Epilepsia, **45**(Suppl. 1):14–18, 2004
Blackwell Publishing, Inc.

Epileptic Syndromes and Visually Induced Seizures

*Renzo Guerrini and †Pierre Genton

*Epilepsy, Neurophysiology and Neurogenetics Unit, Division of Child Neurology and Psychiatry University of Pisa & IRCCS Fondazione Stella Maris, Pisa, Italy; and †Centre St. Paul, Marseille, France

Summary: Seizures induced by photic (or visual) stimuli or photosensitive seizures can be observed in generalized or focal, idiopathic, or symptomatic epilepsies, in progressive neurodegenerative disorders, and even in the context of situation-related (acute symptomatic) seizures. In addition to this "transversal" presence of the photosensitive trait across various epilepsy types and diseases, some syndromes in which all, or almost all, seizures are induced by photic stimuli seem to have sufficient specificity and may be considered as syndromes of pure reflex photosensitive epilepsy. Here we review the clinical characteristic of the different types of photic-induced seizures and the main epileptic syndromes that are characterized by visual sensitivity either as the sole manifestation or as an accessory feature. **Key Words:** Photic—Photosensitive—Visual.

SEIZURE TYPES

Various seizure types have been associated with clinical photosensitivity (or visual sensitivity).

Eyelid myoclonus

Eyelid myoclonus may occur either as a very short event lasting ~1–2 s without any detectable impairment of consciousness or, as in *absences with eyelid myoclonus,* be prolonged and accompany an absence seizure (1). Eyelid myoclonus must be differentiated from the orbitofrontal photomyoclonus that is not an epileptic seizure in strict terms. Patients with eyelid myoclonus often indulge in *self-inducing behavior,* which is characterized by a complex repetitive self-stimulation habit with deliberate fluttering of the eyes and hyperextension of the head in front of any bright light source, including intermittent photic stimulation (IPS). Under these circumstances, attempting to draw any distinction between eyelid myoclonus and self-inducing behavior may be particularly difficult.

Focal asymmetric myoclonus

In exceptional cases, focal myoclonic jerks can be evoked by IPS (2). Consciousness is retained.

Generalized myoclonic jerks

Generalized myoclonic jerks are usually symmetric and predominate in the upper limbs. In most cases they are mild, producing only nodding of the head and slight arm abduction. More generalized jerks, involving the face, trunk, and legs, may occasionally cause the patient to fall. Isolated myoclonic jerks occur without impairment of consciousness. However, generalized jerks may be repeated, especially if the stimulus continues. In this situation, consciousness may be impaired, and a generalized tonic clonic seizure (GTCS) may follow.

Tonic, versive phenomena

On rare occasions, IPS has been shown to produce version of the eyes and the head toward one side. The versive posture may be sustained as long as the triggering stimulus is continued (3), representing a stimulus-dependent localized ictal phenomenon. It also may outlast the stimulus as a feature of a simple partial seizure that may then evolve to a complex partial or to a GTCS. In this case, it indicates that focal seizure activity precedes seizure generalization.

Absence seizures

A small subgroup of patients has loss of awareness as the only symptom. When stimulation is performed with the eyes being held closed, the absences may be manifested only by opening the eyes. Mean age at onset is ~12 years (4). Absences may outlast the stimulus. A mild myoclonic component and evolution into a GTCS are possible.

Generalized tonic clonic seizures

These are usually, but not always, triggered after sustained exposure to photic stimuli. They may follow an absence, a myoclonic jerk, a series of jerks, or a partial seizure, but also can occur without any preceding

Address correspondence and reprint requests to Dr. R. Guerrini at Division of Child Neurology and Psychiatry, University of Pisa & IRCCS Fondazione Stella Maris, via dei Giacinti 2, 56018 Calambrone, Pisa, Italy. E-mail: renzo.guerrini@inpe.unipi.it

phenomenon. Secondary generalization may be slow or very fast, after mild clinical signs such as head deviation or visual symptoms, which could possibly indicate generalization of an initially focal, possibly occipital seizure.

Focal seizures

In ≤65% of patients with photic-induced seizures, ictal onset, usually in the occipital neocortex, is clinically demonstrable (5,6). Photic-induced FSs are often characterized by a sequence of visual and vegetative symptoms, sometimes accompanied by headache (7,8). These seizures can be mistaken for migraine, especially if motor manifestations are not recognizable.

Clinical seizure semiology is similar to that of spontaneous occipital-onset seizures. Spread may be rapid, but it must be stressed that it also may be remarkably slow, occurring after many minutes of ictal activity limited to the occipital lobe (9,10).

Simple visual symptoms

Most patients experiencing subjective symptoms describe visual phenomena as the initial ictal manifestation. These are usually reported as bright, multicolored, or occasionally manifesting dark rings, spots, or simple geometric forms, which are continuous or flashing. These are usually, but not necessarily, in the periphery of the visual field, crossing to the opposite side while rotating or moving slowly (7,8,11). Ictal amaurosis, blindness or severe blurring of vision, limited to one hemifield, quadrant, or involving the entire visual field, may follow the visual hallucinations but may occasionally constitute the first symptom (10,12,13). It can be impossible to distinguish between ictal and postictal blindness.

Complex visual symptoms

More-complex visual hallucinations may include scenes often related to past experience and may be accompanied by macropsia, micropsia, or perceived scenes of people or animals described as static or moving horizontally, approaching or receding.

Illusions also may occur and can include alterations in the size, shape, or motion of objects, a change in color perception manifested by monochrome vision, or diminished intensity of hue (achromatopsia). More-complex illusions may result in an altered perception of objects in space, accentuating distance or proximity (14). Ictal palinopsia (i.e., the persistence or recurrence of visual images once the real object of perception is no longer present) is reported fairly frequently (15). As this phenomenon often co-occurs with hallucinations, difficulty may be found in distinguishing the two components.

Visual phenomena are often accompanied or followed by "conscious" tonic or, rarely, clonic eye, or eye and head deviation, usually toward the side of the initial visual symptoms. Clinically, it may be impossible to determine whether eye and head turning is a manifestation of the seizure or whether they are attempts by the patient to follow perceived images and hallucinatory figures.

Eyelid fluttering or forced blinking with a dragging sensation in one eye represent other seizure manifestations that have been correlated to occipital localization of seizure discharges. Visual phenomena, both positive and negative, may spread to involve the entire visual field.

Propagation of seizure activity to mesiotemporal limbic structures is frequent (16,17) and accompanied by automatisms typical of temporal lobe epilepsy. The most frequent ictal pattern is a sequence of epigastric discomfort, unresponsiveness, and automatisms. Some patients experience vomiting, which seems to be particularly frequent during the course of prolonged seizures triggered by photic stimulation (7,8). Suprasylvian propagation to the lateral motor cortex is accompanied by focal motor or hemiclonic activity, and propagation to the supplementary sensorimotor cortex, by asymmetric tonic posturing (10,18).

Early limbic symptoms

In exceptional cases, visual stimuli can induce simple partial seizures with vegetative symptoms or an epigastric aura, without any preceding visual manifestations (5,19).

SYNDROMES WITH PHOTIC-INDUCED SEIZURES

The International Classification of epilepsies (20) did not recognize visual sensitivity (VS) or IPS sensitivity only as characteristic of any given epileptic syndrome, nor did it consider that VS justifies the individualization of a "photogenic epilepsy." VS belongs to various forms of human epilepsies and, as a trait, a photoparoxysmal response (PPR) or VS can be found in generalized or focal, idiopathic, cryptogenic, or symptomatic epilepsies, and even within the context of situation-related (acute symptomatic) seizures. In spite of this "transversal" presence of the trait across various conditions, some syndromes in which all, or almost all, seizures are induced by photic stimuli seem to have sufficient specificity and may be considered syndromes of reflex epilepsy (21). Here we review the clinical characteristic of photosensitivity in the different syndromes.

Benign myoclonic epilepsy in infancy

Benign myoclonic epilepsy in infancy is the earliest presenting form of idiopathic generalized epilepsy (IGE) associated with visual sensitivity. Its onset is before the age of 1 year. Generalized spike and wave (SW) discharges are always associated with myoclonic jerks and can be elicited by IPS in ~10% of children (22). Although most children that are diagnosed with this condition have a good seizure outcome and do not need being treated beyond the age of 6 years, in several series, the main cause for continuing treatment after that age was photosensitivity that had either persisted or had emerged after the spontaneous myoclonic

jerks had disappeared (22). These observations should be interpreted in view of the difficulties often encountered in defining a clear-cut nosologic distinction between the less "benign" cases of benign myoclonic epilepsy and the less severe cases of myoclonic astatic epilepsy (23). Indeed, as Dravet and Bureau (22) recently discussed, the denomination of the syndrome as "benign" may be questionable, according to the most recent definitions of the International League Against Epilepsy (21).

Childhood absence epilepsy (CAE) and juvenile-onset absence epilepsy (JAE)

CAE and JAE are associated with PPRs and visually induced seizures in ~13–18% of patients (24,25). In a minority of them, photic stimulation precipitates only absences. Photosensitivity in epilepsies with spontaneous absence seizures seem to herald more severe syndromes with greater likelihood of myoclonic attacks and GTCSs (26).

Juvenile myoclonic epilepsy (JME)

JME is the form of epilepsy that has the closest association with photosensitivity (25). Thirty to thirty-five percent of patients (≤40–45% of girls) exhibit a PPR, although the prevalence of clinical visual sensitivity may be lower. In these individuals, the same myoclonic jerks or GTCSs that may occur spontaneously also can be triggered by environmental stimuli, especially television, videogames, or flashing lights in the discotheque. It is unknown whether this IPS-sensitive subgroup also has a life-long occurrence and a high relapse rate after a withdrawal of medication.

Epilepsy with myoclonic–astatic seizures

Although in this form of epilepsy, a PPR is often found during childhood (23), little is known about its clinical correlates and prognosis.

Other generalized epilepsy syndromes

Epilepsy with GTCS on awakening is accompanied by a PPR in 13% of the patients, whereas this prevalence is lower in IGEs with GTCSs that do not specifically occur at awakening (4–10%) (27).

Primary reading epilepsy, although previously classified as a localization-related form of epilepsy, is now considered to be closely related to JME (28). It is associated with PPRs, evoked by IPS or a pattern in <10% of cases (29).

Epilepsy with myoclonic–astatic seizures is often accompamied by a PPR in childhood (30), but little is known about its clinical correlates and prognosis.

Severe myoclonic epilepsy of infancy

Early photosensitivity is rather characteristic of the syndrome. A PPR has been recorded in children as young as 3 months and at some point during the follow-up in ~40% of the children who have repeated EEG recordings (30,31). However, considerable inconsistency is found in eliciting a PPR in the EEG laboratory, even in the same child. Children who are sensitive to environmental light or contrast, and sometimes indulge in self-stimulating behaviors, do not necessarily show an abnormal EEG response to IPS. Takahashi et al. (32) suggested that there is a quantity of light-dependent PPR in SME that is different in mechanism from the predominantly wave-length–dependent response in patients with idiopathic generalized photosensitivity. Generalized myoclonic jerks are often provoked by IPS, and they may be triggered by eye closure, viewing television, or contrasted pattern in the environment (31,33).

Idiopathic photosensitive occipital lobe epilepsy

In a number of patients in whom visually induced seizures are primarily focal, clinical and EEG characteristics suggest a syndromic subgroup of pure photosensitive idiopathic occipital lobe epilepsy, typical of adolescence (8,21,34). In this condition, reflex seizures are characterized by the succession of visual symptoms, especially elementary visual hallucinations and blurring, followed by epigastric discomfort, vomiting, and ictal headache (8). Seizure duration is extremely variable, and secondary generalization can occur rapidly or after several minutes. Underrecognition of such seizures may be due in part to poor attention to early visual symptoms when rapid secondary generalization obscurates initial manifestations, and in part, to misdiagnosis with migraine, when ictal activity does not spread above the sylvian fissure and no motor manifestations are recognizable (35,36). Some patients developed this type of epilepsy after having had typical benign rolandic epilepsy at school age (37). Focal seizures provoked by photic stimuli also have been reported in children with cerebral palsy, brain malformations, or ischemic occipital lesions, with or without spontaneous occipital seizures (7). The frequency of seizures in patients with this form of pure photosensitive epilepsy is quite variable and is closely related to the photosensitivity range and exposure to the trigger(s). Most patients have a narrrow photosensitivity range and, if they can manage to avoid environmental triggers, experience infrequent seizures, maybe single seizures. Drug treatment is not necessary in such cases. However, a few patients having a wide photosensitivity range are difficult to control, even with drug treatment, and are severely disabled by frequent seizures and by fear of facing provocative stimuli in the everyday life (8).

Progressive myoclonus epilepsies (PMEs)

Visually induced seizures are often apparent both clinically and as an EEG trait (38,39). Rarely they may be the first symptom of the disease. Photosensitivity in these patients is often associated with giant somatosensory and visual evoked potentials. Among the most frequently

encountered forms of PMEs in which an abnormal response to IPS is an important trait are the following.

Neuronal ceroid lipofuscinoses (NCLFs) include clinically and genetically heterogeneous storage disorders, which can be found in very young patients, but also in adults. Visual sensitivity is found especially in the late infantile and adult forms (40,41). This may be characterized by a PPR, but particularly by high amplitude of the following responses to low-frequency flicker and giant evoked potentials to single flashes. Patients with NCLFs experience progressive loss of vision, and VS may decrease during the progression of the disease.

Lafora's disease: VS is a major trait persisting throughout the evolution. In this condition, VS is often associated with spontaneous focal occipital seizures (42,43).

Unverricht-Lundborg disease: VS is a major, early, clinical and EEG trait that tends to remit after the second or third decade of evolution (44); the clinical course of the disease is variable and differs between families (45).

Myoclonus epilepsy and ragged red fibers (MERRF): the clinical spectrum is extremely broad, and VS may occur (46).

REFERENCES

1. Jeavons PM. Nosological problems of myoclonic epilepsies in childhood and adolescence. *Dev Med Child Neurol* 1977;19:3–8.
2. Gastaut H. *L'Epilepsie photogénique. Rev Prat (Paris)* 1951;1:105–9.
3. Genton P, Lavernhe G, Guerrini R. Epilepsie photogénique et phénomènes moteurs lateralisés: une observation EEG. *Epilepsies* 1995;7:431–5.
4. Harding GFA, Jeavons PM. *Photosensitive epilepsy*. London: MacKeith Press, 1994.
5. Guerrini R, Bonanni P, Parmeggiani L, et al. Induction of partial seizures by visual stimulation: clinical and electroencephalographic features and evoked potential studies. *Adv Neurol* 1998;75:159–78.
6. Hennessy MJ, Binnie CD. Photogenic partial seizures. *Epilepsia* 2000;41:59–64.
7. Guerrini R, Ferrari AR, Battaglia A, et al. Occipitotemporal seizures with ictus emeticus induced by intermittent photic stimulation. *Neurology* 1994; 44:253–9.
8. Guerrini R, Dravet C, Genton P, et al. Idiopathic photosensitive occipital lobe epilepsy. *Epilepsia* 1995;36:883–91.
9. Naquet R. Photic epilepsy problems raised in man and animals. *Ital J Neurol Sci* 1987;8:437–47.
10. Aso K, Watanabe K, Negoro T, et al. Photosensitive partial seizure: the origin of abnormal discharges. *J Epilepsy* 1988;1:187–93.
11. Ricci S, Vigevano F. Occipital seizures provoked by intermittent light stimulation: ictal and interictal findings. *J Clin Neurophysiol* 1993;10:197–209.
12. Maeda Y, Kurokawa T, Sakamoto K, et al. Electroclinical study of video-game epilepsy. *Dev Med Child Neurol* 1990;32:493–500.
13. Bauer J, Schuler P, Feistel H, et al. Blindness as an ictal phenomenon: investigations with EEG and SPECT in two patients suffering from epilepsy. *Neurology* 1991;238:44–6.
14. Critchley M. Metamorphosia of central origin. *Trans Ophthalmol Soc UK* 1949;69:111–21.
15. Lefebre C, Koelmel HW. Palinopsia as an epileptic phenomenon. *Eur Neurol* 1989;29:323–7.
16. Jones EG, Powell TPS. An anatomical study of converging sensory pathways within the cerebral cortex of the monkey. *Brain* 1970;93:793–820.
17. Olivier A, Gloor P, Andermann F, et al. Occipitotemporal epilepsy studied with stereotaxically implanted depth electrodes and successfully treated by temporal resection. *Ann Neurol* 1982;11:428–32.
18. Fischer-Williams M, Bickford RG, Whisnant JP. Occipito-parieto-temporal seizure discharge with visual hallucinations and aphasia. *Epilepsia* 1964;5:279–92.
19. Isnard J, Guenot M, Fischer C, et al. A stereoelectroencephalographic (SEEG) study of light-induced mesiotemporal epileptic seizures. *Epilepsia* 1998;39:1098–103.
20. Commission on Classification and Terminology of the International League Against Epilepsy. Proposal for revised classification of epilepsies and epileptic syndromes. *Epilepsia* 1989;30:389–99.
21. Engel J Jr. A proposed diagnostic scheme for people with epileptic seizures and with epilepsy: report of the ILAE Task Force on Classification and Terminology. *Epilepsia* 2001;42:1–8
22. Dravet C, Bureau M. Benign myoclonic epilepsy in infancy. In: Roger J, Bureau M, Dravet C, et al., eds. *Epileptic syndromes in infancy childhood and adolescence*, *3rd ed.* London: John Libbey, 2002:69–79.
23. Guerrini R, Aicardi J. Epileptic encephalopathies with myoclonic seizures in infants and children (severe myoclonic epilepsy and myoclonic-astatic epilepsy). *J Clin Neurophysiol* (in press).
24. Smith SJM. Clinical neurophysioloby in humans. In: Duncan JS, Panayiotopoulos CP, eds. *Typical absences and related syndromes*. London: Churchill Communication Europe, 1995:92–101.
25. Wolf P, Goosses R. Relation of photosensitivity to epileptic syndromes. *J Neurol Neurosurg Psychiatry* 1986;49:1386–91.
26. Panayiotopoulos CP, Obeid T, Tahan AR. Juvenile myoclonic epilepsy: a 5-year prospective study. *Epilepsia* 1994;35:285–96.
27. Wolf P. Epilepsy with grand mal on awakening. In: Roger J, Bureau M, Dravet C, et al., eds. *Epileptic syndromes in infancy, childhood and adolescence*. 2nd ed. London: John Libbey Eurotext, 1992:329–41.
28. Mayer T, Wolf P. Reading epilepsy: clinical and genetic background. In: Berkovic SF, Genton P, Hirsch E, et al., eds. *Genetics of focal epilepsies*. London: John Libbey, 1999:159–68.
29. Matricardi M, Brinciotti M, Paciello F. Reading epilepsy with absences, television-induced seizures and pattern sensitivity. *Epilepsy Res* 1991;9:145–7.
30. Dravet C, Bureau M, Guerrini R, et al. Severe myoclonic epilepsy in infants. In: Roger J, Bureau M, Dravet C, et al., eds. *Epileptic syndromes in infancy, childhood and adolescence*. *2nd ed.* London: John Libbey, 1992:75–88.
31. Dravet C, Bureau M, Oguni H, et al. Severe myoclonic epilepsy in infancy (Dravet syndrome). In: Roger J, Bureau M, Dravet C, et al., eds. *Epileptic syndromes in infancy childhood and adolescence*. *3rd ed.* London: John Libbey, 2002:81–103.
32. Takahashi Y, Fujiwara T, Yagi K, et al. Photosensitive epilepsies and pathophysiologic mechanisms of the photoparoxysmal response. *Neurology* 1999;53:926–32.
33. Ohki T, Watanabe K, Negoro T, et al. Severe myoclonic epilepsy in infancy: evolution of seizures. *Seizure* 1997;6:219–24.
34. Porciatti V, Bonanni P, Fiorentini A, Guerrini R. Lack of cortical contrast gain control in human photosensitive epilepsy. *Nature Neurosci* 2000;3:259–63.
35. Swanson JW, Vick A. Basilar artery migraine: 12 patients with an attack recorded electroencephalographically. *Neurology* 1978;28:782–6.
36. Walker MC, Smith SJM, Sisodiya SM, et al. Case of simple partial status epilepticus in occipital lobe epilepsy misdiagnosed as migraine: clinical, electrophysiological, and magnetic resonance imaging characteristics. *Epilepsia* 1995;36:1233–6.
37. Guerrini R, Bonanni P, Parmeggiani L, et al. Adolescent onset of idiopathic photosensitive occipital epilepsy after remission of benign rolandic epilepsy. *Epilepsia* 1997;38:777–81.
38. Genton P, Roger J. Progressive myoclonus epilepsies. In: Wyllie E, ed. *The treatment of epilepsy: principles and practice*. Philadelphia: Lea & Febiger, 1993:571–83.
39. Rubboli G, Meletti S, Gardella E, et al. Photic reflex myoclonus: a neurophysiological study in progressive myoclonus epilepsies. *Epilepsia* 1999;40(suppl 4):50–8.
40. Pampiglione G, Harden A. Neurophysiological identification of a late infantile form of neuronal lipidosis. *J Neurol Neurosurg Psychiatry* 1977;36:323–30.

41. Berkovic SF, Andermann F, Carpenter S, et al. Kufs'disease: a critical reappraisal. *Brain* 1988;111:27–62.
42. Roger J, Pellissier JF, Bureau M, et al. Le diagnostic précoce de la maladie de Lafora: importance des manifestations paroxystique visuelles et intérêt de la biopsie cutanée. *Rev Neurol* 1983;139:115–24.
43. Tinuper P, Aguglia U, Pellissier JF, et al. Visual ictal phenomena in a case of Lafora disease proven by skin biopsy. *Epilepsia* 1983;24:214–8.
44. Kasteleijn-Nols Trenite GA, Guerrini R, Binnie CD, et al. Visual sensitivity and epilepsy: a proposed terminology and classification for clinical and EEG phenomenology. *Epilepsia* 2001;42:692–701.
45. Berkovic SF. Progressive myoclonus epilepsies. In: Engel J Jr, Pedley TA, eds. *Epilepsy: a comprehensive textbook*. Philadelphia: Lippincott-Raven, 1997:2455–68.
46. So N, Berkovic SF, Andermann F, et al. Myoclonus epilepsy and ragged-red fibers (MERRF) 2: electrophysiological studies and comparison with the other progressive myoclonus epilepsies. *Brain* 1989;112:1261–76.