TECHNICAL PAPERS

A New Electroencephalogram Associated With Thinking

John L. Kennedy, Robert M. Gottsdanker, John C. Armington, and Florence E. Gray

Institute for Applied Experimental Psychology, Tufts College, Medford, Massachusetts

In the course of experimentation on counting eye movements in reading by means of the corneoretinal potential (*1*), a 10-cycle/sec disturbance in the reading record was noted. Further investigation indicated that this disturbance was, in actuality, a new electroencephalogram. This paper will report certain interesting characteristics of the new EEG, which we shall call "kappa waves."

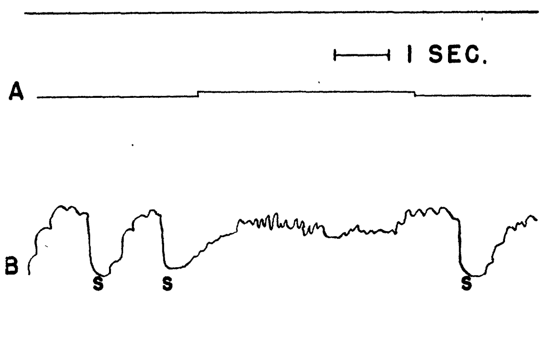

Fig. 1. Kappa bursts during reading.

Fig. 1 shows an electroculogram obtained while a subject was reading. The large potential changes at S are return sweeps from the end of a line to the beginning of the next line. Successive saccadic movements are recorded as smaller, sudden potential changes. The steps in the record are fixations through the line of print. In the middle of the section of record, the subject fixated the first word of a new paragraph and signaled the duration of fixation on line A. The kappa waves (line B) appear most clearly during this period of fixation when the eyes are still. Close examination of the records obtained when the eyes are moving in reading shows that the waves are present but obscured by the activity of the eyes. From such records it has been found that kappa waves characteristically occur in intermittent, spindle-shaped bursts. They have an average frequency of 8–12 cycles/sec and an average amplitude of around 20 microvolts. The following studies have been conducted to find the circumstances producing kappa waves and the relation of these waves to other physiological phenomena.

The standard Grass 4-channel EEG apparatus was used in these studies. Filters of the power amplifiers were set to maximize the low frequencies. In addition, two accumulators (*2*) were employed to integrate (time constant, .2 sec) the 8- to 12-cycle/sec component of two of the channels. Two d-c amplifiers were used to record the integrated level of kappa and alpha waves as deviations from a base line. Electrodes were sponge-rubber tabs soaked in saline and glycerine solution (*3*). All records were made by means of the Grass ink writer on standard EEG recording paper.[1] Kappa waves were detected by electrodes placed just back of the external canthi of the eyes. The two ends of a metal headband, constructed from two bicycle clips, held these electrodes in place. When simultaneous occipital records (alpha) were taken, electrodes were placed under an elastic headband, about 2 cm above the inion and the same distance to the side. A ground electrode was attached to the subject's right cheek with adhesive tape. A similar electrode on the left cheek was used for the indifferent placement in the cases where monopolar records were taken from the right occiput.

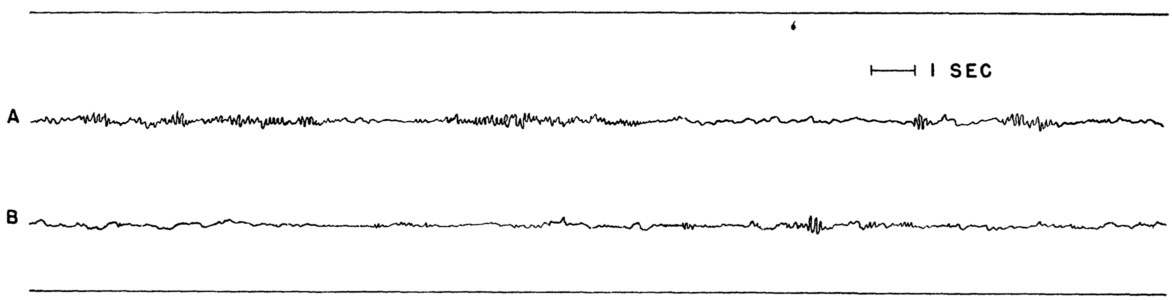

Fig. 2. Mental multiplication compared with "keeping the mind a blank."

Several situations have been found which dependably produce kappa waves. One of these is mental arithmetic

[1] Tracings of sections of these records are presented as objective evidence. The original records are available for inspection by qualified investigators.

Fig. 2 is a composite tracing of two equivalent sections of record. Line A is the electroencephalogram taken from the canthal placement on a subject engaged in multiplying two-digit numbers (eyes fixated). Line B is a comparable record when the subject was attempting to ''keep his mind a blank'' (eyes fixated). The greater amount of kappa rhythm in mental multiplication is evident. Kappa intrudes occasionally when the subject is trying not to think. Introspective reports suggest that the intrusions of kappa correspond to ''thoughts'' during the period of attempted voluntary inhibition of thinking.

the upward deflection is the response of the subject. Line B is the canthal electroencephalogram and line C is the 8- to 12-cycle accumulation. Bursts of kappa waves are again seen to be associated with making decisions. Other situations which have been found to bring out a large amount of this rhythm are (1) learning tasks, such as nonsense syllables; (2) memory tasks, such as naming the 48 states; and (3) problem solving, such as that involved in mastering a finger maze. In general, kappa waves have been found to be most prevalent in situations which are usually classed as involving thinking.

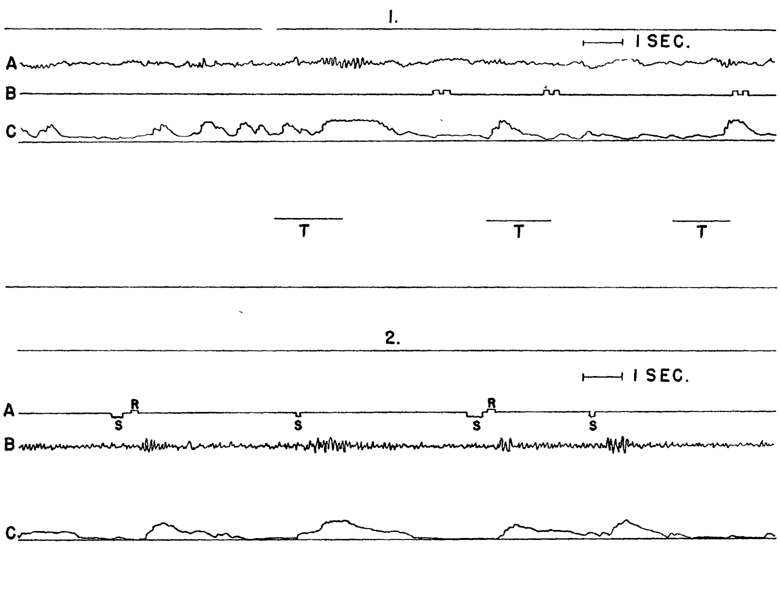

FIG. 3. Part 1, temporal discrimination (Seashore Record); Part 2, choice reaction.

Difficult discriminations evoke kappa bursts. Line A in Fig. 3, part 1, is the canthal electroencephalogram of a subject responding to the Time discrimination record of the Seashore Measures of Musical Talent. The subject, who is required to tell whether the second of two tones is longer or shorter than the first, pressed the signal key (recorded on line B) twice if the second tone was longer and once if it was shorter. Fifty rather difficult discriminations are presented on the record. Line C is the 8- to 12-cycle accumulation. The short straight lines marked by T indicate the interval between the start of the first tone and the end of the second tone. A burst of kappa is seen to be associated with each choice situation, especially the first. In Fig. 3, part 2, the subject was given a choice reaction test, in which he decided whether a sound was ''long'' or ''short.'' The technique was first to use sounds that were obviously either long or short and then to reduce the time difference. The subject was instructed to respond by pressing a key to long sounds but not to short ones. The downward deflection on line A shows the duration of the stimulus;

A number of different controls have been employed. First, there was the possibility that kappa waves were due to periodic physiological changes. However, there was no relation to the breathing cycle or to unusual or forced breathing. Likewise, the bursts were independent of pulse rate. Eye movements and blinks are not correlated with the kappa bursts. Talking aloud or to oneself is not associated with the rhythm. Finally, merely hearing a stimulus or making the response of key-pressing did not produce kappa waves.

The voluntary control by the subject induced by verbal instructions has been found to be important in the production or nonproduction of kappa waves. For example, the accumulated record of one subject was above a constant base line 54% of the time while doing mental multiplication and only 17% while attempting to ''keep his mind a blank.'' He was fixating in both cases. Corresponding percentages of another subject were 35% and 2%. Large differences were also found on the Time discrimination record of the Seashore measures. When the subject tried to make correct discriminations, a burst of kappa waves above a constant base line occurred during 85% of the choices for one subject; when he merely pressed the key without trying to discriminate, only 17% of the paired tones resulted in this level of activity. Comparable figures for another subject were 36% and 16%.

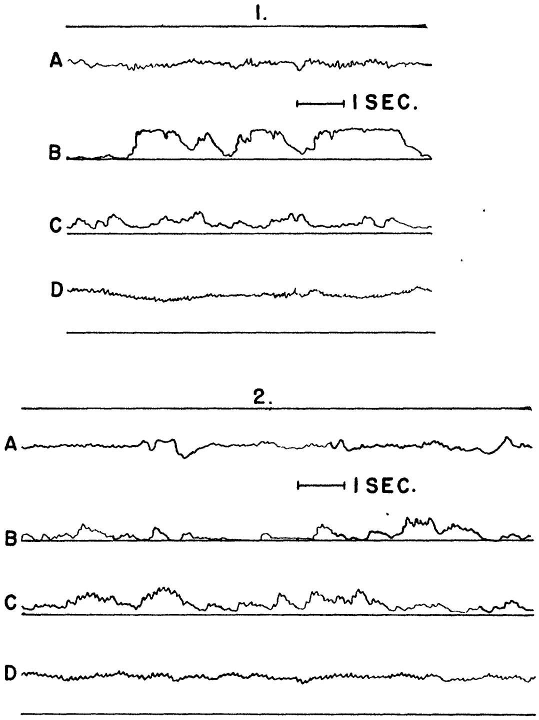

FIG. 4. Part 1, Simultaneous record of kappa and alpha waves during mental multiplication; Part 2, simultaneous record of kappa and alpha waves with "mind a blank."

Out of 31 subjects tested, 18 have shown a recognizable amount of 8- to 12-cycle/sec activity from the canthal placement. Attempts were made to record these waves on subjects not initially exhibiting them by using other electrode placements on the front part of the head. For the most part, these attempts were unsuccessful. Also, the difference in level due to the conditions previously described seems most clear cut for the subjects whose amplitude of kappa activity is highest. Further investigation is required to determine whether kappa waves are actually absent in subjects showing little or no 8- to 12-cycle bursts from the canthal placement. The possibility of such artifacts as poor conduction through the skull and surrounding tissues must be taken into account.

It appears certain from the data available that kappa waves are not directly related to previously described bioelectrical phenomena. Of course, they closely resemble the alpha rhythm in frequency. The conditions for occurrence are, however, different—or perhaps opposite. Alpha waves generally increase in amplitude when the eyes are closed, but kappa waves show no regular differences between conditions of eyes open and eyes closed. Mental arithmetic often inhibits alpha (*4*), whereas kappa waves appear frequently during mental addition or multiplication. Fig. 4, part 1, shows a section of record in which kappa (line A) and alpha (line D) were recorded simultaneously while the subject was doing mental multiplication (eyes fixated). Line B is the accumulation of kappa; line C shows the accumulation of alpha. It is evident that kappa bursts are frequent and are unrelated to alpha activity. Part 2 of Fig. 4 shows a comparable section of record when the subject's eyes are closed and he is trying to "keep his mind a blank." Here, alpha activity is high and kappa low.

The position of the electrodes suggests that the source of kappa bursts may be the temporal lobes of the brain.

The following summary statements may be made:

(1) An intermittent spindle-shaped electroencephalogram with a frequency of 8–12/sec and a maximum amplitude of 20–30 microvolts has been recorded from bipolar electrodes placed just back of the external canthi of the eyes.

(2) These bursts appear to be associated with the process of thinking (discrimination, choice reaction, mental arithmetic, problem solving, etc.).

(3) The bursts are unrelated to previously described alpha activity.

(4) Half of the subjects so far tested exhibit the phenomenon.

(5) It is suggested that the source of the new EEG may be the temporal lobes of the brain.

References

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Autoradiographs of C^{14} Incorporated in Individual Blood Cells[1]

GEORGE A. BOYD, GEORGE W. CASARETT, KURT I. ALTMAN, THOMAS R. NOONAN, and KURT SALOMON

Department of Radiation Biology, University of Rochester School of Medicine and Dentistry

Since Altman, *et al.* (*2*) demonstrated that the alpha-carbon atom of glycine labeled with C^{14} is incorporated into the hemin and globin moieties of hemoglobin, it was believed that the incorporated C^{14} in an individual blood cell could be demonstrated by an autoradiograph. To this end a male rat weighing 120 gm was given a

[1] This paper is based on work performed under contract with the U. S. Atomic Energy Commission at the University of Rochester Atomic Energy Project, Rochester, New York.