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EFFECT OF BRIGHT LIGHT ON EEG OCULAR ARTIFACTS

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Abstract

The Electroencephalogram (EEG) reflects electrical functionality of the brain as an advanced medical spectroscopy tool. EEG derives potential from the scalp electrodes, which occurs because of the neuronal firing. It records the strength of neuron firing in relation to time. Generally, the potential of EEG readings are observed to be in the order of microvolt seems as low amplitude and are highly prone to contamination of artifacts from other induced bioelectrical sources exhibited by nearer human organs such as the eye, etc. On precise statistical data analytics study on artifacts contaminating in EEG, it has been found that artifacts contaminating from Ocular organ into EEG has noticeable impact. It is also observed that light plays a vital role in defining amount of ocular artifact contaminating into EEG. This article synchronizes variables of light, ocular organ with EEG and through the statistical 'Z' test. Based on the calculated 'P' value comparing with 95% of level of Significance (α), confirms the alternate hypothesis that illumination in the EEG recording room also affect ocular artifacts. This is presented along with mathematical model and experimental analysis.

Keywords*: Electroencephalogram (EEG), Ocular Artifacts, Light*

I. Introduction

Electroencephalogram is the physician recommended method for evaluating and recording brain electrical behavior. The human brain comprises of millions of neurons, and the electrical potential of this neuron is induced over the scalp at respective regions. Light is a transverse and electromagnetic wave, which human beings experience through sight. There are different physiological modifications in individuals when they are subjected to bright light [1,2,4]. However, light exposure causes natural physiological changes such as melatonin hormone suppression and the variation in core body temperature. The visible light into the human eyes causes the state of electroencephalographic measurements to change [3-11,14].

Ocular artifacts happen as a result of the superimposition of the ocular potential on the actual electric activity in the brain. The sort of motion performed by the eye of the subject and even the blink of the optic can illustrate this. In practice with ocular artifact, electrodes around the Ocular organ, such as the Front Polar (Fp) and Frontal (F) are mainly impacted. The eye functions as a dipole in which the retina is charged more negatively than the cornea. The possible distinction from the cornea to the retina is approximately 100 mV [11,16]. The ocular artifact in contaminated EEG signal is extracted using EEGLAB toolbox for MATLAB is shown in Fig. 1.

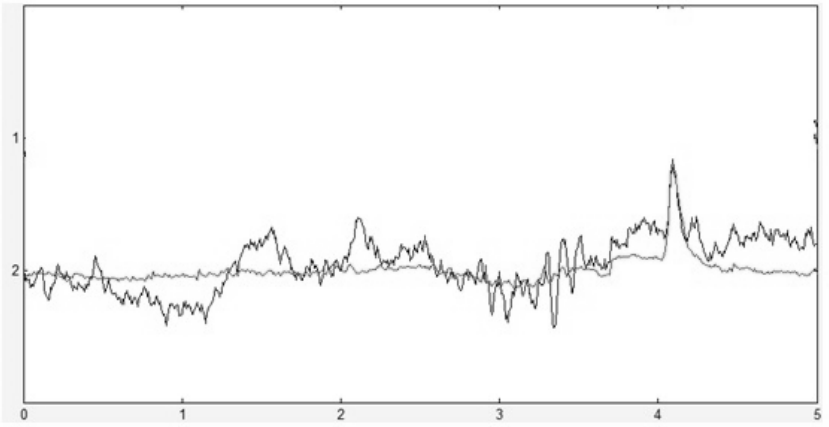

Fig.1. Occurrence of Peak in EEG signal due to contamination of EOG

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It is observed that, the potential of the ocular artifact is induced to the nearest electrode of the eye region when the eyeball moves vertically upwards. When the eyeball moves down, the charge of the retina is induced to the electrodes. The potential varies from left to right of the hemisphere for horizontal motions of the eye [11]. The odd numbered electrodes in International 10-20 standard placement get more induced when eyeball turns to the left. Even numbered electrodes are impacted with ocular artifact when eye ball shift to right side. To some extent, the ocular objects are recognizable. Motions on the horizontal, vertical and radial eyes generate rectangular EOG shapes, while blinks on the eyes generate spike-like shapes. These prospective signals overlap the EEG recording, making analyzing and interpreting electrical brain activity difficult [9,11,15].

To remove ocular artifacts in the EEG signal and make it physician friendly, various algorithms were proposed. But, every algorithm has its own merits and demerits. Still the research goes on and leads way to propose various hybrid algorithms using soft computing and machine learning to eliminate artifacts and achieve clean EEG [7]. Some of the important algorithms existing in the literature and its advances and disclosures are tabulated below in Table I.

Table I Advances And Drawbacks Of Artifact Removal Algorithms

Algorithm	Drawbacks	Advances
Eye fixation method.	EEG Readings will be altered in other Brain regions	Cannot contaminate major artifacts of the eye
EOG Rejection	Brain data is severely lost	Artifacts that are noticeable can be Rejected
Regression	Proper EOG is required as a reference	In specific, the contamination of the ocular artifact in EEG is known
PCA	Artifact correction cannot be performed if the artifact and brain signal have comparable amplitude	Key components can be readily divided
ICA	In order to identify autonomous parts to be removed, visual inspection is necessary	The underlying artifact can also be removed.
Wavelet Transform	Scaling parameters are a critical job to identify	Artifact can be recognized on multiple scales
Soft Computing	Proper EOG contaminated dataset required to estimate artifacts	Artifacts can be identified precisely on large dataset

II. Experimental Procedure

The experiment was conducted in a laboratory on 104 subjects where a room temperature is maintained in recording room. The experiment carried out with the guidelines given by the EEG and neurological societies. To study the characteristics of ocular artifacts, electrodes are configured near around ocular region i.e. front polar and frontal regions of International 10-20 standard on the scalp. Now each subject was asked to perform an episode of blink voluntarily without regular time interval. The average of the seven peaks of blink amplitude are calculated and tabulated. This experimental procedure is carried out in enough light that subject can perform any behavioral task. The same experiment on every subject is repeated in darkness sustained in the EEG recording room. The amplitude of blink episode for every subject is tabulated as V_1 and V_2 for amplitude peak in light and amplitude peak in darkness conditions respectively. TABLE II amplitude of blink ocular artifacts at standard light conditions (V_1) and darkness (V_2)

S	Age	Gender	V1	V2
1	27	Male	51.3	48.3
2	23	Male	46.2	45.1
3	27	Male	47.	45.
			8	3
4	25	Male	41.2	39.8
5	29	Male	39.9	37.7
6	30	Female	52.6	52.8
7	30	Female	52.8	51.3
8	20	Female	47.3	45.8
9	44	Male	46.7	45.4
10	41	Male	44.	43.

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			3	2
11	40	Female	45.2	45.9
12	21	Female	47.8	47.3
13	28	Female	53.9	52.1
14	48	Female	56.7	55.3
15	31	Female	55.3	53.4
16	30	Female	48.9	47.5
17	36	Male	51.6	47.9
18	45	Female	53.9	51.4
19	51	Female	52.6	50.3
20	23	Male	49.2	47.2
21	52	Male	51.3	48.9
22	39	Female	49.6	47.8
23	34	Female	51.8	48.4
24	40	Male	48.4	49.1
25	28	Male	51.3	50.4
26	33	Male	46.2	43.4
27	29	Female	42.6	40.1
28	34	Female	51.8	48.2
29	58	Female	39.7	39.4
30	30	Female	46.8	47.1
31	27	Female	43.5	44.8
32	53	Male	51.3	50.9
33	28	Female	39.9	42.1
34	41	Male	54.3	51.1
35	27	Female	48.2	47.6
36	34	Male	41.8	40.8
37	29	Male	50.1	48.3
38	46	Female	48.3	46.8
39	34	Female	44.6	42.7
40	25	Male	48.2	46.8
41	36	Male	46.7	47.1
42	28	Female	50.4	49.1
43	42	Female	48.6	46.2
44	31	Male	43.7	41.8
45	26	Male	45.2	46.1
46	29	Female	42.8	42.1
47	45	Male	42.8	43.7
48	43	Male	52.7	48.3
49	27	Female	42.8	41.2
50	34	Female	54.3	49.6
51	29	Male	48.5	50.4
52	41	Male	54.2	51.6
53	43	Male	42.8	41.2
54	28	Male	49.1	46.8
55	38	Male	52.8	50.3
56	34	Male	43.1	42.8
57	36	Male	46.7	44.1
58	27	Male	44.3	43.1
59	31	Male	45.1	46.8
60	26	Male	39.9	40.6
61	26	Male	41.5	40.2
62	34	Female	38.4	37.1
63	31	Female	45.1	45.1
64	43	Male	43.8	40.9
65	28	Male	50.4	48.2
66	26	Male	45.8	41
67	45	Male	43	41.3
68	41	Male	42.7	40.1
69	27	Female	49.6	46.8
70	34	Male	42.5	41.1
71	30	Male	47.5	47
72	24	Female	42.9	42.1
73	33	Male	51.2	48.3
74	27	Male	43.8	42.1
75	46	Male	42.1	41.8
76	31	Male	48.6	46.7
77	29	Male	42.5	41
78	37	Female	47.1	47.4
79	42	Female	43.2	43
80	40	Female	51.2	50.4
81	46	Male	43.6	41.8
82	48	Male	44.8	42.1
83	29	Male	47.2	46.2
84	27	Male	39.4	38.4
85	20	Male	42.8	41
86	26	Female	46.8	44.2
87	28	Female	51.7	48.1
88	24	Male	45.7	42.2
89	43	Male	48.2	46

90	37	Male	49.8	47.9
91	50	Male	50.7	51
92	27	Male	51.2	50.1
93	29	Female	49.7	50.4
94	27	Male	49.1	48.2

95	41	Male	42.1	41
96	28	Male	46.8	45.1
97	31	Female	51.3	49.3
98	29	Male	53.2	51.8
99	29	Male	51.4	49.7

100	36	Male	47.1	45.8
101	24	Male	42.8	41.1
102	28	Female	38.9	37.1
103	27	Male	42.1	40.8
104	25	Male	48.7	47.1

Observations

As expected, it has been observed that the effect of light on EEG ocular artifacts is much more noticeable. For the same subject, the amplitude of the blink ocular artifact taken in standard light seems to be more compared to the amplitude of blink ocular artifact episode in darkness. It is also can be assumed that amplitude of the EEG ocular artifacts is proportional to the light in the EEG recording room.

III. Mathematical Model

The unwanted biological potency of the eye along with the potential of the Neuro behavior is ocular artifact. A perceptible variation in recordings of EEG is originated by the ocular blink or ocular movements. These episodes are unintended or voluntarily caused from the subject. Here ocular organ artifacts are considered a leader of all EEG contaminated artifacts because the region of the ocular organs is quite close to the frontal region for the acquisition of EEG. The ocular potential is induced around ocular region because the eye operates like a dipole. In this ocular organ dipole, cornea is positively charged and retina is negatively charged. The episode of blink occurs when the cornea is covered with the eyelid and goes back. The potential of this episode's positively charged cornea is taken up by the eyelid, imposed on close-by frontal EEG electrodes around the Ocular region. This process of contamination and light impact on ocular artifacts is given in below equations.

$$Contaminated\ EEG = True\ EEG + Ocular\ Artifact + L_q \quad \text{Eq.1}$$

$$L_q = Charge\ induced\ on\ Cornea\ due\ to\ light\ through\ Ocular\ Artifact$$

It is therefore interesting to observe that the different light levels also affect the ocular artifacts. In accordance with above experiment, increase in peak amplitude of the artifact when the subject is exposed to lighting i.e., EEG acquired in presence of luminous objects (light source) in the EEG recording room. During subject experiencing light, charge by the external light source is added to the potential of the artifact. This makes increment in the charge added to EEG recordings as Ocular artifact.

$$Ocular\ Artifact\ Potential\ (OA) = Ocular\ Dipole\ Potential\ + L_q \quad \text{Eq.2}$$

The electrical field from cornea-retina ocular dipole induced by the electrode can be determined through the correlation between fundamental electrostatic physics and ocular organ dipole, given as

$$V_{Dipole} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_c}{r_c} - \frac{q_r}{r_r}\right] \quad \text{Eq.3}$$

Where q_c and q_r are corneal and ocular dipole retina charges and r_c and r_r are the distance between poles of dipole and the electrode.

V_{OA} can be used to specify the total ocular artifact potential and the visually induced potential at the closest frontier.

$$V_{OcularArtifact} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_c}{r_c} - \frac{q_r}{r_r}\right] + L_q \quad \text{Eq.4}$$

When potential from artifact is amplified by the bright light and added with the potential accumulated from brain, this collective voltage induces across the electrode will be given as $V_{Electrode}$

$$V_{Electrode} = V_{Neuro\ Potential} + V_{Dipole} + L_q \quad \text{Eq.5}$$

$$V_{Electrode} = V_{Neuro\ Potential} + V_{Ocular\ Artifact} \quad \text{Eq.6}$$

The potential evoked visually varied because of several factors, such as age, gender, acuity of vision, pupil size, etc. Potential evoked visually alters the wave's amplitude and latency. Latency increases as the subject's age increases. This occurs because of visual acuity is reduced with increase in age.

IV. Hypothetical study

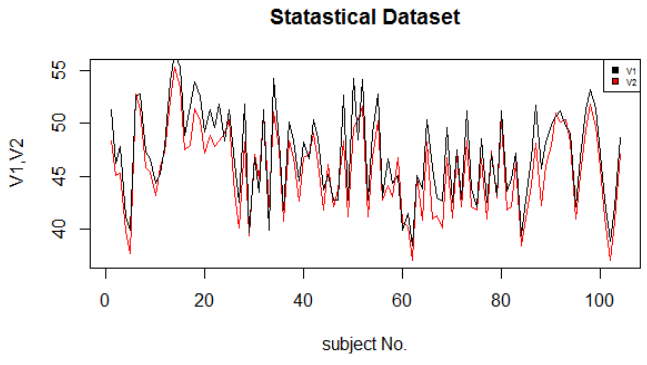
It is a hypothesis that there is a variation in amplitude of ocular artifacts with respect to light conditions in the EEG recording room. This hypothesis has been analyzed by conducting experimental analysis and creating dataset of amplitude voltages of Blink episode at different light conditions in EEG recording room.

H_0: There is no variation in the amplitude of the Ocular artifact with respect to light

H_1: There is a variation in the amplitude of the Ocular artifact with respect to light

TABLE III Summary of V1 and V2

Parameters	**V_1**	**V_2**
Min. Value	38.40	37.10
1st Qu.	43.17	42.10
Median	47.15	46.20
Mean	47.11	45.66
3rd Qu.	50.83	48.30
Max. Value	56.70	55.30
Standard deviation	±4.287	±4.051



To have concrete evidence that ocular artifacts in light conditions have high amplitude than the blinks occurred in darkness, null hypothesis is compared with alternate hypothesis. The statistical parameters of V2 are compared with the V1and tests whether the amplitude in darkness is decreased, so its results to left tail test as to check statistically V2<V1 are not with the defined hull and alternate hypothesis. This execute with level of significance (α) of 0.05.

Test statistic is calculated from the summarized data given in table II by given equation

$$Z = \frac{\bar{x} - \mu}{\frac{\sigma}{\sqrt{n}}}$$

The Z score is resulted as -3.45. Based on the obtained Z score, P value determined with Z table represents area to the left as P=0.00028. Now, this P value is compared to the level of significance (α) = 0.05. This gives enough evidence to draw conclusion on the hypothesis that $P \leq \alpha$ which makes to reject the null hypothesis and accept the alternate hypothesis and accepting the variation in the EEG ocular artifacts in different light conditions.

Analysis

On observation, there is a variation in amplitude (V_1 and V_2) of blink ocular artifact in light and darkness. There are some cases that V2 >V1 and V2=V1. To have some concrete decision on variation in the amplitude due to light impact on ocular organ hypothetical analysis is carried out. This helps to reject the null hypothesis and start accepting the alternate hypothesis or to fail to reject the null hypothesis and variation can be totally ignored. Statistical 'Z' test is conducted on V2 Versus V1 of Table II.

V. Conclusion

Light brings various alterations in the neuronal behavior in turn reflected in Electroencephalographic readings. Although Ocular artifacts are treated to be unwanted with respective to EEG, these artifacts give proportional information about the light experiencing by the subject. This has been verified by creating dataset of experimental analysis carried on 104 subjects following the guidelines of EEG societies. This is intended to caution and make watchfulness Neuro physicians, EEG practitioners and researchers to involve light as a prime parameter that bring variations in EEG recordings which is prone to misinterpretation and lead to wrong diagnosis. Ocular artifacts especially blink episode at various light conditions gives prominent synchronization between light, eye and brain.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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