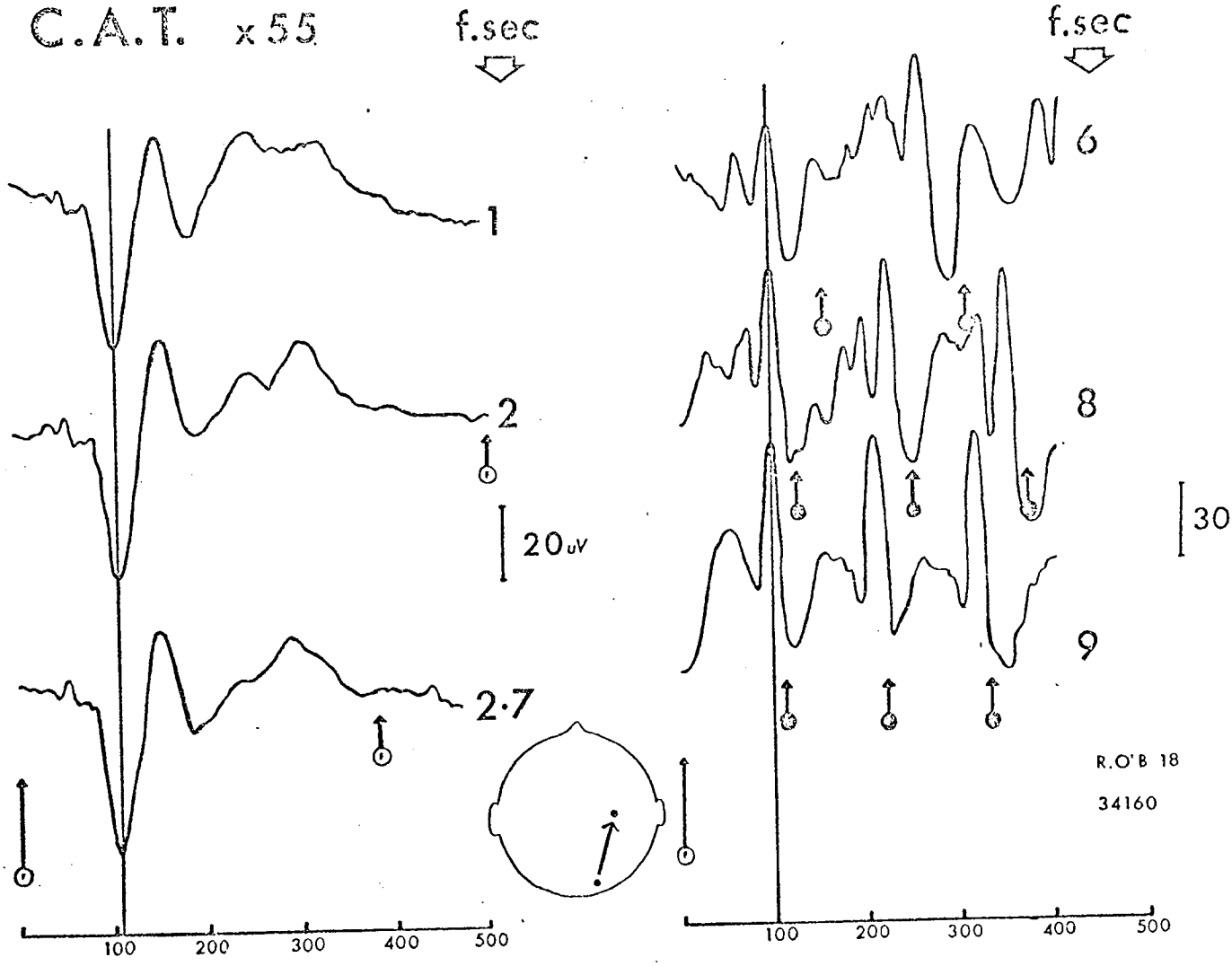
C.A.T. x55
f.sec
1
2
2·7
20uV
100
200
300
400
500
f.sec
6
8
9
30
R.O'B 18
34160
100
200
300
400
500

Fig. 4.41.2

obtained at a wide flash range. Figs. 4.41.4, 4.41.5, 4.41.6 and 4.41.7 illustrate the results obtained from these patients and it can be seen that despite the V.E.R. changes which occurred in some patients at different flash rates, the occipital spikes showed constant latency irrespective of the flash frequency and there was no latency relationship between components of the V.E.R. (at any flash frequency) and occipital spikes.

In Fig. 4.41.4 for example, the average response obtained at 5 fl/s. (which is harmonically related to the flash frequency) has a positive component which is of the same latency as P_2 component of V.E.R. obtained at slower flash rates. No obvious N_2 component can be seen at 5 fl/s. The occipital spike obtained at 8 fl/s. has a negative (vertical line) and a positive (vertical bars) component which do not correspond to any V.E.R. waves of the same polarity.

In Fig. 4.41.5 the latency of the negative occipital spike remains constant from 6.5 to 11 fl/s. despite the noticeable changes of the V.E.R. components from 1-6 fl/s. In addition there is no latency relationship between the negative occipital spike and V.E.R. components of the same polarity.

Fig. 4.41.3 Responses to I.P.S. in Three Photosensitive Patients.

The upper trace shows the V.E.R. and the lower trace the occipital spike of each patient.

Flash stimuli are indicated by arrows.

V.E.R. at 1 fl/s.

Upper Vertical bars: 20μV (for averaged V.E.R.).

Lower vertical bars: 50μV (for occipital spikes).

Horizontal bars: 100 ms.

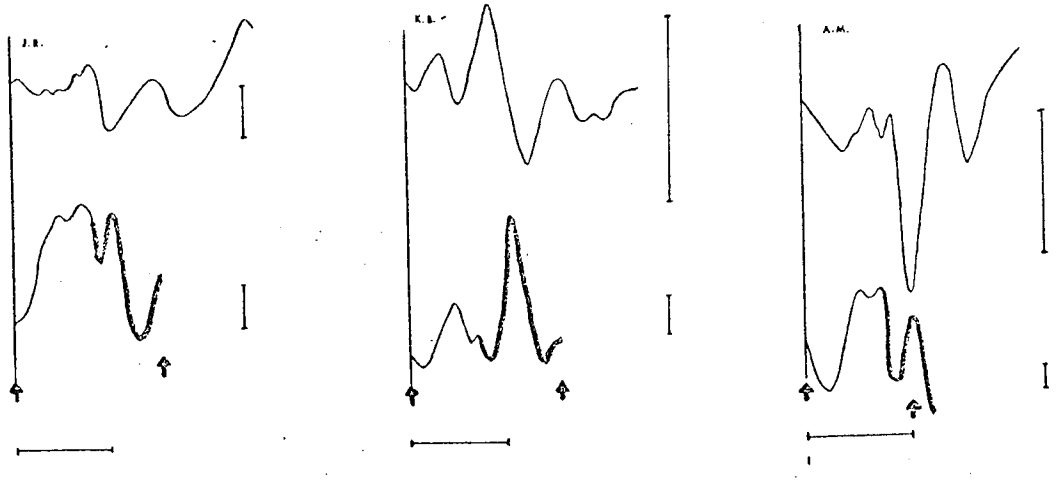

Fig. 4.41.3

Fig. 4.41.4 V.E.R. (four upper traces) to 2, 3, 4 and 5 fl/s. Stimuli and Occipital Spike at 8 fl/s. of a Photosensitive Patient.

The latency of the occipital spike as shown by the vertical line (negative occipital spike) and the vertical bars (initial positive component) does not show any relation with V.E.R. components of the same phase, despite the noticeable V.E.R. changes at 5 fl/s.

Flash stimuli are indicated by arrows.

The C.A.T. write-out is the average at 55 sweeps (for the V.E.R.).

One sweep was used for the occipital spike.

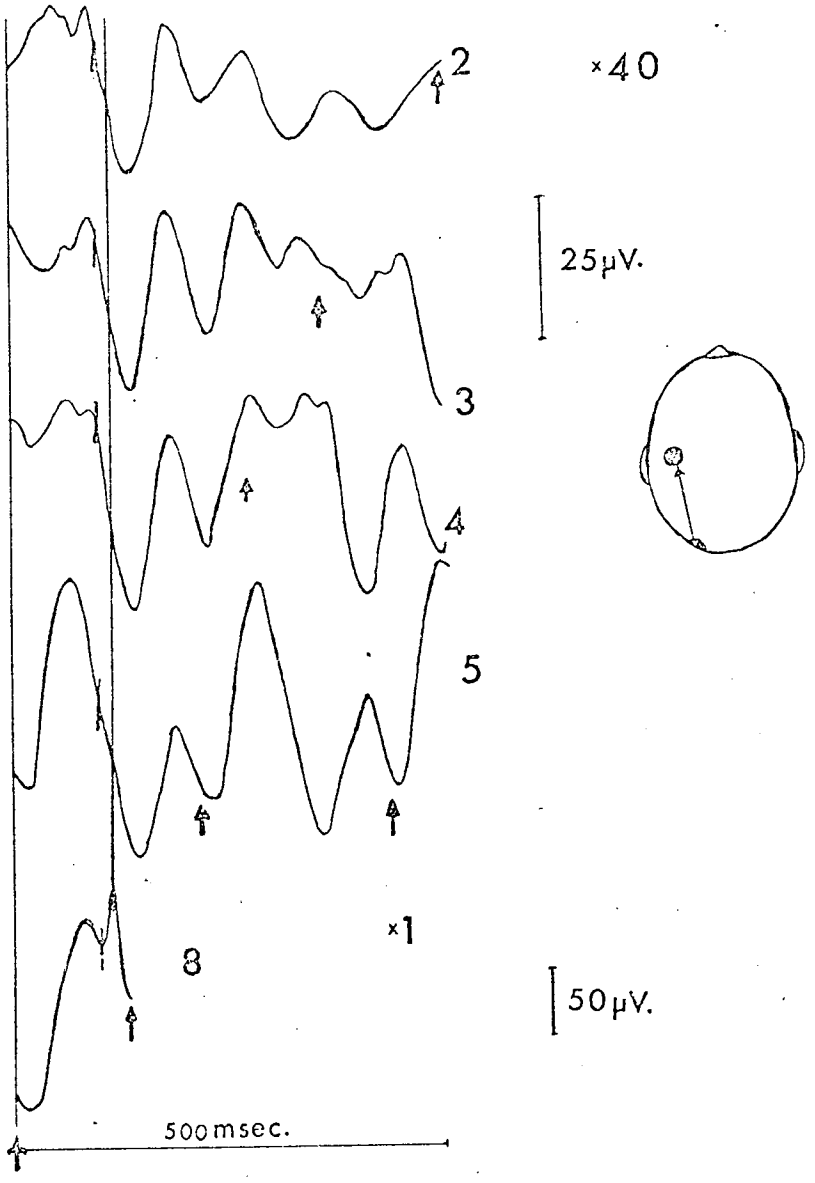

Fig. 4.41.4

In patient No. 19, 10 fl/s. was the lowest frequency provoking occipital spikes. This allowed us to obtain V.E.R. from 1-9 fl/s. and compare them with the occipital spikes in response to 10 fl/s. The results of this comparison are illustrated in Fig. 4.41.6. It is again clear that the latency of the negative occipital spike does not correspond to any of the V.E.R. components of the same polarity.

In Fig. 4.41.7 (patient No. 20) the V.E.R. obtained from the right and left occipito-central derivations are illustrated. In addition, the occipital spikes obtained from the left occipito-central derivations are shown. It can be seen that: a. the latency of the negative occipital spike remains constant irrespective of the flash rate; b. there is no latency relationship between the negative occipital spike and V.E.R. components of the same polarity; c. the intermittent occipital spike which appeared at 6 fl/s. (and is illustrated in the upper trace on the left) was averaged in L_2 trace and appeared to be related to the positive P_2 component of the V.E.R. obtained at the same flash frequency (L_1); d. the V.E.R. did not show any significant changes when occipital spikes appeared (compare L_1 and L_2).

Fig. 4.41.5 Responses to I.P.S. in Patient No. 15.

On the left are the average V.E.R. to 1, 2, 3, 4, 5 and 6 fl/s. stimuli from top to bottom respectively. The vertical line, on the right, crosses the negative occipital spike obtained at 6.5, 9, 10 and 11 fl/s. The latency of the negative occipital spikes is constant irrespective of the flash frequency. It should be noted that the negative occipital spike (bottom trace on the right) outlasted the inter-stimulus interval.

The vertical line on the left indicates the latency of the negative occipital spike and as can be seen does not cross any of the negative V.E.R. components.

The C.A.T. write-out is the average at 73 sweeps for the V.E.R.

Flash stimuli are indicated by arrows.

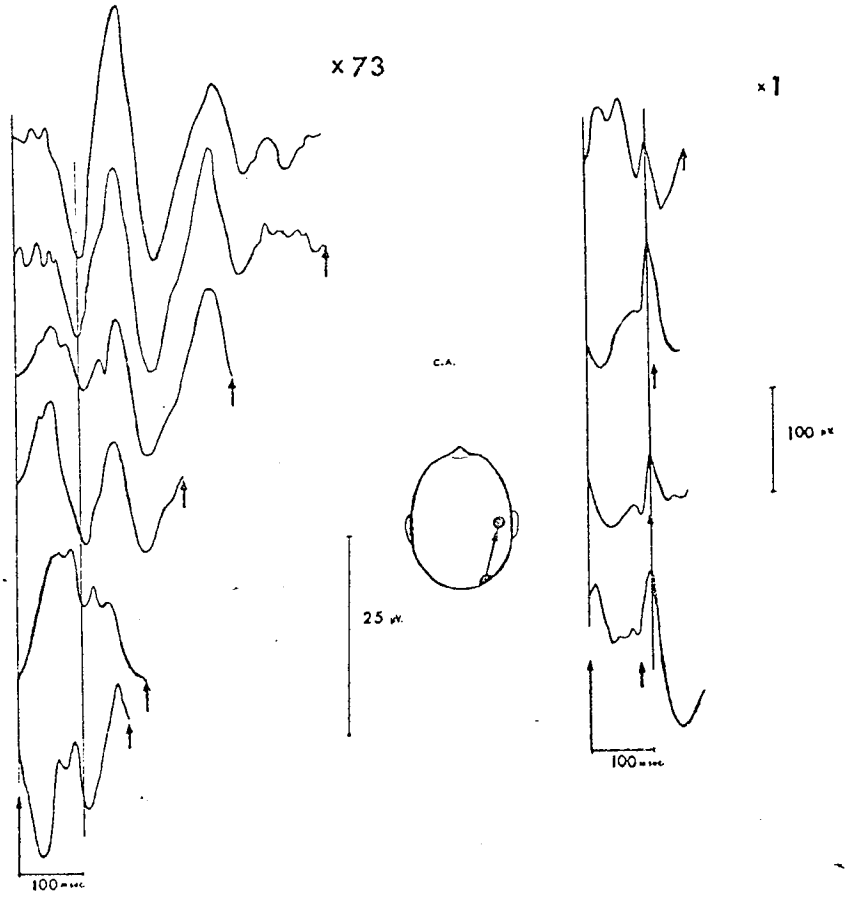

Fig. 4.41.5

4.41.6 Responses to I.P.S. In Patient No. 19.

The average V.E.R. from 1-9 fl/s. are compared with the occipital spike (obtained at 10 fl/s. and shown in the bottom trace on the right). Despite the noticeable changes of the V.E.R. obtained at different flash rates the negative occipital spike does not show any latency relationship with negative V.E.R. components.

The broken vertical line indicates the latency of the negative occipital spike.

Horizontal bars indicate ms.

Vertical bars indicate μV (30μV for all V.E.R. and 50μV for occipital spike).

Arrows indicate flash stimuli.

Numbers by the four upper traces (on the left) indicate flash frequency.

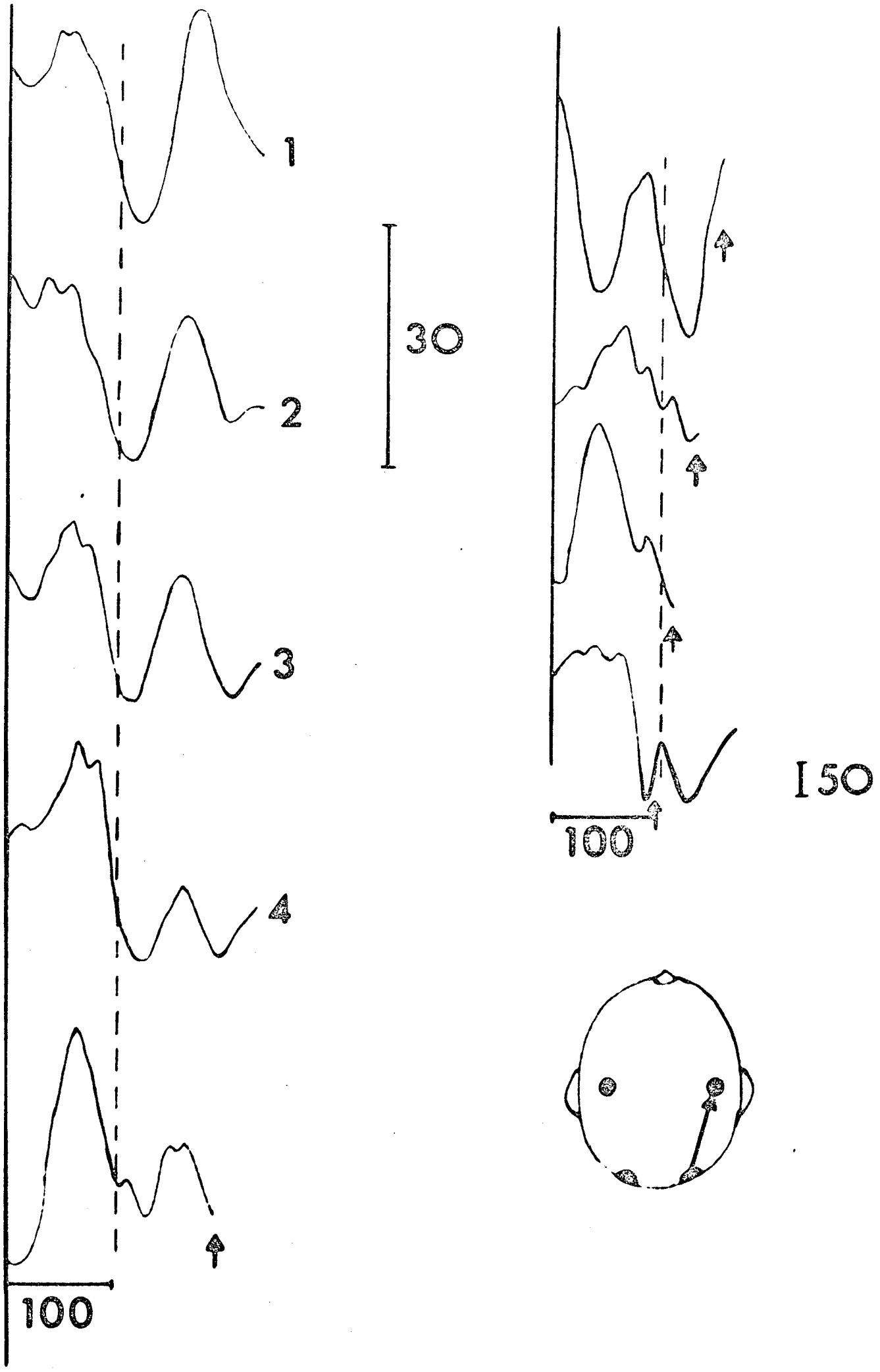

Fig. 4.41.6

Fig. 4.41.7 Responses to Photic Stimulation in Patient No. 20.

On the left the average V.E.R. recorded from the right (R) and left (L) occipito-central derivations. The upper two traces (on the left) are the V.E.R. at 1 fl/s.

L_1 shows the V.E.R. at 6 fl/s. without the presence of occipital spikes. L_2 is the average record from the same derivation as L_1 and at the same flash frequency, but with the presence of a few intermittent occipital spikes in the E.E.G. record.

On the right the occipital spikes recorded at different flash rates from the left occipito-central derivations.

The top trace (on the right) shows the intermittent occipital spike which appeared in response to the same flash frequency as L_1 and L_2 trace.

Broken vertical lines indicate the latency of the negative occipital spike.

Horizontal bars indicate time in ms.

Vertical bars indicate amplitude in μV.

Arrows indicate flash stimuli.

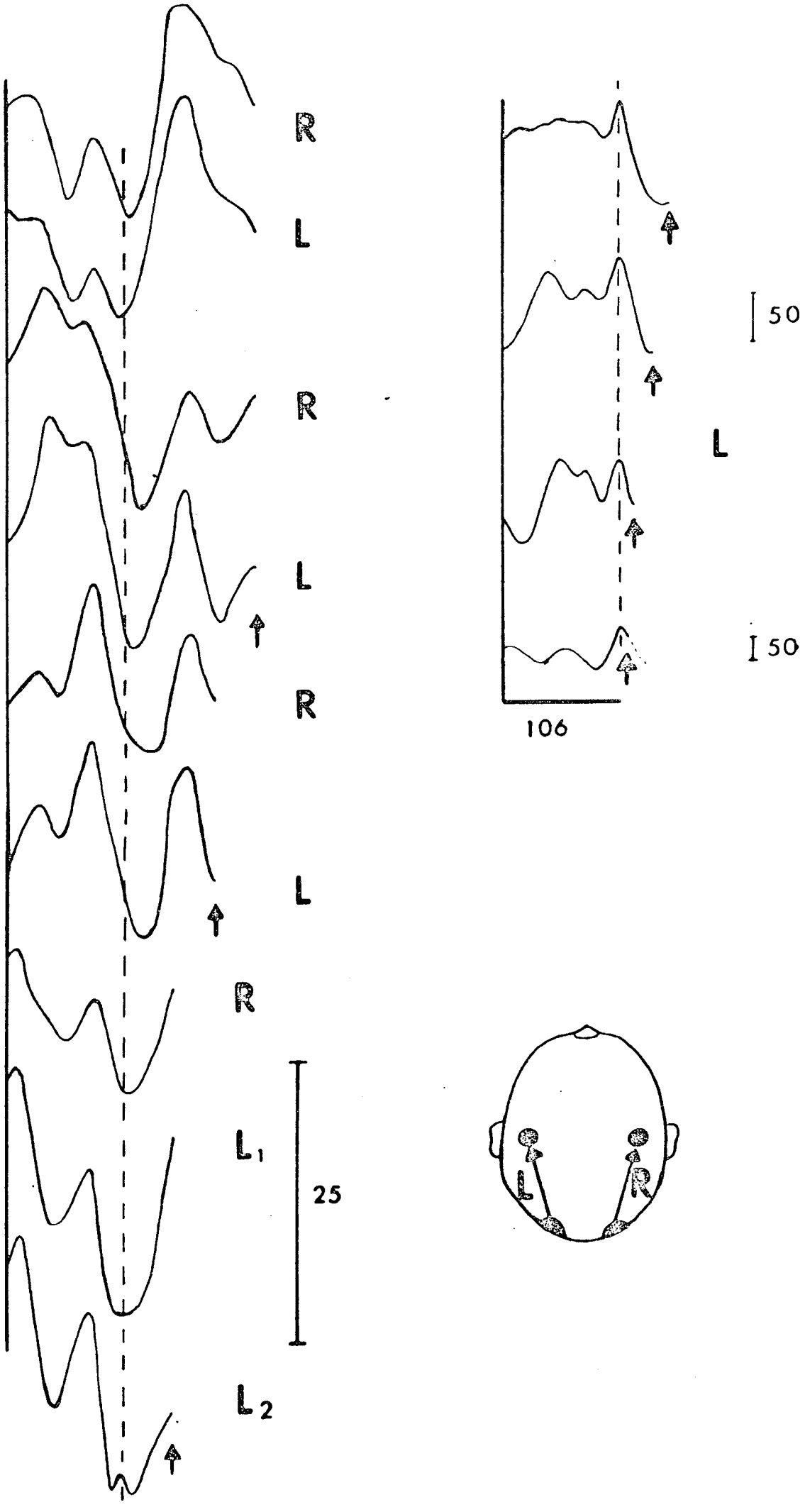

Fig. 4.41.7

4.42. Occipital Spikes and V.E.R. in Patients with Epilepsy who are not Clinically Photosensitive.

The latencies of V.E.R. components N_2 and P_2 of five patients with epilepsy are compared in Table 4.42.1 with those of the occipital spikes of the same patients. It can be seen that there is no simple relation between the V.E.R. components and the occipital spikes.

Patient No. 52 is of interest in that the occipital spikes did not occur when she was tested on a second occasion, and it was therefore possible to obtain V.E.R. from flash rates of 1 to 10 s^{-1}. These were compared to the latencies of occipital spikes obtained on the first occasion and there was no constant relation between the occipital spikes and the V.E.R. obtained at the same or different flash rates (Fig. 4.42.1, Table 4.42.1). Patient No. 55 is also of interest because, although the occipital spikes obtained from the right and left occipito-central derivations showed the same latencies, V.E.R. components obtained from these derivations differed (Fig. 4.42.2).

It can also be seen (Table 4.42.1) that despite the differences in the V.E.R. of some of the five patients the occipital spikes show similar latencies. Patients, for example, Nos. 53 and 55 have negative occipital spike with approximately the same latency whilst both N_2 and P_2 components show considerable differences i.e. patient No. 53

Table 4.42.1 Epilepsy with E.E.G. Abnormalities During I.P.S. -

Latency of Occipital Spikes and V.E.R.

Abbreviations.

P.N. Patient's code number.

M.V. Mean value.

P. Positive

N. Negative.

Table 4.42.1 Epilepsy with E.E.G. Abnormalities During I.P.S. - Latency of Occipital Spikes and V.E.R.

P.N.	Occipital Spikes		V.E.R. Latency (ms)		
	Latency (ms)				
	Early Positive	Negative		N2	P2
51	85	97		88	100
52	85	103	1-4 fl/s. 5-10 fl/s.	70 70-90	116 119-130
53	88	102		70	85
54	94	104	1-7 fl/s.	81	103-110
55	77	103	Right Left	83 83	100 P. N. P. 100-117-131 Triphasic
M.V.	85.8	101.8		74.4	109.2

has a positive V.E.R. component of an 85 ms. latency while the same approximate latency is accounted for the N_2 component of patient No. 55.

Patient No. 54 had an N_2 V.E.R. component of the same latency (81ms.) from 1-7 fl/s. whilst the negative occipital spike had a latency of 104 ms.

Fig. 4.42.1 Responses to I.P.S. in Patient No. 52. Obtained on Two Different Occasions.

On the right the occipital spikes (obtained on the first occasion) using fast paper speed ($30^{cm}/s.$) and high gain ($50\mu V/cm.$) are retraced from the E.E.G.

On the left the average V.E.R. from 2-10 fl/s. obtained on the second occasion where no occipital spikes were provoked by I.P.S.

The vertical line which crosses the V.E.R. indicates the latency of the negative occipital spike (as measured from the E.E.G.) and the dots indicate the latency of the early positive component of the occipital spike.

It can be seen that there is no constant latency relationship between occipital spike and V.E.R. obtained at the same or different flash frequencies.

Arrows indicate flash instant.

The C.A.T. write-out is the average at 72 sweeps.

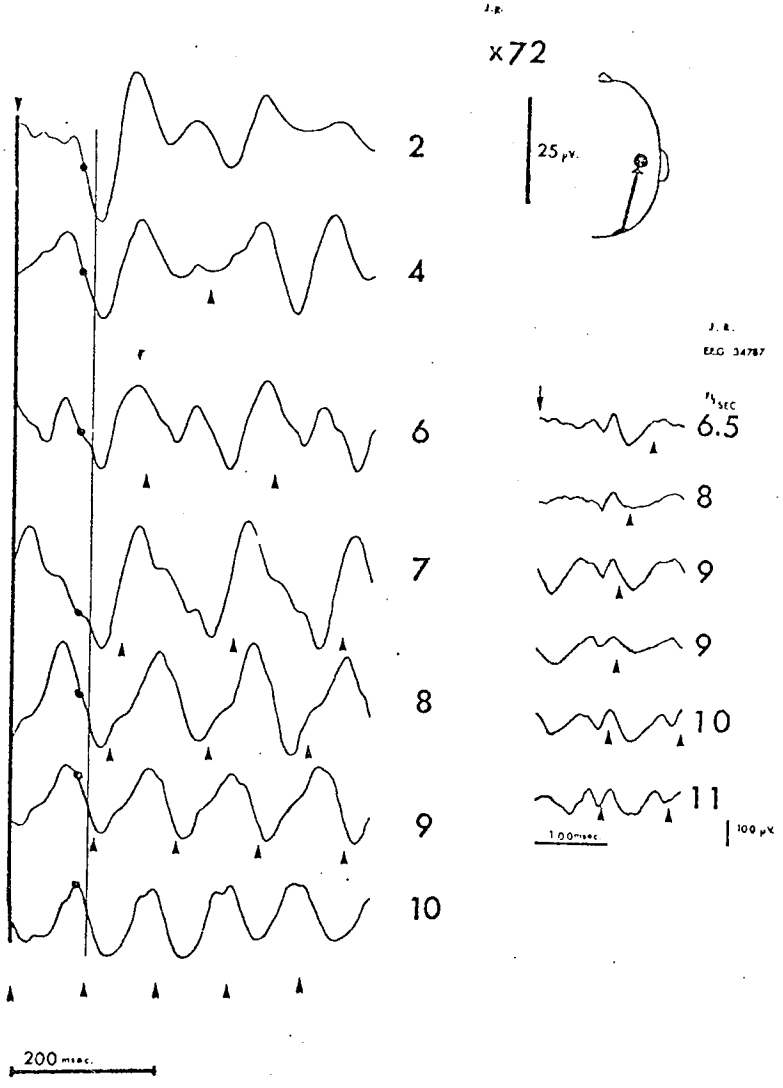
J.R.
x72
25 μv.
2
4
6
7
8
9
10
200 msec.
J. R.
EKG 34787
1/5 SEC
6.5
8
9
9
10
11
100 msec.
100 μv

Fig. 4.42.1

Fig. 4.42.2 Responses to I.P.S. in Patient No. 55.

The upper two traces show the average V.E.R. obtained at 1 fl/s. from the right and left occipito-central derivations respectively. The lower two traces show the occipital spikes obtained from the same, as the V.E.R., derivations. It can be seen that although the V.E.R. are different in the two derivations the occipital spikes do not differ.

Arrows indicate flash instant.

Horizontal bar indicates time in ms.

The C.A.T. write-out for the V.E.R. is the average at 72 sweeps.

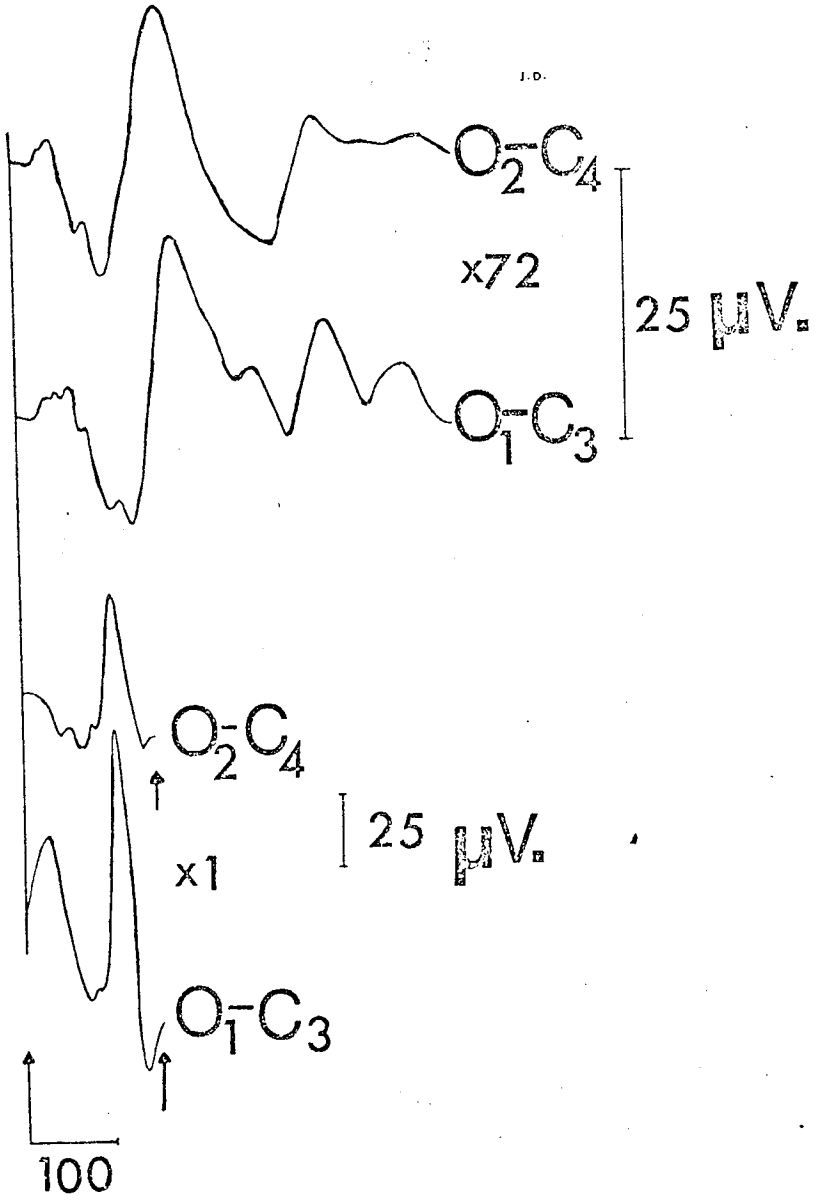

Fig. 4.42.2

4.43 V.E.R. Evoked by Flash Rates From 1-10 per second, in Normal Subjects.

The latencies of N_2 and P_2 components of the V.E.R. obtained from stimulation at 1-4 fl/s. are shown in Table 4.43.1 where they are compared with the latencies of P_1, N_2 and P_2 components of the V.E.R. obtained from stimulation at 5-10 fl/s. These components were selected because they were within the limits of the latency of the occipital spikes. In all normals the latencies N_2 and P_2 were constant at rates of stimulation between 1 and 4 fl/s.* In 10 normals (Nos. 71 - 79 and 92) the N_2 and P_2 components showed constant latencies over the whole range of flash rates 1-10 s^{-1} (Fig. 4.43.1). Six normal subjects (Nos. 80-83 and 89-92) showed constant latencies for the P_2 components irrespective of the flash frequency, over the tested range 1-10 per second, but the N_2 component of these subjects showed changes in latency. With 5-10 fl/s. I.P.S. the latency of N_2 was either constant but different to the latencies at 1-4 fl/s. (Nos.80-82 and 89-92) or it varied with each flash frequency (No. 83).

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* Slight variations occurred in a few subjects, but these were not constant and they were considered of no significance.

Table 4.43.1 Normal Subjects - Latencies of V.E.R.

Subject	V.E.R.(1-4 flash/s) Latency in ms.		V.E.R.(5-10 flash/s) Latency in ms.		
	N_2	P_2	P_1	N_2	P_2
71	74	99	60	77	99
72	70	109	55	73	109
73	83	116	68	83	116
74	79	117	65-75	79	117
75	87	114	77	87	114
76	84	107	70-80	84	107
77	96	127	75-85	96	127
78	77	116	67	77	116
79	93	113	65-77	93	113
80	70	115	77	83	115
81	83	117	80-90	100	117
82	-	100	70	83	100
83	75	117	69	76-90	117
84	83	100	73-80	90-108	113
85	84	116	67-83	86-100	134
86	77	93	68	77-83	100
87	72	97	70-79	97	109
88	86	100	80	86	105
89	77	113	66	83	113
90	83	123	-	67-87	123-136
91	77	103	67	84	103
92	84	107	77	84	107
Mean Value	80.67	109.95	71.57	85.50	113.73

In five other normals (Nos. 84-87 and 92) both N_2 and P_2 components showed different latencies at stimulation rates of 5-10 fl/s. as compared to those obtained at 1-4 fl/s. In four of these normals (Nos. 84-86 and 92) the N_2 component showed different latencies at different flash rates. In one (No. 87) the latency of the N_2 component was constant at 5-10 fl/s. stimulation, but different to the latencies at 1-4 fl/s.

The V.E.R. of the remaining normal subject (No. 88) showed constant latencies for N_2, but the latency of P_2 was longer with stimulation at 5-10 fl/s., compared to 1-4 fl/s.

In five normals (Nos. 77,81, 84, 85, 87) the N_2 latencies from stimulation at 5-10 fl/s. were longer than 94 ms., which is the shortest latency for a negative spike in the photosensitive patients with epilepsy. From these five, two (Nos. 84, 85) showed different N_2 latency at different flash frequency, one (No. 77) had a constant latency over the whole range (1-10 fl/s.) and two (Nos. 81, 87) showed constant N_2 latencies irrespective of the flash frequency from 5-10 fl/s.

Only two normal subjects (Nos. 81, 87) therefore, showed a negative V.E.R. component evoked by I.P.S. at 5-10 fl/s.

with latencies comparable to the negative occipital spike of the patient groups.

Fig. 4.43.1 V.E.R. in Two Normal Subjects.

On the right the N_2 and P_2 V.E.R. components did not show any significant change in latency from 1 fl/s. (upper trace) to 10 fl/s. (lower trace).

On the left the P_2 V.E.R. component of another subject did not show any constant change of latencies (except at 7 fl/s., 5th trace from the top) but the latency of the N_2 V.E.R. component is longer at 5-10 fl/s. as compared with the N_2 latency at 1-4 fl/s. The vertical lines cross the P_2 V.E.R. component.

The number of the C.A.T. sweeps (70 and 36) is shown on the top of the figure.

Arrows indicate flash stimuli.

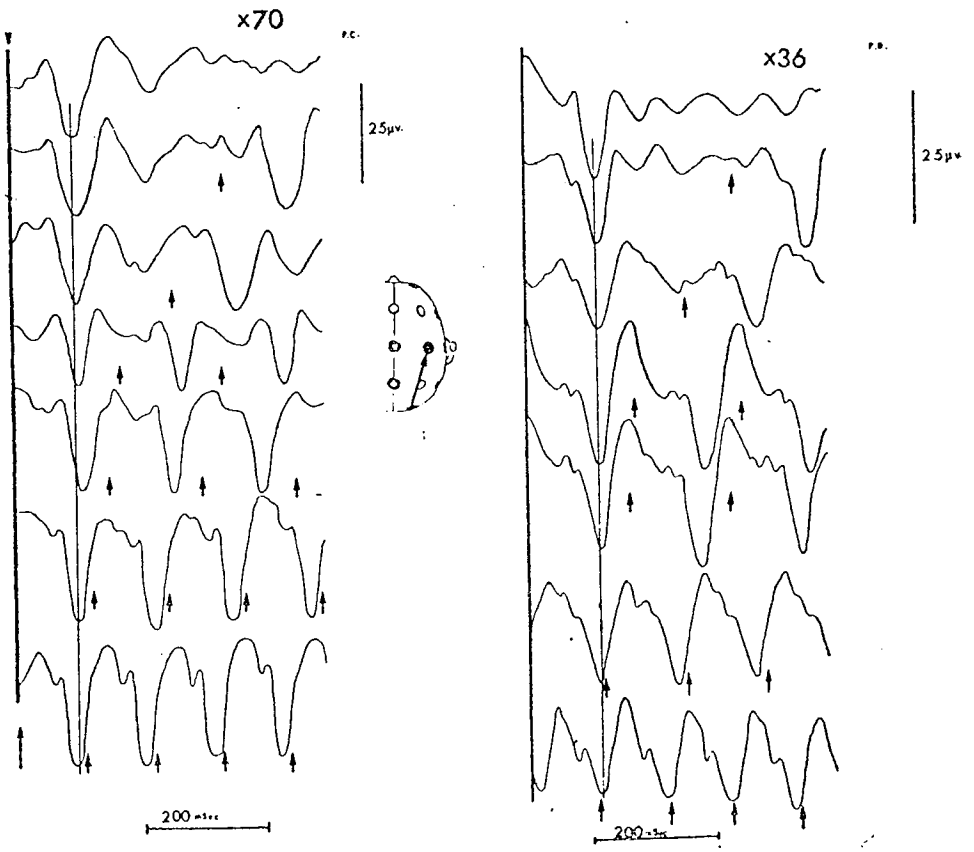

Fig. 4.43.1

SECTION 5

DISCUSSION

5.10 CLINICAL ASPECTS

5.11 Light-Sources as Precipitant of Fits.

Our findings suggest that T.V. is the commonest precipitant of fits of all other light sources (discussed in section 1.33) in photosensitive epilepsy. In fact 90% of the photosensitive patients had fits whilst watching T.V. and in only 10% of the patients epileptic seizures were precipitated by light sources other than T.V. (section 3.30 and Table 3.30.1). It should be emphasized that the above figures refer to people living in Great Britain. The weather conditions and time spent viewing television are factors which may contribute to the high percentage of T.V. epilepsy in Great Britain. To the best of my knowledge there is no current literature concerning the geographical distribution of photosensitive epilepsy.

5.12 Sex and Age of Photosensitive Patients.

Our findings indicate that there is a clear preponderance of female patients (72% in the photosensitive group and 90% in the epilepsy group). Although the proportion of females in our patients is a little higher than those given by other authors (section 1.32 and 1.42.2) the results should be considered as similar.

There is also a high percentage of young patients in our material (88% of our photosensitive patients were younger than 20 years of age, see fig. 3.31.1) which is in agreement with reports made by other authors (section 1.32). The percentage of our patients between the age of 15-20 years (40%) is higher than in any other age group (fig. 3.31.1). This is not necessarily in contrast with reports made by other authors (Gastaut et al, 1962., Jeavons, 1969 b.) who found a higher proportion in patients younger than 15 years of age. The above authors were concerned with the age onset whilst we reported the age when the patient was seen. The latter can easily explain the shift towards an older group in our patients. The high proportion of females and the peak onset around puberty may rise the possibility of the influence of hormones in photosensitive epilepsy. This view was supported by Jeavons (1969 b) who also found that the preponderance of females in the youngest group of patients (8-12 years of age) is higher than in the age group of 13-17 years. Since puberty occurs earlier in females the above difference might be further support for the theory that hormones influence photosensitivity.

Another argument supporting the above theory is that in some females light-induced fits only occur in the pre-menstrual or menstrual phase (Jeavons, 1969 b). It should be noted that the sex and age distribution (compare figs. 3.31.1 and 3.41.1) was similar between the two groups of patients with epilepsy i.e. those who are clinically photosensitive and those who have spontaneous fits and E.E.G. abnormalities during I.P.S. but there is no evidence of seizures precipitated by light.

5.13 Types of Fits Induced by Light.

Various types of seizures can be induced by light, the most common being a grand mal attack (section 3.32, Table 3.30.1). Our findings are similar to those previously reported by other authors (section 1.33.1).

5.13.1 Patients Compulsively Attracted to T.V. Set.

It is apparent from the current literature (section 1.33.1) that little attention has been given to the condition in which the patient is compulsively attracted "drawn like a magnet" to a T.V. set. Our findings that 10 of 45 patients with television epilepsy were compulsively attracted to a T.V. set indicates that this is not an uncommon condition and it certainly merits more interest and research.

Children suffering from T.V. epilepsy do not get satisfaction from epileptic attacks induced by watching T.V., are not in general of low intelligence and it does not seem that they have psychological disturbances. This distinguishes them from children suffering from "self-induced" epilepsy (pp. 21-23); a comparison, therefore, of the "compulsive attraction" to the "hand-waving" would seem arbitrary. The role of conditioning in the "compulsively attracted" children might be important but it has not been studied in this thesis.

5.20 RESTING E.E.G.

5.21 Photosensitive Patients.

The finding that nearly half of patients with fits induced only by T.V. (section 4.12 and fig. 4.12.1) had a normal resting E.E.G. may indicate that external stimuli are more important than internal factors in triggering epileptic seizures in these patients. If this assumption were correct then anticonvulsant treatment may not be necessary if recommended precautions towards external stimuli were taken. Precautions recommended for T.V. photosensitive patients have been given by Jeavons et al., (1970).

The above finding also indicates the need for caution in the interpretation of E.E.G. of photosensitive patients if I.P.S. has not been carried out.

The small number of normal resting E.E.G. in patients of group B was expected as these patients have both spontaneous and light induced attacks.

The number of examined patients of the remaining groups of photosensitive epilepsy is too small for conclusions to be drawn from.

5.22 Abnormalities Following "Eye-Closure".

"Eye-closure" induced abnormalities in 13 of the 70 epileptic patients and in 6 of them this was the only detectable abnormality in the resting E.E.G.

The significance of light in the provocation of "eye-closure" induced abnormalities is shown by our findings when "eye-closure" was preformed in darkness. The finding also that passive "eye-closure" when rapidly performed induced E.E.G. abnormalities in normal room illumination suggests that voluntary "eye-closure" is not the important factor.

Our findings differ from those of Green (1968) who found that E.E.G. abnormalities can be induced by "eye-closure" in darkness (although an attenuation was noticed) and that passive "eye-closure" was not effective. The discrepancy between our results and those of Green (1968) may be attributable to the following:

a. We might possibly be concerned with different types of abnormalities. (In their figure 2B, p.393 abnormalities did not occur immediately after "eye-closure" and are mainly unilateral. Compare also the above figure with fig. 4.14.1).

b. Some of the abnormalities occurring in the patients of the above author immediately after "eye-closure" in darkness might have been fortuitous as there was a great number of spontaneous abnormalities in the resting E.E.G. (see fig. 2, 5 p.393, 395 respectively).

c. In some patients voluntary "eye-closure" and in others light may be more important in the causation of abnormalities induced by "eye-closure".

It is known that more "off-responses" than "on-responses" are induced in the visual cortex by light (Landau, 1967) and this might explain why "eye-closure" and not "eye-opening" provokes E.E.G. abnormalities.

Our finding also that the "squeak" of the alpha rhythm disappears in darkness may suggest that this phenomenon is related to "off-responses" of the visual cortex. Our finding is supported by the finding of Cruikshank, (1937) that the "squeak" is more noticeable when the intensity of light is high and decreases with decreasing intensity.

5.30 E.E.G. DURING I.P.S.

5.31 Normal Subjects.

In none of the normal subjects did I.P.S. induce occipital spikes or photoconvulsive responses. The above finding does not necessarily mean that E.E.G. abnormalities are not induced by I.P.S. in normal subjects as our subjects were mainly males and their number was small. Our finding may only indicate that E.E.G. abnormalities during I.P.S. are not seen as often as has been reported (section 1.42.1). The high percentage of E.E.G. abnormalities during I.P.S. in normals reported by some authors may be attributable to the different criteria in the selection of normal subjects, evaluation of E.E.G. abnormalities and also in the different techniques of I.P.S. presentation. Some of the above different criteria have been emphasized in section 1.42.1.

5.32 Photosensitive Epilepsy and Epilepsy With I.P.S.-Induced Abnormalities.

Our finding that all photosensitive patients show E.E.G. abnormalities during I.P.S. is in accordance with previous reports made by other authors (see sections 4.23 and 1.42.2). It is interesting that only 1 of the 50 photosensitive patients had occipital spikes only and not photoconvulsive

responses during I.P.S. whilst three of the 20 epileptic patients did not show photoconvulsive responses but occipital spikes only. This indicates that photosensitive patients with a clinical history of epilepsy have a lower convulsive threshold to photic stimuli than those who have no history of light-induced fits. The finding that in one patient (No. 33) only occipital spikes occurred during I.P.S. verifies the quantitative model of Bickford et al (1970) and emphasizes the significance of the fluctuations of internal factors in some of the photosensitive patients.

Our finding that occipital spikes precede photoconvulsive responses in the majority of photosensitive patients (sections 4.23 and 4.24) confirms our previous reports (Panayiotopoulos et al., 1970 a, b, 1971). These findings are the extreme opposite to what has been reported by other authors (section 1.41.3). The belief that photoconvulsive responses are not preceded by occipital spikes was so great that authors whose names have been connected with pioneer work in photosensitive epilepsy used the argument that because the photoconvulsive responses are synchronous and generalized the non-specific thalamocortical system must be implicated in the genesis of I.P.S. induced abnormalities, (Bickford et al., 1953, 1969; Gastaut et al., 1962).

Gastaut (Gastaut et al., 1962), for example stated that "I remain faithful to the non-specific factor (in the pathogenesis of television epilepsy) and I do not think of the cortical factor or of anything that would approach the epilepsy of Clementi... I have many reasons for believing this, because (a) photosensitive epilepsy is characterized by synchronous generalized complexes of spikes and waves or with multiple spike-wave patterns without any occipital preponderance".

The difference between our results and those reported by others (section 1.41.3) may be attributable to the following: a. The use of fast paper speed, increased gain and special montages as used by us make it easier to see the occipital spikes, especially in those cases where only one or two low amplitude spikes immediately precede the generalized discharge, evoked at relatively fast rates of stimulation, e.g. 20 fl/s. b. The addition of patterns (grid) increases the photoconvulsive range (section 4.33) and thus, occipital spikes appear at low flash frequencies which would be ineffective if straight light had been used as shown in fig. 4.33.1.1.

It is known that any neuron may undergo an epileptic transformation as a result of continuous bombardment by nervous activity (Moruzzi, 1950).

Hughes (1966) reported in detail the development of secondary discharging foci (mirror foci) in the cerebral hemisphere opposite to that containing an E.E.G. epileptic focus. Morrell (1959) has also demonstrated that contralateral homotopic foci can develop as a result of primary epileptogenic lesions.

It is therefore possible that s secondary autonomous epileptic focus can be set up by continuous intermittent light bombardment of the occipital cells. The latter should be borne in mind if long term experiments using I.P.S. are going to be carried out in photosensitive patients.

5.40 SOME OF THE FACTORS WHICH CHANGE THE I.P.S.EFFECTIVENESS

5.41 "Eyes-Open", "Eyes-Closed", "Eye-Closure" and "Monocular" I.P.S.

Our findings (sections 4.31, 4.32) indicate that in nearly all patients I.P.S. is more effective when the eyes are open than when they are closed. These findings are the extreme opposite of what has been reported by almost all authors (section 1.43.6) i.e. that I.P.S. is more effective when the eyes are closed than when they are open. The belief that there is an increase in sensitivity to I.P.S. when the eyes are closed was so strong that numerous theories (detailed in pages 66-69) have been attempted in order to explain this.

The difference between our results and those reported by other authors (Bickford et al., 1953; Robertson, 1954; Pallis et al., 1961; Pantelakis et al, 1962; Troupin, 1966; Bickford et al., 1969) may be attributable to the following:

a. Some authors (i.e. Pantelakis et al, 1962) did not consider the "eye-closure" as a separate state. In their investigation (Pantelakis et al, 1962) the patient kept his eyes open for the first 5 s. of I.P.S. and then he was asked to close his eyes whilst the flicker continued for a further 5 s. The responses occurring during the last 5 s.

were regarded as responses during "eyes-closed" state and were compared to the responses occurring during the first 5 s. ("eyes-open" state). It is apparent from the above that what was considered as "eyes-closed" state was in fact "eye-closure" state. Under these circumstances it is not surprising that the authors(Pantelakis et al, 1962) found more abnormalities on "eyes-closed" (in fact on "eye-closure") than on "eyes-open".

It has been shown in this thesis (pp. 176-179) that in all examined patients the photoconvulsive range was invariably wider during "eye-closure" than in any other eye-state. This increased sensitivity on "eye-closure" must be borne in mind when testing photosensitive patients in the E.E.G. laboratories (Jeavons, 1969).

b. The comparison of responses occurring during the first 5 s. of I.P.S. with those occurring during the following 5 s. of I.P.S. might have contributed to the above discrepancies. It has been shown in this thesis that abnormalities are most likely to occur sometime after the onset of I.P.S. (fig. 4.21.1.2).

Jeavons et al., (1966) reported that more abnormalities were found during "eyes-open" than "eyes-closed" I.P.S. when the above stated factors were taken into account.

The difference of the effectiveness of I.P.S. in "eyes-open" and "eyes-closed" I.P.S. may be attributable to the following:

a. The intensity of the photic stimulus diminishes during "eyes-closed" as a result of absorption of light by the eyelids.

b. The position of the ocular axis changes when the eyes are closed due to the upward rotation of the eye-balls thus, the patient "on eyes-closed" does not "look" at the centre of the lamp as he or she does during "eyes-open" I.P.S. It has been shown recently in our laboratory (Jeavons et al, 1971) that E.E.G. abnormality is evoked only when the patient looks directly at the centre of the stroboscope. If the patient looks upwards, downwards, laterally or even at the edge of a five inch lamp (placed 30 cm. from the eyes), no abnormality occurs even with increased intensity light. Furthermore, if the stroboscope is placed at an angle of 90°, 45° or 30° from the direction of the patient's forward gaze, no abnormality is evoked, provided the patient looks straight ahead.

Since illumination from 90° is equivalent to monocular stimulation (due to nasal shielding) we have used two stroboscopes, one on each side of the patient's head, at a distance of 30 cm. from the eyes, and at angles of 90°, 45° and 30°. Provided that the patient looks directly ahead between the stroboscopes, no E.E.G. abnormality is evoked even with increased intensity light (Kaiser o.6 joule, Grass Intensity 8).

c. The pattern image disappears or greatly attenuates when the eyes are closed. Strong experimental evidence is produced in this thesis (section 4.33) that patterns combined with light stimuli greatly enhance the abnormalities induced by I.P.S.

Our finding that "eye-closure" is the most effective of all other "eye-states" in eliciting E.E.G. abnormalities (section 4.32) is not surprising. "Eye-closure" produces abnormal responses even in continuous light interrupted only by eye-lid closure (section 5.22). It is therefore more likely that "eye-closure" is more potent when the light, switched off by the eye-lids, is intermittent.

The finding that monocular I.P.S. is less effective than binocular (section 4.30) is in agreement with previous reports by other authors (section 1.43.7).

The majority of the cells in the striate cortex, particularly those of the simple type, are reported to be exclusively monocular i.e. they receive input information from one eye only (Hubel et al, 1962, 1968) although binocular visual cortex also exists (Marg et al, 1968, Henry et al, 1969). As the result of the above connections, the number of impulses impinging upon the binocular cells will be less on monocular than binocular I.P.S. In addition there will be a smaller number of stimulated cortical cells. Hence, the lesser effect of monocular as compared to binocular I.P.S. may be the result of a critical reduction of spatial summation in the visual cortex. Spatial summation is known to be one mode of increasing excitation. A similar view was supported by Chatrian et al (1970) for pattern sensitive patients.

In the Lateral Geniculate Nucleus the closely packed visual relay cells are formed of several layers which receive their input from contralateral and ipsilateral eyes respectively (Bishop et al, 1942). It is, therefore, possible that the non-activated layers corresponding to the patched eye play an important role in the arrest of the E.E.G. abnormalities on monocular I.P.S.

Patients in whom I.P.S. was more effective in one eye than the other have been previously reported (Okumura, 1969; Chatrian et al., 1970). Okumura, (1969) suggested that photosensitive mechanism may be dominant on the left side of the brain because his patient had abnormalities only when the right eye was stimulated and no abnormalities occurred when I.P.S. was given to the left eye. Two of our patients had more abnormalities when I.P.S. was given to the right eye than the left eye and we cannot therefore offer experimental evidence to the speculation of the above author.

5.42 Combination of Patterns and I.P. Stimulation.

From our results (section 4.33) it is clear that I.P.S. has a greater provocative effect in eliciting E.E.G. abnormalities when combined with geometric patterns. The most effective pattern appears to be one of small squares formed by thin lines. Next in efficacy are parallel stripes with narrow spaces; a vertical presentation being slightly more effective than a horizontal one. Patterns consisting of thick lines were less effective than those formed by thin lines.

Our findings as to the efficacy of pattern combined with I.P.S. is not surprising in view of the following experimental evidence:

a. The receptive field of the simple visual cortex neurons and their arrangement have an elongated shape. The excitatory zone (0.6. degrees across) is always much smaller than the surrounding inhibitory region, (6 degrees across) and both are in the nature of bands, the inhibitory zone being on each side of the excitatory one (Hubel et al, 1959, 1962, 1968, Bishop, 1970).

b. Optimal stimuli, i.e. stimuli that simultaneously inhibit inhibitory and activate excitatory input fibers, for the visual cortex cells, are narrow bars of light or darkness (Creutzfeldt, 1970).

c. As a stimulus, stationary spots of light flashed on and off are not as effective as a moving slit and may be completely ineffective (Bishop, 1970).

d. The visual cortical responses are sensitive to the degree of contrast between neighbouring areas not only in respect of luminance, but also of higher-order pattern features, such as the presence and direction of line elements (Jeffreys, 1969).

It is, therefore, obvious that line stimuli (slits, bars, edges) combined with intermittent light are more effective in producing an occipital cortical discharge in the visual cortex than straight light.

Our findings as to the efficacy of patterns in combination with I.P.S. are strikingly similar to those of Bickford et al., 1962 and Chatrian et al., 1970 (section 1.43.5) who were concerned mainly with straight pattern presentation. Some of the patients of the above authors had clinical pattern epilepsy and all of them presented E.E.G. abnormalities during pattern presentation. The similarities between our results and the results of the above authors suggest that pattern and photosensitive epilepsy are closely related and that the mechanism by which the pattern enhances the efficacy of I.P.S. in photosensitive epilepsy is similar to that in pattern sensitive epilepsy,the difference being that flickering light is more potent in photosensitive epilepsy than patterns alone,whilst patterns have a more provocative effect than light in pattern sensitive epilepsy. Our findings suggest that patterns in addition to other factors (intensity, macular stimulation, flash frequency etc.) play an important part in the triggering of fits by television.

The combination of the above factors is mainly met in a faulty T.V. set with the patient close to it and this may explain why most of the patients have an epileptic attack under these conditions.

It should be suggested that in order to ensure that the majority of patients with photosensitive epilepsy can be identified during routine E.E.G. investigations, stroboscopes should be suitably modified by fitting a small square pattern on the glass of the stroboscope. This can be done easily by fitting a transfer paper sheet of 2 mm x 2 mm squares on the glass of the stroboscope.

The clinical importance of this can be seen in Table 4.33.2.1. where 100% of the patients (at intensity 8) and 70% of the patients (at intensity 16) would not have been diagnosed as photosensitive if I.P.S. was given alone without being combined with small square patterns.

5.50 RELATION OF OCCIPITAL SPIKES AND V.E.R.

The main task undertaken in this thesis was to study the occipital spikes and their possible relation to V.E.R. in photosensitive patients.

We first compared the latencies of the occipital spike components to the latency of various waves (P_1, N_2, P_2, N_3) of their V.E.R obtained in response to I.P.S. at 1-4 fl/sec. (section 4.41). With the exception of two patients the occipital spikes did not show any simple relationship with the same polarity components of the V.E.R.

Although this finding was a strong argument against the existence of a relationship between V.E.R. and occipital spikes, the comparison of V.E.R. obtained at low frequency stimulation (1-4 fl/sec.) with responses (occipital spikes) induced at higher frequencies (5-9 fl/sec.) might be arbitrary.

Van Hof (1960) considers the V.E. Responses to a rapid train of stimuli (5-9 fl/sec.) to be an effect of the linear superposition of individual responses, and this was confirmed in only two patients by Rietveld (1963).

If the above opinion were correct, one would expect that such superposition would result in a graphically different pattern at 6, 7, 8 9 fl/sec.

However, it has been shown in this thesis (p.141-142) that the occipital spikes occur at constant latency irrespective of the flash rate. Despite this theoretical argument which supported the view that there is no latency relationship between occipital spikes and V.E.R., we felt that further experimental evidence was needed. In five patients therefore, we compared the latency of the occipital spikes with the latency of V.E.R. obtained at flash rates faster than 4 s^{-1}. Our results detailed in pages 196-212 and 216 show that no relationship exists between the latencies of occipital spikes and V.E.R. at any of these flash rates. These latter findings are of great importance because the changes in V.E.R. if they occur do so at flash rates faster than 4 s^{-1} (Van Hof, 1960).

Our results from the study of V.E.R. in normal subjects (section 4.43), are a little confusing in that 10 subjects showed V.E.R. with constant latencies over the whole range of flash rates 1-10 s^{-1}, whilst the remaining 2 showed some alternations of V.E.R. at flash rates faster than 4 s^{-1}. No doubt the subject needs further research to see why in some normals each flash at higher frequencies produces a V.E.R. irrespective of the previous flash i.e. interrupts the time

course of the response to the previous flash, whilst in others the above finding is not true.

The normal subjects did not show, with two exceptions, components comparable with the occipital spikes seen in photosensitive or epileptic patients. Whether the two exceptions have an abortive photosensitivity is too arbitrary to say.

A good opportunity for comparison of V.E.R. and occipital spikes had arisen for us when one epileptic patient (No. 52, section 4.42) examined for a second time did not show occipital spikes at 6-10 fl/sec. I.P.S., as she did on the first test, and only V.E.R. were obtained. The comparison (fig. 4.42.1) revealed that the latency of the occipital spikes obtained on the first occasion differed greatly from the latency of the V.E.R.

The following findings also suggest that there is no relationship between occipital spikes and V.E.R.

a. Although large variations of the latencies of the V.E.R. were observed in the patients the latency of the occipital spikes show little or no variation suggesting that the underlined mechanisms for the two phenomena are different.

b. In one epileptic patient the V.E.R. recorded from the right occipito-central derivation was different from that recorded from the left occipito-central derivation, but the occipital spikes from these derivations did not differ in latency.

c. In one photosensitive patient (No. 20, fig. 4.41.7) the V.E.R. did not change when intermittent occipital spikes appeared which suggests that the brain channels for the V.E.R. and occipital spikes are different.

The above findings lead us to the conclusion that there is no simple relationship between the occipital spikes and the V.E.R. in photosensitive patients.

The discrepancy between our results and those of Hishikawa et al., (1967) may be attributable to the following factors:

1. The I.P.S. was given by them while the patients kept their eyes closed.

2. In three of their photosensitive patients, flash rates between 10 and 16 s^{-1} were used, and this means that the interval between the flashes was shorter than the latency of the negative occipital spikes.

Thus, it is possible that the above authors were observing occipital spikes which had outlasted the inter-stimulus interval. This would also explain the difference in latencies of the occipital spikes reported in this thesis and those which they report.

3. The V.E.R. components which they reported for normal subjects show a very wide range and in fact overlap. The relatively short interval between flashes and the wide range of the latencies of the V.E.R. components may have resulted in fortuitous relationship between occipital spikes and V.E.R. components.

4. The above authors also found that latencies of V.E.R. components were similar in patients and control subjects and they therefore consider it justifiable to compare the latencies of the occipital spikes induced by a single flash in three patients with the V.E.R. of normal subjects. This comparison may be misleading as shown by the following example:

In one patient they suggested that a positive component of the occipital spikes with a latency of 50-55 ms. corresponded to the P_3 V.E.R. component of normal subjects (73 ± 12.6 ms. i.e. 61.4 - 85.6 ms.) whilst in another patient they suggested that a negative component of the

occipital spikes with a latency of 45-55 ms. corresponded to the N_2 V.E.R. component of normal subjects (45 $\pm$ 7.3 ms.).

There is also a discrepancy between our results and those of Rodin et al., (1969), but as these authors were concerned with normal animals and the seizures were induced with megimide, different findings from photosensitive human beings are not surprising.

In two patients (Nos. 5 and 6, Table 4.41.1) the latency of the occipital spikes appeared to be related to the latency of triphasic P_2 component (Va, Vb, Vc of Gastaut and Regis, 1964). In one of these two patients the Vb component appeared to increase in amplitude with increasing flash rate, finally becoming the negative occipital spike (fig. 4.41.1). It is interesting that these two patients were the only patients who showed a V.E.R. triphasic P_2 wave and also a latency relationship between V.E.R. and occipital spikes.

Gastaut et al (1964) have also found an augmented Vb wave in photosensitive patients. This V wave has been related by Gastaut et al (1964) to the photopic and scotopic system of the retina.

Whether the negative component of the triphasic P_2

wave is an abortive (small) negative occipital spike which does not become manifest at these slow flash rates, or in these two patients a true latency relationship exists between V.E.R. and occipital spikes is too difficult to be proved.

The fact that no other photosensitive patient and all normal subjects did not show triphasic P_2 waves makes the first hypothesis possible.

It should also be emphasized here that in ten patients (page 196) the negative occipital spike occurred within 5 m.secs of the P_2 V.E.R. latency i.e. a latency relationship exists in these patients between negative occipital spike and the positive P_2 wave.

There is experimental evidence in animals that the negative and positive V.E.R. components are summated post synaptic potentials which are predominantly excitatory and inhibitory respectively (Creutzfeldt et al, 1967, 1969)

If the relation between V.E.R. and intracellular activity in the occipital cortex of animals is such, as the above authors supported, that inhibition of cortical cells coincides with the surface positivity, then P_2 wave of V.E.R. is the result of summated inhibitory post synaptic potentials (I.P.S.P.) of visual neurons.

If the assumption of the above authors was correct for human beings, then our findings that in 10 patients the negative occipital spikes have similar latencies with the P_2 V.E.R. component may indicate that I.P.S.P. (corresponding to the P_2 wave) are suppressed and replaced by Excitatory Post Synaptic Potentials (corresponding to the negative occipital spike). Our assumption is therefore, that a failure of inhibitory mechanisms exists in photosensitive epilepsy. This failure is more evident at flash rates above 4 s^{-1} (where occipital spikes occur) which is in agreement with recent experimental evidence in cats that the amplitude of I.P.S.P. decreases at flash rates above 2-4 s^{-1} (Kuhnt et al, 1971) and the I.P.S.P. disappear completely at flash frequencies above 10-15 s^{-1} i.e. at flash frequencies where photoconvulsive responses appeared in most of our patients.

Our assumption is in accordance with the speculation that one cause of epilepsy may be a disturbance of inhibitory mechanisms (Eccles, 1969) and that inhibition plays an important role in the sculpturing of epileptic activity (Spencer et al, 1969). It is also known that in certain neuronal formulations i.e. hippocampus the recurrent inhibition is frequency sensitive and the efficacy of recurrent

inhibition is greatly reduced by longstanding tetanic stimulation (Andersen et al, 1969). That such frequency-dependent inhibition exist in the visual cortex is indicated by the above mentioned experimental work of Kuhnt et al, (1971).

5.60 MECHANISMS OF PHOTOSENSITIVE EPILEPSY.

Despite the vast amount of research of photosensitive epilepsy, both in human beings and "model photosensitive animals" the underlying mechanisms are not known although various theories have been proposed.

Bickford et al (1953) supported that the non-specific thalamocortical system, activated by impulses from the lateral geniculate body, was responsible for the photosensensitive epilepsy.

Gastaut et al, (1962) suggested the participation of the non-specific system in photosensitive epilepsy because the I.P.S. induced discharges "are synchronous and generalized complexes of spikes and waves" without any occipital preponderance.

Naquet et al (1960), without rejecting the possible role of the non-specific systems in provoking seizure attacks, speculated that "firing off" the temporo-parieto-occipital region may be facilitated by the arrival of specific visual afferents in the cortex, neighbouring the striate area as in the epilepsy described by Clementi (1929). Naquet et al, (1960) attributed the seizures induced by I.P.S. in 12 patients (some of whom were not epeleptics) to a state of

hyperexcitability of the occipital cortex. They did so because the E.E.G. abnormalities provoked in these 12 patients were localized to the posterior cerebral regions.

Hishikawa et al (1967) suggested that the occipital spikes were the result of an abnormal augmentation of V.E.R. which in four patients (with spontaneous occipital E.E.G. abnormalities) occurred in the occipital cortex whilst in another four patients (without spontaneous occipital abnormalities) the augmentation was suggested to occur in the geniculate body. In the same paper the authors found an increased photosensitivity in the waking and Rapid Eye Movement (R.E.M.) stage of sleep as compared to that of other stages of sleep. This was attributed to an increased facilitation of synaptic transmission in the lateral geniculate body and the increase in reticulocortical responsiveness in the waking and in the R.E.M. stage of sleep.

The occipital preponderance of the epileptogenic activity induced by I.P.S. in the majority of our patients (sections 4.23 and 4.24) indicates that the visual cortex is the primary site of cortical excitation in photosensitive epilepsy. This may be the result of a. an increased sensitivity of the occipital cortex b. an abnormal excitation of deep structures

specifically bombarding the occipital cortex and c. a combined increased sensitivity to light stimulation of both deep structures and occipital cortex.

Our findings as to the efficacy of patterns combined with I.P.S. in photosensitive epilepsy are similar to those of Chatrian et al, (1970) in pattern sensitive epilepsy. The above observations i.e. geometric patterns consisting of thin lines enhance the E.E.G. abnormalities induced by I.P.S. indicates that the visual cortex shows an increased excitability in photosensitive epilepsy. This is because the receptive fields of the visual cortex in contrast to the concentric form of retinal and geniculate receptive fields (Hubel et al, 1960) have a side by side arrangement of excitatory and inhibitory areas separated by parallel lines (Hubel et al, 1962, 1968). As a consequence of the above special organization, the enhancement of the E.E.G. abnormalities may be attributed to an increased convulsive susceptibility of the visual cortex as was also postulated by Chatrian et al (1970) for pattern sensitive epilepsy. The nature of this cortical excitability has been discussed in the previous section. It is difficult to condemn the non-specific systems as responsible for enhanced excitation due to highly specific stimulation i.e. pattern stimulation.

Some of the authors (Bickford et al, 1953, Gastaut et al, 1962) who supported the participation of the non-specific thalamocortical system in the pathogenesis of photosensitive epilepsy did so because they found that the E.E.G. abnormalities induced by I.P.S. were synchronous and generalized. This argument cannot support any more the above hypothesis because there is recent experimental evidence that generalized discharges, as for example 3 c/s spike and wave, may be entirely cortical (Marcus et al, 1966, 1968, Gloor, 1969) with or without the participation of the non-specific thalamocortical system. Furthermore, it has been shown in this thesis (section 4.23 and 4.24) that occipital spikes precede photoconvulsive responses in the majority of photosensitive patients.

On the other hand when someone studies the characteristics of the occipital spikes as detailed in section 4.21.1 he cannot fail to be impressed by their close resemblance with the recruiting responses (R.R.) described by Morison and Dempsey (Morison et al, 1942, Dempsey et al, 1942).

The following are the characteristics of the R.R. as summarized by Jasper (1960).

a. The optimal frequency to obtain the R.R. is from 6-12 stimuli per second.

b. The R.R. is characterized by a successively increasing cortex surface negative wave, reaching a maximum after two to five successive stimuli.

c. With continued repetitive stimulation the R.R. may progressively decline in amplitude and then occur again and finally may dominate the cortical activity.

d. When the R.R. is diphasic there is a positive surface wave of smaller amplitude, preceding the negative wave.

e. The R.R. has long latencies, as compared to the latencies of the specific responses.

f. The waves of the R.R. are timed to the frequency of the stimulus. Latency increases occur synchronously with the augmentation of the negative wave (Klee, 1966).

If the similarities between the occipital spikes and the R.R. are not coincidental, then the non-specific thalamocortical system must be implicated in the genesis of occipital spikes. The fact that the recruiting response is less prominent in the sensory receiving areas of the cortex (Jasper, 1960) is not a strong argument against the occipital spikes being related to the R.R. Hanbery et al., (1953) found a part of the thalamic reticular system which evoked good recruiting responses in the visual cortex, and therefore

topographical organisation within the non-specific system is most likely. A coexistent decrease of the convulsive threshold of the occipital cortex (as speculated above) may explain the topographic discrepancy between occipital spikes and R.R.

If the geniculate-cortical volley were increased as suggested by Hishikawa et al (1967) the occipital spikes could be expected to occur earlier i.e. within the latency limits of the early evoked responses. The long latencies of the negative occipital spikes are in favour of the assumption that the thalamic transmission of specific afferent impulses is not affected. The concentric topographic organization of the lateral geniculate body (Hubel et al, 1960) is also against the suggestion that the above optic relay is directly implicated in the pathogenesis of photosensitive epilepsy (see above).

How can these various pieces of evidence which at first sight may appear mutually contradictory be reconciled?

We must consider photosensitive epilepsy as the result of a particular and abnormal interaction between the cortex and the non-specific thalamocortical system.

It is therefore suggested that photosensitive epilepsy is the result of an abnormal oscillation within a cortico-reticular group of neurons, which may result from the break-down of negative feed-back control systems, regulating cortical and subcortical interaction. Positive feed-back systems from the occipital cortex to subcortical nuclei and to other cortical areas may exist to enhance excitation.

The above suggestion that both the non-specific thalamocortical system and the occipital cortex are implicated in the pathogenesis of photosensitive epilepsy is in accordance with experimental research on animals (Hubel et al, 1960, Stevens, 1962, Stevens et al, 1964), that combined epileptogenic lesions of the visual cortex with brain stem lesions provided animals showing excellent stimulation of spike and wave discharges and photosensitivity in addition to induced seizures.

The similarities between the clinical photosensitive patients and those who have epilepsy but are not clinically photosensitive may indicate that the E.E.G. abnormalities induced by I.P.S. in both groups are provoked by the same underlying mechanisms, namely abnormal activations of the occipital cortex and the non-specific thalamocortical system.

5.70 CONCLUSIONS AND PROSPECTUS

At the end of a long experimental study it is reasonable to attempt an account of the contribution made and on the basis of the experience gained, what further research should be pursued.

The results contained in this thesis have confirmed observations made previously by other authors as for example sex and age distribution, types of attacks, monocular stimulation etc.

Other aspects of photosensitive epilepsy, studied previously, have been extended, enlarged or clarified as for example I.P.S. on "eyes-open" "eyes-closed" and particularly on "eye-closure". The significance of this latter eye stage has been emphasized for both resting E.E.G. and E.E.G. during I.P.S.

The main contribution of this thesis concerns the occipital spikes and their relation to V.E.R. in photosensitive epilepsy.

The characteristics of the occipital spikes were studied in detail and various experiments were done to see whether a latency relationship exists between V.E.R. and occipital spikes. It has been concluded that such a relationship does not exist.

Further research on the relation of V.E.R. and occipital spikes should include a. topographic distribution b. recovery cycle c. pharmacological studies and the influence of different chemical agents d. V.E.R. and occipital spikes during light and dark adaptation e. influence of the various stages of sleep on V.E.R. and occipital spikes f. simultaneous recording of electroretinograph and occipital cortex responses to I.P.S. g. selective retinal stimulation etc.

It is expected that experiments carried out on the above lines will give more information and insight into the mechanisms, pathways and neuronal nets involved in the genesis of occipital spikes and V.E.R. in photosensitive epilepsy.

Another aspect of photosensitive epilepsy namely enhancement of E.E.G. abnormalities induced by I.P.S. when combined with patterns has been studied. This was brought in by the observation that different stroboscopes, one with a grid and another without a grid, were different in potency of producing E.E.G. abnormalities during I.P.S. It was convincingly shown that I.P.S. when combined with patterns induced more E.E.G. abnormalities than straight intermittent light. The clinical significance of this finding has been

emphasized. Further research, no doubt, is needed to study the effect of pattern in photosensitive epilepsy (visual angles subtended by adjacent lines of the patterns, orientation and oscillatory movements of patterns and other various parameters as studied by Chatrian et al, 1970 in pattern sensitive epilepsy).

The more one becomes familiar with a problem the more questions arise in ones mind. We refer in this thesis to photosensitive epilepsy as an entity.

If one looks at the clinical histories of the patients, the types of E.E.G. abnormalities induced by I.P.S., the differences of V.E.R. and occipital spikes etc., one finds it difficult to accept that photosensitive epilepsy is identical for all patients.

How can we for example explain the clinical finding that some patients who have E.E.G. abnormalities during I.P.S. do not have seizures other than those without a precipitating factor? Why some patients have epileptic attacks only when watching T.V., whilst others respond to other light precipitating factors and some other patients have spontaneous and triggered attacks? Why in some patients I.P.S. is more potent when the eyes are closed, whilst in others who are highly sensitive to I.P.S. on eyes open, the stage of "eyes-closed" is completely ineffective?

Do the patients for whom a relationship was found between negative occipital spikes and P_2 V.E.R. component form a different group of photosensitive epilepsy from those where no such relationship was found? Are the operative mechanisms different for these two groups of patients? We suggested that inhibition plays an important role in the first group; what is the important factor for the second group?

Why in some patients are photoconvulsive responses without any occipital preponderance induced by I.P.S., whilst in the majority of patients occipital spikes precede I.P.S. provoked generalized discharges?

Every small piece of information creates a new question for which the attempted answer is again questionable.

This thesis is the end of some years of effort on photosensitive epilepsy, and it is hoped that some "psifides" were added to the mosaic of epilepsies. The pathways to the solutions of the various clinical and research problems is still long and laborious. "Though much is taken, much abides".

APPENDIX

This appendix contains reprints of four publications the results of which are contained in this thesis.

4 Occipital spikes during photic stimulation and their method suggested by Saunders (1963) for the separation of

THE PROCEEDINGS OF THE ELECTRO-PHYSIOLOGICAL TECHNOLOGISTS' ASSOCIATION

EVOKED RESPONSE DIAGNOSIS IN VISUAL FIELD DEFECTS

by

G. F. A. Harding, C. R. S. Thompson and C. Panayiotopoulos

(Neuropsychology Unit, University of Aston, Birmingham)

(accepted for publication 29th August, 1969)

4. Occipital spikes during photic stimulation and their relation to visual evoked responses in photosensitive epilepsy. — C. P. Panayiotopoulos, P. M. Jeavons and G. F. A. Harding (Birmingham).

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EPILEPSY[1]

n in Birmingham

Relation of Occipital Spikes evoked by Intermittent Photic Stimulation to Visual Evoked Responses in Photosensitive Epilepsy

[illegible] photosensitive epilepsy show

Aston University

Electroencephalography and Clinical Neurophysiology
Elsevier Publishing Company, Amsterdam – Printed in The Netherlands

OCCIPITAL SPIKES AND THEIR RELATION TO VISUAL EVOKED RESPONSES IN EPILEPSY, WITH PARTICULAR REFERENCE TO PHOTOSENSITIVE EPILEPSY[1]

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