Epilepsia, **40**(Suppl. 4):28–30, 1999
Lippincott Williams & Wilkins, Inc., Philadelphia

Mechanisms of Video-Game Epilepsy

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Summary: *Purpose:* We aimed to elucidate the mechanisms underlying video-game epilepsy by comparing the flicker- and spatial-frequency ranges over which photic and pattern stimulation elicited photoparoxysmal responses in two different populations: (a) 25 patients with a history of seizures experienced while playing video games; and (b) 25 age- and medication-matched controls with a history of photosensitive epilepsy, but no history of video-game seizures.

Methods: Abnormality ranges were determined by measuring photoparoxysmal EEG abnormalities as a function of the flicker frequency of patterned and diffuse intermittent photic stimulation (IPS) and the spatial frequency of patterns on a raster display.

Results: There was no significant difference between the groups in respect of the abnormality ranges elicited by patterned or diffuse IPS or by spatial patterns. When the groups were compared at one specific IPS frequency (–50 Hz), however, the flicker frequency of European television displays, the video-game patients were significantly more likely to be sensitive.

Conclusions: The results suggest that video-game seizures are a manifestation of photosensitive epilepsy. The increased sensitivity of video-game patients to IPS at 50 Hz indicates that display flicker may underlie video-game seizures. The similarity in photic- and pattern-stimulation ranges over which abnormalities are elicited in video-game patients and controls suggests that all patients with photosensitive epilepsy may be predisposed toward video-game–induced seizures. Photosensitivity screening should therefore include assessment by using both IPS at 50 Hz and patterns displayed on a television or monitor with a 50-Hz frame rate. **Key Words:** Photic stimulation—Flicker frequency—Pattern stimulation.

Reports of seizures associated with playing video games have appeared in the literature since 1981 (1,2) and have suggested that such seizures are elicited by photic or pattern stimulation. Specifically, patients show abnormal sensitivity to intermittent photic stimulation (IPS) and high-contrast patterns (3). Awareness of the risk of video-game seizures has increased in manufacturers of video games, many of whom include warnings of the risk of seizures on their games. Accordingly, the perception of risk has increased in video-game users who have epilepsy, and this is not confined to individuals with photosensitive epilepsy (4). Perception of risk is confounded by the often prolonged period individuals spend playing games; seizures in individuals with no electrophysiologic evidence of photosensitive epilepsy may be fortuitous. Alternatively, these individuals' predisposition toward video-game epilepsy may not have been identified because of inadequate testing procedures. It is essential, therefore, to devise an effective test for predisposition toward video-game epilepsy. A prerequisite for such a test is an understanding of the mechanisms underlying video-game seizures.

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This study aimed to elucidate the mechanisms of video-game epilepsy by comparing the abnormal photo- and pattern-sensitive ranges of patients with a history of video-game epilepsy with those of patients with a history of photosensitive seizures but no history of video-game seizures. As many video games are displayed on a standard television set, the flicker introduced by the screen's refresh rate (50 Hz in Europe) may underlie video-game seizures. We therefore examined the incidence of EEG abnormalities elicited in response to IPS at 50 Hz in patients with and without a history of video-game seizures. The results are discussed with respect to testing protocols for optimal detection of patients who are at risk of video-game seizures.

METHODS

Patients

Twenty-five patients with a history of video-game epilepsy were compared with a group of 25 patients with photosensitive epilepsy but with no history of seizures while playing video games. The video-game group comprised 18 male and seven female subjects; their ages ranged between 9 and 29 years, with a mean of 17 years. This increase above the male-to-female ratio observed typically in photosensitive epilepsy is likely to be due to

the greater number of males who play video games (3). Eleven patients were medicated: four with valproate (VPA), two with carbemazepine (CBZ), two with lamotrigine (LTG), and four were receiving multitherapy. The control group comprised six male and 19 female subjects; their ages ranged between 7 and 30 years, with a mean of 18 years. Eleven patients were medicated: six with VPA, two with a CBZ, two with LTG, and one was receiving multitherapy.

Procedure

Our standard IPS protocol (5) was used to determine each patient's range of abnormal photo and pattern sensitivity. The presence of photoparoxysmal responses indicated abnormal sensitivity to the stimulus. A Grass PS22 photostimulator was positioned 30 cm away from the patient's nasion, and the patient asked to fixate a small marker in the centre of the lamp. The strobe subtended 25 degrees, and the mean luminance at 20 flashes per second was 1,363 cd/m^2 (68 cd · s/m^2 per flash). Flash frequencies of 1–60 Hz were tested with (patterned IPS) and without (unpatterned, or diffuse IPS) the presence of a line grid. Patients were then tested for pattern sensitivity. Patterns were generated by an SC Electronics T22 grating generator and displayed on either (a) a Philips television with 50-Hz frame rate, a mean luminance of 190 cd/m^2, and a field size of 18 degrees horizontally by 14 degrees vertically when viewed at a distance of 1.5 m; or (b) a Hitachi monitor with refresh rate of 50 Hz, a mean luminance of 49 cd/m^2, and a field size of 20 degrees horizontally by 15 degrees vertically when viewed at a distance of 1 m. The patterns comprised vertical square-wave and sine-wave gratings of 96% contrast and spatial frequencies between 0.5 and 7 cycles/degree. The gratings were onset from a blank screen with a square-wave temporal envelope and were presented first oscillating at 1 Hz, and then stationary, for periods of 15 s. The patients fixated on a central marker for a period of 5 s, closed their eyes for 5 s, and then opened their eyes and fixated the pattern for a further 5 s before the gratings were offset. Only photoparoxysmal activity that occurred when the eyes were open and the stimulus was on were included in this study; occipital spikes, spontaneous and fixation-off abnormalities, and abnormalities elicited by eye closure were discounted. The presence of EEG abnormalities while viewing these epileptogenic patterns was used as an indication of the patient being at risk of experiencing a seizure while playing a video game whose content may also be epileptogenic.

RESULTS

The range of diffuse and patterned IPS frequencies and the range of pattern spatial frequencies that elicited EEG abnormalities were determined for both groups of patients. Patterned IPS elicited more abnormalities than diffuse IPS, with 84% of video-game patients and 76% of controls displaying abnormalities to patterned IPS, but only 36% and 53%, respectively, displaying abnormalities to diffuse IPS. Patterns displayed on a television or monitor elicited abnormalities in all the video-game patients and in 76% of controls. The mean ranges over which each stimulus type elicited abnormalities were calculated for each group and are shown in Table 1. There was no significant difference between video-game patients and controls in the range of diffuse IPS frequencies that elicited abnormalities ($t = 0.033$; $p = 0.974$; $df = 48$ two-tailed). For patterned IPS, video-game patients showed EEG abnormalities over a greater range than controls, but this did not reach statistical significance ($t = 1.568$; $p = 0.124$; $df, = 48$, two-tailed). There was no significant difference between video-game patients and controls in the range of pattern spatial frequencies that elicited EEG abnormalities ($t = 1.294$; $p = 0.170$; $df = 48$, two-tailed).

The interaction between sensitivity to IPS at 50 Hz and a history of video-game seizures is shown in Table 2. Patients with a history of video-game epilepsy were significantly more likely to be sensitive to 50-Hz IPS than were controls ($\chi^2 = 5.128$; $df = 1$; $p = 0.024$).

DISCUSSION

The results support the hypothesis that video-game epilepsy represents a form of photosensitive epilepsy, with patients particularly sensitive to flickering light at 50 Hz. As the television screen refresh rate is 50 Hz, this sensitivity places patients at risk of experiencing a seizure while watching television. Indeed, all but one of our video-game epilepsy group experienced a seizure while playing video games displayed on a television set.

Our results demonstrate the importance of incorporating patterned IPS and pattern-sensitive tests into routine photosensitivity testing protocols; only 45% of patients were sensitive to diffuse IPS, compared with 80% who were sensitive to patterned IPS, consistent with our previous results (6). Furthermore, not all patients were sensitive to IPS; 20% of patients displayed abnormalities only to patterned stimuli displayed on the television or monitor. In our sample of patients, 20% would therefore not have been identified as being at risk of seizures if they were not tested for pattern sensitivity. These results

TABLE 1. *Mean range over which diffuse and patterned IPS and spatial patterns elicited EEG abnormalities in patients with and without a history of video-game seizures*

	Video-game patients	Controls
Mean diffuse IPS range (Hz)	5.7	5.6
Mean pattern IPS range (Hz)	18.1	10.6
Mean pattern range (c/deg)	3.9	3.1

IPS, intermittent photic stimulation.

TABLE 2. *Number of patients with and without a history of video-game seizures showing EEG abnormalities to IPS at 50 Hz*

	Video-game patients	Controls
Sensitive to 50-Hz IPS	16	8
Not sensitive to 50-Hz IPS	9	17

IPS, intermittent photic stimulation.

are unlikely to have been caused by medication, as half of these patients with abnormalities to patterns but not IPS were not medicated.

The results go some way to elucidating the mechanisms of video-game epilepsy. Patients with a history of video-game seizures are significantly more likely to be sensitive to IPS at 50 Hz than are patients with a history of photosensitive epilepsy, but not of seizures while playing video games. As this frequency corresponds to the refresh rate of the television on which the games were typically played, the results suggest that in this group of patients, video-game seizures were elicited by screen flicker in the video-game display medium.

In other respects, the two groups were similar in terms of mean abnormality ranges. Our results therefore suggest that video-game epilepsy does not represent a syndrome distinct from that of photosensitivity. Instead, we posit that patients are sensitive to flicker rates present in television displays, and the often prolonged periods spent playing video games places them at risk of experiencing seizures. These patients may therefore be equally likely to experience seizures during prolonged television-viewing sessions. We further suggest that, as our two groups show similar sensitivity profiles, all patients with photosensitive epilepsy, particularly those sensitive to 50-Hz IPS, are predisposed to video-game seizures. All photosensitivity-testing protocols should therefore include testing using IPS at 50 Hz, and patterns displayed on a television or monitor with a frame rate of 50 Hz.

Acknowledgment: This work was supported by a grant from the Japanese Epilepsy Association.

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