THEORY AND DEVELOPMENT OF THE ELECTROENCEPHALOGRAPHIC ALPHA WAVE

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The purpose of this paper was to investigate the use of the electroencephalographic occipital alpha wave for optometric analysis. Exploration of the theory and relevant literature was combined with firsthand recording and analysis of the alpha wave.

THEORY:

There are millions of nerve cells making up the occipital cortex for the purpose of visual analysis. The neurological activity of one single neuron would seem impossible to measure from scalp electrodes. When scalp electrodes are used the activity detected is the summed electrical potential difference change of thousands if not millions of neurons discharging simultaneously. The more neurons that discharge at the same time the higher the voltage is for the scalp electrodes. If the cells were to be firing but in a completely random fashion then the potential difference as noted by scalp electrodes would be a constant with no wave features. Waveforms are generated if neural cells fire in some type of non-random harmony.

When electrodes are attached to the scalp with a bipolar arrangement the potential difference is measured between the two points. A third electrode should be attached at an earlobe or on the forehead to act as a ground. The ground-lead helps the recording device to ignore "noise" that doesn't originate from in between the two electrodes.

The placement of the electrodes depends upon the physical areas of the brain that are to be recorded. With certain types of electroencephalography as many as 16 or 32 electrodes may be used in order to evaluate the function of the brain and then be able to locate abnormal signals or lesions.

The electroencephalogram (EEG) uses many electrodes for recording multiple bipolar readings and then locations of abnormalities are determined by evaluating the matrix of normal versus abnormal vectors. With multiple lead recordings the physiograph can compare the electrical potential between any two electrode lead locations and therefore consider the underlying neural activity between the two locations in question.

To test the occipital cortex the surface electrodes need to be placed so that the occipital area underlies the scalp area between the recording electrodes. One method of locally recording the occipital area is to place the two electrodes approximately five centimeters to the left and right of a point 25 millimeters above the inion. The ground can be placed on an earlobe or the forehead.

When evaluating brainwave recordings it is very difficult to sort out meaningful data. As Dr. Donald Scott has written "artifacts are usually the most obvious characteristic of the tracings.[8]" Various artefacts that can be encountered with brainwave recording will be shown later.

Analysis of the EEG shouldn't be over-simplified. All the neural activity of the brain is summed and recorded into the EEG. Besides the occipital alpha wave at 8-13 hertz, there exists beta waves at 14-28 hertz originating from parietal and frontal areas. Theta waves (4-7 hertz) originate from parietal and frontal areas. The different waves often exist in unison along with any noise picked up from muscle activity.

When one surveys the vast amount of literature involving brainwaves especially the alpha wave there exist dozens of viewpoints of how and why the brainwaves exist as they do.

Often the individual researcher has expressed specific brainwaves to fit a model as it relates to his own speciality interest. Therefore when theories of the brain are made care must be taken to realize the multiplicity of inputs and influences to brain physiology.

Dr. William Ludlam has been a leading proponant for the value of alpha wave research.[3] He believes that the neurological-physiological changes associated with visual training can be observed by means of electronics and the electroencephalogram.

Dr. Ludlam believes that suppression of the occ occipital alpha wave represents attention to a visual stimulus. In order for a person to "attend" efficiently to a situation he would have to suppress his alpha wave. Ludlam used a classification system as established by Walter to describe individual alpha responces. The "R" (responsive) group has alpha suppression when their eyes are open in comparison to when their eyes are closed. The "P" (persistant) group tends not to suppress the alpha waves when their eyes were open and reportedly are dependant more upon auditory, kinesthetic or tactile stimuli rather than visual perception. The "M" (minus) group has no significant alpha wave pattern and appears heavily dependant upon visual imagery.

There are many sensory inputs to the human brain and different methods by which the brain can cope with these inputs. Obviously visual and auditory inputs are major componants of sensory information. There are also inherant individual behaviors of the human brain as explained by neural pathways or psychology that determine such things as arrousal states, information processing and attention.

Computer averaging allows the recording of brain waves but excludes brain noise that is not time-linked to the sensory stimulus. The visual evoked responce is the computer averaged brain responce time-linked to a changing visual stimulus. The visual evoked responce (VER) is an excellent tool for evaluation of the visual pathway but is limited in use currently to the stimulus for brain changes originating from television screens or lights being flashed. The EEG can be used to supply information of visual processing without averaging out the information not time-linked to the visual stimulus and allowing for more stimulus options than a flashing checkerboard pattern. The human alpha wave can provide information concerning the development and physiology of the occipital cortex.

DEVELOPMENT OF THE ALPHA WAVE:

Novikova with his extensive studies of the electroencephalogram (Blindness and the Electrical Activity of the Brain: Electroencephalographic Studies of the Effects of Sensory Impairment) has contributed a wealth of knowledge concerning alpha waves.[7] With the use of the centralized computer medical records within the Soviet Union, Novikova selected hundreds of patients with particular visual anomalies. He was able to select patients in consideration of the type and extent of visual loss, the etiology of the loss and the age at which the visual loss occurred. Electroencephalograms were taken of the selected patients using sophisticated sixteen lead recorders. From his studies the neurological-physiological development of the alpha wave is better understood.

In patients congenitally blind and without experience of visual stimulation no occipital alpha activity was found. Novikova states that he hasn't found occipital alpha waves in one single case of blindness since birth.

If the patient had normal vision up to the age of one to three years before an onset of blindness the occipital alpha wave appears within normal limits in respect to amplitude and frequency. Even if the vision loss occurred decades previously the alpha wave appeared within normal limits for these subjects. The first year appears critical for the development of normal alpha activity.

Alpha wave development was found dependant upon the extent of form vision attained during the first year of life. If only light perception was present since birth then occipital alpha rhythm was rarely if ever present. For visual acuities of 20/2000 to 20/500, occipital alpha activity was found in 38% of the subjects. For visual acuities of 20/400 to 20/200, occipital alpha rhythm was found in 50% of the patients. For visual acuities better than 20/200 attained within the first year of life the alpha wave usually was within normal limits. Those people that had some degree of occipital alpha rhythm with reduced form perception often had decreased amplitudes and frequencies of their alpha rhythm.

The alpha wave development of the electroencephalogram is a milestone in neural development dependant upon form vision within the critical period of the first year of post-natal life. Good visual acuity helps maximize the occipital neural development. Good visual acuity was statistically correlated with increased amplitudes and frequencies of resting alpha wave levels in a study of hundreds of subjects.[7]

Alpha waves by definition are brain waves of the EEG within the frequency range of eight to thirteen hertz. The alpha waves originating from the occipital cortex are of interest in relation to vision. During the first several years of life the brain waves that eventually evolve into the occipital alpha pattern only have a frequency of five to seven hertz.

As the normal infant neurologically develops the occipital wave pattern increases in frequency from the range of five to seven hertz to the normal range of eight to 13 hertz. Adult occipital alpha waves usually have a frequency of ten hertz.

Subjects blind since birth tend to develop an alpha wave rhythm but the origin of the waves are found to be from the area of Rolando's Fissure of the central cortex. These waves from a non-occipital origin but within the frequency range of an alpha definition are termed Rolandic Rhythms. Rolandic Rhythm is rarely found in sighted people but is common in people without form vision since birth. Rolandic Alpha Rhythms closely match occipital alpha rhythm in frequency and shape but are said to be more spindle shaped.

Changes of Rolandic Rhythm Alpha seem maximally sensitive to tactile and proprioceptive stimuli. As stated, Rolandic Rhythm is rare in sighted people but common in people without form vision and therefore could be a neural adaptation or alternate development pattern for the blind. Probably Rolandic Alpha Rhythm represents an increased utilization of the sense of touch and hearing since the brain is unable to use form vision.

When the onset of blindness occurs after the critical period of one to three years, in most cases the alpha wave characteristics were't significantly different in amplitude or frequency from those waves in sighted people. The neural system had developed previous to the loss of vision and the neural development was reflected by the occipital alpha wave.

Zsubek,Weber and Saunders 7 through a careful study found a decrease in occipital alpha rhythm of one to one and a half hertz after two weeks of decreased visual stimulation by wearing dark sunlenses.

Granit's Theory stated that retinal activity provides neural support for cortical tone especially in the occipital area. Hubel and Weisel anatomically examined cat brains void of visual experience.[4] Those brains without previous visual stimulation showed decreased physical development in the occipital area and that occipital cortex development is dependant upon visual input.

In several cases of congenital onset homonymous hemianopsias, alpha wave activity was generated from only one side of the occipital cortex.[7] The cause of the hemianopsias was due to a lesion just posterior to the optic chiasm. One side of the occipital cortex developed vision and a typical alpha wave pattern but the other hemisphere deprived of visual input never developed an occipital alpha wave pattern.

Lippold believed that the cortical alpha wave was generated by the tremors of the extraocular muscles.[8] It is true that noise from the extraocular muscles can be recorded on the EEG. Saccades are recorded as large jumps. Electrical activity does originate from the firing of the ocular muscles and the comparitively weaker signal of the moving retinal dipole which is also recorded on the electro-oculogram (EOG).

The alpha wave however is not strictly noise from the EOG or extraocular muscles because patients having bilateral enucleation still have an alpha wave.[7] Without the globes there would be no EOG potential and the extraocular muscles should be without stimuli for pursuits and fixations. The alpha wave however exists after bilateral enucleation.

Noise from the tremors of the extraocular muscles as found on the EEG shouldn't be confused with alpha rhythm because the frequency of the muscle tremors is between 30 and 70 hertz compared to the eight to thirteen hertz frequency of alpha waves.

The occipital alpha wave seems to be a recording of the physiological activity of the occipital neurons. In order for normal occipital alpha activity to develop good visual acuity is necessary during the critical period from birth to age one to three. Cohen has argued that alpha rhythm will develop if blindness occurs after three months of sight after birth.[7] Occipital alpha waves represent a milestone of neural development for normal brain and vision function.

ALPHA WAVE SUPPRESSION:

Occipital alpha wave suppression has been associated with fluctuations of neural activity but with dozens of different and non-encompassing explanations. An attempt will be made to explain the significance of alpha waves in consideration of the vast experimentation done but with the humility that we don't know all the answers yet.

Studies by Novikova[7] show that good form visual acuity is needed in the first several years of life to develop a normal resting alpha pattern. In order for alpha wave suppression to occur there first must be the [illegible] developmental milestone of the wave pattern. The wave pattern must first be established before neural activity can suppress the waves.

There are no occipital alpha wave patterns during sleep. However Berger, Adrian, and Matthews as well as firsthand recordings show that the alpha wave is enhanced with the subject's eyes being closed but not asleep. When the eyes are closed it depends on the state of [illegible] consciousness (asleep or awake) if the alpha wave will be generated.

Scott found that a patient will suppress alpha activity if conditioned to expect an imminent stimulus.[8] Suppression of the alpha pattern was conditioned by the expectation with subtle auditory clues for a visual stimulus following several seconds later. It follows that the alpha wave is suppressed when the brain readies itself to recieve visual information.

Martinius and Hoovey found that alpha waves were enhanced when a group of normal children performed auditory discrimination tasks with their eyes closed.[3] Perhaps this represents a shift away from visual attention to auditory attention and therefore a resting of the occipital cortex with resulting alpha wave enhancement.

The brain must first have good form visual acuity for one to three years after birth for the normal occipital alpha pattern to form. The alpha wave then represents a milestone of development showing that the visual occipital cortex had reached a certain level of visual processing physiology. Only after the occipital alpha wave is developed can it be suppressed.

Fluctuation between alpha wave enhancement and alpha wave suppression represents a facility of the occipital brain tissue from relative rest to attention. The large alpha waves present when the mind is at rest and the eyes are closed reflect relative inactivity of the visual processing centers. When the eyes are open and the brain attentive the alpha wave should be suppressed. The wave characteristics readily fluctuate from second to second but with averaging the trends reveal themselves.

Alpha wave suppression doesn't necessarily reflect the visual input into the occipital cortex or the actual neural processing of the occipital cortex. The suppression of the alpha wave is probably from central cortex control.

The alpha wave varies in respect to attention and perception with control from central cortical areas, perhaps the reticular activating system. Central processes determine whether alpha waves are suppressed or not.

This explains why researchers have correlated changes in alpha wave levels with hundreds of different factors such as tactile stimuli, auditory stimuli and the attention state. One researcher[9] even claims that biofeedback techniques to induce alpha activity can eliminate headaches, allergies, asthma, over-eating, smoking, drinking, tension, anxiety and even improve the sex life. But the alpha wave represents in these varied claims only an indicator of the workings of the more central cortex. How could visual processing cells contribute to a drinking problem?

Many researchers have probably investigated the alpha wave because it is the easiest brain wave to record. The alpha wave is usually noted as the most powerful and dominating of the brainwaves in the conscious state. The relatively powerful alpha wave is found to fluctuate in correlation with many different variables. Variables that affect the alpha wave include information from all five senses and the attentive receptability to the stimuli. Alpha suppression seems to be an indicator of underlying central processes of attention and perception.

Greg Walter theorized that the alpha wave represents a perceptual gating mechanism.[3] The gating mechanism was to scan input and represent an analog for the psychological process of attention.

Adrian theorized that the alpha wave actually is the rhythmical discharge of resting cortical neurons.[3] The alpha wave is to be present when the cortex is at rest and not recieving an input of patterned visual stimulus.

Glass set up an experimental design comparing the calculation performance to alpha status.[3] High motivation and good performance was associated with a relatively intense blocking of alpha waves. Inefficient blocking of alpha waves was correlated with increased calculation error. The finding that increased concentration is correlated with alpha wave suppression is accepted in other literature findings.

Gaarder, Koresko and Kropfl found a correlation between the phase phase of the alpha rhythm to the onset of ocular saccades.[3] Their conclusion was that either the alpha rhythm paces saccades and or that both saccades and the alpha wave are paced by something else.

Callaway and Yeager found a relationship between the phase of the alpha wave and the time interval before the visual sensory system could react to a stimulus.[3]

Kahneman and Norman found the interval of temporal summation of Bloch's Law to be 100 milliseconds.[4] One-hundred milliseconds is also the time for a ten hertz (alpha) wave. Possibly as Walter speculated, occipital alpha wave activity reflects the perceptual "gating mechanism." Possibly occipital visual neurons are able to summate visual stimuli over time intervals of one-hundred milliseconds before the ten hertz rhythmic en-masse cellular discharge that produces the alpha wave.

Mulholland, Evans and Peper have recorded the alpha wave in relationship to oculomotor functions.[3] They note that accommodation, vergence, fixation, pursuit and saccade eye movements are found in conjunction with alpha suppression. Their evidence suggested that attention of the subject was reflected in oculomotor functions as well as alpha wave suppression.

A young child often holds his reading material very close to his eyes and uses high amounts of accommodation and convergence. Perhaps he uses the near visual demands to help attend to the material and at the same time suppress the alpha wave. More research needs to be done but it seems that the alpha wave is an indicator of central cortex processing.

Ludlam places great emphasis upon the occipital alpha wave to document learning problems and visual training.[3] He believes that with further research visual training will be justified and scientifically backed by improvement in the level of alpha wave suppression. He found learning disabled subjects to be unable to to suppress their alpha wave activity.

Alpha waves represent a promising avenue for biofeedback therapy. Like other signs such as pulse rate, respiration rate or muscle tension, the alpha wave can be used to monitor physical stress. An awareness of these signs can be used as a feedback tool to help control them.

A current trend of popular psychology has emphasized the use of meditation to enhance the alpha wave. Zen Buddism, Transcendental Meditation and other groups which teach meditation to help reduce stress have found that the alpha waves become enhanced. Some authors have preached the use of meditation for the primary purpose of enhancing alpha waves.

There is a confusion whether the alpha wave should be suppressed or enhanced. Meditation experts preach the value of alpha wave enhancement and relaxation from stress. Educators may be more concerned that a learning disabled student has difficulty suppressing his alpha wave. The ideal situation appears that a person should have a degree of alpha facility.

Assuming that the alpha wave changes reflect fluctuations in attention it is desirable that a person be able to relax (alpha enhancement) or concentrate his attention (alpha suppression); whichever is appropriate. Alpha facility from suppression to enhancement and back again seems to be a desirable ability.

The presence of occipital alpha waves represents a neurological milestone of development that usually occurs one to three years after birth presuming good form visual acuity. The occipital alpha waves are enhanced during periods of cortical rest and when the eyes are closed. Alpha wave suppression usually occurs when the eyes are open and moreso when attention processes are aroused. Alpha waves represent an indicator of cortical attention processes and all the different sensations, emotions and motivations that can influence cortical activity.

OCCIPITAL ALPHA WAVE SUPPRESSION:

PURPOSE:

Recordings were taken of the occipital alpha wave to gain experience in the mechanics of measuring the alpha wave, to test theories stated in the literature and to gain insight into the physiology of the alpha wave function.

THEORY:

The occipital alpha wave is generated from neural activity of the visual cortex. Good visual acuity must be present for the first several years of post-natal life in order for occipital alpha waves to develop. After the neurological milestone of alpha wave pattern is established alpha wave suppression and enhancement reflect a complex relationship of cortical relaxation versus attention. Sensory input or anticipation of stimuli tends to suppress alpha wave activity and reflect central cortical processes of attention. Alpha wave enhancement is found with cortical relaxation or when the eyes are closed.

EXPERIMENTAL DESIGN:

Variables were chosen that have been found to correlate with alpha wave changes. Testing situations were planned so that only the variable was changed and the other factors were constant. In each situation the two recordings compared were taken one after another with the same subject, instrumentation, recording sensitivity and control factors.

The recordings were made using bipolar techniques on a physiograph. One electrode was placed approximately two and a half centimeters laterally on each side of a point twenty-five millimeters above the inion. The ground lead was placed on the earlobe.

To analyze the wave patterns, one hundred successive waves were recorded and measured as to relative amplitude. A millimeter rule was used to measure the amplitudes. Statistical analysis was done on a hundred consecutive amplitudes to compare the two recordings in respect to the experimental variable. The measuring of amplitudes is a crude method to analyze brain waves but hopefully shows the subtle trends of wave characteristics.

DATA:

Situation I.

The subject is seated comfortably. Steady Fixation.
Instruction to subject-

	"Add the odd integers from one to twenty."	"Relax."
mean amplitude	4.93	6.10
standard deviation of amplitudes	2.53	2.68
variance	6.33	7.15

A 19% suppression of alpha amplitude was found with a calculation task.

Situation II.

The subject is seated comfortably.
Instuction to subject-

	"Close your eyes."	"Open your eyes."
mean amplitude	16.1	6.72
standard deviation of amplitudes	4.39	2.78
variance	19.0	7.56

A 58% suppression of alpha amplitude was found when the patient was told to open his eyes.

Situation III.

The subject is seated comfortably, and a ganzfeld stimulus is presented to both eyes.

Instruction to subject-

	"Open eyes" (observation of ganzfeld)	"Close eyes"
mean amplitude	10.8	14.0
standard deviation of amplitudes	5.13	4.16
variance	26.1	17.2

A 22.5% suppression of alpha wave amplitude was found with the eyes open and visualizing a gansfeld.

Situation IV.

The subject is seated comfortably and the eyes are open.

Instruction to subject-

	"Fixate at distance"	"Fixate at near" (40cm)
mean amplitude	8.35	5.84
standard deviation of amplitudes	5.76	8.81
variance	32.9	76.9

A 30% suppression of alpha wave amplitudes was found when the subject fixated at forty centimeters versus five meters.

CONCLUSION:

The findings from experimentation agree with the theories of alpha wave physiology. The alpha wave is usually suppressed when the eyes are open. Mental concentration and oculomotor functions tend to suppress the alpha wave.

The method of analyzing amplitudes is a crude method. The use of Fourier Analysis would take amplitude, frequency and waveshapes into consideration. Hopefully research will continue with insight and the aid of sophisticated computerized instrumentation.

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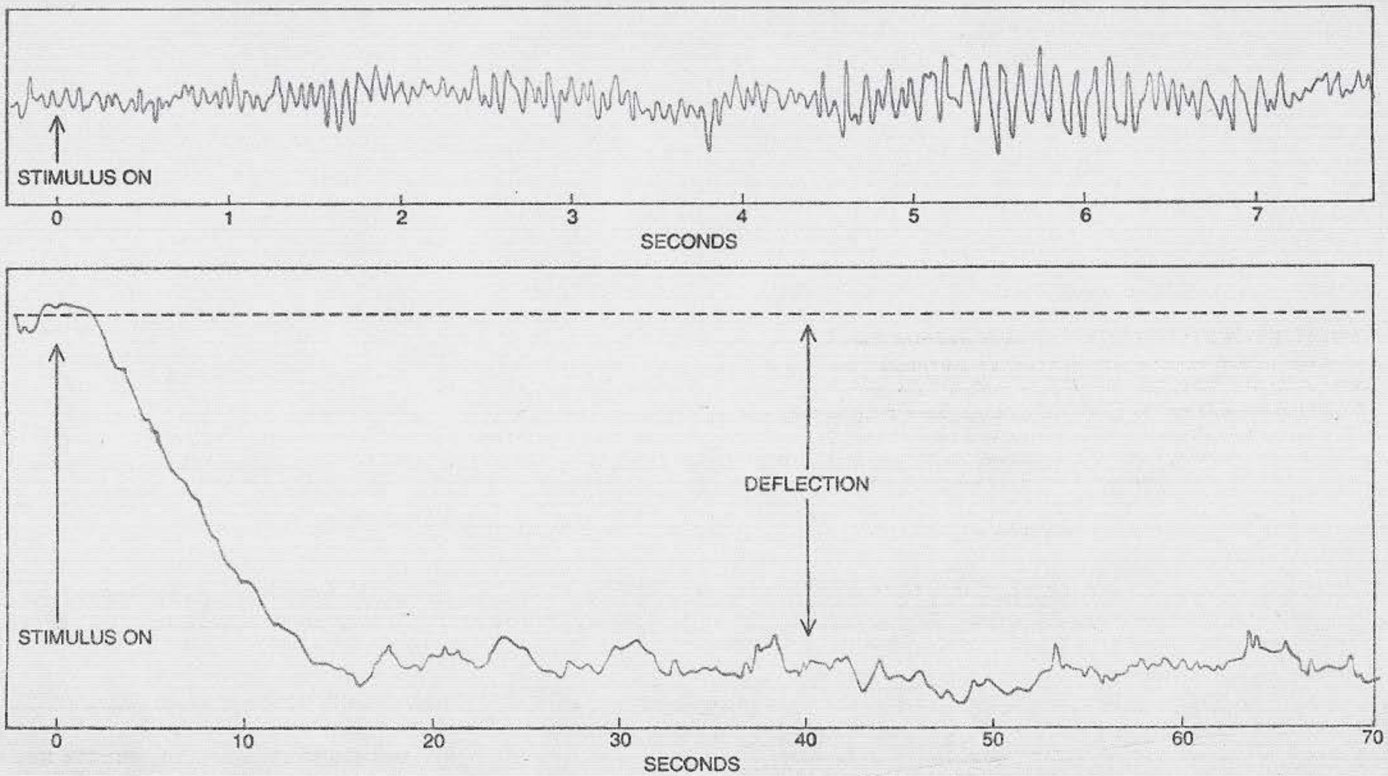
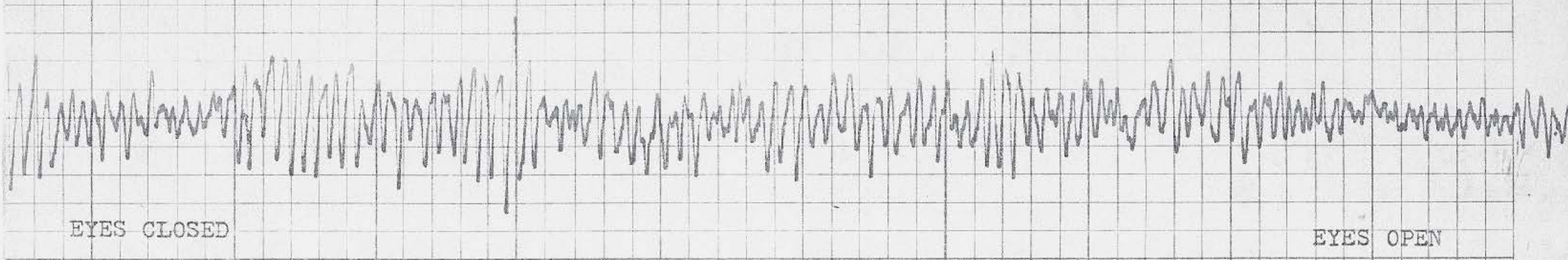


STEADY-STATE EVOKED POTENTIAL can be elicited by a repetitive sensory stimulus, such as a flickering light. The upper trace shows a continuous record of whole-brain activity (the electroencephalogram, or EEG) recorded from scalp electrodes placed over the visual cortex. Powerful bursts of alpha-wave activity with a frequency of 10 hertz (cycles per second) and an amplitude of about 50 microvolts are evident. For the first second of the recording there is no visual stimulation; then a light starts to flicker 15.5 times per second. No evoked potential can be detected in the EEG trace because the response is buried in the background noise. The lower trace shows the output of a Fourier analyzer whose input was the EEG trace. When the light starts to flicker, the analyzer shows the presence of an evoked potential. Amplitude of the deflection is about five microvolts. The evoked potential remains approximately constant for the entire recording period and is not affected by bursts of alpha activity in the EEG. Recording was made by author at the University of London.

from reference #5



THE ALPHA WAVE ACTIVITY IS VERY STRONG IN THIS EEG. NOTE THE LARGE SIN WAVE RHYTHMS OCCURING ABOUT TEN TIMES PER SECOND.

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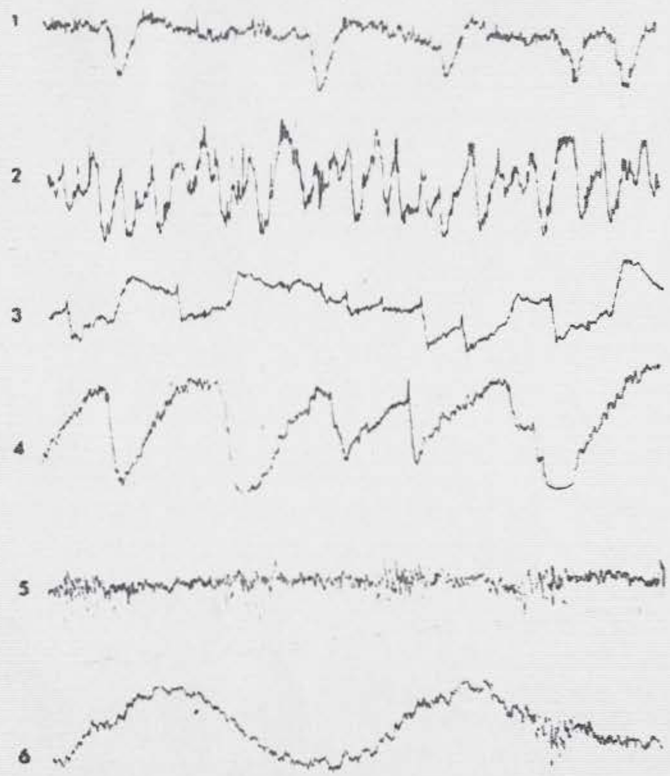


Figure 2.2 (a) Biological artefacts. (1) Eye blink. (2) Eyelid flutter. (3) and (4) Other eye movements. Note how (4) mimics delta activity. (5) Bursts of muscle spikes. (6) Sweat artefact.

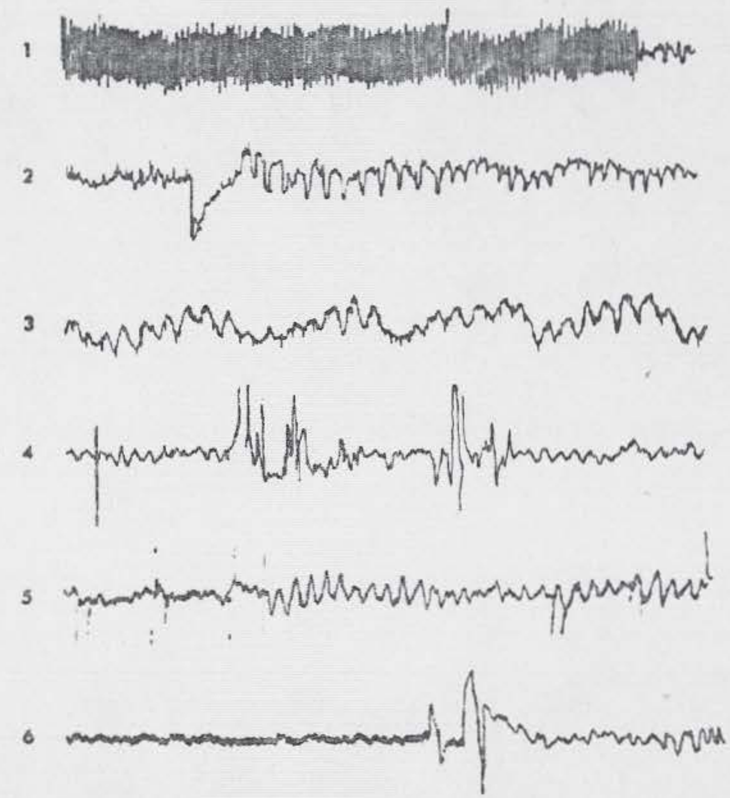
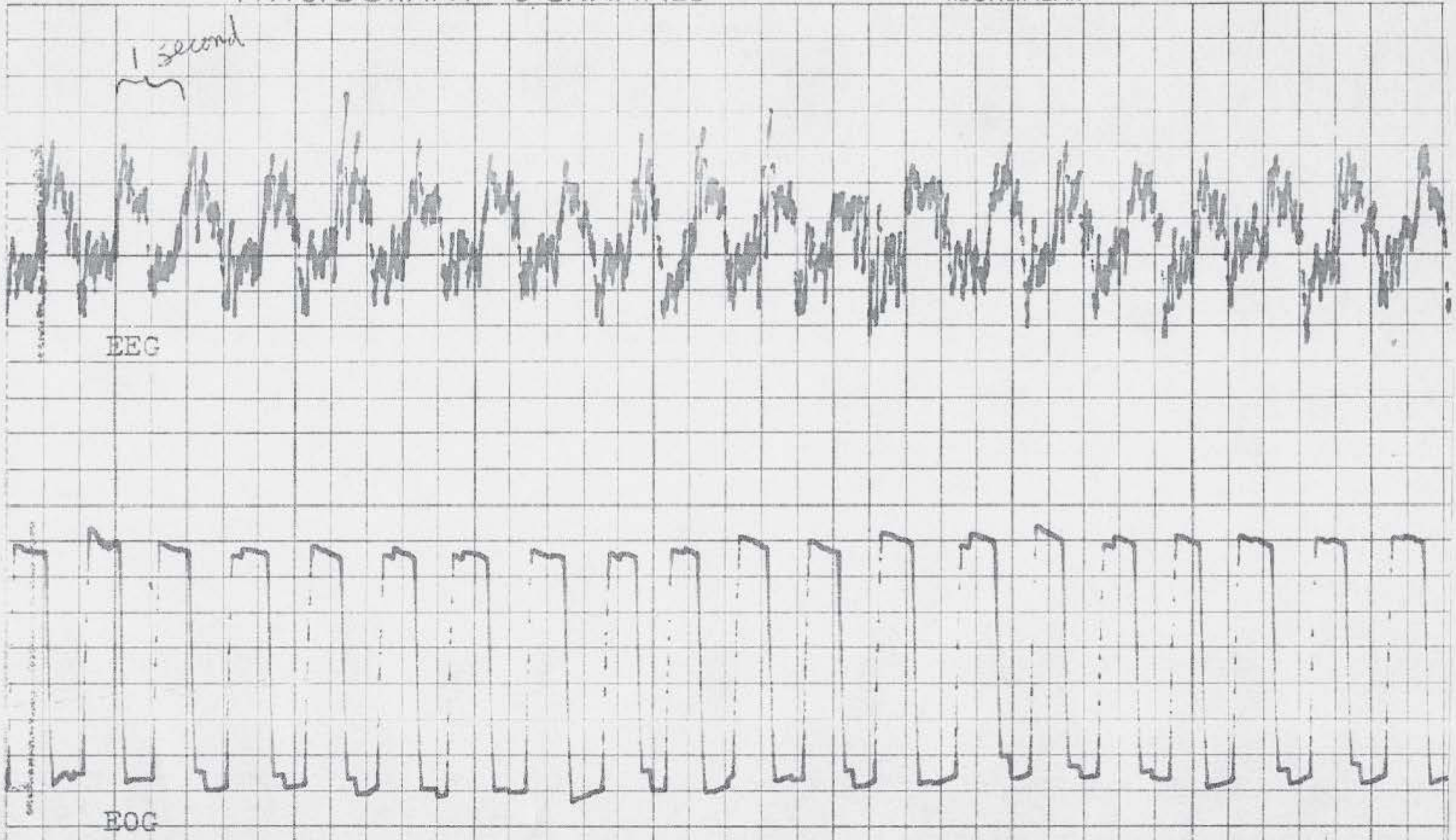


Figure 2.2 (b) Non-biological artefacts
1. Fifty-cycles artefact. Note that when it ceases some cerebral activity can be seen
2. Clip artefact. Note how it mimics sharp waves
3. Artefact produced by movement of the electrode, in this case because it was placed near the occipital artery — the pulse artefact
4. Artefact arising because of a faulty socket in the head box
5. 'Bleep' artefact. Note the grouped 'spikes' at the beginning and end of the section shown; these recur at regular intervals
6. Artefact created by 'dirty switch'. Note that cerebral activity returns when this has been corrected

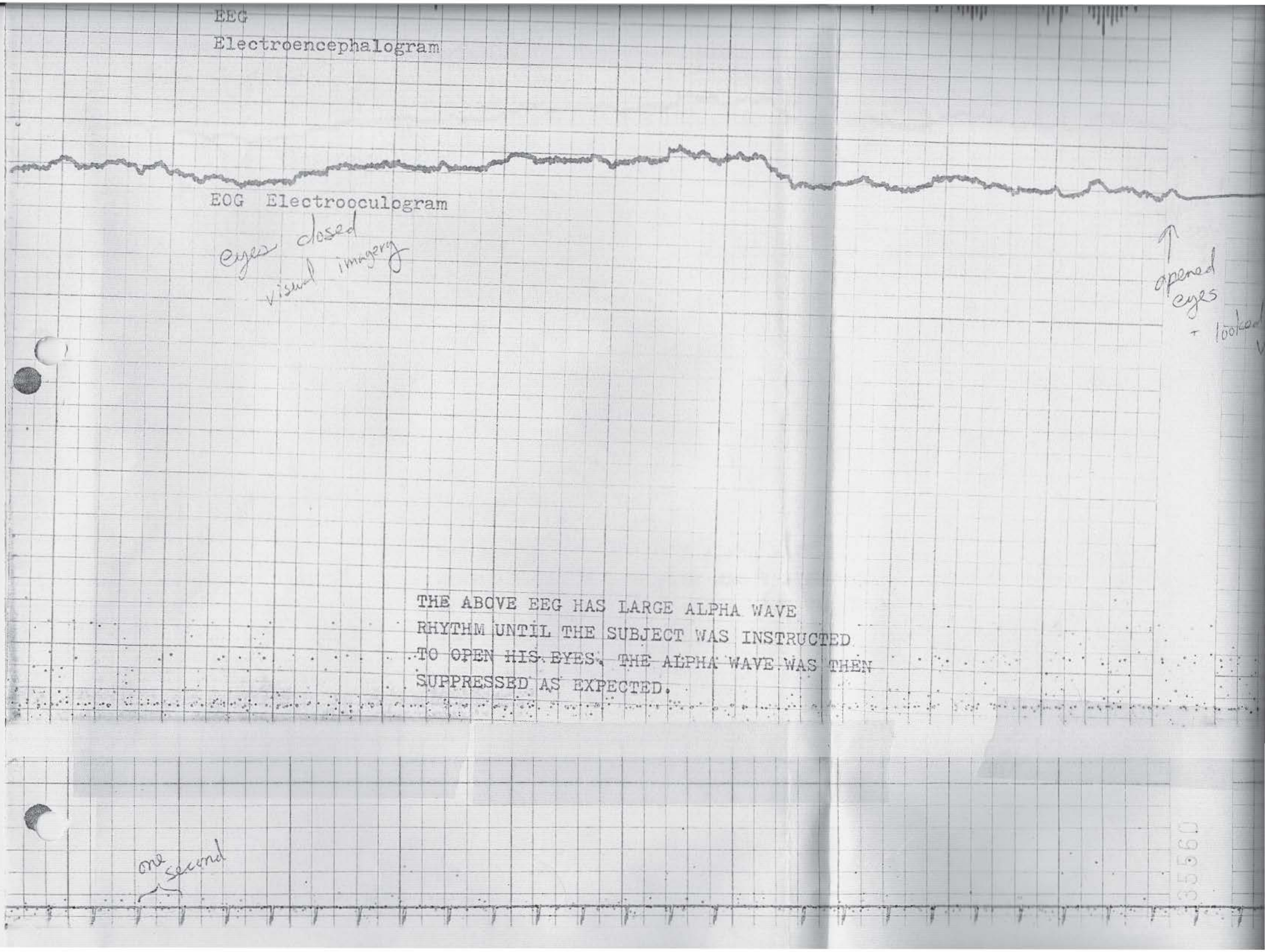
Examples of EEG artefacts from reference #8.

PHYSIOGRAPH® 6-CHANNEL RECTILINEAR



thumb saccades at 35 cm
thumbs separated by 25 cm

THE ABOVE RECORDINGS OF THE EEG AND EOG SHOW HOW NOISE FROM THE EXTRAOCULAR MUSCLES CAN APPEAR ON THE EEG.


EEG
Electroencephalogram
EOG Electrooculogram
eyes closed
visual imagery
opened eyes
+ looked
THE ABOVE EEG HAS LARGE ALPHA WAVE
RHYTHM UNTIL THE SUBJECT WAS INSTRUCTED
TO OPEN HIS EYES. THE ALPHA WAVE WAS THEN
SUPPRESSED AS EXPECTED.
one second
35560