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Epileptic Seizures Induced by Animated Cartoon, "Pocket Monster"

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Summary: *Purpose:* A large number of children had fits while watching the animated cartoon television (TV) program "Pocket Monster." To elucidate the seizures associated with the TV program, we administered a questionnaire survey in Aichi Prefecture, Japan.

Methods: The questionnaires were sent to 75 hospitals located in and around Aichi prefecture. The presence of epileptic seizures and the types of seizures were determined by three pediatric neurologists.

Results: Sixty-one hospitals responded to the questionnaire survey. Among 95 patients living in Aichi prefecture for whom enough information on seizure manifestations and EEG was available, ≤93 patients were considered to have epileptic seizures while watching the TV program. Most seizures occurred at a scene in which red and blue frames alternated at 12 Hz. Sixty-nine (74%) patients had no history of epilepsy. Thirty-nine patients had generalized seizures, and 49 patients had partial seizures. Partial seizures occurred more frequently in the younger age group than did generalized seizures. The EEG revealed a photoparoxysmal response (PPR) in 43% of patients. PPR was present not only in patients with a history of epilepsy (54%) but also in those with no history of epilepsy (38%).

Conclusions: Almost all seizures induced by the TV program "Pocket Monster" were epileptic, and partial seizures were induced more frequently than generalized seizures. The incidence of this "Pocket Monster"–induced seizures was roughly estimated as ≥1 in 4,923 individuals aged 6–18 years. **Key Words:** Photosensitive seizure—Partial seizure—Generalized seizure—Photoparoxysmal response—Visual seizure.

Almost at the same time in the evening of December 16, 1997, emergency calls for ambulances began to ring in fire stations all over Japan. The phone calls were from families whose children had fits while watching television. It soon appeared that, when seized, these children were watching the same animated cartoon series titled "Pocket Monster," which at the time was very popular among Japanese children as "Pokemon." In Aichi prefecture (population, 6.95 million) alone, ambulances brought 64 patients to the local hospitals. Some other children were reported to visit hospitals for symptoms associated with the TV program at the same night or later. Most of the episodes were considered to be due to visually induced epileptic seizures, but many questions have remained unanswered, including detailed information about the seizures, and the incidence and circumstances when the fits occurred. To elucidate the seizures associated with the animated TV program "Pokemon," we performed a questionnaire survey in Aichi Prefecture.

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METHODS

On December 22, 1997, 6 days after the incident, questionnaires were sent to 75 hospitals located in and around Aichi prefecture with at least one full-time pediatrician. The questionnaire was of two types: one for families of patients and another for the physicians. The questionnaire for the family contained 26 items, including family and individual history of epilepsy, febrile convulsions, and migraine; history of periodic vomiting, motion sickness, and other chronic disorders; the time at seizures, scene of the TV program when seizures occurred; the TV set, luminance of the room, viewing distance, posture, seizure manifestations (including the presence of visual symptoms, headache, nausea, vomiting, eye deviation, unconsciousness, cyanosis, convulsive movements, laterality); persons who witnessed seizures; the presence of lack of sleep and sleepiness,

cough, rhinorrhea, fever and diarrhea; and history of visual, myoclonic, and absence seizures. Before medical examination, the families were requested to answer the questions. Most of the items could be answered in yes-or-no manner or with simple numbers, but seizure manifestations were written in detail, as possible. After the family fulfilled the questionnaire, physicians complemented the answers, wrote the results on questionnaire sheets for physicians that contained the same items as those for the family, and additional information on the arrival time of the patients and transport measures (with an ambulance, the same night as the program was televised without an ambulance, the next day, later), EEG results (especially responses to IPS), and drugs administered. The protocol for testing of IPS varied among hospitals and was not particularly standardized for this project. However, photoparoxysmal response (PPR) was defined as generalized spike–wave complex induced by IPS. Any focal epileptiform discharges associated with IPS, especially confined to posterior arrays, were not regarded as PPR.

The presence of epileptic seizures and the types of seizures were determined by three of us (H. T., K. W., and K. A.) at first independently, mainly based on the detailed description of seizure manifestations, and later each diagnosis was discussed and tailored if there was disagreement among them, then a consensus was reached. Seizure type was diagnosed according to the International Classification of Epileptic Seizures (1).

Fisher's Exact probability or Mann–Whitney's *U* test was used for statistical analysis.

RESULTS

Sixty-one (81% of hospitals to which questionnaires were sent) hospitals responded to the questionnaire survey within 3 months. One-hundred-eleven patients visited 40 hospitals (70% of hospitals to which questionnaires were sent) for some symptoms associated with the "Pokemon" program. We excluded nine patients from analysis because they lived outside Aichi prefecture. Another girl was excluded because she had a convulsion an hour after watching the program. The seizure occurred during sleep and was characterized by tonic contraction of the left arm. The EEG showed sharp waves in the right central area. In six patients of the remaining 101 patients, the diagnosis of epilepsy could not be made because of the lack of enough information on seizure manifestations and EEG.

Among the remaining 95 patients, the diagnosis of epilepsy was not established in two patients: one was a 7-year-old boy who did not complain of any epileptic manifestation except dizziness while watching the TV program. He had a history of idiopathic localization-related epilepsy and had been treated with carbamazepine (CBZ). Another was a 12-year-old girl, who had visual symptoms characterized by flickering light and fogging, which was followed by occipital headache, nausea, and vomiting. This could be an occipital lobe seizure, but there is no information of the EEG at all.

The remaining 93 patients were considered to have epileptic seizures associated with the animated "Pokemon" TV program. There were 44 male and 49 female patients. The age ranged from 2 to 28 years (mean, 11 years). Twenty-five patients had a family history of febrile convulsion, 19 of epilepsy, and eight of migraine. There were 24 patients with a history of epilepsy and 21 of febrile convulsion; 57 (61%) patients did not have any history of convulsive disorder, either epilepsy nor febrile convulsion. Seven patients had mental retardation, and two, motor disturbance. In addition, 24 patients had a history of motion sickness, five of periodic vomiting, three of orthostatic hypotension, three of bronchial asthma, and two of autism. A history of migraine was present in only one patient. Fifty-three patients had no chronic disease. When watching the "Pokemon," 13 patients allegedly had a lack of sleep, but sleepiness while watching the program was documented only in one. Fifteen patients had some upper respiratory symptoms (cough and/or rhinorrhea), but none had fever. Diarrhea was present in one patient. Twenty-seven patients were taking some medications: valproate (VPA) in nine patients, cold medicines in 7, carbamazepine in 6, phenobarbital in 4, zonisamide (ZNS) in two, phenytoin (PHT) in one, antithyroid drug in one, and prednisolone in one. No patient was taking clonazepam (CZP).

Most of patients were watching the program in well-lit rooms when they had seizures. The room was reported to be dark by only two patients. When viewing TV, six patients were standing, 14 lying on the floor, and the remaining 73 sitting. The animated program was on the air for 30 min from 18:30 to 19:00. The time when seizures occurred was concentrated on the latter half of the program. Forty-seven patients were documented to have seizures at 18:50, and 74 patients at 18:45–19:00. At around 18:50, the TV program was showing a scene of explosion of a rocket bomb that contained flickering of red and blue light at ~12 Hz. Fifty-five patients were alleged to have seizures during this scene. Another seven patients had an attack at 18:30–18:44. Five patients had seizures while watching the videotaped program. One of them had no symptom when she viewed the TV program on the air, but the next day, she had a visual seizure followed by generalized convulsion while watching the videotaped program. The time at the seizure was not specified in the remaining seven patients.

At seizures, patients were viewing the screen at a distance of 10–600 cm, with a mean of 182 cm. Fourteen patients were $\geq$2.5 m away from the screen, and 56 patients were at a distance of $\geq$1.5 m from TV screen.

The diagonal size of the screen ranged from 14 to 35 inches, with a mean of 25 inches. The maximum visual angle against the TV screen was estimated to be 6–74°, with a mean of 26°.

While watching the "Pokemon" program, 39 patients had generalized seizures, and 49 patients had partial seizures (Table 1). In the remaining five patients, the seizure type could not be determined. The generalized seizures consisted of generalized motor seizures (GMSs; 37 patients) and myoclonic seizures (two patients). Most of GMSs were assumed to be generalized tonic–clonic convulsions, but the documentation on the seizure manifestations often lacked one phase, either tonic or clonic. The partial seizures were characterized by simple partial seizures (SPSs) in two patients, SPSs followed by complex partial seizures (CPSs) in seven, SPSs that evolved into GMSs through CPSs in one, SPSs evolving directly into GMSs in 13, CPSs in 22, and CPSs evolving into GMSs in four. All SPSs except four consisted of visual symptoms, such as flickering spots, fogging, visual hallucination, or blindness. The patients with partial seizures was significantly younger than those with generalized seizures (the mean age was 10 vs. 12 years; $p = 0.0015$), and partial seizures were predominant among the younger age group, whereas generalized seizures predominated in the older group (Fig. 1). In addition to the seizures, many patients vomited or complained of headache or nausea: headache in 35 patients, nausea in 34, and vomiting in 35. These symptoms were often present in a patient concomitantly, but not always combined: 23 (66%) and 20 (57%) patients with headache had nausea and vomiting, respectively, for instance. The symptoms occurred before, during, or after seizures, and it was often difficult to determine whether they were real ictal phenomena.

Forty-four patients were brought to hospitals in ambulances, and only three (7%) of them had a history of epilepsy. Including eight patients who came to hospital without an ambulance, 50 (72%) of 69 patients without any history of epilepsy rushed to hospital on the night of the TV program. On the contrary, only four (17%) of 24

TABLE 1. *Seizure types*

Seizure types	No. of patients
GMS	37
Myoclonic seizures	2
SPS	2
SPS → CPS	7
SPS → CPS → GMS	1
SPS → GMS	13
CPS	22
CPS → GMS	4
Unable to determine	5
Total	93

GMS, generalized motor seizure; CPS, complex partial seizure; SPS, simple partial seizure.

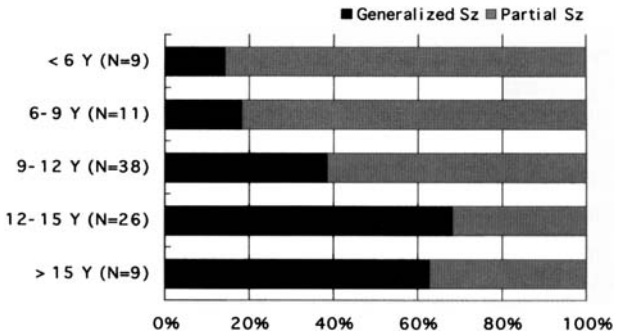

FIG. 1. The relation between seizure types and age.

patients with a history of epilepsy came to hospital on the same night. One patient with nephrotic syndrome had a convulsion in a hospital where he had been admitted.

IPS was performed in 81 patients during EEG recordings, and 35 patients (43%) showed PPR. The incidence of PPR tended to be higher in patients with a history of epilepsy (55%) than those without (38%), in patients with partial seizures (49%) than in those with generalized seizures (38%) or in female (48%) than in male patients (38%), but these differences did not reach statistical significance. PPR tended to be predominant in the anterior electrodes in five patients and in the posterior electrodes in six. In the remaining 11 patients, PPR did not show any predominance. Patients with PPR with the anterior accentuation tended to have generalized seizures (80%) more than those with the posterior accentuation (33%), but the difference was not statistically significant. In a 12-year-old boy with no history of convulsive disorder, who had a seizure characterized by shaking of arms and trunk, upper deviation of the eyes and loss of consciousness while watching the TV program (therefore regarded as having a generalized motor seizure for the present analysis), IPS induced a partial seizure with secondary generalization (Fig. 2). The EEG revealed low-amplitude fast waves in the left occipital area followed by rhythmic spike–waves over the left hemisphere.

In addition to PPR, the EEG revealed spontaneous epileptiform discharges in 34 patients: focal spikes in 15 patients, generalized spike–wave complex in 11, and both in the remaining six. The spontaneous epileptiform discharges were present in significantly higher incidence in patients with a history of epilepsy (70%) than in those without it (40%; $p = 0.043$). On the other hand, the spontaneous epileptiform discharges did not have any significant correlation with seizure type at viewing "Pokemon." Of patients with focal spikes, 60%, and 72% of those with generalized spike–wave complexes had partial seizures.

DISCUSSION

This questionnaire survey showed that most of the patients who visited hospitals for symptoms associated

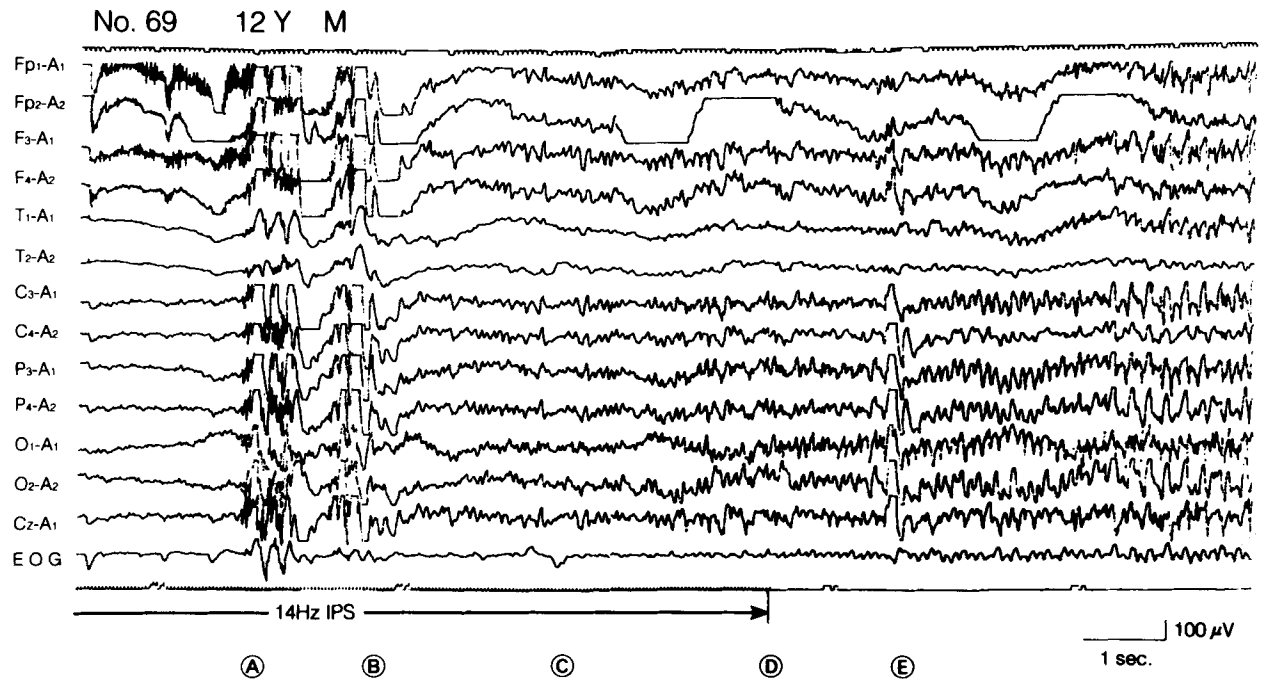

FIG. 2. Ictal EEG of a 12-year-old boy who had a seizure characterized by shaking of arms and trunk, upper deviation of the eyes, and loss of consciousness while watching the animated "Pokemon" TV program. After the attack he had headache, nausea, and vomiting. During 14-Hz IPS, generalized polyspike–wave complex was evoked (A). Around 2 s after he closed the eyes, low-amplitude fast waves or spikes appeared in the left occipital area (B) and, despite cessation of IPS (D), the rhythmic spikes increased their amplitude, spread into the left centroparietotemporal areas and were replaced by spike–wave complexes over the left hemisphere (E). He became poorly responsive with staring. The partial seizure finally evolved into a generalized tonic–clonic convulsion.

with the animated "Pokemon" TV program had epileptic seizures of several types. Among 95 patients who lived in Aichi prefecture and in whom enough information on seizure manifestations and EEG were available, at least 93 (98%) patients were considered to have an epileptic seizure while watching the TV program. The viewing circumstances when they had seizures were not necessarily aberrant. Only two patients were watching TV in a dark room. It is true that 37 patients were viewing the TV program as close as $\leq$1.5 m away from the TV screen, but 14 patients were at a distance of $\geq$2.5 m from the TV screen, the distance recommended for preventing TV epilepsy (2). There are no data on how Japanese people in general were watching TV, but a mean distance of 182 cm from the TV screen or visual angle of 26° does not seem to be unusual in Japan. Neither were there specific TV sets that the patients were watching. Some patients had upper respiratory symptoms or diarrhea or were sleepy, but most of the patients were healthy and alert when they had the seizures. These results suggest that the "Pokemon" seizures were mainly ascribed to the animated cartoon program itself.

Most of the seizures occurred around 18:50 and during a scene in which red and blue light alternated at 12 Hz. In fact, this scene has been considered most responsible for the "Pokemon" seizures. Immediately after the incident, Takahashi (3) commented that the red flicker could have been provocative of seizures, even if of a relatively low luminance, as stressed for a long time in the literature on photosensitivity (4,5). According to Harding (6), the red frames used in the scene have two sharp peaks at 625 and 704 cd/m^2 and stimulate only red cones. If stimulated with this kind of frame, no matching inhibitory signals are elicited from the other cone populations, which results in maximal stimulation of the visual cortex, and possibly seizures in photosensitive individuals (7). Harding (6) examined the provocative effects of the flickering scene of the cartoon in six patients. Five patients produced EEG abnormalities when presented with colored cartoon frames, but all EEGs were normal when patients watched the monochromatic version.

Among 81 patients in whom IPS was performed during EEG recordings, 46 (57%) patients did not show PPR. However, it does not necessarily mean that the patients without PPR did not have visually induced seizures. In this questionnaire survey, the protocol for IPS varied among hospitals. It is well known that induction of PPR depends on the color, intensity, and frequency of IPS. Furthermore, the fact that many patients without PPR had seizures at the time when those with PPR had seizures suggests that both had seizures due to the same etiologic factor, that is, the flickering image of the TV

program. One possible explanation may be that those without PPR had photosensitivity so low that a routine IPS could not produce PPR on the EEG.

It had long been believed that the vast majority of patients with photosensitive epilepsy had generalized seizures, such as myoclonic, absence, and generalized tonic–clonic seizures, and little attention had been paid to photosensitive partial seizures (8–10). In 1987, we reported three patients who had visual seizures that seemed to be induced by photic stimulation (11), and the next year we suggested that most of photosensitive partial seizures may be of occipital lobe origin (12). Furthermore, our experience in simultaneous video-EEG recording suggested that partial seizures might not be exceptional in photosensitive epilepsy (13). Recently other investigators also noted the importance of partial seizures in photosensitive epilepsy. Photosensitive seizures of partial onset have been increasingly reported in recent literature (14–16). Most of the reported cases had photosensitive partial seizures of occipital origin (17), if not exclusively (18). Some investigators suggested that photosensitive partial seizures may have been underestimated and that this type of seizure constitutes around one third of seizures induced by TV or videogames (14,16). In this respect, it is not surprising that more than half of patients had partial seizures, especially of occipital onset, while watching the TV program.

This survey showed that partial seizures were found more in the younger age group in comparison with generalized seizures (Fig. 1). This is in agreement with the fact that idiopathic localization-related epilepsy is more frequent in the younger age group than are idiopathic generalized epilepsies such as juvenile myoclonic epilepsy. The report of the Special Investigative Panel for Photosensitive Seizures, induced by the animated TV program "Pocket Monster" promoted by the Ministry of Health and Welfare, revealed that the audience rate of "Pocket Monster" was much higher in the younger age group. Therefore the incidence of partial seizures may be exaggerated in this study. It should be also noted, however, that there might be some patients in whom a witnessed seizure seemed to point to a generalized motor seizure but who in fact had a partial seizure with secondary generalization, like a patient of Fig. 2.

It is impossible precisely to estimate the incidence of "Pokemon" seizures. The Special Investigative Panel reported that the audience rate of the TV program under question was 44% in young people aged from 6 to 18 years, with 39% in girls and 48% in boys. When these figures were applied to Aichi prefecture where there are 1,040,472 youngsters aged 6–18 years (534,388 boys and 506,084 girls), 457,808 of this age group (256,506 boys and 197,372 girls) are estimated to have watched this TV program. On the other hand, in the present survey, 41 (20 boys and 21 girls) of 75 patients at age 6–18 years were documented to have been brought into hospitals by ambulance. The Aichi Prefectural Fire Department announced that 51 patients of this age group (23 boys and 28 girls) rushed to local hospitals by ambulance, suggesting that our questionnaire survey may have covered ~80% of sufferers of this age group. A rough estimation is that the incidence is one in 4,923 of those of this age group (one in 6,933 boys and one in 3,463 girls).

Photosensitivity has been classified on the basis of clinical history and EEG findings (8–10,19). However, photosensitivity may not be an all-or-none phenomenon as has been believed. It may be possessed by any individual in whom an maximal visual stimulus can eventually produce abnormal paroxysmal discharges, as chemical convulsants or electric shock will do. The TV program may have been so highly epileptogenic as to induce epileptic seizures even in "subphotosensitive" persons. If this is the case, avoiding such a stimulus would be much more important than taking an anticonvulsant such as VPA or CZP. It is unknown whether the patients who previously did not have any epileptic seizures will have spontaneous or photosensitive seizures in the future. To elucidate these compounding problems, a follow-up study is mandatory.

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