Analysis of EEG Signals Under Flash Stimulation for Migraine and Epileptic Patients

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ORIGINAL PAPER

Analysis of EEG Signals Under Flash Stimulation for Migraine and Epileptic Patients

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Abstract Migraine and epilepsy are both persistent disorders characterised by recurrent neurological attacks. Visual symptoms and hypersensitivity to light stimuli are frequent in migraine. Analysis of EEG signals under flash stimulation for migraine and epileptic patients is not a new method. But magnitude increasing under flash stimulation for migraine patients has not been studied yet. The aims of this study is the analysis of multichannel electroencephalogram (EEG) in migraine and epileptic patients by visual evoked potentials (VEP) and investigate the existence of magnitude increasing under flash stimulation for migraine patients. In this study as a method of flash stimuli at frequencies of 2, 4 and 6 Hz were applied to different migraine and epileptic patients under pain-free phase with the EEG recorded from 18 scalp electrodes, referred to the linked earlobes. We used AR parametric method to analyze and characterize EEG signals in migraine and epileptic patients. The variations in the EEG power spectra shapes were examined in order to obtain medical information. These power spectra were then used to compare the applied method in terms of their frequency resolution and the effects in determination of migraine and epilepsy. Global performance of the proposed methods was evaluated by means of the visual inspection of power spectral densities (PSDs). For the migraine patients, an increase in amplitude has observed at the beta bands of EEG signals under flash stimulation as compared to EEG signals without stimulation. As opposed to this, for epileptic patients, an increase in amplitude has observed at the alpha bands of EEG signals without flash stimulation. Meanwhile for the control groups, there is no change between EEG signals under flash stimulation and without flash stimulation.

Keywords Electroencephalography (EEG) · Migraine · Epilepsy · Spectral analysis · Burg AR

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Introduction

Different kinds of electroencephalogram (EEG) abnormalities have been described in patients with dissimilar types of headache. Migraine and epilepsy are very common neurological diseases observed in outpatient neurological settings. A recurrent neurological attack with a partial clinical and therapeutic overlap is embodied in both disorders. A number of symptoms, including post-event lethargy, impaired or loss of consciousness, visual disturbances, visual and hormonal triggering factors, vertigo, paraesthesias, hemiparesis and aphasia, can be commonly observed in both conditions [1, 2].

Visual disturbances in migraineurs are generally observed in clinical practice. There are different visual evoked methods have been used in clinical research to study about migraine disease such as color perception and flash stimuli [3, 4]. In our study we used visual evoked potentials by flash stimuli, since the majority of migraine attacks are caused by environmental light stimuli, like sunshine or restless and intermittent lights. Visual evoked potentials (VEP) are a practical alternative which makes it easy to evaluation of the visual pathway. The occurrence of VEP changes was reported in previous studies, but the results were often conflicting. In the headache-free interval, some authors showed a difference in amplitude or latencies of P100 between migraineurs and healthy control subjects; others did not show any difference [5–10]. But in this study we have presented a solution to this conflict.

Furthermore, there is indication of an epidemiological association between these two conditions. However, there are number of significant differences between migraine and epilepsy. The occurrence of idiopathic types is much more frequent in migraine than in epilepsy; the definite female prevelance reported in migraine is not evident in epilepsy [11]. Finally, since the consequences of even occasional seizures are more health-threatening than those of migraine, the conventional aim of epilepsy treatment is the comprehensive control of seizures, whereas migraine treatment may be customized in order to reduce the disability to acceptable limits [2].

Since there is no definite criterion with which experts evaluate, visual analysis of EEG signals in time domain may be insufficient. Routine clinical diagnosis includes the analysis of EEG signals. Therefore, some automation and computer techniques have been used for this aim. These techniques are based on kinds of mathematical EEG analysis methods. Examples are corelation analysis, coherence analysis and autoregressive analysis. All of these methods's aim to calculate the PSDs of EEG signals. EEG signals have wide frequency bands, but the clinical and physiological frequency of interest is between the 0.5 and 30 Hz. According to this approach lean observation on the spectrum of EEG signals have four basic frequency bands the names of which are delta (0.5–4 Hz), theta (4–8 Hz), alfa (8–13 Hz) and beta (13–30 Hz) [12]. Migraine detection has been tried to implement using EEG signals in previous studies by using phase synchronization method of the alpha band from a multichannel EEG recorded under repetitive flash stimulation [13]. In this study, we have used AR Burg method to determine migraine and epilepsy. PSDs of EEG signals, obtained from control and unhealthy (migraine and epileptic patient) subjects, were analysed by using Burg AR method. AR Burg method resolves closely spaced sinusoids signals with low noise levels, and estimates short data records, in which the AR power spectral density estimates are very close to the true values. In addition, the Burg method ensures a stable AR model and is computationally efficient [28]. Also effects of flash stimulation on the control, migraine and epileptic subjects have been investigated. The results were compared in terms of their frequency resolution and the effects in determination of migraine and epilepsy.

Materials and methods

Data recording

We performed electroencephalography (EEG) for acute migraine attack and epilepsy at the Kahramanmaras Sutcu Imam University Neurology Department. Migraine headache was diagnosed according to the diagnostic criteria proposed by the International Headache Society. Also the data pertain to epilepsy patient has been diagnosed epilepsy according to International League Against Epilepsy (ILAE) and International Bureau for Epilepsy (IBE) criteria. In all patients EEG recordings were obtained with an 18-Channel Nicolet One Machine. Electrodes were positioned according to the international 10–20 system, at Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, C4, T4, T5, P3, Pz, P4, T6, O1 and O2. The EEG signals were sampled at a rate of 256 Hz. Each recording process took minimum 30 min is a hyperventilation and 30 s is a flash stimulation. In these 30 s flash stimulation time period for each 2, 4 and 6 Hz stimulus frequency, the 30 s stimulus interval was followed by a 30 s rest period. In our study the EEG data was obtained from 15 migraine patients (two male, 13 female), 14 generalize epileptic patients (five male, nine female), and 15 healthy subjects (five males, 10 females). In the same criteria no patients had taken any drug before the recordings. For all group's age range are chosen 20–35 years. All the migraine patients EEG recordings had been taken in pain-free phase.

Visual evoked potentials

Since visual disorders are so often accompany in major headache, an increasing concern has emerged for the practical evaluation of migraine sufferers by means of visual evoked potentials [14]. Increased amplitude of F1 component has been observed by using continuous flicker stimulation, producing a steady state visual evoked potential (VEPs) [15]. Amplitude variation of VEPs with flash or pattern reversal stimulation have been reported in migraine; in addition, increased amplitudes were detected but lower amplitudes have been recorded [16]. In our study, the flash stimulation periods are 10 s with 2, 4 and 6 Hz stimulus frequencies. Afterwards differentiated time periods has been joined following one another. Thus time period related to stimulated data has been implemented as first 10 s of new 30 s of time period has a 2 Hz frequency, second 10 s has a 4 Hz frequency and last 10 s has a 6 Hz frequency. That is to say stimulated time period has been constituted 30 s time period which starts from 2 Hz frequency and increasing 2 Hz per 10 s. This way each stimulated 30 s time period takes approximately 7,500 data samples per channel. In order to compare the stimulated period with approximately 30 s of non-stimulated time period, another 7,500 data samples per channel pertain to the same records has been prepared to be a model.

AR method for spectral analysis

Model-based (parametric) methods are based on modelling the data sequence $x(n)$ as the output of a linear system characterized by a rational structure. In the model-based methods, the spectrum estimation procedure consists of two steps. The parameters of the model-based method are estimated from a given data sequence $x(n)$, $0 \le n \le N-1$. Then, the power spectral density (PSD) estimate is computed from these estimates. Since the estimation of AR parameters can be done easily by solving linear equations, the AR method is the most frequently used parametric method. In the AR method, data can be modelled as output of a causal, all-pole, discrete filter whose input is white noise. The AR method of order p is expressed as the following equation:

$$x(n) = -\sum_{k=1}^{p} a(k)x(n-k) + w(n) \tag{1}$$

where $a(k)$ are the AR coefficients and $w(n)$ is white noise of variance equal to σ^2.

The Burg method is based on minimizing forward and backward prediction errors and estimates the reflection coefficient. From the estimates of the AR parameters, PSD estimation is formed as [17–20]:

$$\widehat{P}_{BURG}(f) = \frac{\widehat{e}_p}{\left|1 + \sum\limits_{k=1}^{p} \widehat{a}_p(k)e^{-j2\pi fk}\right|^2}, \tag{2}$$

where $\widehat{e}_p = \widehat{e}_{f,p} + \widehat{e}_{b,p}$ is the total least squares error.

One of the most important aspects of the model-based methods is the selection of the model order. Much work has been done by various researchers on this problem and many experimental results have been given in the literature [17–20]. One of the better known criteria for selecting the model order has been proposed by Akaike [21], called the Akaike information criterion (AIC). In this study, model order of the AR method was taken as 10 by using AIC. In this study we used MATLAB software to compute AR PSDs of EEG signals. Sampling frequency is 256 and window length is selected as 256.

Results

Research from electroencephalographic assessments in patients with primary headaches has yielded controversial results. Some studies verified the existence of bioelectrical abnormalities in the EEG in primary headache patients, particularly in migraine patients. Furthermore, subjective visual analysis without EEG quantification limited the comparison between EEG findings. These limitations have been overcome by the advent of computerized EEG analysis [22]. In this study, we have proposed AR Burg method to compute PSDs of EEG signals to achive a computerized analysis of EEG signals of control and unhealthy (migraine and epileptic patients) subjects. PSDs of EEG signals for healthy and unhealthy (migraine and epileptic patients) subjects are presented in Fig. 1a–f respectively with and without flash stimulation. The selection of the model orders in the AR spectral estimators is a critical subject. Too low order results in a smoothed estimate, while too large order results in spurious peaks and general statistical instability. The AR spectral estimator offers the promise of higher resolution. When the dimension of the autocorrelation matrix is inappropriate and the model orders are chosen incorrect, poor spectral estimates are obtained by the AR spectral estimators. Heavy biases and/or large variability may be exhibited. In this study, model order of the AR method was taken as 10.

The AR Burg offers a good quality spectrum output in terms of frequency resolution. Due to this better frequency resolution, explanation and determination of the activities in the signal is easier by using AR method. Both EEGs, taken from normal (Fig. 1a) and migraine subjects (Fig. 1c) without flash stimulation, produce similar spectral characteristics. But the EEG, taken from an epileptic subject (Fig. 1e) without flash stimulation, produces different characteristic. Since the signal is taken from an epileptic patient, the results fit with the typical characteristics of epilepsy that is delta and theta activity (low frequency and high amplitude range). Also, both EEG taken from normal (Fig. 1b) and epileptic subjects (Fig. 1f) with flash stimulation produce similar spectral characteristics with nearly identical peak frequencies. This similarity held for both EEG signals obtained from healthy and epileptic subjects indicating that the frequency peaks can be accurately estimated using AR Burg method. Also in these spectrums, delta, alpha, and beta activities can be seen easily. As seen in Fig. 1d when different frequencies (2, 4, 6 Hz) of flash light is applied to migraine patient, increased amplitude has been observed in the beta bands (13–30 Hz) of EEG signals taken from T5-T3 channels. But, this increase has not been observed for the control group and epileptic patients, shown as Fig 1b and f.

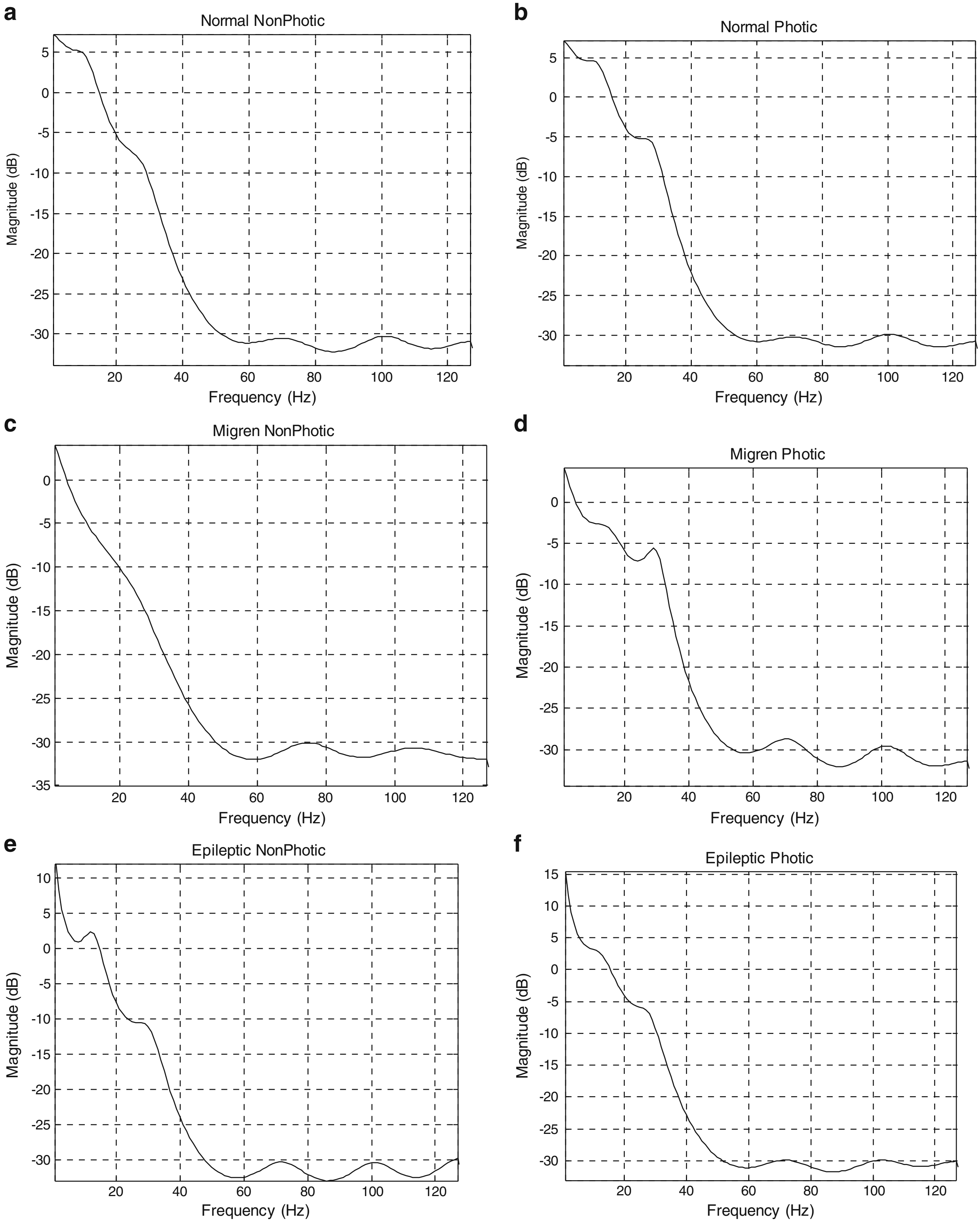
a
Normal NonPhotic
Magnitude (dB)
Frequency (Hz)
b
Normal Photic
Magnitude (dB)
Frequency (Hz)
c
Migren NonPhotic
Magnitude (dB)
Frequency (Hz)
d
Migren Photic
Magnitude (dB)
Frequency (Hz)
e
Epileptic NonPhotic
Magnitude (dB)
Frequency (Hz)
f
Epileptic Photic
Magnitude (dB)
Frequency (Hz)

Fig. 1 Power spectrum of T5-T3 data of migraine patient and control groups' member **a** power spectrum of non-stimulated data of control group member. **b** Power spectrum of stimulated data of the same control group member. **c** Power spectrum of non-stimulated data of migraine patient. **d** Power spectrum of stimulated data of the same migraine patient. **e** Power spectrum of non-stimulated data of epileptic patient. **f** Power spectrum of stimulated data of the same epileptic patient

Hence, for the migraine patients, an increase in amplitude has been observed at the beta bands of EEG signals under flash stimulation as compared to EEG signals without stimulation. As opposed to this, for epileptic patients, an increase in amplitude has observed at the alpha bands of EEG signals without flash stimulation. Meanwhile, for the control groups, there is no change between EEG signals under flash stimulation and without flash stimulation. Also, the statistical results are shown in Tables 1 and 2, related to each subject. In this table, observed means, angle of slope increasing in PSD plot is related to an increase in magnitude; little observed means, angle of slope increasing in PSD plot is related to increased magnitude is small but it can be seen by visually. Very little observed means, angle of slope increasing in PSD plot is related to increased magnitude is too small and can not be seen. Non-Observed means, angle of slope decreasing in PSD plots can be seen or there is not any changing slope in PSD plots.

Table 1 Changes of power spectrum in the positive potentially T5-T3 signals of EEG for the migraine patients and control groups member

Patients name	Amplitude increasing in the BETA bands of positive potentially EEG signals	Patients name	Amplitude increasing in the BETA bands of positive potentially EEG signals
M1	Observed	N1	Non-observed
M2	Observed	N2	Non-observed
M3	Observed	N3	Non-observed
M4	Observed	N4	Non-observed
M5	Observed	N5	Non-observed
M6	Observed	N6	Non-observed
M7	Observed	N7	Non-observed
M8	Observed	N8	Non-observed
M9	Observed	N9	Very little observed
M10	Observed	N10	Non-observed
M11	Observed	N11	Non-observed
M12	Observed	N12	Non-observed
M13	Observed	N13	Non-observed
M14	Observed	N14	Non-observed
M15	Observed	N15	Non-observed

Table 2 Changes of power spectrum in the positive potentially T5-T3 signals of EEG for the migraine patients and epileptic patients

Patients name	Amplitude increasing in the BETA bands of positive potentially EEG signals	Patients name	Amplitude increasing in the BETA bands of positive potentially EEG signals
M1	Observed	E1	Little observed
M2	Observed	E2	Non-observed
M3	Observed	E3	Non-observed
M4	Observed	E4	Non-observed
M5	Observed	E5	Non-observed
M6	Observed	E6	Non-observed
M7	Observed	E7	Non-observed
M8	Observed	E8	Non-observed
M9	Observed	E9	Little observed
M10	Observed	E10	Non-observed
M11	Observed	E11	Non-observed
M12	Observed	E12	Non-observed
M13	Observed	E13	Non-observed
M14	Observed	E14	Non-observed
M15	Observed		

Discussion

In spite of contradictory reports on the prevalence and type of EEG abnormalities in migraine, it is essential to express that in clinical samples the incidence of paroxysmal discharges, typical of epileptic syndromes, has been identified. High rates of epileptic EEG activity have been depicted in chronic headache. EEG findings of migraine attacks have verified sequences of spikes or sharp waves in different brain regions, similar to the ictal recording of epilepsy. The evolution of seizure activity with an increase or decrease of paroxysms and the appearance of fast rhythms are more rarely observed. Unspecific slowing in the theta range at centrotemporal regions is widespread, and even EEG recordings within normal limits are frequent in patients with migraine. Consequently, a wide range of electroencephalographic findings is expected. During headache-free intervals, the most consistent abnormality reported with migraine is a flash driving response at frequencies greater than 20 Hz. This is called the "H response". Although it has low specificity, it is the most important marker of migraine and of cortical hyperreactivity to visual stimuli. EEG recording in headache is important, especially in migraine associated with epileptic syndromes. Migraine features, such as visual disorders resembling the aura phase, headache and autonomic symptoms have also been observed in specific epilepsy syndromes. Epileptic and epileptiform discharges are frequently described, suggesting a common, altered neurophysiological background [23, 24]. Also headache has been observed in idiopathic photosensitive occipital epilepsy, generally after paroxysmal discharges have been elicited by flash stimulation [25]. Occipital spike-wave complexes suppressed by eye opening necessitate a careful approach since it takes place in idiopathic as well as in symptomatic occipital epilepsies. At present, it is far from clear the difference among these forms in spite of ordinary EEG abnormalities. In particular, the association of occipital epilepsy and migraine has been detailed. Occipital seizures generally are followed by headache. The sequence is then reversed, because seizures generate a migraine-like attack. In spite of the controversies of the past, in this case there is now a relevant agreement widely accepted and documented. From a clinical perspective, much concern has been directed to visual symptoms that are present in migraine as well in visual seizures of occipital epilepsy [16].

In our study migraine patients under flash stimulation high amplitude beta waves revealing, has been observed for T5-T3 channels of EEG. According to this when we take into consideration under flash stimulation phase synchronization changes has been discovered for the migraine patients in the former studies [26], hence we can say that data of T5-T3 channels are important for the migraine patients. Because of amplitude changes in the positive potentially EEG signals for other patients names are schizophrenia, depression, obsessive compulsive disorder, dementia [27] researching the relationship between migraine patient and this other patients, has been a reference.

Conclusions

Epilepsy and migraine remain two considerably dissimilar diseases, perhaps showing more differences than similarities. A shared neuronal hyperexcitability may be the pathophysiological link accounting for their bidirectional comorbidity and for the effectiveness in migraine. If the exposure to the side effects profile can be always justified in epileptic patients, in migraine subjects the risk/benefit ratio must be individually considered. We have presented new alternative methods to compute PSDs of EEG signals. It can be easily seen that the plots obtained by using AR methods has discriminate migraine and epileptic seizure clearly. Interpretation and performance of this method was compared in terms of their frequency resolution and the effects in clinical applications. The results of this study clearly demonstrate the power of AR burg method in resolution of frequencies, and the performance characteristics have been found extremely valuable for the use in migraine/epileptic seizure detection.

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