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Study on the Impact of Light on Human Physiology and Electroencephalogram

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Abstract: The influence of light on Electroencephalogram seems to be more critical, when physician depends on its readings to diagnose subject brain disorder according to its level. Although, bright light brings various changes in human physiological variables. But, Neurophysiological changes for specific light level still remain unclear. Thereby, in the present study, the response of brain electrical activity towards various light levels has been classified and verified. The reasons for alteration in different physiological variables due to bright light which results change in the state of electroencephalographic recordings has been reviewed. Additionally, the effects of bright light towards Ocular artifacts are also put forward. A novel hypothesis has been made using subjective analysis and experimental analysis in low luminance or darkness. It is observed that a poor lighting condition affects both behavioral task and brain activity.

Introduction

The electroencephalogram is a significant neuromedical imaging tool for the analysis and interpretation of brain electrical activity. Human brain consists of millions of neurons. Due to firing of these neurons the electric potential induced over the scalp. This potential would be in an order of microvolt and millivolt when acquired using subdural electrodes [8, 13, 16, 18, 19, 20]. Light is a transverse and electromagnetic wave that be experienced by the humans by perception of vision. There are various physiological changes occurs in humans when exposed to bright illumination. Neurophysiology and Ocular Physiology factors are noticeably affected. The luminosity reflected into the human eyes elicits changes in the state of electroencephalographic recordings. Here, Type of the surface, the angle of the incidence and spectral composition are prime factors to study about the lighting parameters. If the EEG experimental rooms colored with reflective color like silver results in more effect of light on the subject. Though, Exposure to light brings alterations in human physiology like suppression of melatonin hormone and core body temperature [11]. Thus, affects the neurobehavioral measures like alertness, performance and reaction time which consequences to Change in EEG frequencies [10]. To contemplate changes in neural behaviour, Central study weighting upon the alpha activity in occipital region, which is correlated to the light exposed. Another important study that light alters the state of subject alertness which is entirely dependent on the release of melatonin hormone in the human brain during poor lighting conditions. However, exposure to bright illumination does not affect behavioral task perform by the subject, but it affects the brain electrical activity.

Physiological changes when exposed to bright light

When a subject exposed to a bright illumination condition without changing the behavioral task, it alters many physiological changes like subjective alertness, incidence of slow eye movements, plasma melatonin hormone, core body temperature and other ocular physiological changes.

The illumination caused by the luminous object in a distance d is given in Eq. (1).

$$E = I / d^2 \tag{1}$$

Where E is the illumination caused by the light source from a distance d, I is the luminous intensity of a respective light source. From Eq. 1 it is to be known that, the illuminating conditions done by the light source is entirely dependent on the distance between the light source and illuminating region. Various physiological effects of illumination are studied below.

The study on the Melatonin hormone extends the correlation between the lighting parameters and the physiological variables. Melatonin is the natural hormone which is found in the human brain, which is originated in the pineal grand of the human brain. It is entirely reliant on the circadian rhythm generated by the light and dark cycles [11]. Melatonin synthesis was inhabited when the retinas of eyes detected the amount of light. Iain M. McIntyre, et al. (1989) gives the relation and response between the percentage suppression of Melatonin to various levels of illumination conditions. The percentage of suppression increases with an increase in illumination levels which results increase of alertness in the subject. Thus, change in the EEG spectra with change in illumination [4, 6, 7, 9, 14]. The response curve of percentage suppression of melatonin hormone in increase in amount of lux is shown in below Fig. 1.

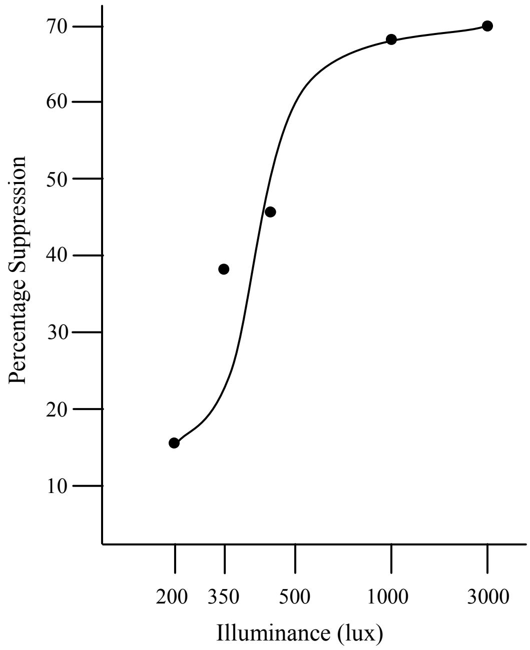

Fig. 1. The Response to a Percentage Suppression of a Melatonin Hormone with different illumination levels

As exposure to bright illumination suppress the release of melatonin hormone also affects the subjective alertness. The response of subjective alertness is proportional to the increment of illumination levels. The suppression of melatonin hormone is greater than 50% when subject is exposed to illumination of 100 lux and more. Incidence of Slow eye movements is another physiological change which is a quiet reversal to subjective alertness towards increment of illumination levels. Here, the incidence of slow eye movements is optimum till the subject is exposed to less than 100 lux. The incidence of slow eye movements has decreased when the melatonin hormone is suppressed to more than 50% with an increment of illumination levels. The subjective alertness, response is obtained to the different levels of illumination given by Christian cajochen (2007) shown in below Fig. 2. Where closed symbol identifies individuals whose suppression of melatonin hormone is less than 50%, while open symbol identifies individuals whose melatonin suppression is greater than 50%.

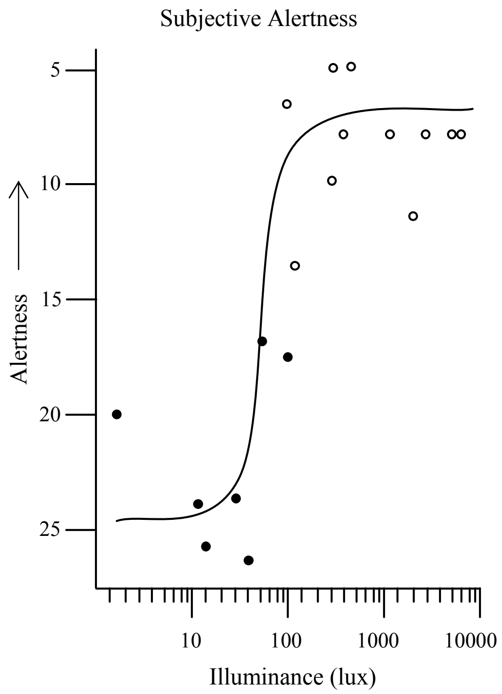

Fig. 2. The subjective alertness response to with increment of illumination level

It can be observed that the incidence of slow eye movements is high with low subjective alertness and vice-versa. This is shown in Fig. 3.

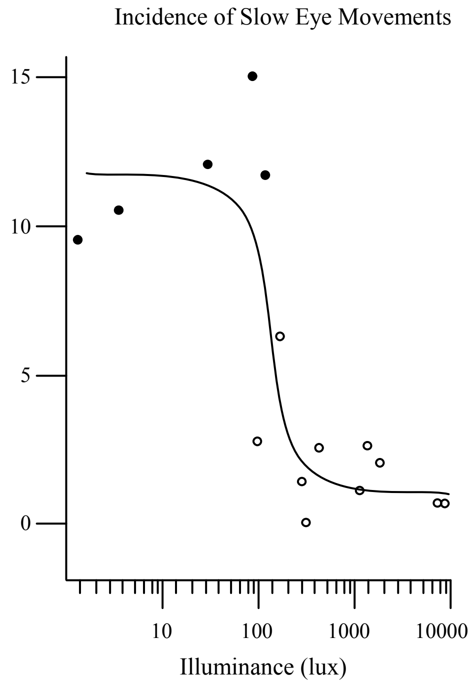

Fig. 3. The reduction of incidence of slow eye movements with increase of illumination levels

It is verified that the effects when the subject is exposed light are not limited to physiological variables, but also neurobehavioral performance which is replicated into electroencephalographic readings.

Electroencephalographic changes when to exposure to bright light

As light results in various physiological changes in the human circadian rhythm, incidentally effect on the electroencephalographic readings. Considering alpha rhythm which occurs usually in the occipital and temporal region alters when subject is in relaxed state.

The electroencephalographic alpha spectra range in frequency of 8-13 Hz, which is between theta and beta frequencies [2, 5, 13, 15]. It can also be rephrased as it is the range between more conscious to subconscious state. By analysis and interpretation of this frequency stretches the status of subject's state of alertness. This range of frequency usually strong when subject is very much relaxed like inability to focus or day dreaming. It is observed that when subject's eyes are closed and makes visual suppression for duration, which drops subject alertness into relaxation mode results in an increment of alpha activity in the occipital region.

Alpha blocking is the phenomena which reduces alpha activity when subject shows any anxiety and concentration to do any mental activity. This makes suppression in production of alpha activity and increase in higher frequency. On this aspect, it can be stated that vision alters the alpha activity, thus affects the state of the subjective alertness. A subject can have the clear perceptive vision over a specific region only when that region has good lightning conditions. Alpha spectral power increases with the visual suppression. Alpha rhythm replicate changes in physiological variables with increment in illumination levels. It can be illustrated that less illuminated environment or no light cause increase of alpha rhythm in the occipital region of the EEG. The Alpha frequency range is very much similar to the spindle which range from 7-14 Hz [2]. As alpha waves behave like a sleep spindles which usually occurs between two states of alertness.

An additional important electroencephalographic change due to light is EEG power density. It is observed that the percentage of total power in theta and lower alpha frequency is reduced. Here, presence of theta and lower alpha frequency were found in the normal adult during drowsiness and sleep. As an effect of bright light, this alters the state of the subject by suppressing the EEG power density of the frequency 5-9 Hz and increase in alertness. The response of the percentage of total power of frequency 5-9 Hz to different illumination levels are given by Christian cajochen, et al. (2000) shown in Fig. 4.

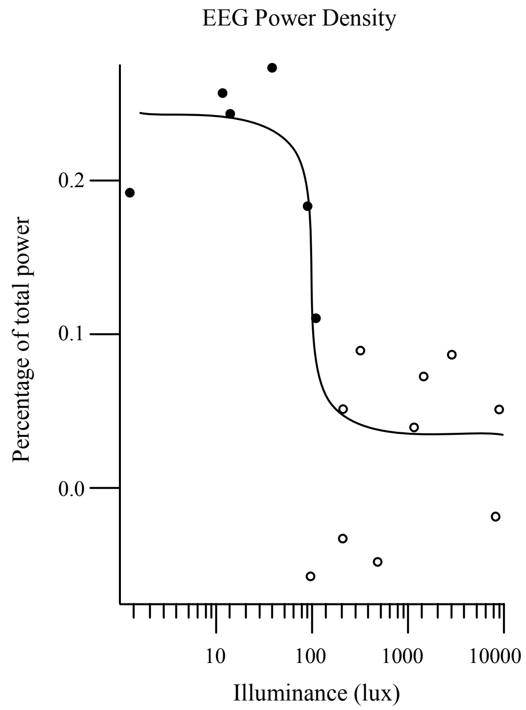

Fig. 4. Percentage Reduction of EEG Power Density of frequency 5-9 Hz with Increment of Illumination [3]

Effect of bright light on electroencephalographic Ocular Artifacts

Ocular artifacts are the undesired bio-potential induced by eye along with brain Neuro potential. The artifacts which are caused by the ocular blink or movements of an eye create a noticeable change in EEG recording. These artifacts are caused voluntary or involuntarily from the side of patient. Here, ocular organ artifact is considered as a chief artifact among all the artifacts contaminated into EEG. Because Ocular organ region is very much near to the electrodes placed on the frontal region to acquire EEG [17]. Ocular potential is induced near and around the ocular region because the eye acts as a dipole where the cornea is more positive than the retina [13, 19]. The episode of the blink takes place, when the eye lid slides over the cornea. In this episode eye lid picks up the potential from the positively charged cornea and imposed on to the nearby frontal electrodes of EEG which are placed near around Ocular region [19, 21, 22], equivalent is obtained in Eq. (2).

$$\text{Contaminated EEG} = \text{True EEG} + \text{Ocular Artifact} \tag{2}$$

In this consequence, it is interesting to know that the ocular artifacts are also affected by the various illumination levels. When acquiring EEG, it is observed that the increase in amplitude of artifact when subject is exposed to illumination caused by the luminous objects in EEG recording room. Visually evoked potential attains by external illumination is added to the Cornea-Retina dipole potential results as developed superimposed artifact potential, specified in Eq. (3). Visually evoked potential depends on the lighting parameters around the acquisition system.

$$\text{Ocular Artifact Potential (OA)} = \text{Dipole Potential} + \text{Visually Evoked Potential (VEP)} \tag{3}$$

By correlating basic electrostatic physics to the ocular organ, the electric field due to Cornea-Retina dipole potential induced on to the electrode is given as

$$V_{Dipole} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_c}{r_c} - \frac{q_r}{r_r}\right] \tag{4}$$

Where q_c and q_r are the charges of cornea and retina of an Ocular dipole. Cornea is more positive than the Retina where r_c and r_r are the distance between the poles and the nearest electrode respectively. The total Ocular artifact potential along with visually evoked potential induced on to the nearest frontal can be specified as V_{OA}.

$$V_{OA} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_c}{r_c} - \frac{q_r}{r_r}\right] + V_{VEP} \tag{5}$$

The resultant voltage across the electrode when artifact potential in bright illumination is added with desired neuro potential, which is given in Eq. (6) and Eq. (7).

$$V_{Electrode} = V_{Neuro\ Potential} + V_{Dipole} + V_{VEP} \tag{6}$$

$$V_{Electrode} = V_{Neuro\ Potential} + V_{OA} \tag{7}$$

This visually evoked potential is varied in the various factors like subjects Age, gender, visual acuity, pupillary size etc. Visually evoked potential alters the amplitude and the latency of Peak of the wave. Latency increases with increase in subject's age. This happens because of reduction in visual acuity with increase in age [12].

Hypothetical observation

It is a hypothesis that behavioral task done in the no luminance or darkness condition which results to increase in the frontal frequency. This hypothesis has been analyzed and verified using subjective analysis and experimental analysis which is to be correlated with the frequency characteristics in the frontal region.

Experimental Procedure

This study was carried out in the laboratory on 25 healthy subjects containing 14 male and 11 female participants of age ranges from 18 to 60 years, who are studying and working in the university. All the participants are first allowed and arranged to be relaxed before the test in the recording room, where the room temperature is maintained at around 25°C. Examination room is set to perform experimental analysis in no luminance or darkness. In order to eliminate contamination of muscular artifacts (EMG) into EEG, all the participants were made to sit on a proper base with headrest. AgCl electrodes are placed on the scalp in the frontal and front polar regions of international 10-20 standard. The reference electrode is clipped on lower end of left ear. Now each participant was asked to perform different behavioral task like locating objects which their place was interchanged from earlier. The acquired bio potential is amplified using bioamplifer and smoothed using filters. The resultant frequency characteristics of experimental analysis are compared with the ratings given by participant for subjective analysis.

Observation

As expected, It is observed that the increment in the frontal region frequency when the subject apply more mental activity. In this experimental task, subject applied more mental activity in order to approximate the location of the object in the poor light levels. The response frequency of the mental activity done by the subject is in the range of 12-25 Hz, which falls in to the range of Beta frequency. The state of occurrence of Beta activity in the frontal region shows up when subject applies more mental activity to perform the task. This observation brings out that subject goes into the problem solving mentality which result in increase in the frontal frequency. Here, on the observation of all the participants with good health and in normal mental condition. The low luminance condition alters the behavioral task and the frontal brain activity. This assessment can also use to test the subjects electroencephalographic Beta rhythm. Deficiency of Beta activity in the subject to perform any task results in lack of concentration and problem solving. Extreme Beta activity may results in sleep disorders.

Discussion

After completing the hypothetical examination in the laboratory, each participant is asked to give the rating for mental ability or stress applied to do any behavioral task in the darkness condition. It is a rating from point 1 to 5. Where rating 1 indicates the very less mental ability and rating 5 indicates subject applies high mental ability or stress to perform such behavioral task. Many of the subjects feel to apply more mental ability to do any behavioral task with 3-5 rating. If 4 and 5 rating shows requirement of high mental application, 76% of the participants feels to apply high mental activeness to do any behavioral task in darkness. From this outcome of subjective analysis, it can be stated that the subject feel to apply high mental activity to perform any behavioral task in darkness condition. When comparing the results of subjective analysis with the electroencephalographic rhythm in frontal region, we found similar characteristics between subjective and experimental analysis. The graphical representation of a subjective analysis is given in below Fig. 5.

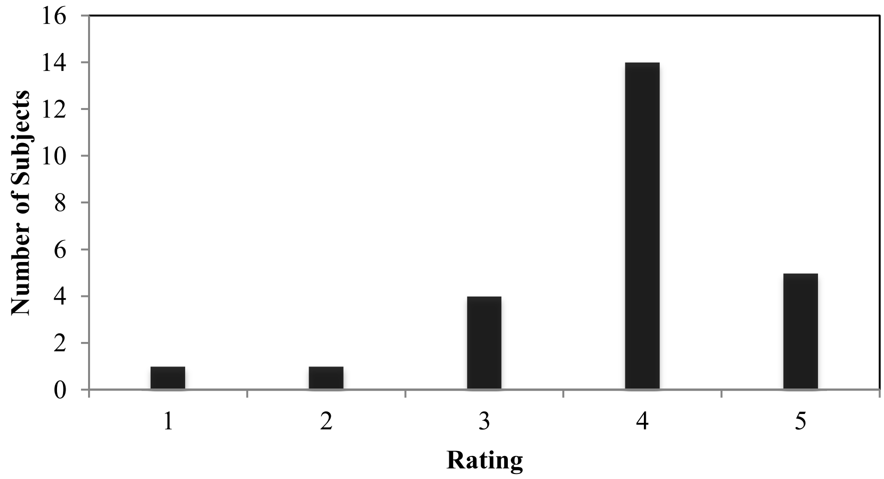

Fig. 5. Graphical representation of ratings given by the number of subjects to do any behavioral task in darkness

On correlating the experimental outcome with the subjective analysis, the frame of mentality of the subject on performing any task is replicated as characteristics of the frontal frequency. As subject feels more stress and complicated to perform any task in the darkness than in luminance condition. If the subject does not exhibit such frequency characteristics while performing any behavioral task in low luminance is considered as abnormal frequency rhythm. Abnormalities like sleep disorders and poor concentration can be evaluated. The subject who exhibits abnormal characteristics may call for the diagnosis by the physician. Different case studies are observed on performing different tasks to study the neural behaviour in darkness or low luminance condition.

Conclusion

As the light alters the various physiological variables, it also alters the spectral rhythm of various regions of the brain. The illumination conditions caused by the luminous objects in the EEG recording room bring enormous changes in human physiology and brain activity. An increment in the illumination level leads to inhibition of melatonin hormone, which increases the subjective alertness and reduction in incidence of slow eye movements. It also affects the brain activity by suppressing the EEG power density of 5-9Hz which increases in subjective alertness. Blocking Alpha frequency in the occipital region is another change due to increment in light levels. Improper lighting conditions also bring unusual results in neural behavior which can be misjudged by the physician and call subject for diagnosis. The study on Melatonin hormone analysis with effect of light brought various physiological changes are brought onto the screen. Characteristics of Blink artifact are also altered due to addition of visually evoked potential results in change of amplitude and latency. The novel hypothesis observation verified using experimental and subjective analysis. The behavioral task performed in darkness results in increase of frequency in the frontal region. From this it is to be known that no luminance or darkness condition affects both the behavioral task and brain electrical activity.

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