Indian J Physiol Pharmacol 2017; 61(1) : 43–51

Original Article

Objective Evaluation of The Effect of Visual Imagery With Closed Eyes on Retinal Activity in Humans

M. Aswin Kumar and Ch. N. Rajkumari

Department of Physiology,
Osmania Medical College,
Hyderabad

Abstract

In contrast to a normal Electroretinogram (ERG) which is obtained with light as an adequate stimulus, the present study proposes the possibility of obtaining electrical retinal activity in the absence of light stimulus during the process of visual imagery with the eyes remaining closed. Electrical retinal activity was recorded in 30 healthy subjects who were comfortably seated in a dark and silent room with their eyes closed. Surface skin electrodes placed near the eye were connected to a Digital Physiograph for recording. The electrical activity thus obtained not only showed ERG-like patterns but also isolated positive and negative peaks. It was seen that the number of positive peaks were more than negative peaks and ERG-like patterns. The principal and novel conclusion of the study was that retinal activation was possible during imagery even without external light stimulus. This kind of retinal activation could be via functional centrifugal fibers in man.

Introduction

The purpose of the present study was to find answer to the question, “Is retina just a receptor that will transduce light from exterior into action potentials and feeds them into the brain or does it function as an effector tissue also subject to modulation by higher brain areas?” Centrifugal nerve fibers to hair cells of cochlea have already been well documented in structure and function in human beings. Hence, the study tries to find if similar centrifugal modulation does exist for retina also. Phenomenal vision, i.e., seeing of brightness, darkness, colours and movements depends upon the processing of the inputs from retina by various brain areas and comes in veridical and non veridical forms. The veridical vision is the situation in which retina as a receptor transduces the incident light into nerve impulses which are eventually transformed into visual perception. In non-veridical vision, other means to evoke phenomenal vision like Phosphenes, Afterimages, Dreams and Imagery are included. Research has been actively carried on to understand the physiology of these non veridical forms of vision. In this context, the authors of the present study wanted to explore the physiology of visual imagery. Whether visual imagery, a conscious effort, is purely a function of some higher brain areas or does it involve retina also was the question. An f-MRI study or a PET scan would have shown the areas of the

***Corresponding author :**

Dr. M. Aswin Kumar, Upgraded Department of Physiology, Osmania Medical College, Hyderabad

(Received on December 12, 2016)

brain involved in visual imagery, but the present study stands novel in its approach to prove that the process of imagery involves the receptor activation, probably through functional centrifugal pathways. The centrifugal pathways to retina do extend from such important sub cortical areas in man, which are directly or indirectly involved in sub-conscious perception of vision and other activities like emotional states, imagery and even sleep states of the brain (1-6).

Evolutionary studies show that the centrifugal neuronal connections to retina served the basic function of influencing the retinal processing of incident Electro-Magnetic Radiation for a better resolution and complex psycho-neuro-endocrine reflexive activities in lower animals like defensive avoidance of light gathering behaviour or mating behaviour (7-11). It appears that they gradually got selected and established in human. Recent studies showed their role in learning and development (5). Imagination seems to be such an advanced property of human brain wherein, the beautiful colours and contours of the world are all presented within the darkness of the skull, creating all possible changes to the objective reality which is otherwise not possible in the real world which is bound to physical and chemical principles of nature. Such a unique property, therefore, does it work in coordination with the aid of the natural transducer, retina, to obtain good spatio temporally resolved imagery or is totally independent and working in an abstract internal state was the question. Whether visual imagery evokes the phenomenal vision with or without retinal activation should be answered. Hence, choosing imagery with closed eyes as the property of brain that affects retina centrifugally was appropriate.

Methodology

The study sample of 30 included 11 female participants and 19 male participants. All of them belonged to medical fraternity, being MBBS students, post graduates and faculty. Study time was fixed to be between 4-6 PM when the subjects were relatively free from academics and the lab could be maintained adequately silent and dark. Subject's voluntary participation was given utmost importance and an informed consent was taken. No kind of persuasion or urgency was imparted. All of them had enough orientation to the Physiology department and hence their co-operation during the recording could easily be achieved and apprehension related to procedure could probably be ruled out. Subjects with obvious ophthalmic pathology of any kind and of any degree were not included. Subjects were enquired about any addictions to drugs of any kind, and history of chronic usage of any medicine. Such subjects were excluded. Most of them being adolescents rapport could be established with ease. Denial of any degree was seriously considered disadvantageous and such subjects were excluded. The digital Physiograph, supplied with software, "Lab Chart Pro version 7.2 supplied by AD Instruments pvt. Ltd." was used. Two channels were run which recorded Electrical activity from both retinae simultaneously. Channel settings included a Digital Filter of low-pass type, cut-off frequency being 50 Hz. During analysis, if required, the cut-off frequency was re adjusted accordingly. Range for the recorded data was set to be 10 mV, low pass filter set at 200 Hz, high pass filter at 0.5 Hz, with mains filter and anti-alias on. Data was fed into Power lab 15T-0797 with master timer and data was recorded at a rate of 1 k/sec. MLAWBT9 EEG gold plated flat electrodes were used to pick up the activity from the skin which were connected to MLA2540 Shielded Bio Amp Cable which was in turn connected to channel 3 & 4 of the Bio Amp slot in the power lab. In the air conditioned laboratory, the subject was comfortably seated in the wooden chair with good back support, the area around both eyes and behind the ear was cleaned with a Medi- Swab (70% w/v isopropyl alcohol swab) and allowed to dry. Using the Ten20 conductive EEG paste (supplied by D.O. Weaver and Co., Aurora, USA), the flat EEG electrodes were applied to the skin, the active electrodes conveniently placed close to lower eye lids of both eyes, and reference electrodes were placed on the fore head (12). Ground electrode was placed behind ear and was fixed using Transpore adhesive tape (13-15). Having made the room adequately dark and silent after preparing the subject, instructions were given to relax with eyes closed. Subject was asked to minimize the body movements to near zero once they attained the

relaxed posture feasible for them. A time period of 20 min was taken to assure dark adaptation (13, 14). In view of inter individual differences, slight adjustments were made in the software settings to get the best possible record and filter out the noise due to eye movements. They were told to minimize the eye movements but not deliberately fix them with effort. Because the eye movements do follow certain imagery, their conscious fixation would lead to minute twitches in the facial muscles or the lids, which would add to noise. Even though proper filters were set to minimize the disturbance caused by the eye movements the subjects were requested not to make any gross movement. This ensured a good record, in spite of minimal degree of eye movements in the subject. After assuring the subject complete safety, the examiner gave the subject enough space and departed from the room into adjacent part of the lab. The subject then started the imagination process. The period of imagery ranged between 5-20 minutes. Few subjects volunteered for a longer time of imagination as they wanted “continuity in their stream of imagination”. Conversely, those who could imagine only for few minutes, e.g., 5 minutes, reported that they had fatigue of imagery and no longer could carry out the process. Whatever may be the period, during the imagery process, the subject was noticed by the examiner from beside the glass partition to find any gross movements, deliberate opening of their eyes or any kind of discomfort being expressed in their gestures. Fortunately, all the subjects were extremely co-operative and enthusiastic in their participation. At the end of the stipulated period, the record was stopped, and the subject was asked to open the eyes, lights were turned on and they were shown their record. An imagery questionnaire was prepared and given to each subject in a printed paper. Unfortunately, very few could be retrieved as most of them did not want to reveal the content of their imagery. Few of them reported they were not able to recollect the content back. Few of them expressed some part of their imagery but that was found to be not authoritative through their gestures. Hence, content of their imagery could not be collected for study. However, care was taken to find out if they fell asleep during the period. Therefore this totally non invasive procedure was in accordance with the ethical standards as in Helsinki Declaration 1975.

Results

The electrical activity originated from the retinae of both eyes was recorded simultaneously from the two channels, which showed isolated positive peaks, negative peaks and complete ERG-like patterns in the order of their frequency of appearance. Those peaks which were recorded from both eyes at the same instant were not considered for they might have arisen from the eye movements during imagery, as the eye movements are always conjugate and produce activity at the same instant. Even though the characteristics of such peaks were close to that of isolated b waves of a normal ERG, they were not considered so as not to raise controversy. Peaks or waves which were seen only in one eye were readily considered for they reflect retinal activity only. Clearly identifiable ERG activity, with a wave, b wave and Oscillatory Potentials was also readily considered and they were mostly present in only either of the eye. If the wave form being analyzed was similar to ERG, calculations were done in accordance to standards only, i.e., e.g., ‘b’ wave amplitude is taken from the preceding ‘a’ wave negative peak. Durations of only those wave forms are considered which resemble ERG activity. The record obtained in the present study strictly could not be called as Electroretinogram because International Society for Electrophysiology of Vision (ISCEV) guidelines have the clear definition for a clinical ERG. There was no standardised light source at all to elicit retinal activation. When all the major and minor components of ERG have been described and standardised on the basis of alteration of various study conditions like dark adaptation, light adaptation, stimulus intensity and hence forth, it was decided that our records should not be compared with their corresponding standards. Hence we did not perform a comparative analysis of each wave form obtained with normal clinical ERG and we called the observed wave forms (electrical activity of retina) as ERG-like patterns. Nevertheless, it was very clear from the tracings that what was recorded from the retina was indeed ERG, recorded in spite of deprivation of its natural stimulus, light. Therefore, results shall be presented about the positive peaks, negative peaks and ERG-like patterns in the following pages.

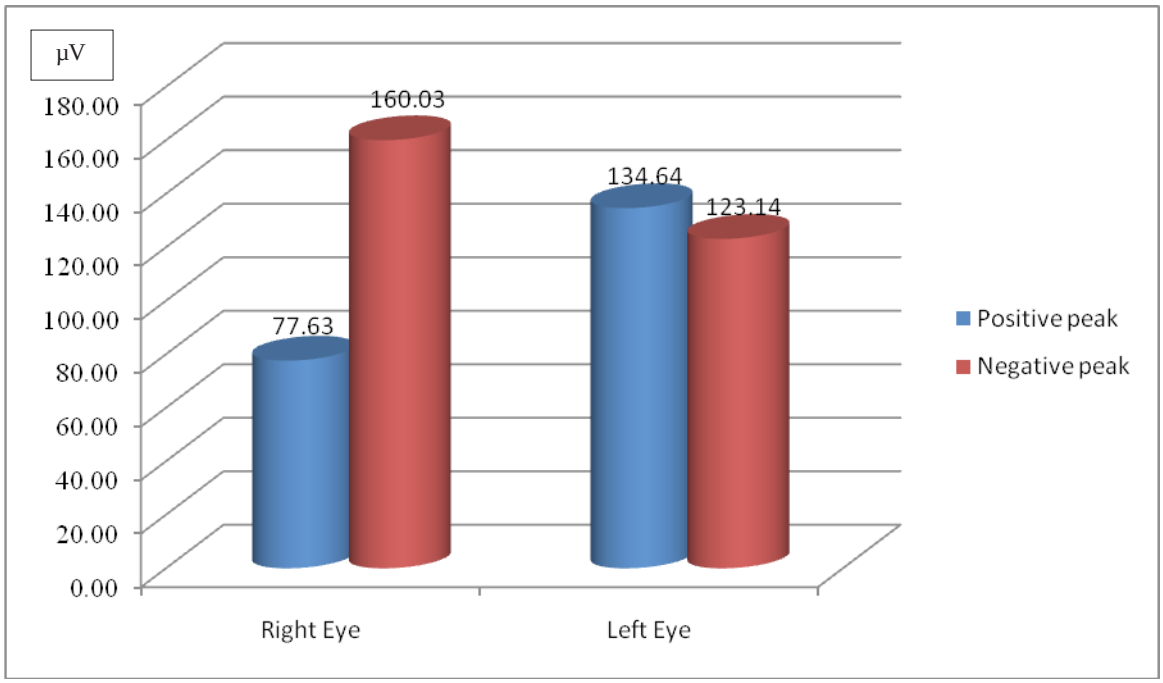


Chart 1: Comparison of Mean Amplitudes (in µV - microvolts) of Positive peaks & Negative peaks in both eyes.

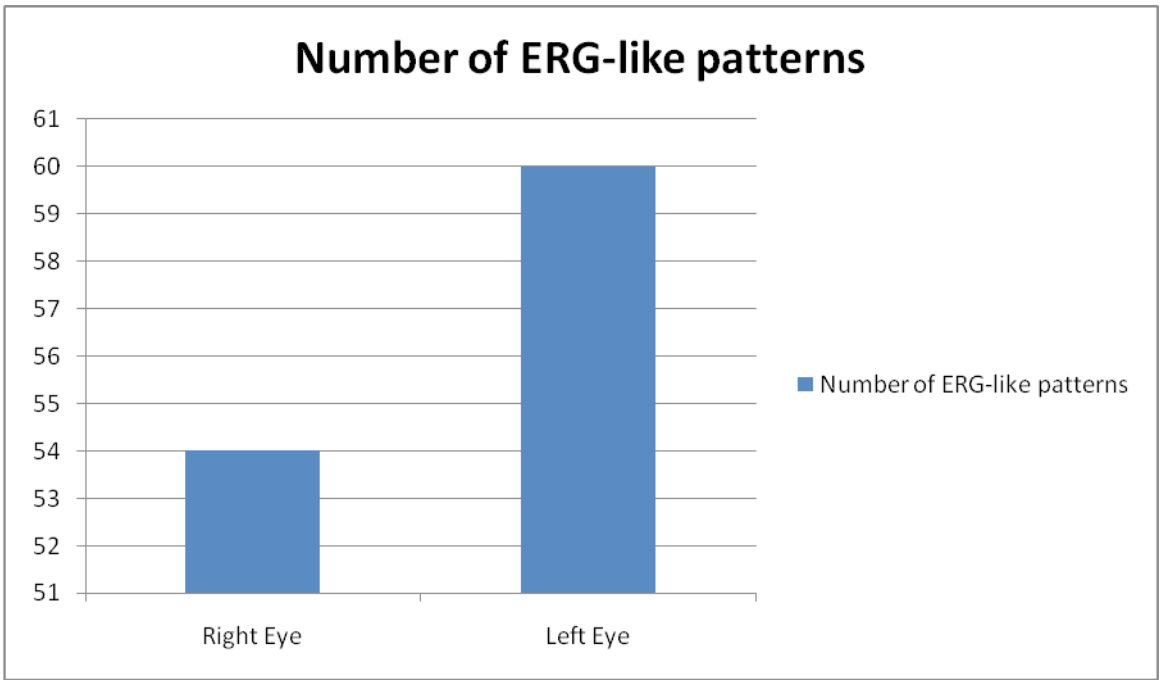


Chart 2: Comparison of number of ERG-like patterns in both eyes.

Evidence of these traces proves that retina does get activated even when eyes are closed and there is no light stimulus. The recorded activity is akin to a clinical ERG.

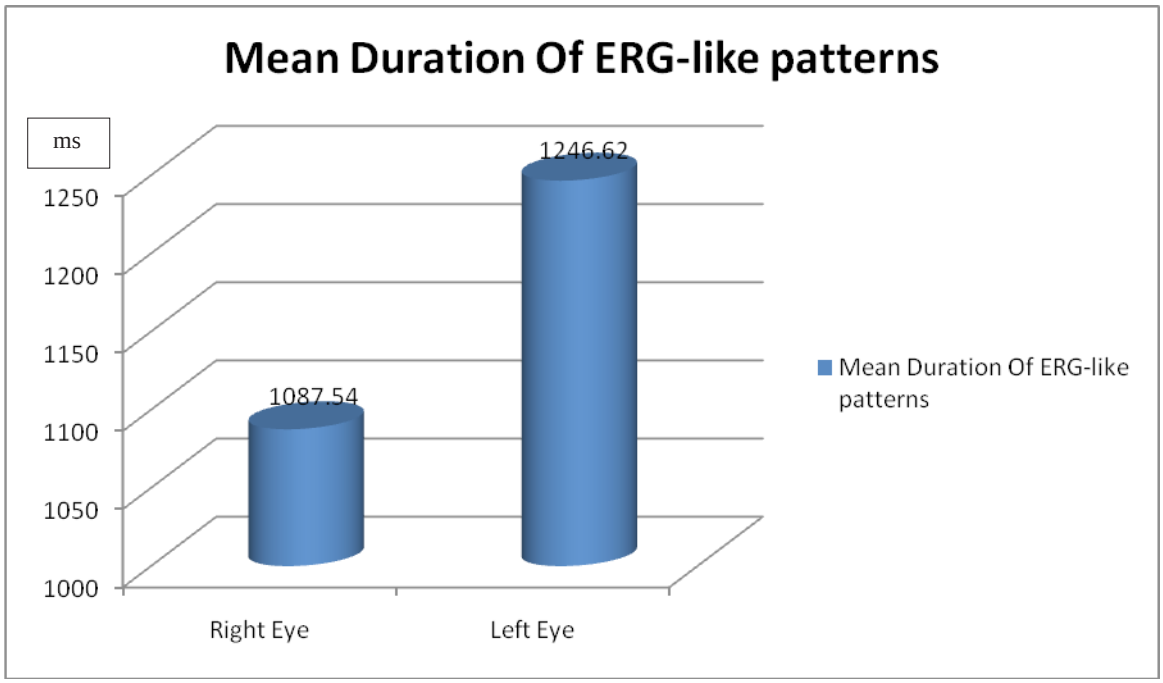


Chart 3: Comparison of Mean Duration (ms - milliseconds) of ERG-like patterns in both eyes.

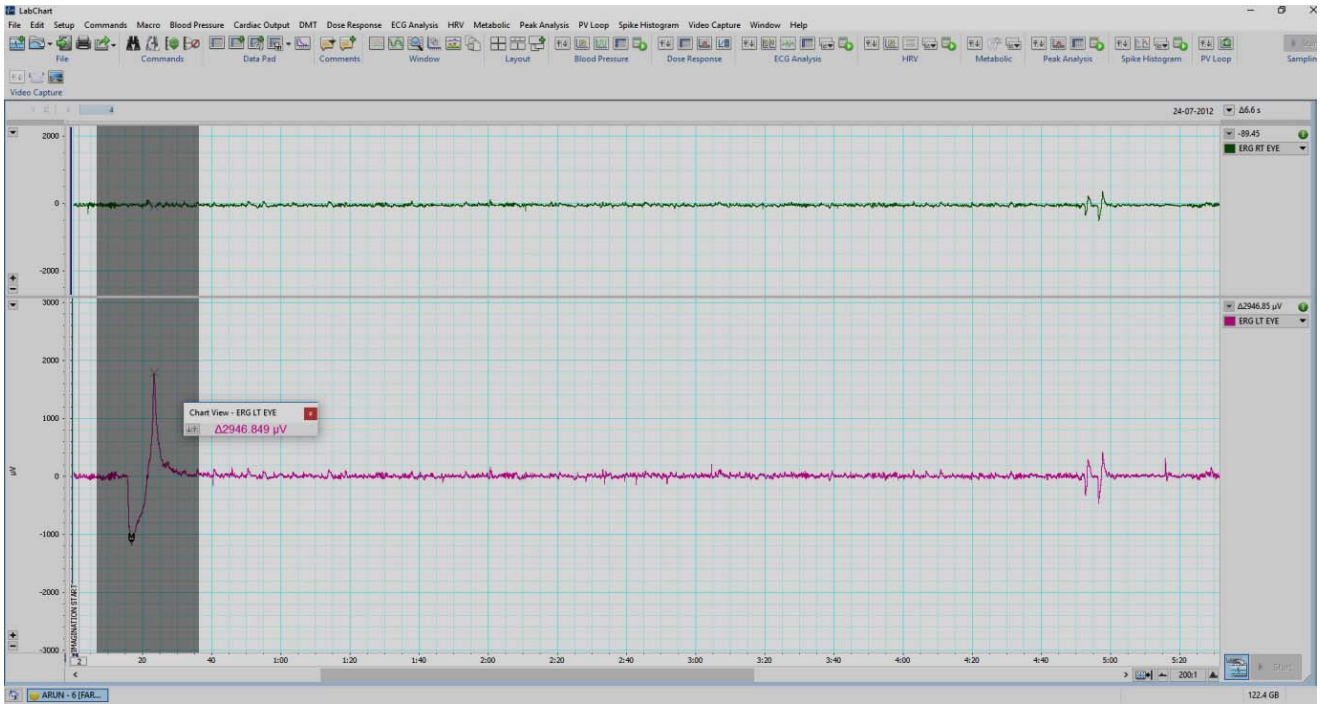
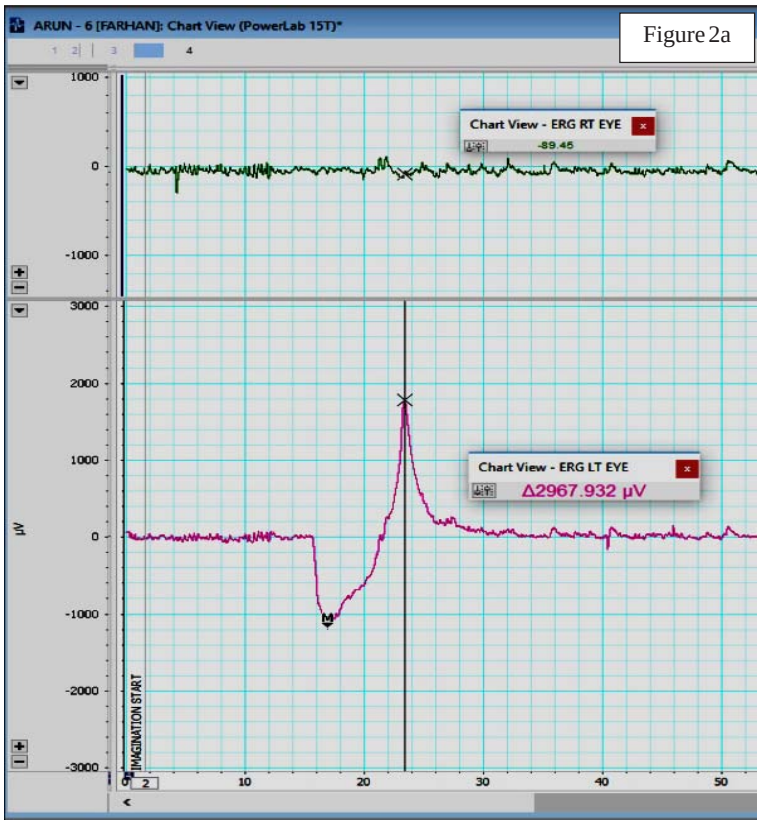


Fig. 1: This is a screenshot of the lab chart software panel as it appears when the electrical activity from both retinae was being recorded. Two channels were run simultaneously. The upper panel corresponds to right eye and the lower panel, to the left eye. Note the ERG-like pattern recorded about 15 seconds after the start of imagination in the left eye.



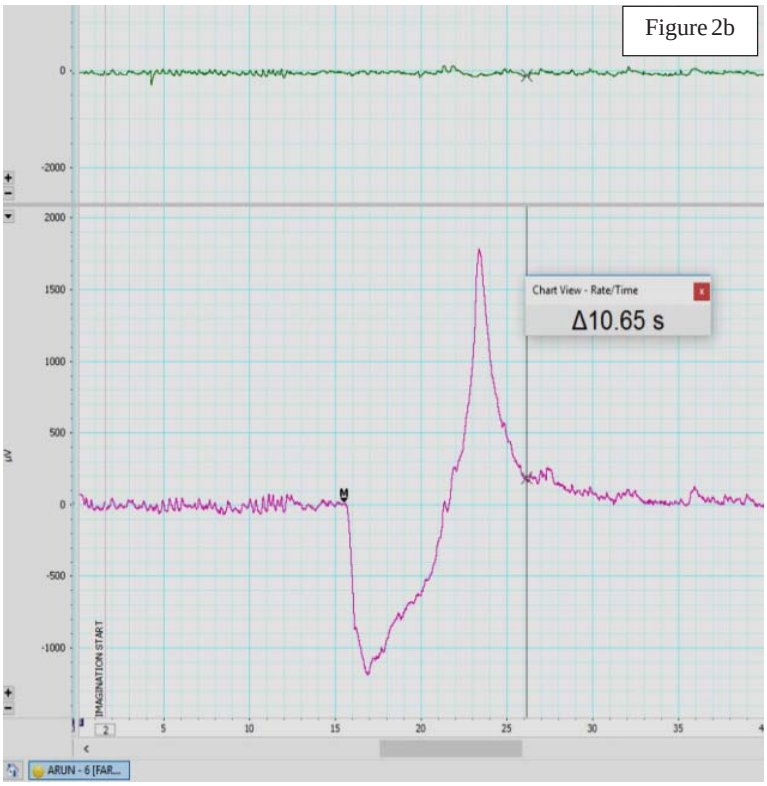


Fig. 2 : ERG-like pattern in a subject recorded from left eye, about 15 seconds after the start of imagination. Note that there is no simultaneous record from right eye. Also note that the amplitude b wave of 2967.932 µV (Fig. 2a) and duration of total ERG-like pattern of 10.65 s (Fig. 2b) of the record is more than that recorded in a clinical ERG. This trace belonged to a 28 year old male, who reported to imagine him diving in the sky. He felt the cool breeze touching his body while he was in air. This subject showed ERG-like patterns of unusual amplitude (Fig. 2a) and duration (Fig. 2b).

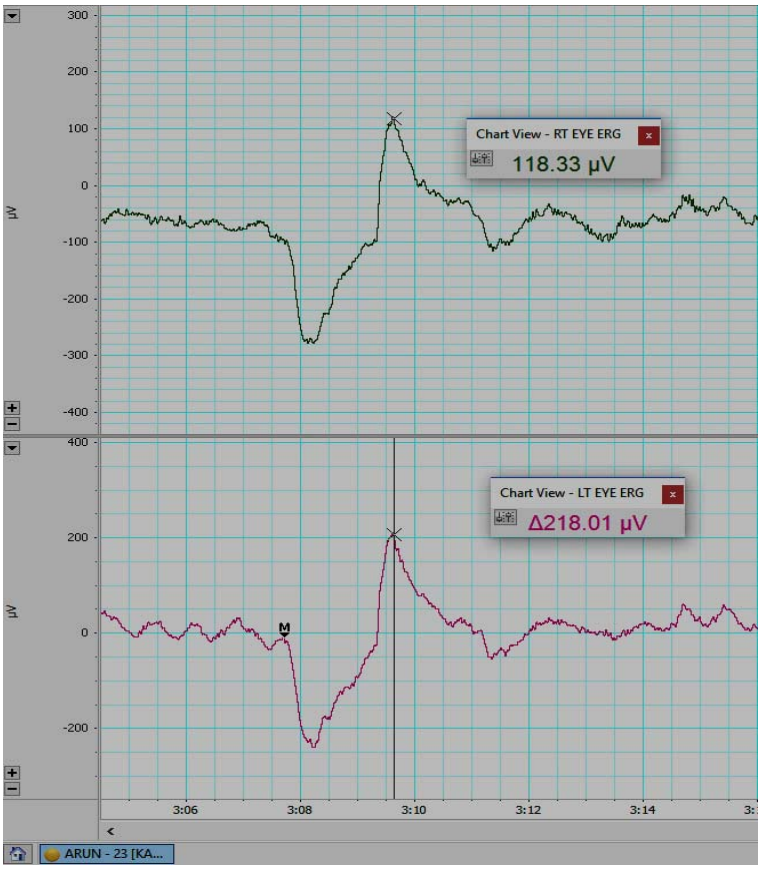


Fig. 3 : ERG-like pattern in a subject recorded from both eyes upper panel from right eye and lower panel from left eye. Note the difference in the amplitudes between both eyes. The right eye showed b wave amplitude of about 118.33 µV whereas left eye showed b wave amplitude of 218.01 µV. Note that the electrical activity is more from left eye compared to right eye. This trace belonged to a 21 yr old male, who reported to imagine a familiar face of a lady whom he did not reveal. He said he tried to imagine the detail of her face.

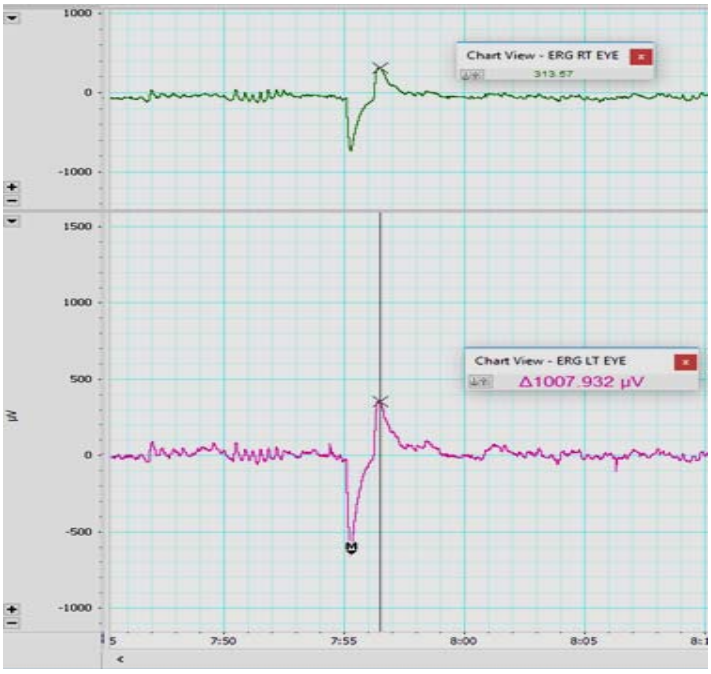


Fig. 4 : ERG-like pattern in a subject recorded from both eyes but with different amplitudes. Note that the electrical activity is more from left eye (lower panel) compared to right eye (upper panel). The amplitude of the b wave about 1007.932 µV in the left eye is more compared that recorded from right eye about 313.67 µV.

Discussion

The present study demonstrated a novel function of human retina, i.e., in the absence of its adequate stimulus, retina could be electrically activated during non-veridical forms of phenomenal vision, visual imagery in the present example. There were few previous studies which recorded ERG from the eyes during imagery but the present study design was totally different and new as there was no external stimulus at all. Even though the electrical activity recorded during the present study may not be strictly called as an Electroretinogram- owing to the standardised methods of recording and reporting an ERG- the wave patterns obtained were very much akin to a normal ERG and hence were called ERG-like activity. Analysis of the obtained record yielded the following conclusions. First – predominance of isolated positive peaks in the overall recorded retinal electrical activity from both eyes. These positive peaks could be ascribed to 'b' waves of a usual clinical ERG. Except for a higher amplitude and duration, the positive peaks observed were similar to 'b' waves of a clinical ERG (16). In a dark adapted retina, the mechanism for production of these waves is slow depolarization of muller cells, the glial cells in distal retina. This raises a question in the present study whether muller cells are activated during imagery. Second – followed by the positive peaks were the negative peaks, similar to 'a' and 'M' waves of a normal clinical ERG (16). In a dark adapted retina, these negative waves are produced due to light induced photoreceptor activity. Presence of the negative peaks hence supports evidence for photoreceptor activation during imagery. Third - the most probable conclusion drawn from this observation, therefore would be that the process of visual imagery, basically a function of sub cortical brain areas, for ways yet to be discovered, would affect retinal muller cells and photoreceptors through the centrifugal fibers in the optic nerves. The centrifugal fibers are the only possible pathway to affect the retinal function. Probably those sub cortical areas which are involved in the imagery would send efferent signals to the retina and are responsible for the electrical changes recorded from the retina during imagery.

The existence of centrifugal fibers to retina in man which have been documented in the past through post mortem studies is now confirmed in the living individual by the way of recording of the effects of visual imagery with closed eyes on retinal activity, proving their physiological significance. Moreover, previous studies showed that during the process of visual imagery areas of brain concerned with storage of images are often activated, the Hippocampus, the ventral parts of Temporal lobe and Frontal lobe (17-19). The present study hence puts forth an assumption that during imagery process, activity from such sub cortical areas will reach retina via centrifugal fibers and the results obtained strengthen this assumption.

There were many studies conducted in the past to know the effect of various neurotransmitters and neuromodulators on the retinal function in various animal models (7). Retinopetal axons arising from various sub cortical structures and the type of neuro modulators they release were also studied in detail (4). It was reported that a similarity exists in spontaneous firing ability of mesencephalic dopamine secreting neurons and the retinal Amacrine cells *in vitro* (11). It was also later shown that if certain conditions are satisfied within the intact retina, such firing would also be possible *in vivo*. Dopamine was found out to be the modulator in such spontaneous activity. Dopamine is not only a local modulator released from Amacrine cells but also released at the terminals of the retinopetal axons. The Dopaminergic Amacrine cells are also targets in some species, and because dopamine influences so many types of retinal neurons, this greatly amplifies the effects of the other retinopetal axons. Also, from posterior hypothalamus, axons releasing Histamine and from the dorsal raphe nucleus, axons releasing Serotonin enter retina centrifugally and modulate the activity (4). Localization of these receptors in the retina has also been done and was suggested that the effects of retinopetal axons were also mediated by volume transmission. As a result, retinopetal axons are able to influence many types of retinal neurons. However, it must also be noted that more recently, the neurons in the brain stem that give rise to these axons have been localized, and their neurotransmitters have been identified in humans. If the data from molecular studies which demonstrate the interaction

between various neurotransmitters within the retina and their centrifugal modulation by brain areas be obtained and if studies are conducted to show that those areas were also activated during the process of imagery, then the secret behind modulation of retinal activity in the absence of light would be unravelled. For such a challenging task, the present study undoubtedly stands as the take-off point.

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