■ Clinical commentary

Epileptic Disord 2021; 23 (1): 161-166

Epileptic Disorders

Television-induced electronegative photoparoxysmal response: an extratemporal seizure mimic?

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Received June 8, 2020;
Accepted September 8, 2020

ABSTRACT – Video-EEG monitoring is an established gold-standard procedure for diagnosis and differentiation of epileptic and non-epileptic seizures. Epilepsy misdiagnosis, to which factors such as EEG artifact misinterpretation contribute to, is common, and can have long-lasting iatrogenic repercussions to the clinical management of affected patients. Among the many types of responses to photic stimulation, artifacts and physiologic and epileptic responses are possible. All of these can interfere with EEG interpretation when provoked by a source of illumination. Photic-induced responses are of increasing relevance given the ubiquity of screens and other light-emitting electronics in our modern world. One of these, the photoparoxysmal response, is a frequent finding in photosensitive patients with genetic generalized epilepsies. Various responses beyond abnormal occurrence of cortical spikes or spike-and-wave discharges are known to occur on EEG in response to intermittent photic stimulation (IPS), with different clinical implications. To our knowledge, we report a unique electronegative photoparoxysmal response during video-EEG monitoring induced by fluctuating illumination caused by a distant television screen. This response mimicked an extratemporal seizure in a young woman with frontal lobe epilepsy, admitted for presurgical evaluation. Novel electronegative responses to electronic devices during video-EEG monitoring merit consideration by EEG interpreters to help avoid misdiagnosis.

Key words: video-EEG; photic stimulation; television-induced electronegative photoparoxysmal response; extratemporal seizure

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doi:10.1684/epd.2021.1239

Photosensitivity is a condition detected by electroencephalography (EEG) as a paroxysmal reaction to intermittent photic stimulation (IPS) or other visual stimuli. IPS is a routine method of activation with stroboscopic light flashing during EEG to diagnose epilepsy by eliciting a paroxysmal response (PPR). A PPR is an abnormal response to photic flash, however, the pathogenicity of the condition, such as a genetic trait independent of a clinical phenotype, can vary. Overall, there are several common photic-induced responses seen during EEG, some of which are normal and others, abnormal [1]. Abnormal photosensitivity is typically coupled with generalized seizures, and most often seen in patients with photosensitivity associated with genetic generalized epilepsies [2, 3]. However, photosensitivity also includes features of focal seizures including those arising from the occipital lobe and temporal-parietal region [4, 5].

The PPR is an uncommon abnormality for patients with focal-onset epilepsies.

Normal responses include photic driving, a normal physiological response commonly observed in response to IPS. When it manifests as "spike-driving" (at lower flash frequencies), it may create an appearance of repetitive spikes and falsely serve as a mimic for an epileptiform abnormality [6]. Artifacts such as the photoelectric response may occasionally be confused with the physiological effect from the electroretinogram during IPS, but the latter differs due to a delay from the time of photic stimulation. Repetitive epileptiform-appearing discharges occur in the form of trains of brief spiky potentials, typically most prominent in the frontopolar electrode derivations and time-locked to the flash frequency of the light source [7]. Like a photoelectric response, the photomyogenic response is a continuous anterior predominant myogenic artifactual response that often occurs in normal individuals. Pitfalls may occur with a photomyogenic response falsely mimicking myoclonic seizures, potentially leading to misdiagnosis.
Modern technology has led to a dramatic increase in environmental exposure to potential photic trigger stimuli, such as video games and television, as common triggers. The importance of recognizing physiological responses and artifact during photic stimulation lies in their potential for being overinterpreted as abnormalities [8]. We report an atypical PPR in an epilepsy patient undergoing video-EEG monitoring (VEM) during presurgical evaluation. An electrodecremental response was elicited by a distant television (TV), mimicking diffuse attenuation associated with frontal lobe seizures. This finding adds to the information on photic sources leading to the variety of physiologic response to illumination and adds to the potential pitfalls challenging accurate interpretation of EEG during VEM.

Case study

A 27-year-old right-handed female with migraine and drug-resistant focal epilepsy was admitted for VEM as part of a comprehensive presurgical evaluation. Seizure onset occurred at 19 years of age without preceding personal risk factors or family history for epilepsy. Seizures were nocturnal and began with an abrupt "internal feeling" in her head, followed by sudden head-turning to the right and then whole-body jerking for one minute, followed by post-ictal return to sleep. She was suspected to have left frontal lobe epilepsy, though previous high-resolution brain MRI was normal and a standard EEG obtaining N2 sleep was also normal, without evidence of photosensitivity or photic-induced abnormality reported.
During VEM, interictal EEG demonstrated occasional low-amplitude left frontal polyspikes in N2 and N3 sleep, supporting her clinical diagnosis. Interictal epileptiform discharges occurred outside light sleep. She reported two seizures described as "tics" though these were without scalp ictal EEG change. Following failure of antiseizure medication, lamotrigine, 500 mg daily, was reduced by 50% on Day 1 following admission, and subsequently further reduced and discontinued by Day 3 of VEM. Overnight, on Day 3 of EEG during VEM, "possible subclinical" seizures were identified by the technologist. During this time, the patient appeared to sleep with her head turned to the right after falling asleep while watching the news on a 42-inch liquid crystal television; positioned 15 feet in front of her bed. Upon review of the video-EEG, light of fluctuating intensity could be seen upon repeat review, varying in intensity and emanating from the television in the darkened room, reflecting off the patient. During drowsiness and light sleep, brief generalized attenuations with persistent low-voltage fast activity were found to be time-synched with fluctuating intensity of higher luminance generated by the nearby television screen playing the news.

Discussion

New physiological responses are being identified during long-term VEM [8]. Our report serves to heighten awareness of new features during VEM, particularly this unique electronegative photoparoxysmal response which, in many cases, conceivably manifests itself under considerably more subtle circumstances that could be easily missed and possibly misinterpreted as an abnormal finding, contributing to the risk of misdiagnosis [9]. The photoparoxysmal response requires the presence of epileptiform discharges though other, non-specific responses, have been identified (*table 1*). Furthermore, the photoparoxysmal response is under the influence of several confounding variables including age, sex, ethnicity, genetics, antiepileptic medication use, state of alertness (sleep vs wakefulness), sleep deprivation, and the stimulation technique, with the response to photic stimulation defined as self-sustained when the epileptiform discharges outlast the stimulus by ≥100 ms [10]. Our patient's EEG demonstrated time-locked, reproducible generalized attenuations, varying in response to the degree of illumination generated by the television screen facing her in the room. Multiple qualitative variables involved during VEM limit the ability to define precise minimum and maximum levels of illumination necessary to produce a response. Source distance, mixed quality of light source illumination, acuity and degree of light contrast, and the state of alertness are important variables producing the atypical PPR. Admixed beta activity and the paroxysmal nature made brief electrographic extratemporal focal seizures

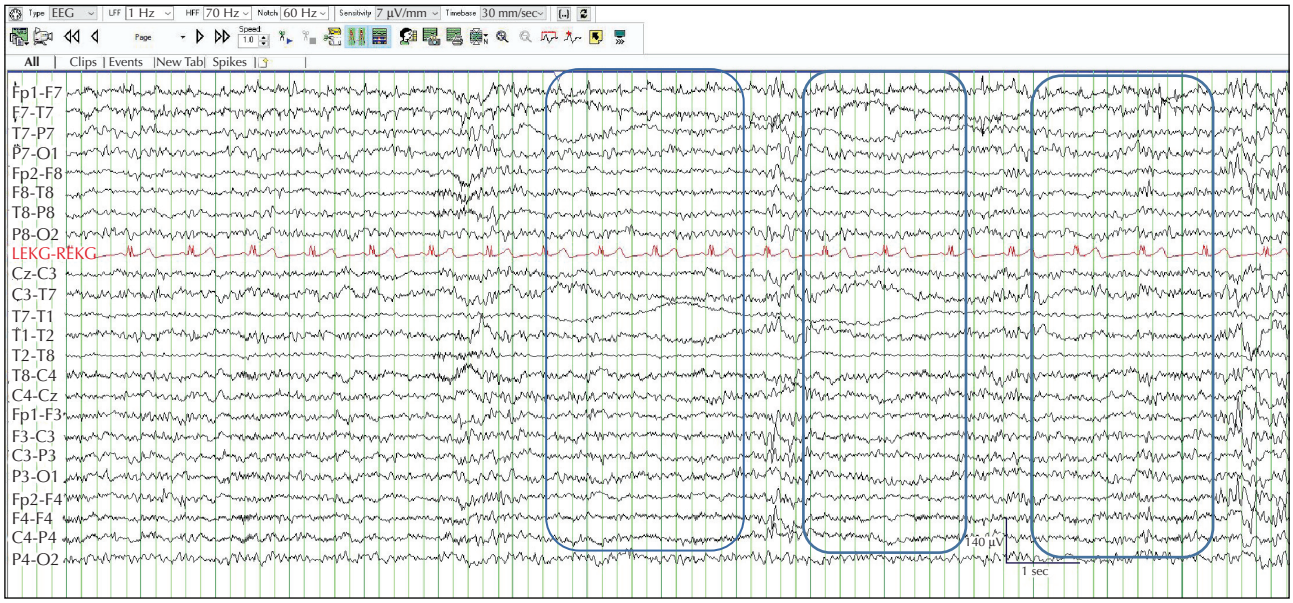
▼ **Table 1.** Photic-induced responses during EEG.

Type	Name	Localization	Characteristics	
Physiologic	Photoparoxysmal	Occipital	Paroxysmal response to intermittent photic stimulation consisting of bilaterally synchronous spikes, spike-waves or intermittent slow waves.	Self-limited Non-self-limited*
	Photomyogenic	Anterior	Polymorphic artifact resulting from contraction of frontalis muscle.	
	Photomyoclonic	Anterior	Brief, repetitive muscle artifact (eyelid flutter) time-locked to stimulus. Disappears upon opening of eyes or end of light stimulus.	
	Photic driving	Parieto-occipital	Time synched entrainment of potentials coupled to the flash frequency of the photic generator. Sharply contoured, positive, monophasic transients (P100) of 80-150 msec may follow the stimulus ("spike-driving") at low flash frequencies.	
	Electroretinogram	Corneal	Usually consists of an a-wave (initial corneal-negative deflection) and a b-wave (corneal-positive deflection). Reflects electric potentials of various cell types in the retina.	
Non-physiologic	Photoelectric	Variable (exposed electrodes)	Train of brief, spiky potentials maximal in the frontal electrode derivations. Time-locked to the light flash frequency.	

*Non-self-limited (prolonged) photoparoxysmal response beyond the flash has been associated with increased seizure frequency when compared to self-limited response.

suspect by the technologist. However, when video was reviewed, the luminous flux of light emitted by television fluctuated in intensification to time-synch attenuations present on EEG (*figure 1*). The luminous intensity radiated light toward the patient's face (and electrode F7), directed toward the source. Normally, the wavelength of light that is part of the electromagnetic spectrum is perceived by our eyes between the range of 380 to 780 nm. The photoparoxysmal response is typically an inherited response via autosomal dominant transmission and identified at white light of high intensity of the wavelengths of about 400-700 nm (visible spectrum with many patients responding especially to the 700-nm deep red spectrum) and at the flicker frequencies of 10-30 Hz). Cones are activated for interpreting color during the day, whereas rods predominate at night to interpret shades of grey. TVs using cathode ray tubes produce flickering light at higher frequencies beyond those often used to provoke photosensitive patients. Plasma TVs and those based on a liquid crystal display on the other hand, do not use the scanning lines of the cathode ray tubes, minimizing flicker and reducing the chance for photosensitivity, although the (colored) content of (flashing) programs can be provocative in itself. It is possible that during drowsiness and light sleep, when eyes were closed, television-induced fluctuation stimulated rods preferentially to produce this pseudo-photoparoxysmal effect. Rods are more sensitive to photic stimulation than cones [11] and during light sleep are likely to be more active in a relative state of ambient darkness. Identification of the state as drowsiness and light sleep is readily identifiable using normal parameters of EEG recording to validate state changes [1]. Our case of pseudo-photoparoxysmal response is unusual in that, despite using an liquid crystal display (LCD) TV, and lack of visualizing an image or changes in contrasting color (*i.e.*, red to blue), the response still occurred in a patient positioned 15 feet from the source. We suspect that EEG changes observed in this patient were a physiological response in light sleep to fluctuating illumination.

The PPR is a highly heritable EEG trait. It is characterized by an abnormal cortical response to intermittent photic stimulation. In patients with a PPR, intermittent photic stimulation may induce spikes, spike-and-slow waves, polyspike-and-waves or intermittent slow waves [12]. Waltz described four types of PPR including type IV with generalized spikes-and-waves or



■ **Figure 1.** EEG demonstrating brief 2-3-second intermittent diffuse voltage attenuations of the background activity, synchronized with changes in TV luminosity, mimicking subclinical seizures during VEM, as part of a presurgical evaluation for left frontal lobe epilepsy. Note the artifact at the F7 electrode. The patient was discharged after her VEM session without capture of her typical events, with plans for readmission and more aggressive ASM taper.

polyspikes-and-waves as having the most reliable relationship to photosensitivity, while other types had less robust epileptiform features [3]. Typically, the PPR is a "positive" phenomenon consisting of spike-and-wave discharges. Our patient demonstrated a pseudo-PPR with an electronegative response of background attenuation in contrast to the electrophysiologic response of photosensitivity with generalized spike-and-waves in synchrony with the fluctuating intensity of light. With the technological advances in TV electronics, including higher refresh frequency rates, this appears to be less provocative for inducing seizures in patients with epilepsy. An important aspect in triggering a PPR is the distance between the viewer and the television. The American Clinical Neurophysiology Society recommends photic stimulation be performed in a dimly lit room using a lamp placed at least 30 cm (approximately 12 inches) directly in front of the patient [13]. In our patient, the pseudo-PPR was induced by a TV positioned 15 feet from her face. Despite the far distance from the screen, the electronegative PPR was present and reproducible.

This finding heightens our awareness of a unique manifestation of an obscure and subtle type of physiological EEG response to fluctuating illumination caused by a non-medical source. This could have been misinterpreted in the home environment of a patient with epilepsy without additional video. We add to the literature an "electronegative" response to photic stimulation that may serve as a pitfall for an accurate interpretation of epilepsy. While the mechanisms involved in generation of a PPR are poorly understood, genetic influences are felt to play an important role [4]. However, this was absent in our patient with extratemporal focal epilepsy. Technologists should be aware of environmental light sources as a cause of "electro negative photoparoxysmal response", and physicians should recognize paroxysmal attenuations as potential extratemporal seizures may occur as EEG seizure mimics [6].

Societal involvement with technology including television and electronic devices is commonplace. In epilepsy monitoring units, patients now typically surround themselves with laptop computers, televisions, and smartphones. Abundant light sources are encouraged for better visualization of semiology during video recordings. Artifacts are increasingly identified in step with the duration of VEM, potentially leading to the occurrence or potentiation of waveforms that are subject to misinterpretation [10]. Epilepsy misdiagnosis is commonplace during VEM with misinterpretation of standard EEG due to normal variants and artifacts contributing to misdiagnosis and posing the risk of inappropriate prescription of anti-seizure medication (ASM) and life-altering consequences to those affected [14]. Detailed laboratory findings concerning sensitivity to television are of clinically important value, *e.g.* can patients, liable to TV epilepsy, be identified by EEG investigations? A high threshold for what is considered an "abnormality" in EEG interpretation during VEM should involve video review when waveforms are in question [15].

Conclusion

We describe a pseudo-ictal EEG pattern observed during VEM in a patient with frontal lobe epilepsy. An atypical electronegative PPR due to fluctuating levels of illumination was generated by television and mimicked brief nocturnal extratemporal focal seizures. We suggest abrupt changes in unexpected lighting contrast from electronic sources may precipitate photic-induced responses on EEG. Review of the video during VEM remains essential, especially when no apparent motor source is readily identifiable in patients with frontal lobe seizures. ■

Supplementary data.
Summary didactic slides are available on the www.epilepticdisorders.com website.

Disclosures.
None of the authors have any conflict of interest to declare.

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TEST YOURSELF

(1) Which of the following is a non-physiologic, photic response during EEG?
A. Photoelectric response
B. Photogenic response
C. Photic driving
D. Electroretinogram

(2) What type of epilepsy is typically associated with a photoparoxysmal response?
A. Autoimmune epilepsies
B. Genetic generalized epilepsies
C. Parietal lobe epilepsies
D. Occipital lobe epilepsies

(3) What photic response during EEG has the greatest association with epilepsy?

A. 6-Hz occipital generalized spike-and-waves
B. Photomyoclonic response
C. Non-self-limited photoparoxysmal response
D. "Spike-driving"

Note: Reading the manuscript provides an answer to all questions. Correct answers may be accessed on the website, www.epilepticdisorders.com, under the section "The EpiCentre".