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Patterns of intrahemispheric propagation in pediatric photoparoxysmal response

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ABSTRACT

Purpose: The photoparoxysmal response (PPR) is the most important EEG indication of photosensitivity (PS). It may be elicited by intermittent photic stimulation (IPS). PS mostly affects young individuals, with adolescent females at greatest risk. The diagnosis of PS is based on visual EEG assessment. To date, no objective test of PS has been established.
Method: Here we describe 89 individuals of both sexes, aged 5–18 years, epileptic and non-epileptic, in whom a PPR was elicited by IPS during a standard EEG procedure. The distribution of amplitude and intrahemispheric coherence indices were analyzed and, in each case, revealed a unique pattern of PPR propagation.
Results: A lateral (occipito-temporo-frontal) track was found in 52% of recordings, and 55% of individuals tested showed symmetric patterns. A bilateral pattern dominated in all age groups, all grades of PS, and across epileptic and non-epileptic groups.
Conclusion: A symmetric, bilateral pattern is the most common type of PPR across genders and all ages, regardless of grade of PS and the presence of epilepsy. The results of this study show the current PPR classification in a new light and provide a basis for the concept of PPR lateralization based on objective, quantitative findings.

1. Introduction

Despite many years of great interest in this topic, the photoparoxysmal response (PPR) is still a poorly understood phenomenon. PPR is believed to be related to inefficient inhibition mechanisms in the visual cortex and its connections [1]. It constitutes the essence of the photosensitivity (PS) phenomenon, elicited by an intermittent photic stimulation (IPS), strap patterns, or video games [2]. The prevalence of PS in healthy individuals is reported to range from 0.5 to 8.9% [3]. In the European population of epilepsy patients, the incidence rises to 5–10%, and in some genetically determined epilepsy syndromes, such as juvenile myoclonic epilepsy (JME), it may affect up to 90% of patients [4,5]. PS is mainly observed in the pediatric population, of which an estimated 1.3-1.4% of children aged 6–18 years are affected [6].

The inheritance of PS is independent of the genes associated with epilepsy. Currently, only a few genes are suggested to be associated with PS [7,8]. PS can occur in children who do not suffer from epilepsy, but who are genetically burdened with excessive sensitivity to IPS [9]. The relationship of double chromosome X and PS inheritance has also been discussed in literature, which observes the preponderance of females among PS-affected children [10,11].

A standard diagnostic of PS is usually based on the analysis of EEG. The occurrence of PPR following IPS, which is part of the examination protocol, is assessed by means of visual (qualitative) analysis. When a PS diagnosis is established the PS grade is determined according to the four-step Waltz scale [12], which relies on visual examination.

So far, the applied definitions and classifications do not benefit from the quantitative assessment of EEG records (QEEG), which is based on objective parameters. At the same time, most modern EEG devices offer many standard tools for their analysis.

The most commonly used parameters are the amplitude of the discharge, recorded in each channel, and coherence, an amplitude-independent measure of phase synchrony between EEG signals

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[13]. Both may be measured in typical frequency bands (theta, delta, alpha, gamma, and beta). While straight-measured amplitude corresponds to the actual power of the discharge, coherence depends on the structural connections within the cerebral hemisphere (intrahemispheric coherence, HCoh) or between the hemispheres (interhemispheric coherence, ICoh) [14]. The HCoh may vary in conduction-affecting disorders (i.e., mild head injury has been found to raise its value), whilst dementia or Alzheimer's disease is characterized by its decrease [15]. Therefore, coherence is considered to reflect the potential ability of the hemisphere to conduct stimulus-related information between the cortical areas.

To date, among many published papers on the quantitative evaluation of EEG in various diseases, there has not been a study characterising PS by means of objective analysis. The choice of objective independent parameters for the PPR description requires knowledge about the individual pattern of propagation, whereas the only recognized classification of PPR does not offer information about the direction of a possible spread of the discharge. What is known is that the PPR spreads from occipital to frontal regions. According to the scale proposed by Waltz, in patients with PS grade IV, generalized spikes and waves or polyspikes and waves should be observed in occipital, parietal, and frontal regions. Although generalized discharges are detected over all leads, this description omits temporal regions, drawing attention primarily to the occipito-parieto-frontal line. This direction of spread seems the most logical for analytic purposes; however, it may not be the only possible pathway starting from occipital lobes to reach the frontal regions.

Considering that no specific pattern of the discharge transmission within a hemisphere has been defined so far, one must admit that a morphology of PPR is still a matter of visual assessment. Therefore, the goal of this study was to determine the possible patterns of propagation of PPR in PS-affected children with the use of an objective and repeatable method. This information seems fundamental in understanding the PPR morphology, as it influences many aspects of the quantitative approach to the topic and is necessary for further data processing.

2. Material and methods

The study was based on the analysis of EEG records of patients with PS diagnosed in the EEG Laboratory of Bogdanowicz Memorial Hospital for Children in Warsaw, Poland. Parents or legal attendants consented to the study. The study protocol was approved by the local Bioethics Committee.

2.1. Material

The study group consisted of 89 patients of both sexes, aged 5–18 years. The group included 26 boys (23%) and 63 girls (76%), with a mean age of 13.2 ± 3.7 years. Adolescents were the most numerous (45%), and children aged 5–10 years constituted 21% of the studied group.

The study included patients who reported for the first time to our laboratory and were diagnosed with PS grade I, II, III, or IV. Medical indications for the EEG examination were epilepsy or tension headaches. All patients enrolled in the study were assigned to "epilepsy" (42 subjects) or "headache" groups (47 subjects). The epilepsy spectrum in our study covered temporal lobe epilepsy (TLE) – secondarily generalized tonic-clonic seizures (SGTCS), juvenile myoclonic epilepsy (JME), and absence seizures. All headache patients had a history of frequent episodic tension-type headaches (type 2.2 according to ICHD-3 beta classification [16]). Patients with migraine headaches after a head injury or brain surgery were not included in the study.

Prior to the EEG, all patients underwent imaging studies (CT or MRI of the head) in order to exclude organic causes of their medical complaints. None of the patients enrolled in the study had neurological treatment before the EEG examination.

The age, gender, and clinical characteristics of the patients are presented in Table 1.

A control group was not designed due to the observational character of the study.

2.2. Method

The EEG was performed during the day in awake and upright patients, in a quiet room with dim lighting. The examination was carried out with the use of the Elmiko device according to an international 10–20 protocol [17]. The signal was recorded with 19 leads. The IPS was performed in the final part of the EEG, before hyperventilation, according to an updated European IPS protocol [18]: recording with 3 eye conditions, lamp with a circular reflector, and a viewing distance of 30 cm, with two minor modifications: 1) flash frequencies of 1-2-4-6-8-10-12-14-16-18-20-30-40-50–60 Hz, and 2) a flash series lasting 10 s with a 10 s interval. The whole examination was video-recorded.

An artifact-free epoch of 2 s duration, containing IPS-induced discharge, was selected for every patient. The amplitude and intrahemispheric coherence (HCoh) were calculated by EEG software. Power spectra for each lead were obtained with the Fast Fourier Transformation algorithm, although only the maximal amplitude value for each lead was considered representative for the actual power of a discharge and used for further analysis. The amplitudes were measured at 8 points for each hemisphere: O1, P3, T5, C3, T3, F3, F7, and Fp1 for the left side, and O2, P4, T6, C4, T4, F4, F8, and Fp2 for the right side. Coherence indices were computed for 12 intrahemispheric electrode pairs in accordance with the adopted direction of propagation (i.e., the coherence indices for the left hemisphere were: O1-P3, O1-T5, P3-C3, P3-T3, T5-C3, T5-T3, C3-F3, C3-F7, T3-F4, T3-F7, F4-Fp1, and F7-Fp1). The amplitude and HCoh values were then registered at the study database.

2.3. Data processing

An individual map for every patient was created based on the database. The map contained a graphical distribution of amplitude and coherence values transmitted to the respective location. Having done this, we could distinguish the tracks and patterns of PPR propagation.

The tracks were assigned separately for each hemisphere. For the purposes of this study, we assumed that the stimulation always spread forward to reach the frontal lobes (on the left side according

Table 1
Demographic and clinical characteristics of the studied group.

	M	F	Total
Sex	26	63	**89**
Age [years]			
5–10	5	14	**19**
11–14	9	21	**30**
15–18	12	28	**40**
Grade of PS			
PS grade I	0	1	**1**
PS grade II	1	3	**4**
PS grade III	4	9	**13**
PS grade IV	21	50	**71**
Epilepsy	15	27	**42**
absence	3	0	**3**
JME	3	10	**13**
TLE-SGTCS	9	17	**26**
Headache	11	36	**47**