Photosensitive Epilepsy and Image Safety

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Abstract. Photosensitive epilepsy came to prominence in the 1950s with the advent of television. Photosensitive epilepsy occurs in 1 in 4000 of the population. The incidence is 1.1 per 100,000 per annum, however amongst 7-19 year-olds the incidence is more than five times as common. It is twice as common in females as males, the onset is around puberty, but less than 25 per cent of patients lose their photosensitivity in their twenties. Patients are investigated in the EEG laboratory using intermittent photic stimulation. Peak sensitivity is between 16 and 20 flashes per second but 49 per cent of patients are sensitive to 50 flashes per second, explaining the sensitivity to PAL television systems. From 1993 the development of broadcast guidelines was developed restricting both flash rates and the areas of screen involved, as well as the use of long wavelength red. Automatic analysis systems are now developed to test material for compliance with guidelines in real time.

Introduction

Television and other video material are known to be a common precipitant of photosensitive seizures. In Europe they are by far the most common precipitant with more than sixty per cent of patients having their first seizure whilst watching television. Newer forms of electronic screen display such as LCD, plasma etc have partially overtaken the cathode ray tube and removed the flicker inherent in a scanned display. However, all material that is presented on a frame by frame basis has the potential to produce either temporal flicker (flashes) or spatial oscillations or reversal (alternating patterns) whatever the method of presentation. Because television broadcast material simultaneously reaches such a large audience incidents that have occurred with the broadcast of inappropriate material caused large numbers of seizures and are frequently headline news in newspapers. An advertisement screened in 1993 in the UK (Golden Wonder Pot Noodle) produced seizures in three individuals. This incident encouraged the development of the first television guidelines to govern flashes and repetitive patterns (Harding & Harding 1999). Further contraventions of these guidelines took place in the UK, culminating in the UK's Independent Television Commission (ITC) causing the incorporation of the Guidelines in the Programme Code for Broadcasters.

In 1997 in Japan a single episode of the Pokemon cartoon demonstrated the dangers of broadcasting unregulated material. The episode contained four seconds of material in which long-wavelength red frames alternated with cyan blue frames. Six hundred and eighty five persons were admitted to hospital and it was found that five hundred and sixty of these had had definite seizures. Of these 560 seventy six

per cent had never experienced a seizure previously. Guidelines similar to those in the UK, but incorporating the dangers of long-wavelength red light were adopted by the Japanese broadcasters.

A recent event in 2007 in the UK involved the screening of a promotional video for the London Olympics 2012. In one sequence a diver was shown diving into an Olympic pool. As he entered the pool the water changed into multi-coloured flashes which continued for more than two seconds. Thirty individuals complained of seizures elicited by this broadcast video, making this the worst incident experienced in the UK. The material was in clear contravention of the Guidelines in spite of the fact that the television industry has computer-based flash and pattern analysers freely available. Similar problems have occurred with video games. From 1981 there were a number of reports of seizures induced in persons playing video games on a variety of display devices. Usually a domestic TV monitor was used as the game display, but in some cases seizures were induced by hand-held modules or when playing arcade games. A significant number of cases reported in the literature did not appear to be sensitive to intermittent photic stimulation, but of those tested all showed sensitivity to standard gratings presented on a CRT monitor (Harding et al 1994). It became clear from many studies that specific video material was responsible for precipitating seizures and the games Super Mario World, Super Bomber Man 2 and Streetfighter 2 are often implicated (Fylan et al 1999).

Prevalence and incidence

Photosensitive epilepsy has a prevalence of approximately one in four thousand of the population (Harding & Jeavons 1994). In a carefully controlled prospective study carried out in the UK it was shown that the incidence of new cases in the general population was 1.1 per 100,000 per annum. However, in a population restricted to include the ages 7 to 19 years the incidence reached 5.7 per 100,000 per annum (Fish et al 1993). Photosensitivity appears equally prevalent in people of all ethnic origins (Harding & Jeavons 1994). The condition is approximately twice as common in females as in males, however, the majority of cases of seizures to video game material are male leading some authors to conclude that this group differs from the typical photosensitive population (Takahashi 1993). However, marketing statistics show that 82 per cent of video game players are male and this is sufficient to account for the difference. Only 25 per cent of patients lose their photosensitivity in their 20s and 30s, photosensitivity persisting into later life in the other patients (Harding et al 1997). There is a strong genetic tendency, 25 per cent of children of photosensitive mothers show photosensitivity in the laboratory and subsequently half of this number develop seizures with environmental stimuli (Harding et al 1997).

Types of seizures induced by visual image material

The most common form of seizure is a generalized tonic clonic convulsion, 79 per cent of patients demonstrating this type of seizure. Absence seizures occur in ten per cent of patients and myoclonic seizures occur in six per cent of patients with focal seizures occurring in five per cent.

Laboratory Investigations

Laboratory investigations are performed whilst the patient's electroencephalogram (EEG) is recorded.

Flash stimuli. There is now an internationally-agreed method of intermittent photic stimulation (IPS) (Kasteleijn-Nolst Trinite et al 1999). Flash stimuli are provided at 1,2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 60, 50, 40 and 25 flashes per second, in that order. The flash intensity is 1362 candelas per metre squared and the duration of stimulation is five seconds with the eyes open followed by eye closure followed by a further five seconds.

The visual angle is 0 to 12 degrees radius and the lamp is fitted with a diffuser. The background illumination is a dim room light sufficient to observe the patient. The EEG response which is of concern is a photoparoxysmal response (PPR) as seen in Figure 1.

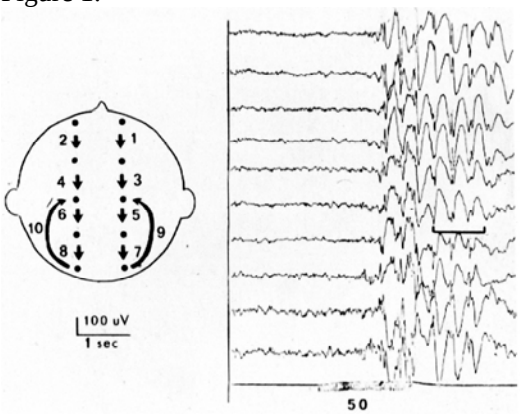

Figure 1 shows a PPR to IPS at 50 fps. It can be seen that all recording channels of the electroencephalogram are involved. From Harding & Jeavons 1994.

This response is used to establish the range of flash frequencies to which individual patients are sensitive. Most patients are sensitive between 13 and 21 flashes per second and very few patients are sensitive to low flash rates of three per second or less and no patients have been found to be sensitive above 65 flashes per second. It is of interest to note that forty nine per cent of patients are sensitive at 50 flashes per second which is the field frequency of broadcast in most countries whereas on the American continent and in Japan the frequency is 60 Hz, thus accounting for the apparent difference in the incidence of photosensitive epilepsy in different countries.(Fig. 2).

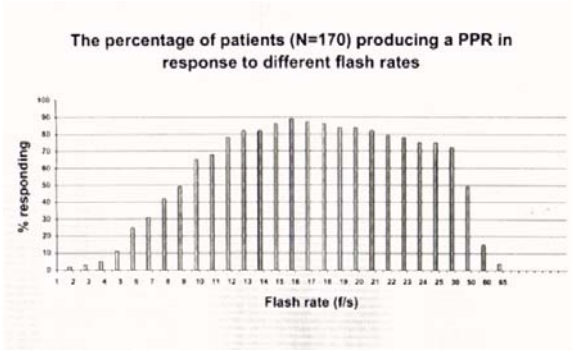

Figure 2. It should be noted that at three fps only 3 per cent of photosensitive patients are at risk. At 50 fps (PAL TV) 49 per cent are at risk whereas at 60 fps (NTSC TV) only 15 per cent are at risk. From Harding & Harding 1999.

In our studies there was no significant difference when the light was coloured, as long as the luminance was a constant (Harding & Jeavons 1994). However, long wave-length red light has been shown to be more provocative, even at low luminance (Takahashi & Tsukahara 1980). Patients are, in general only sensitive to binocular stimulation, 67 per cent of patients showing no evidence of sensitivity to monocular stimulation (Harding & Jeavons 1994). Stimulation in the centre of the visual field is more provocative than stimulation in the periphery of vision, the susceptibility increasing with the representation of the stimulus in the visual cortex (Wilkins 1995).

Pattern stimuli. It has been shown that many patients with photosensitive epilepsy are sensitive to patterns as well as intermittent photic stimulation. Indeed, a few patients are sensitive to patterns but not to IPS (Harding & Jeavons 1994).

The spatial and temporal characteristics of patterns which induce PPRs have been studied in detail (Wilkins 1995). With square wave patterns consisting of light and dark bars of equal width, sensitivity is greatest (Wilkins 1995). As the contrast of the grating increases there is a linear increase in risk of producing a PPR with log contrast (Wilkins 1995, Harding & Fylan 1999). Sensitivity is greatest at spatial

frequencies between one and 10 cycles per degree reaching peak sensitivity at 2 to 4 cycles per degree (Wilkins et al 1979, Soso et al 1980, Harding & Harding 1999) (Fig 3).

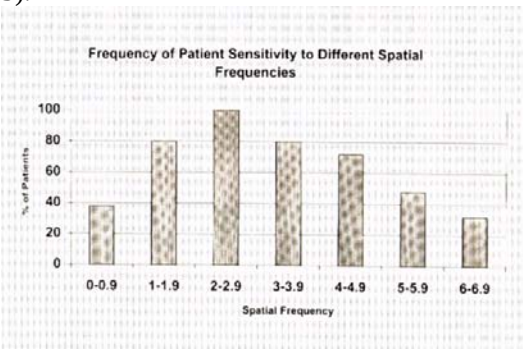

Figure 3. It can be seen that peak sensitivity to a square wave high contrast bar pattern reversing at 1 Hz is maximal at 2 to 3 cpd. From Harding & Harding 1999.

Gratings which oscillate or alternate at 10 to 20 Hz produce maximal sensitivity, but gratings that drift in one direction are not provocative.

Control of broadcast and video material

Two separate approaches have been made to reduce the risk of photosensitive responses occurring in viewers of either TV or video material.

Broadcast guidelines. Following the Golden Wonder Pot Noodle advertisement in the UK the Independent Television Commission (ITC) produced guidelines which have been further developed over the succeeding years for those producing broadcast material. Similar guidelines have been adopted in Japan, Italy and Russia and by the International Telecommunications Union. The principle of these guidelines is similar and is based mainly on the studies of Harding & Jeavons (1994), and Harding & Harding (1999). The guidelines restrict repetitive flash rates, flashes of long wave-length red light and high contrast patterns.

Repetitive flashes greater than three per second are in general not allowed if they exceed 25 per cent of the display device screen area. Since the photoparoxysmal response is dependant, as stated earlier, on involving the central ten degrees of vision and since televisions viewed at the recommended viewing distance at sizes between 20 and 60 inches screen diagonal always occupy the central ten degrees of vision, there is not a difference related to screen size. Flashes of long wave-length red light at more than three flashes per second are usually not allowed.

High contrast patterns, when restricted (these are not included in the ITU guidelines), are restricted in terms of the number of cycles or black and white bars as well as the area of the screen involved. When they oscillate or reverse they are restricted to smaller areas than patterns which are stationery.

The rationale for these restrictions is contained in a paper summarising all previous studies (Binnie et al 2002).

Automatic analysis of broadcast material. Checking broadcast material for compliance with guidelines is a laborious and time-consuming activity for the human observer. The material must be viewed frame by frame and with PAL television at 25 frames per second one minute of broadcast material typically takes between 30 minutes and one hour to evaluate by a human observer, and this method is open to subjective error. Recent developments of computer-based analysers such as that developed by Cambridge Research Systems UK, has allowed analysis of the material on a frame by frame basis in real time and allows automatic assessment of compliance in terms of flashes, pattern, or long wave-length red. All factors including the flash rate or the pattern spatial frequency are taken into account including the screen area and the contrast of the material. Such computer-based machines allow easy modifications to incorporate compliance to specific national guidelines. The availability of such machines to both the broadcast and video game industry has

removed the final hurdle in compliance with published guidelines.

Filtering devices. In Japan there has been a different form of development on the basis that it is better to protect those who are known to be photosensitive than to protect the whole viewing audience. Unfortunately this neglects the finding from the Pokemon incident that 76 per cent of those who were photosensitive were unaware of their photosensitivity. To achieve this protection for photosensitive individuals a device that modifies the TV picture at the receiver is required. To prevent visually-induced seizures due to flash stimulation Nomura developed an adaptive temporal filter able to reduce frame to frame flicker at 10 to 30 Hz (Nomura 1999). This was shown to be effective in preventing PPRs in eleven photosensitive patients (Nomura et al 2000). A further development of this device allowed filtering of geometrical patterned flicker (alternating pattern). This was shown to be effective in thirteen patients (Takahashi et al 2002).

Future developments

The continuing development of new TV broadcast and video game monitors such as LEDs, Plasma, SEDs, although removing some of the problems of inherent flicker on CRT displays, will not of course remove the need for control of broadcast or video game material. When provocative image material is used either in video games, DVDs or in broadcast TV material the potential risk for photosensitive individuals, whether known or unknown, remains the same. This has been well-illustrated in the recent transgression of the ITC (now OFCOM) guidelines by the London Olympic 2012 promotional broadcast material.

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