Alpha and Kappa Electroencephalogram Activity in Eyeless Subjects

Abstract. *Several reports have cast doubt on the cerebral origin of alpha and kappa electroencephalogram activity by charging that they are artifacts related to eye activity. Data are cited which eliminate the corneoretinal potential of the eyeball, tremor of the extraocular muscles, eye position, accommodation, and eye flutter as sources of alpha and kappa electroencephalogram activity. A subject with both eyes removed showed normal alpha and kappa electroencephalogram activity. Marked left-right differences in alpha activity were not found in one-eyed subjects whose eyes and extraocular muscles were completely removed on one side.*

The human electroencephalogram (EEG), which was first reported over 40 years ago by Berger (*1*), has become an important technique for diagnosis of central nervous system damage as well as the topic of a large body of research aimed at investigating brain function. However, several reports (*2–5*) have cast doubt on the cerebral origin of two prominent features of the EEG, alpha and kappa activity, which are hypothesized to be artifacts related to eye activity. Although these reports have all implicated eye activity, their specific hypotheses have varied, including emphases on the corneoretinal potential of the eye, tremor of the extraocular muscles, eye position, accommodation, and eyelid flutter. If their interpretations are correct, it is necessary to reconsider the meaning of the EEG as a measure of cerebral function. Hypotheses that alpha and kappa EEG activity are due to eye activity go considerably beyond the well-recognized fact that eye activity sometimes may intrude on EEG records.

Alpha activity is an EEG rhythm, usually with a frequency of 7 to 13 hz, most prominent over the posterior brain, present most markedly when the eyes are closed, and attenuated during attention, especially visual attention. Kappa activity is an EEG rhythm, usually with a frequency of 7 to 12 hz, most prominent with bilateral bipolar recording from frontal areas, and present most markedly during mental tasks.

It has previously been shown that kappa EEG activity is independent of eye or lid flutter (*6*). It has also been shown in a quantitative study of 22 normal subjects that alpha EEG activity is not influenced by eye position when care is taken to maintain constant visual input (*7*). These two studies used subjects with normal eyes. Here we present data from subjects with either one eye or both eyes absent. Evidence of normal EEG activity from these subjects further argues against the eye artifact hypotheses noted above. A clear distinction should be maintained between the direct electrical effects of peripheral ocular activity carried by volume conduction and the indirect effects—for example, visual input and task difficulty—which influence activity in the visual system of the brain.

Following the hypothesis that "the source of current for generating the waveform of alpha rhythm is the standing potential across the eye" (*5*), we recorded the EEG of a man without ocular globes. A 20-year-old male

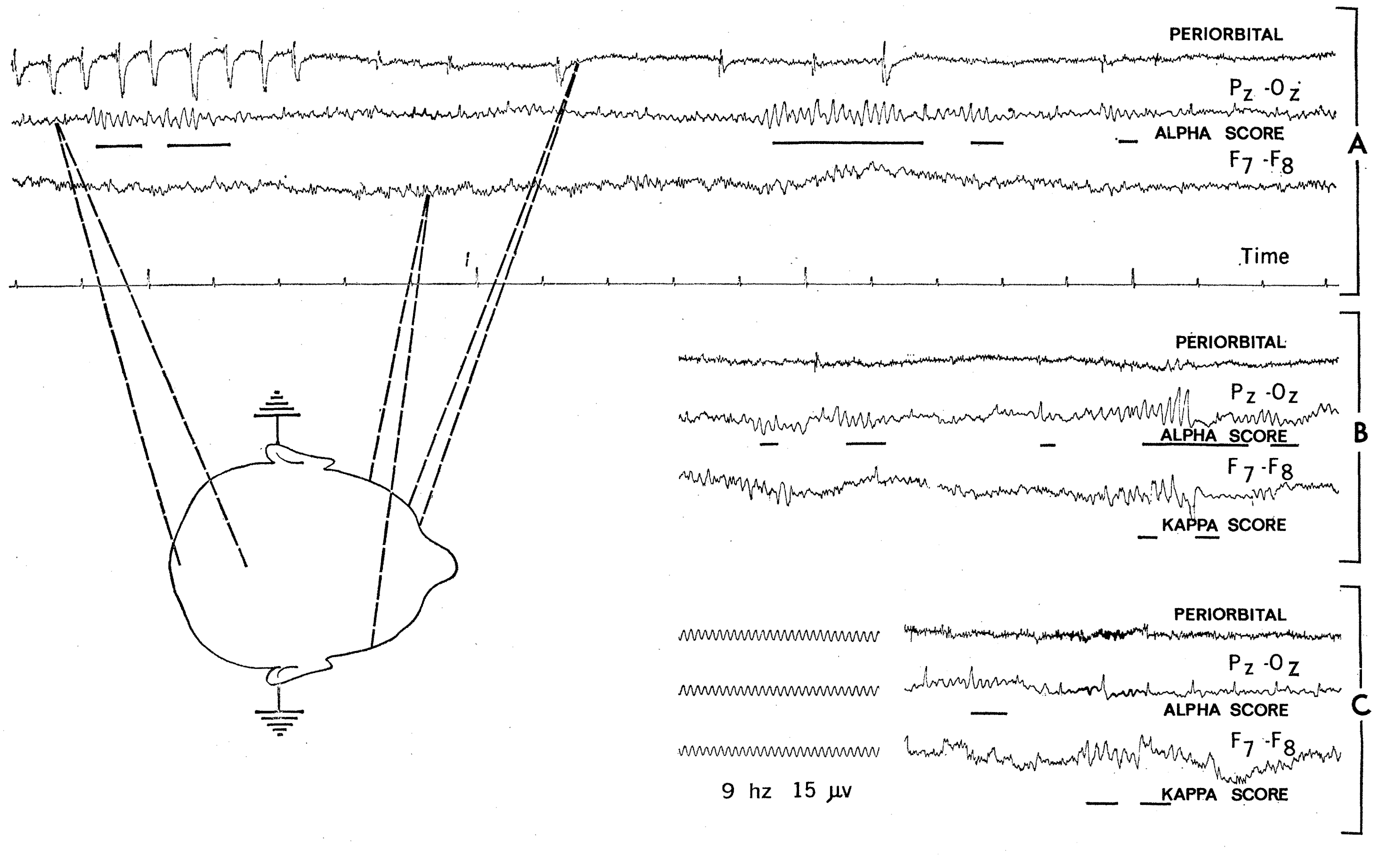

Fig. 1. Sample records of alpha and kappa EEG activity from subject A.A. with both eyes enucleated. The periorbital tracings were recorded near the right orbit. The alpha and kappa activities detected by the electronic scorer are indicated by lines below the appropriate tracings.

Table 1. Amount of alpha, kappa, and simultaneous alpha and kappa activity in seconds for subject A.A. (both eyes absent).

Order	Task	Alpha	Kappa	Simultaneous
1	Count 1 to 10	5.4	1.3	0
2	Add 8's	2.2	6.8	0.4
3	Add 27's	3.0	6.0	0.6
4	"Mind blank"	2.4	1.7	0
5	Add 8's	2.4	3.8	0
6	Count 1 to 10	3.2	2.8	0.6
7	"Mind blank"	8.0	1.0	0.3
8	Add 27's	0.7	2.7	0
Total "easy" tasks		19.0	6.8	0.9
Total "hard" tasks		8.3	19.3	1.0

(A.A.) was tested 43 days after the loss of both eyes. There were multiple fragments in both orbits and the right orbit contained an implant. The extraocular muscles were otherwise normal. The apparatus and procedure were essentially the same as those used in a previous quantitative survey of alpha and kappa EEG activity of 100 normal subjects (*8*). In this procedure eight 2-minute tasks were performed in a fixed order. Half of the tasks were "hard" (cumulative mental addition) and half were "easy" (counting 1 to 10 repetitively or keeping a "blank mind"), and they were presented in a counterbalanced order. Although subject A.A. had relatively little alpha or kappa activity, both activities were modulated by the tasks in the same way shown by the majority of normal subjects in the previous study. The quantitative results yielded by the automatic scoring apparatus for subject A.A. are summarized in Table 1.

The amount of alpha activity decreased during the "hard" tasks, whereas the amount of kappa activity increased during the "hard" tasks. Furthermore, the period of time during which alpha and kappa activity were present simultaneously was extremely brief, which is consistent with earlier findings supporting their independence.

Examples of alpha and kappa EEG activity obtained from subject A.A. are shown in Fig. 1. In record A several bursts of alpha activity are shown and comparison of the left and right parts of the record indicates that the alpha activity is not correlated with the periorbitally recorded muscle twitches recorded from electrodes placed near the empty right orbit. Record B shows an example of kappa EEG activity which occurred at the same time as alpha EEG activity, while record C shows kappa EEG activity that occurred when alpha activity was absent. These records were obtained during the latter part of the session when the subject was more relaxed (pulse rate reduced) and more alpha activity was present. Since both eyes were missing, the data from subject A.A. demonstrate that neither alpha nor kappa EEG activity must originate from the standing potential across the eye; nor must they depend on eye position, accommodation, or eye movement.

It has even been suggested that the extraocular muscles that remain after enucleations may be the source of alpha activity (*4*). We investigated bilateral EEG activity from two subjects who had undergone complete exenterations of one orbit; the entire contents of one orbit were removed including eyeball, extraocular muscles, and periosteum.

Subject A.N. was a 23-year-old male who had developed a tumor of the left maxilla. Three years prior to our testing, the patient had undergone a left maxillectomy and a complete exenteration of the left orbit. The left optic nerve had been excised at the apex of the orbit and the ocular muscles had been detached at their origins and removed with the globe. The right eye was normal and functional. The second subject, N.A., was a 23-year-old female who had developed an olfactory tumor. Nine months before testing, the growth was removed with a complete exenteration of the right orbit. The left eye was normal. If the ocular artifact hypotheses are correct and the alpha EEG activity on each side of the head is due primarily to the orbital activity on the same side, then the alpha EEG activity of our one-eyed subjects ought to be

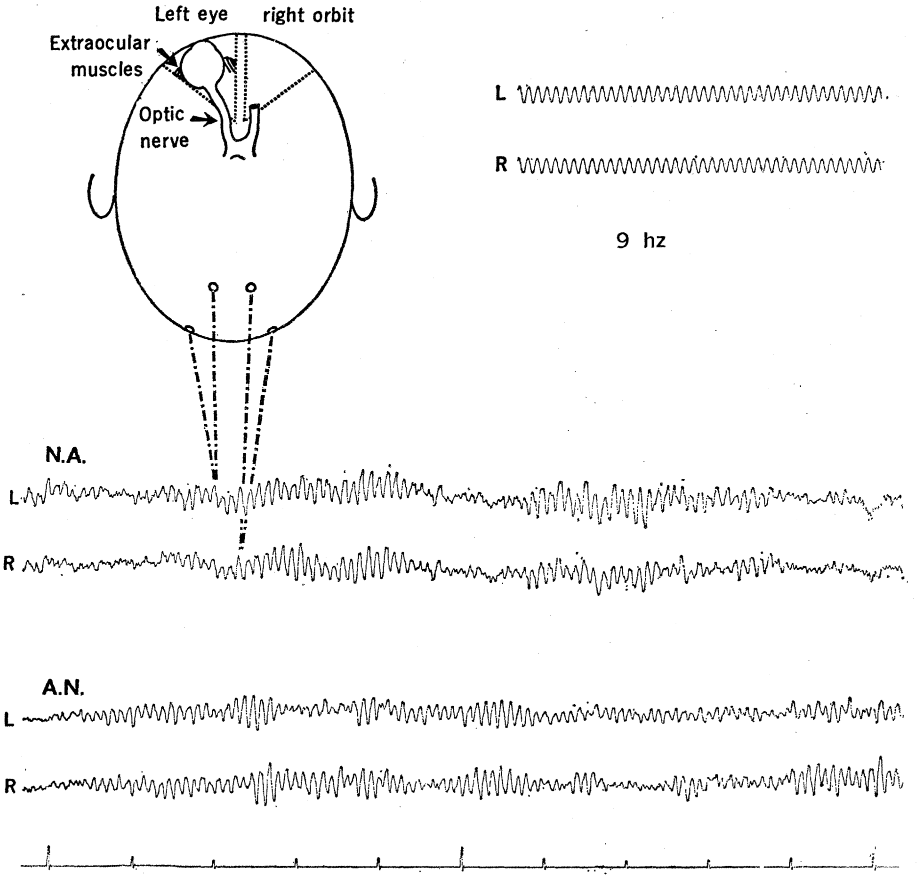

Fig. 2. The upper two tracings are sample records of alpha activity from the left and right sides of subject N.A. (right globe and extraocular muscles absent but normal left eye). The lower two tracings are sample records of subject A.N. (ocular removal on opposite side). For both subjects the amplitudes of the alpha activity from the two sides were approximately equal. For both subjects the alpha amplitude could be greater on either side regardless of whether the right or left eye was absent. Nine-hertz calibration is 7 μv in amplitude.

markedly different on the two sides. For these two subjects, the EEG scoring apparatus was set to score alpha activity above a criterion of 7 μv at 9 hz. Both subjects showed more alpha activity on "easy" tasks than on "hard" tasks, more alpha activity with eye closed than open, and similar patterns of alpha activity on the two sides. When a burst of alpha activity was present on one side, a burst was generally also present on the other side. The amount of alpha activity simultaneously present on both sides far exceeded the probability predictions based on an assumption that the two sides were independent. Sample records from these one-eyed subjects are shown in Fig. 2. Although the amplitude of alpha activity tended to be slightly higher on the side with the normal eye, instances can be found where the reverse is true. A clinical EEG recorded preoperatively from subject N.A. appeared similar to those obtained by us postoperatively, including the tendency for alpha activity to have slightly higher amplitude on the left side. Clearly neither subject showed amplitude differences from the two sides as great as predicted by the ocular artifact hypotheses. If either the corneoretinal potential or the extraocular muscles were needed to produce alpha EEG, we should have found that the amplitude of alpha EEG recorded from the side with the remaining eye exceeded that on the other side by at least twofold. This would follow if the observation of more than a 2 : 1 ratio of alpha EEG amplitude found with an experimental procedure (unilateral light adaptation) is due to change in the corneoretinal of the ipsilateral eye, as Lippold interpreted (*5*). The same electrode placements (*9*) were used to record the data in Fig. 2. Data obtained from additional bipolar electrode placements at O_1–T_5 and O_2–T_6 (standard 10–20 system) yielded the same conclusions: no marked alpha asymmetry.

Kappa EEG activity recorded across the temples (F_7–F_8) was also obtained from both one-eyed subjects. Like normal subjects (*8*) both one-eyed subjects had more kappa EEG scores on "hard" tasks than on "easy" tasks, more kappa activity with eye open than closed (24 percent of normals), and independent occurrences of kappa and alpha activity (amount of simultaneous activity close to chance prediction).

The presence of normal alpha and kappa EEG activity in a bilaterally enucleated subject and the absence of marked left-right differences in two one-eyed subjects whose eyeballs and extraocular muscles were removed refute the explanations of alpha and kappa EEG activity in terms of ocular artifacts. These data, together with those previously reported, lead to the conclusion that alpha and kappa activity are not directly dependent on the corneoretinal potential of the eyeball, tremor of the extraocular muscles, eye position, accommodation, or eyelid flutter (*10*).

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8. R. M. Chapman, J. C. Armington, H. R. Bragdon, *ibid.* **14**, 858 (1962). In the present experiment bipolar recordings, using a Grass model 78 polygraph, were made from (i) the midline over the parietal and occipital regions (P_z and O_z) for alpha activity, (ii) from the left and right temporal areas (F_7 and F_8) for kappa activity, and (iii) from electrodes mounted near the absent right eye (1 cm from the lateral canthus and 1 cm below the middle of the lower lid) for periorbital electrical activity. Both ears were grounded. The half-amplitude frequency response of the recording system was 0.1 to 50 hz. The two EEG signals were then entered into a two-channel automatic scoring apparatus for quantitative determination of alpha and kappa EEG activity [W. J. Kropfl, R. M. Chapman, J. C. Armington, *Electroencephalogr. Clin. Neurophysiol.* **14**, 921 (1962)]. Each of the two identical channels contained a bandpass filter with a center frequency of 9 hz and a half-amplitude bandwidth from 7 to 12 hz, a rectifier, a short time-constant filter, and a trigger circuit that fired whenever the preset voltage level was exceeded (15 μv at 9 hz, except where noted otherwise). When EEG activity met these scorer criteria, markers were displayed on the EEG record and clutches of electric timers were activated. These timers summated the amounts of time that the parieto-occipital EEG contained alpha activity, the transtemporal EEG contained kappa activity, and the amount of time that alpha and kappa activity were present simultaneously. The subject was seated in a comfortable chair inside an electrically shielded, sound-damped, small room.
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10. After this report was submitted for publication, uniocular data supporting our conclusions were reported by M. Abbott and A. M. Dymond [*Lancet* **1970-II**, 933 (1970)].
11. We thank the subjects for their cooperation, John Swain for his technical assistance, Alison Lee for aid with the apparatus, and Marion Northern for help with the manuscript. This work was partially supported by PHS research grant EY 00490 from the National Eye Institute to the Eye Research Foundation which is an affiliate of the University of Maryland.

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Acute Lymphocytic Leukemia in Owl Monkeys Inoculated with Herpesvirus saimiri

Abstract. *Our study demonstrates for the first time that* Herpesvirus saimiri *can induce acute lymphocytic leukemia in owl monkeys* (Aotus trivirgatus) *and that malignant lymphoma can be induced in this species of nonhuman primates by the inoculation of the virus by various routes (intravenous, subcutaneous, and intradermal).*

Herpesvirus saimiri, a viral agent indigenous to the squirrel monkey (*1*), induces malignant lymphoma after intramuscular inoculation in cotton-top marmosets (*Saguinus oedipus*) and owl monkeys (*Aotus trivirgatus*) (*2, 3*). Mortality in marmosets (*Saguinus* sp.) was 100 percent within 18 to 48 days, associated with marked invasion and organ replacement by elements resembling reticulum cells. Some animals showed terminal leukocytosis, lymphocytosis, and the presence of immature lymphocytes, lymphoblasts, and reticulum cells in the peripheral blood. Of ten owl monkeys inoculated with *Herpesvirus saimiri*, all developed malignant lymphoma within 29 days. Peripheral blood was not studied, but the histopathological features were similar to those in marmosets (*3*).

The studies reported here were conducted to determine whether peripheral blood changes characteristic of leukemia develop in owl monkeys; whether routes of inoculation other than intramuscular are effective in inducing malignant lymphoma; and, if not, whether this antigenic exposure would confer immunity to intramuscular inoculations.

A group of 12 owl monkeys were inoculated each with approximately 316,000 $TCID_{50}$ (tissue culture infective dose, 50 percent effective) of *H.*