SOME EFFECTS OF ELECTROSTATIC FIELDS

ON BRAIN ACTIVITY IN RATS

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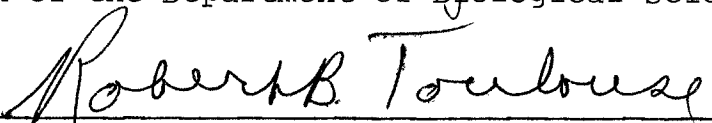McCain, Harry B., <u>Some</u> <u>Effects</u> <u>of</u> <u>Electrostatic</u> <u>Fields</u>
<u>on</u> <u>Brain</u> <u>Activity</u> <u>in</u> <u>Rats</u>. Master of Science (Biological
Sciences), December, 1971, 54pp., 2 tables, 10 figures,
bibliography, 36 titles.

This study concerned the effects of short-term
exposures to continuous (10 kv/meter) and pulsed 20 volts
at 640 cps/100 msecs) electrostatic fields on the EEG
recorded from external electrodes and hypothalamic activity
recorded from implanted electrodes in rats. Each experiment
lasted at least 90 minutes. The total energies of the
waveforms recorded were integrated and printed out for
plotting and analysis. Besides the brain activity, the ECG,
respiration, and temperature of the animals were also
monitored before, during,and after exposure to the electro-
static fields. No significant changes in the latter
parameters were noted, however, distinct changes in both
the EEG and in hypothalamic activity were observed. Every
animal exhibited a distinct and sustained <u>increase</u> in the EEG
immediately upon exposure to continuous fields of 10 kv/m.
After cessation of the field, activity returned to control
levels. On the other hand, a sustained <u>decrease</u> in hypothalamic

activity was noted in those animals exposed to 10 kv/m.

Exposure to a pulsed electrostatic field brought about

a slight but significant increase in the EEG activity.

The same pulsed field brought about a more pronounced

and sustained increase in the hypothalamic activity. In

both instances the activity returned to control levels

upon cessation of the field. The data clearly indicate that

animals are "aware" of changes in their external electrical

fields and the findings point out the need for further

research into the effects of electrical fields on biological

processes.

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ON BRAIN ACTIVITY IN RATS

THESIS

Presented to the Graduate Council of the

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INTRODUCTION

It is well known that in nature a positive electric

power field encircles the entire earth (Kahler, 1937).

This positive field has an average field strength of a

few hundred volts per meter in free spaces at sea level

elevations, and is known to increase as the elevation of

the earth increases, often attaining a strength of up

to several thousand volts per meter (e.g. in mountain

regions). It has also been observed that the field of

strength of this electric field remains relatively

constant during fair weather and normal atmospheric

conditions, but will fluctuate as the atmospheric conditions

change (Konig, 1962).

Much research has come from Europe, concerning the

production and effects of artificial electric power fields

on living organisms. Folix and Rabeau (1951) have

claimed that a person in this partially electrically

shielded environment tends to become mentally fatigued

and drowsy over a period of time, and they have shown

that the creation of an artificial electropower field

1

within such shielded environment will tend to eliminate these undesirable effects. It has thus been determined that all living matter on the earth's surface may be dependent upon and affected by the existing natural electropower field in any particular area (Dull, 1941). In particular, it has been found that airplanes, vehicles, and certain buildings simulate an almost perfect electrically shielded environment or so-called "Faraday Cage" (Missenard, 1937).

Early work on the effects of electric fields on living matter was done primarily on microorganisms and cellular phenomena. Bernstein (1910) tried to explain certain membrane phenomena by placing membranes in electrostatic fields and noting changes in permeability. Marsh (1930) was able to control rate and direction of cell growth by applying various electric fields to tissue cultures. Angerer (1937) noticed that the viscosity of Amoeba protoplasm was greatly affected by the presence of an electrostatic field. Lutkova and Loeshko (1959) produced growth increases up to 24% in tomatoes by passing a

continuous electric current of 1 X 10^{-5} amps between various types of electrodes. Kotoaka, et al. (1965) found that electrostatic fields produced profound changes in the respiration of cereal seedlings. L. E. Murr (1966) did experiments investigating numerous plant species in electrostatic fields by making the soil positive with respect to the negative upper electrode. These experiments showed that plant growth could be inhibited, facilitated, or damaged as a result of varying field strengths. Murr also tried to relate this phenomenon to atmospheric conditions which might exist in the natural environment. Respiration studies by Sidaway (1966) have pointed out the biological significance of polarity reversals in the environmental electric fields. Studies by Wehner (1964) and Hamilton (1967) on bacteria showed that growth of Escherichia coli could be enhanced or terminated with the application of alternating positive-negative electric fields.

Studies on intact mammals have not been overly abundant in this country, and it is difficult to access recent mammalian work because of translation difficulties in the work done in Europe. Reiter (1953) tried to

determine the effect of alternating fields on the pH

concentration in guinea pigs in an alternating field of

20 kilocycles at 300V/cm. He found deviations of 0.1 to 0.2

units in the pH of the tissue and concluded that electric

fields might alter the hydrogen ion formation in tissues.

Schua (1954) studied the effects of electric fields

on nesting behavior of golden hamsters. He found that

hamsters exposed to electric fields moved their nests to

less "electrical" areas in their cages. Hamsters with

litters quickly removed (within 36 hours) their offspring

from a nest exposed to electrical fields.

Data from studies on the effects of electric fields

on man are inconclusive. Schliephake (1939) reported that

certain individuals remaining for a long period of time

in the proximity of a radio wave emitter insufficiently

screened complained of symptoms such as headache, malaise,

insomnia, and depression. Schafer (1949) believed these

symptoms to be the effect of a "primary electrical warming

of the entire organism" which (according to him) places

a stress on thermal regulation and results in the above

symptoms. Sunderman (1954) studied persons exposed to

an electrostatic field varying in strength and frequency.

The subject's pulse rate, blood pressure, and electro-
cardiogram (ECG) were determined before, during, and after
exposure. No significant changes were found to occur.
Konig (1966) claimed that electromagnetic signals varying
in frequency and wave pattern increased or decreased physical
activity depending upon wave form and frequency. Research
at Lockheed Aircraft Corporation by Dr. C. Cristofv
(circa 1965) tested the hypothesis of exposing aircraft
pilots to negative ion electrostatic performance.
Dr. Cristofv was not able to come to any definite conclusions
from his work; however, his results did hint that some
effect on some of the subjects was being elicited. One
investigator, Puharich (1966), reported enhancement
of extra sensory perception (ESP) scores by exposing
subjects to continuous fields, while on the other hand
he observed an inhibition of the ESP response when
exposing the subject to _pulsed_ or alternating electric
fields.

It is clear from the foregoing information that the
effects of electric fields on an organism are most diverse
and inconclusive. After reading the literature on this
subject one might ask several questions. How important

is the external electrical field in the total environment

of living things? Does the external electrical environment

really affect behavior of the entire organism? (Cellular

effects have been known for years). To what extent are

plants and animals cognizant of altered electrical fields?

If they are, where might the receptor loci be?

The specific aims of this present study were three-

fold: (1) to determine if an organism, a laboratory rat,

is "aware" of changes in the external electric field, by

using changes in brain wave activity as the determinant,

(2) to determine if there are particular electrosensitive

loci in the brain, e.g., the posterior hypothalamus, a

radio-sensitive area, and (3) to determine if changes

in certain physiological parameters such as ECG, heart

rate, respiration, and temperature occur in animals exposed

to electrostatic fields.

MATERIALS AND METHODS

A total of 60 adult, male, Sprague-Sawley rats with
an average weight of 190 $\pm$ 70 grams were used in this
study. This number does not include those used in
developing the experimental technique. In this range the
brain size and weight do not vary appreciably. Rats
with electrodes implanted into the posterior hypothalamus
and animals with needle electrodes placed under the scalp
were used to study brain wave activity (encephalogram –
EEG). Other physiological parameters monitored were the
ECG, respiration, and body temperature. The following
apparatus was used in this study:

1. Physiograph, Desk Model Type Dmp-4A (E & M
    Instrument Co., Inc., Houston, Texas).

2. Field Generator, Continuous (Electrofields,
    Miami, Florida).

3. Field Monitor, Rotating Electrostatic Field
    Measuring Instrument Type FM V (Berg. Feingerätebau,
    Wuppertal, Germany).

4. Electrode (Electrofields, Miami, Florida).

5. Model 23 EEG Integrator (Cold Springs Instrument Corp., Huntington, New York).

6. Digital Data Recorder (Cold Springs Instrument Corp., New York).

7. Wide Range Ocillator Model 200 CD (Hewlett-Packard, Dallas, Texas).

8. Audio Amplifier, engineered by H. L. Ferguson, North Texas State University, Denton, Texas.

The experimental apparatus is diagrammed in Figure 1. Each one of the Faraday cages, one for test animals, and one for field monitoring, had two inputs. One input was for producing continuous electrostatic fields, and one was for producing pulsed electrostatic fields. Supplying the continuous field, amounting to 10,000 V/M, was a field generator. Supplying the pulsed field was a wide-range oscillator which also served as a frequency generator (640 cps); the oscillator was connected to an audio-amplifier. This amplifier set up a second frequency, 50% on and 50% off, which "chopped" the original signal of 20 V/640 cps every 100 msec. Simultaneously electrodes
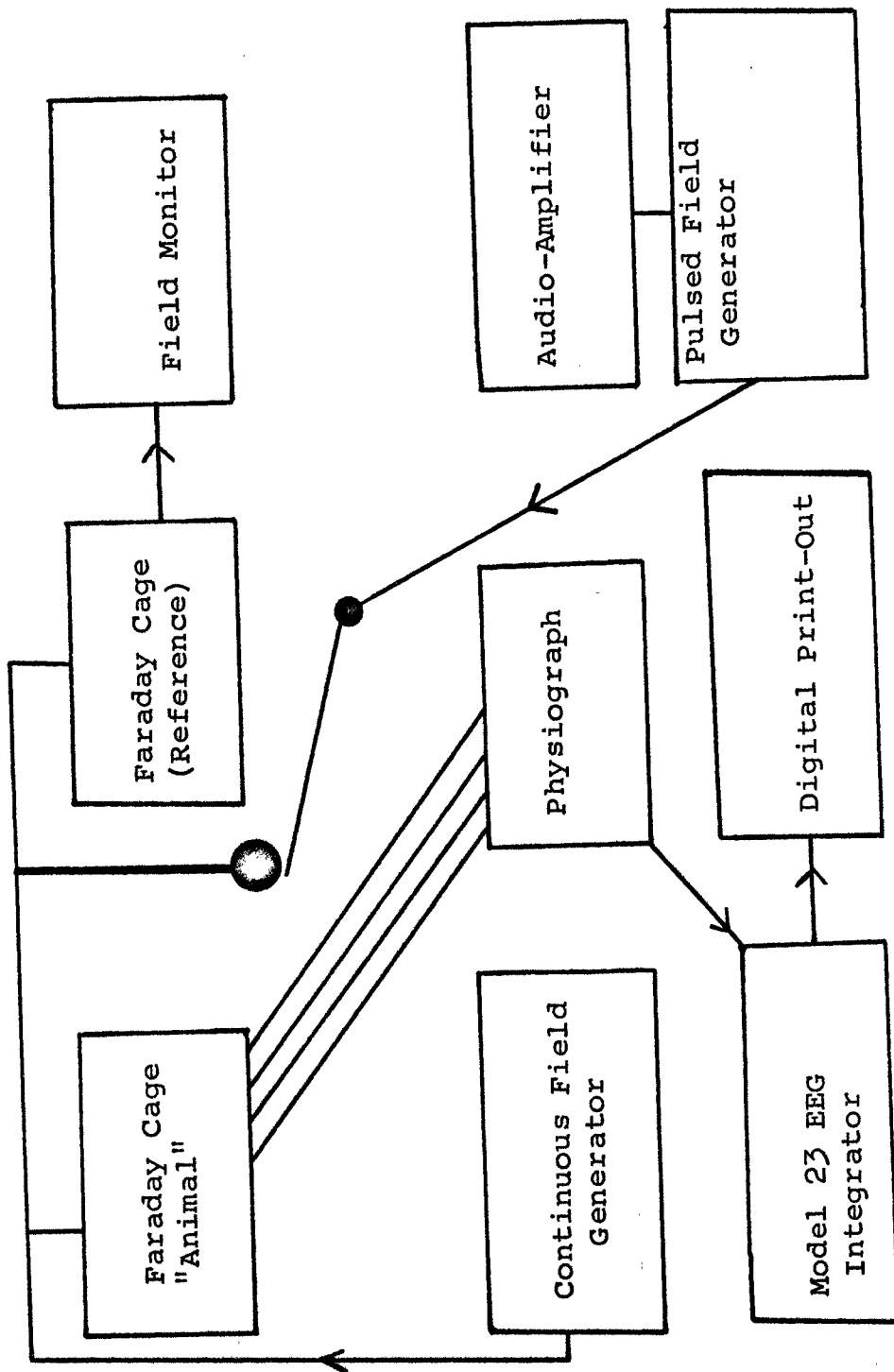
Figure 1 -- Diagram of Experimental Apparatus

attached to the animal recorded the EEG, ECG, respiration,
and temperature during each experiment. The area
under the EEG tracing on the physiograph was simultaneously
integrated, and the resultant curve depicted on the
physiograph. Moreover, the integrated EEG was further
integrated and converted into digital form by means of
a Model 23 EEG Integrator used in conjunction with
Digital Data Recorder (Cold Springs Instrument Corporation).
Specifically, these devices integrate and convert the
total area under the EEG tracing into a numbered print-
out every 60 seconds throughout the experiment. This
number represents the total brain activity (energies)
for one minute. Every precaution was taken to insure
proper grounding of the electrical systems, in order that
no electrical feedback would occur in either the animal
chamber (Faraday Cage) or the recording apparatus.
Grounding was checked before each experiment by crossing
the electrodes in the Faraday cage and slowly turning up
the gain on the EEG preamp to its maximum. If no feedback
was present the tracing on the EEG was noted to be a steady,
straight line.

The preparation of the electrodes for implantation into the hypothalamus was carried out in the following manner. Insect pins (stainless steel, #00) were insulated with a liquid insulator (Epoxylite Corporation, El Monte, California). The electrode was dipped into the insulator and drawn out slowly against the wall of the vessel. The vessel in this instance was a capillary tube filled with insulator material. This method was found to coat the electrode evenly and to eliminate air bubble formation. The electrodes were allowed to dry overnight at room temperature and were checked the next day for uniformity of insulation and the presence of air bubbles. The diameter of the electrode at this point was about 0.4 mm. The distal end of the electrode was scraped so as to expose 0.5 mm of the tip. The entire procedure was carried out under a dissection scope. Sterilization of the electrode was accomplished by soaking it one hour in Zepharin solution diluted 750:1.

The operative procedure for implantation of the electrodes was essentially the same as that described by Miller (1961) and Agnew (1967), with one exception. Instead of two jeweler's screws being attached to the

skull, only one, containing the probe electrode, was

attached in this procedure. A reference electrode

prepared exactly as the others was placed approximately

15 mm anterior to the probe electrode on the midline

and no deeper than the jeweler's screw and then covered

with dental acrylic. This maintained the rigidity of

the electrodes and acrylic cap.

Placement of the implanted electrode was accomplished

by means of a Horsley-Clark sterotaxic apparatus manufactured

by the Kop Instrument Company, Tejunga, California. The

Stereotaxic Atlas of the Rat Brain, by Pellegrino and

Cushman, was used in determining the position of the

electrode. Coordinate System B was employed. In this

system, which is a simple modification of the DeGroot

system, the rostral-caudal zero reference point is the

bregma. Using this point as reference zero, it was

assumed that any variation that might occur because of

brain size might be more accurately eliminated. With

system B coordinates, the section posterior to the bregma

is numbered with a minus sign. For those investigators

who prefer to measure the depth of their placements from

the dura, rather than from the stereotaxic zero. Using

this system, the coordinates would be: rostral-caudal (-1.0),

i.e.,1 mm posterior to the bregma; medial-laterial, 0.6 mm

from the midline; dorsal-ventral, 8.5 mm ventral from

the surface of the dura. These coordinates were used

to position the tip of the stainless steel electrode

(Clay-Adams Company, New York) in the posterior portion

of the hypothalamus. The precise location of the electrode

was later confirmed at autopsy by X-ray and histological

examination.

In general the experiments were divided into the

following series:

    1. Sham-exposed rats, surface electrodes.

    2. Sham-exposed rats, implanted electrodes.

    3. Rats exposed to continuous fields, surface electrodes.

    4. Rats exposed to continuous fields, implanted
       electrodes.

    5. Rats exposed to pulsed fields, surface electrodes.

    6. Rats exposed to pulsed fields, implanted
       electrodes.

After implantation of the hypothalamic electrodes, the

animal was allowed to recover one week prior to the experimentation.

On the day prior to testing the animal was taken
into the room where the experiment would be carried out.
This was to allow the animal to acclimate to lighting,
noise, temperature, etc., and to stabilize its brain
activity. Constant lighting was maintained in this
room and the temperature was relatively constant,
$24^{\circ}C \pm 3^{\circ}C$. Each experiment was carried out at approximately
the same time of day, between 2 pm and 6 pm. Prior to the
time of testing the animals were injected intraperitoneally
with nembutal (33 mg/Kg of body weight). When anesthesia
was complete, as indicated by absence of the eye reflex,
the animal was placed in a Faraday Cage. In the series
involving brain surface recordings, the electrodes
were pushed under the scalp starting at the ears and going
cephalad. Care was taken to prevent the electrodes from
touching. If an implanted rat was to be used, small
alligator clips were attached to the implanted electrode
and the reference electrode.

The experiments involving continuous field effects
were 96 minutes in length and were divided into a 20-
minute control period, a 50-minute test period and a

20-minute recovery or post-test period. Six minutes
were arbitrarily added to the beginning of the test
period to allow the recording instruments to stabilize
following application of the charge to the electrode.
The given stabilization period (6 minutes) were obtained
from a series of preliminary experiments involving
(a) crossed electrodes in an empty cage, (b) implanted
but dead rats, and (c) dead rats with scalp electrodes.
It was found that the period of recording in stability
lasted no less than two and not more than six minutes.
A stabilization period was not required in those
experiments involving pulsed fields. This was assumed
to be due to the considerably lower electrode voltage
used in the pulsed field experiments.

In each experiment 15-second recordings were
displayed on the polygraph every 10 minutes. The tracing
was then analyzed visually for changes in fast brain
activity (10-20 μv amplitude at 6-12 cycles per second (cps)
frequency) and/or slow brain activity (20-30 μv amplitude
at 3-6 cps). Concurrently, one-minute print-outs of
integrated brain wave energies were made during the

entire course of each experiment.   Mean values were

obtained from these figures and plotted.

RESULTS

The data reported here are the results from 60 experiments. This does not include the data from "aborted" experiments, e.g., when animals regained consciousness too soon, or in those implanted experiments in which it was found at autopsy that the electrodes were not in the hypothalamus.

The physiological parameters monitored during the study showed no variation within an experiment. Heart rate varied greatly from one rat to another but varied little during an experiment. What variation was present was attributed to the anesthetic wearing off through the experimental period of 90 minutes. EKG was seen not to change. No abnormalities in the T wave or PQRS complex could be detected. Respiration rate again varied from rat to rat but varied little within an experiment. Temperature was the most constant parameter between rats. The temperature ranged between $97^{\circ}F$ and $101^{\circ}F$ but varied only $0.2^{\circ}F$ in any one experiment. It was concluded

that electrostatic fields in this experimental format

have no measurable effect on respiration, heart rate,

EKG, and body temperature.

The data in Figures 2-7 were obtained by visually

determining the occurrence of fast (6-12 cps) and slow

(3-6 cps) brain wave activity from ten-second samples in

fifteen-second polygraphic recordings taken every ten

minutes throughout each experiment. A frequency spectrum

for fast and slow brain wave activity was then established

and plotted. Each circle in the figures represents a

mean of nine experiments. Figure 2 shows fast and slow

activity in sham-exposed animals with scalp electrodes

for a period of 90 minutes. Two observations of importance

are in evidence in Figure 2. The first is that there

was no significant change in either the fast or slow

brain wave activity during the stated period. The

second is that it was clear that during the experimental

time period, the fast wave activity was more dominant

(mean frequency: 25-40) than slow brain activity

(mean frequency: 12-30).

Fig. 2 -- Frequency spectrum in sham-exposed rats using surface electrodes. Frequency values were determined by analyzing a 10 sec. period from a 15 sec. reading taken every 10 min. throughout the experiment. (Each circle represents a mean of nine experiments.)

Fig. 3 -- Frequency spectrum in rats exposed to continous fields, 10^4 KV/M, using surface electrodes. Frequency values were determined by analyzing a 10 sec. period from a 15 sec. reading taken every 10 min. throughout the experiment. (Each circle represents a mean of nine experiments.)
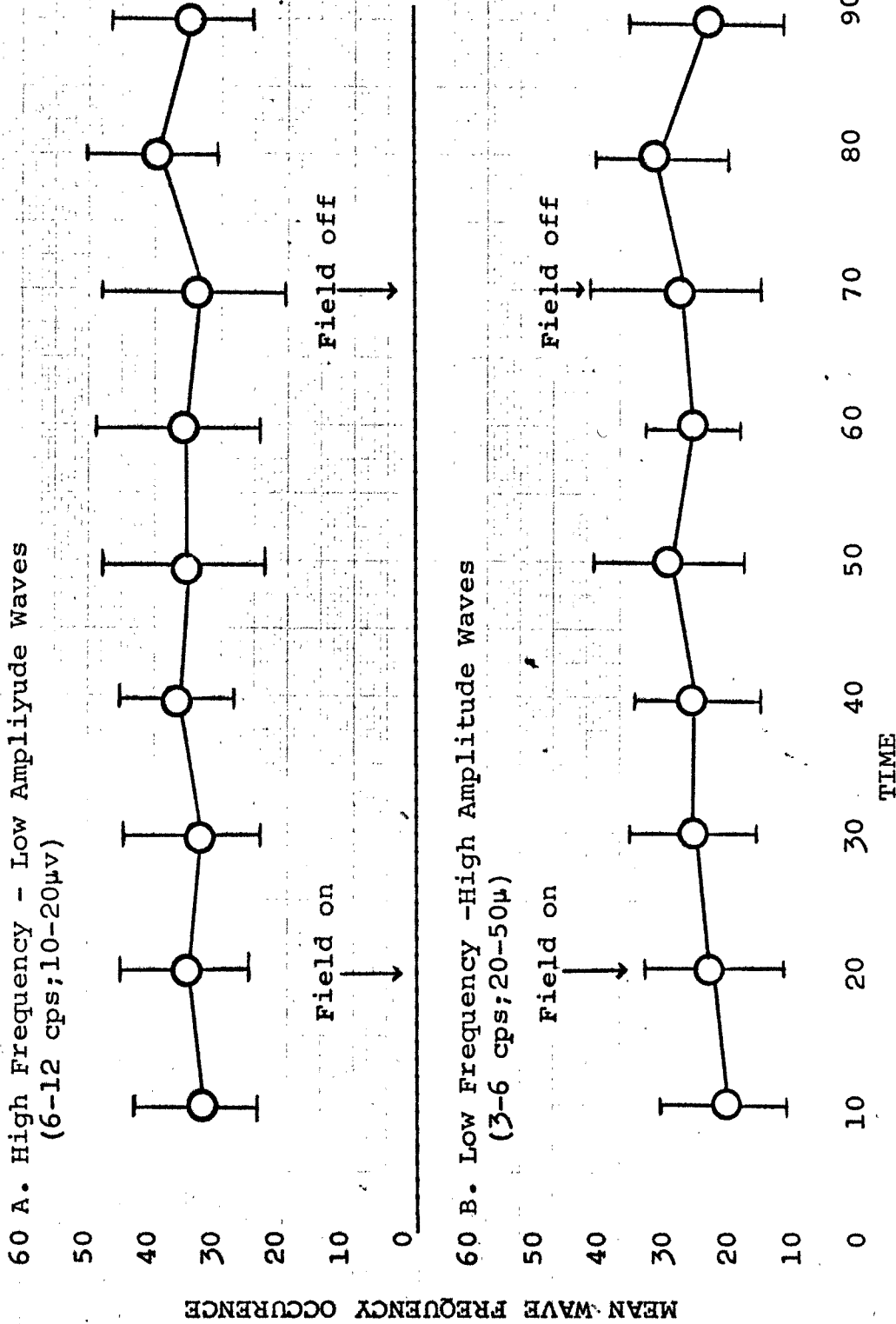
Fig. 4 -- Frequency spectrum in rats exposed to pulsed fields, 20V at 640cps using surface electrodes. Frequency values were determined by analyzing a 10 sec. period from a 15 sec. reading taken every 10 min. throughout the experiment. (Each circle represents a mean of nine experiments.)
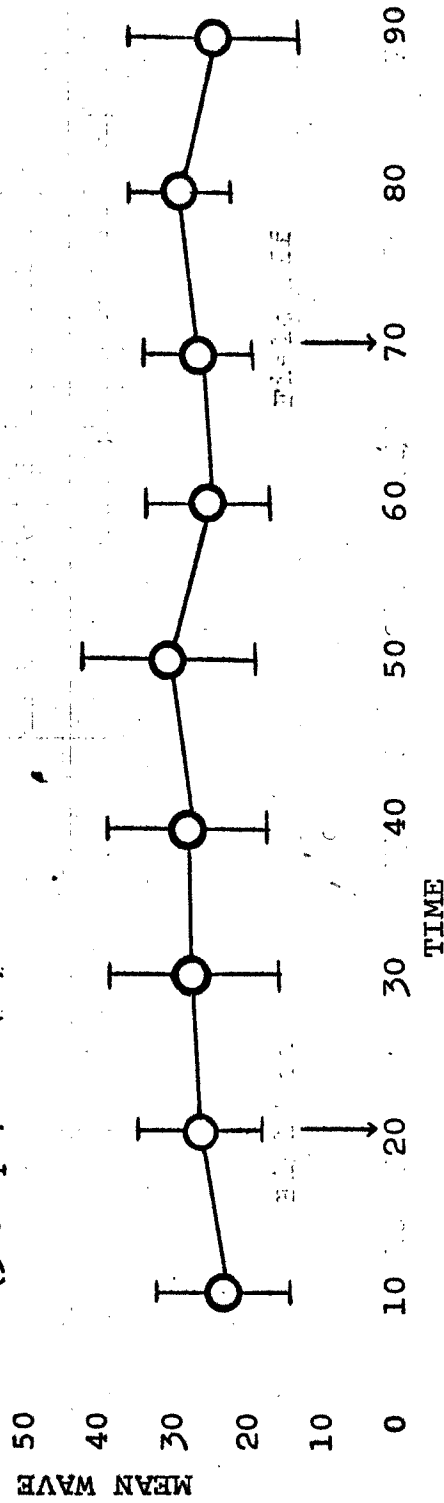
21
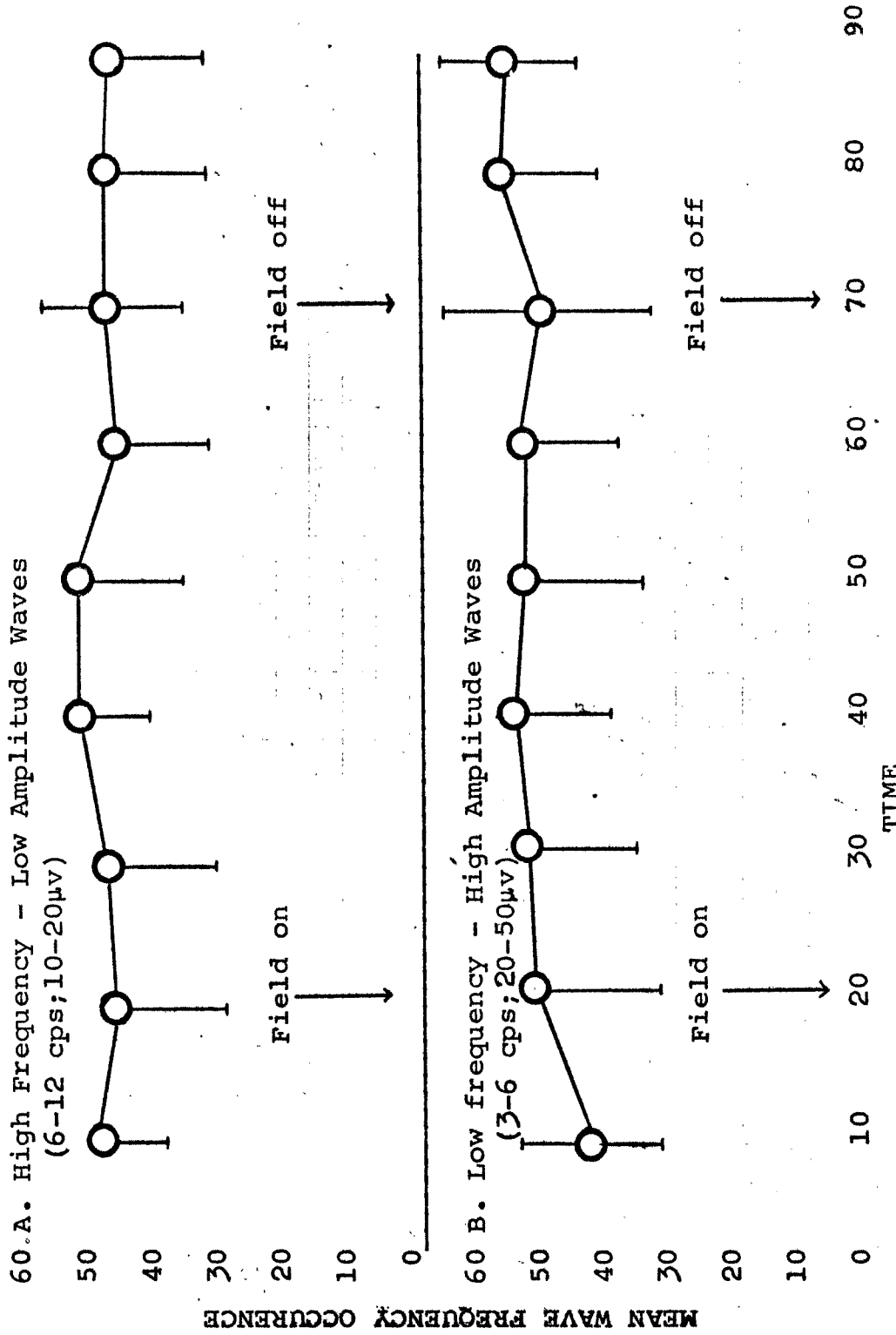
Fig. 5 -- Frequency spectrum in sham-exposed rats using implanted electrodes. Frequency values were determined by analyzing a 10 sec. period from a 15 sec. reading taken every 10 min. throughout the experiment. (Each circle represents a mean of nine experiments.)
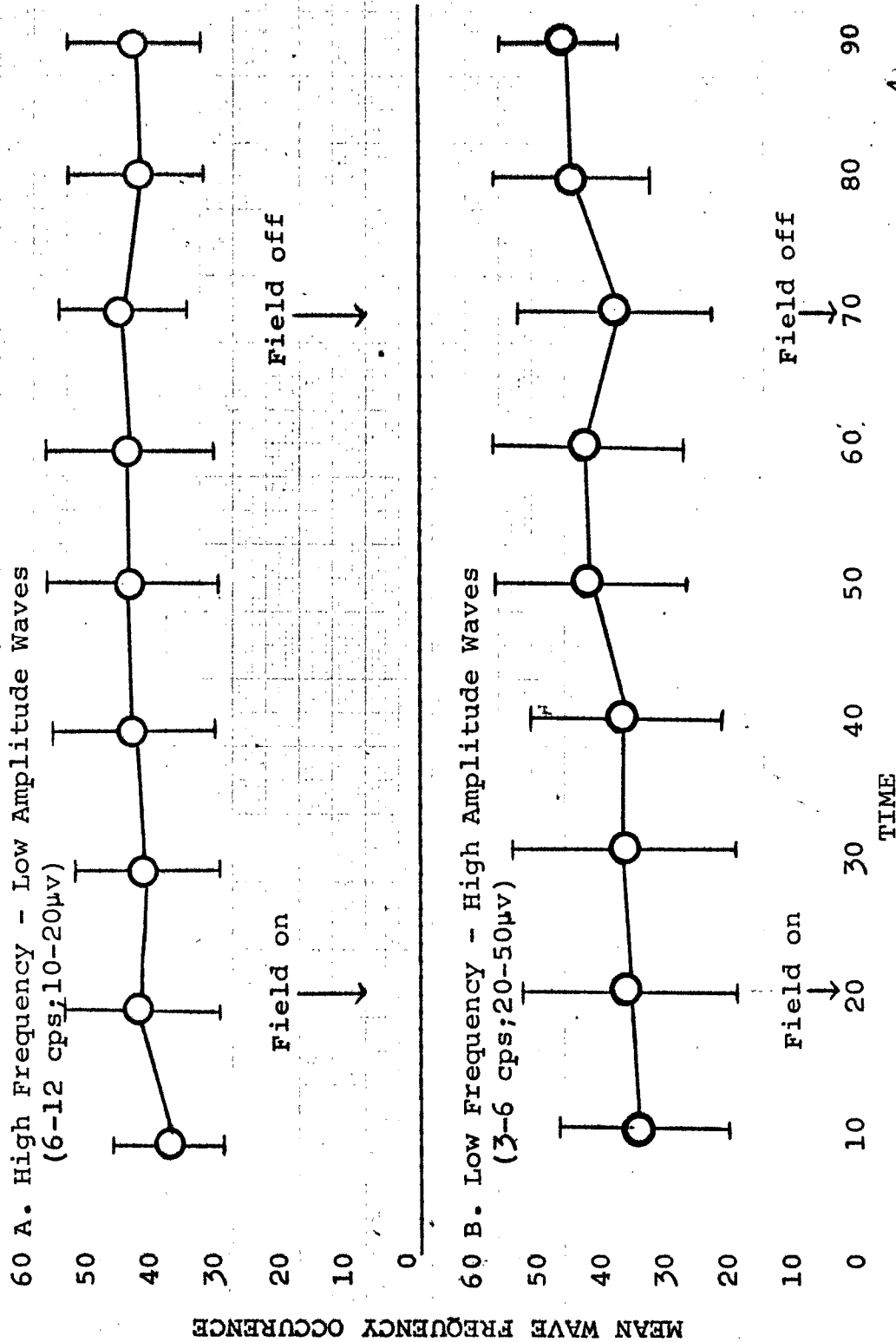
Fig. 6 -- Frequency spectrum in rats exposed to continous fields, 10^4 KV/M, using hypothalamic implanted electrodes. Frequency values were determined by analyzing a 10 sec. period from a 15 sec. reading taken every 10 min. throughout the experiment. (Each circle represents a mean of nine experiments.)
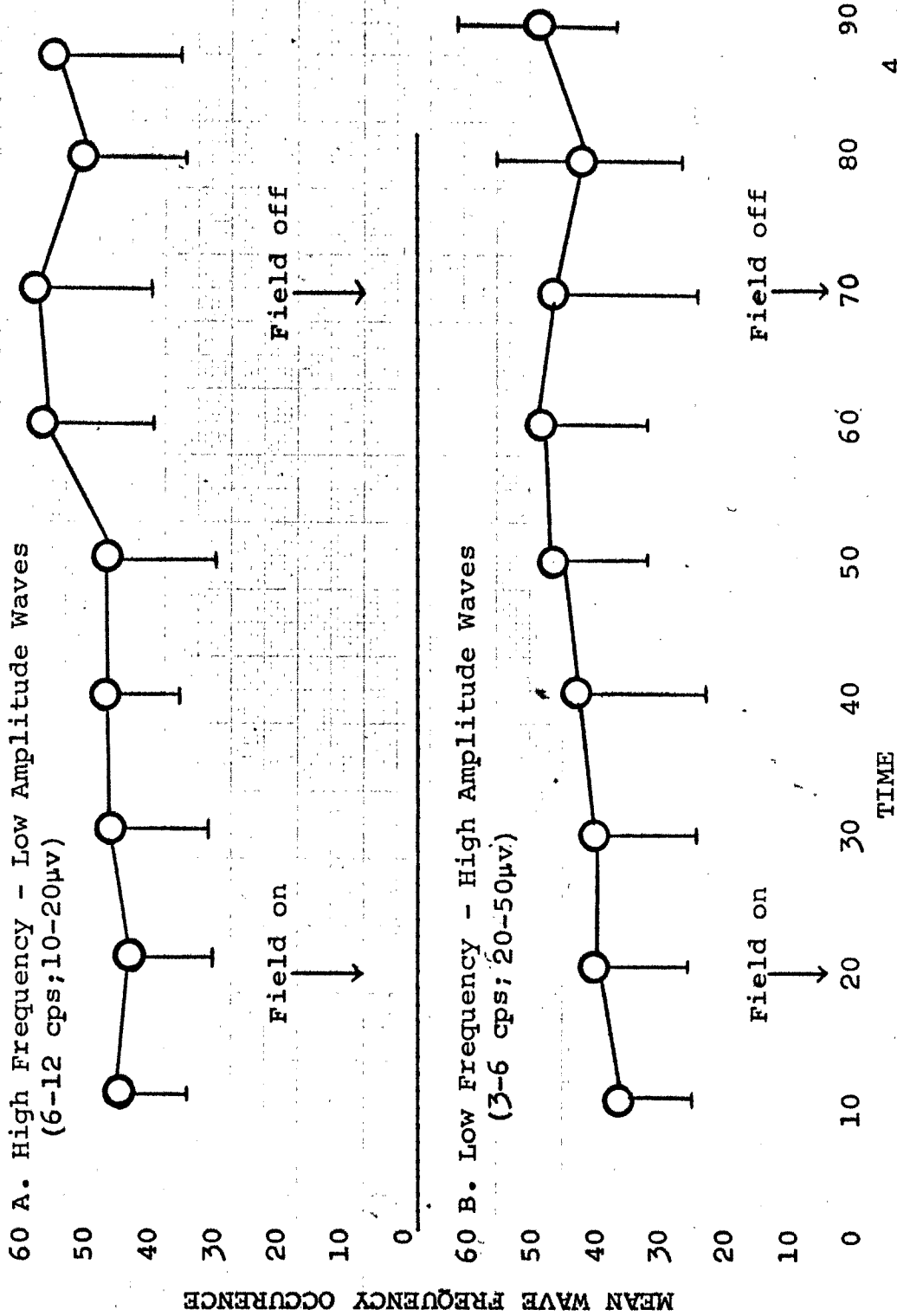
60 A. High Frequency – Low Amplitude Waves
(6–12 cps;10–20μv)

60 B. Low Frequency – High Amplitude Waves
(3–6 cps;20–50μv)

Field on

Field off

Field on

Field off

MEAN.WAVE FREQUENCY OCCURENCE

TIME

50   40   30   20   10   0

10   20   30   40   50   60   70   80   90
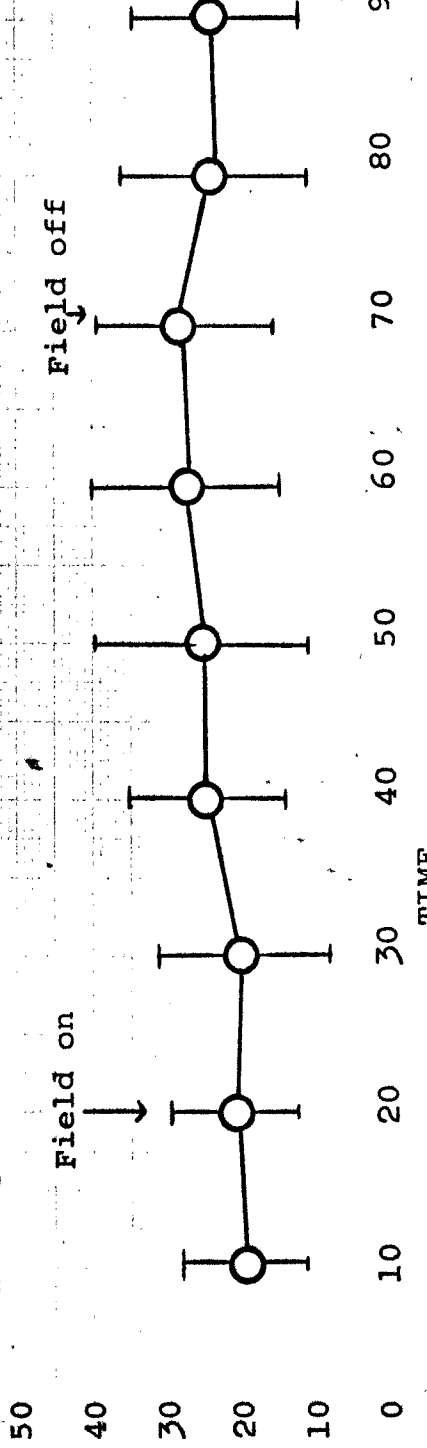
Fig. 7 --Frequency spectrum in rats exposed to pulsed fields,20V at 640cps, using hypothalamic implanted electrodes. Frequency values were determined by analyzing a 10 sec. period from a 15 sec. reading taken every 10 min. throughout the experiment. (Each circle represents a mean of nine experiments.)
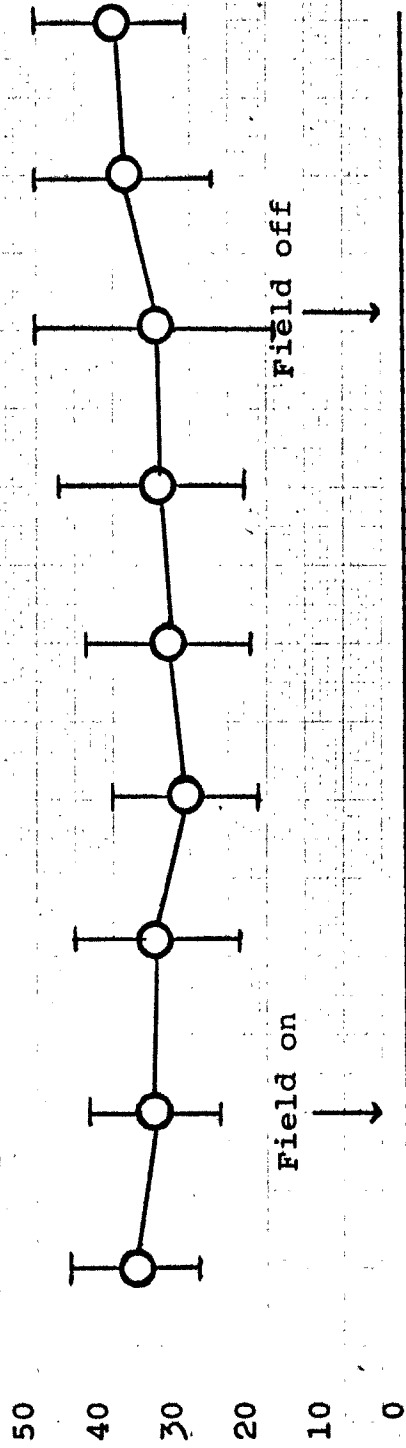
Figures 3 A and B show the frequency spectrum of brain wave activity from surface electrodes in rats exposed to a continuous electric field (10,000 V/M). It is clear that there were no significant changes in slow wave activity; however, at the 40-minute segment during exposure a slight rise in fast activity occurred. The activity returned to the control values when the field was turned off. Whether or not this change was significant is not clear, due to the fact that the values were obtained visually rather than by the more accurate method of wave frequency analysis via computer. Another observation in Figure 3 was that there was a slight predominance of fast activity over slow activity as was the case in the sham-exposed group.

From Figure 4 A and B it is clear that no significant changes occurred in the brain wave activity recorded in those animals with surface electrodes and exposed to pulsed electric fields (20V at 640 cps). Again, a predominance of fast wave activity over the slow brain wave activity in the animals is indicated.

Figures 5 A and B depict frequency spectra obtained from sham-exposed rats with hypothalamus-implanted electrodes.

Two observations in this case were that (a) there were

no significant changes in either the fast or slow brain

wave patterns, and (b) neither activity was predominant

over the other, i.e., the frequency of occurrence for

both the fast and slow activity ranged between 30 and 50.

When comparing the activity from animals with scalp

electrodes with that of the implanted animals, the latter

showed a higher fast and slow wave activity.

Figures 6 A and B also showed that no significant

changes in either fast or slow brain activity occurred

on animals exposed to a continuous electric field; moreover,

there was no evidence of one brain wave frequency dominating

another.

Finally, it is clear from Figures 7 A and B that

exposing animals to a pulsed electric field had no significant

effect of brain wave activity recorded from hypothalamic

electrodes.

Again, one must be reminded that the data depicted

in Figures 2-7 were obtained via visual analysis and not

by a more accurate computerized wave frequency analysis.

A more accurate analysis of the changes in brain wave
activity is depicted in Figures 8-13. In these figures
are curves showing changes in total brain waveform energies
in animals under the varying conditions of electrode
placement and exposure to electric fields. In each of
these figures a circle represents the mean value of
nine experiments, taken at one-minute intervals throughout
the 90-minute experiment. The values were integrated
and printed out by a digital computer.

Figure 8 shows the mean brain activity in sham-exposed
animals with scalp electrodes. The brain activity was
found to be relatively constant throughout most of the
experiment. The slight increase during the last ten
minutes may be due to the animals' recovery from the
anesthetic.

Figure 9 shows a distinct effect of a continuous
electric field (10,000 V/M) on the total brain waveform
energy taken from scalp electrodes in the animals. The
effect was most striking when the field was initially
applied, and again following cessation of the field.
Indeed, the brain activity almost doubled upon application
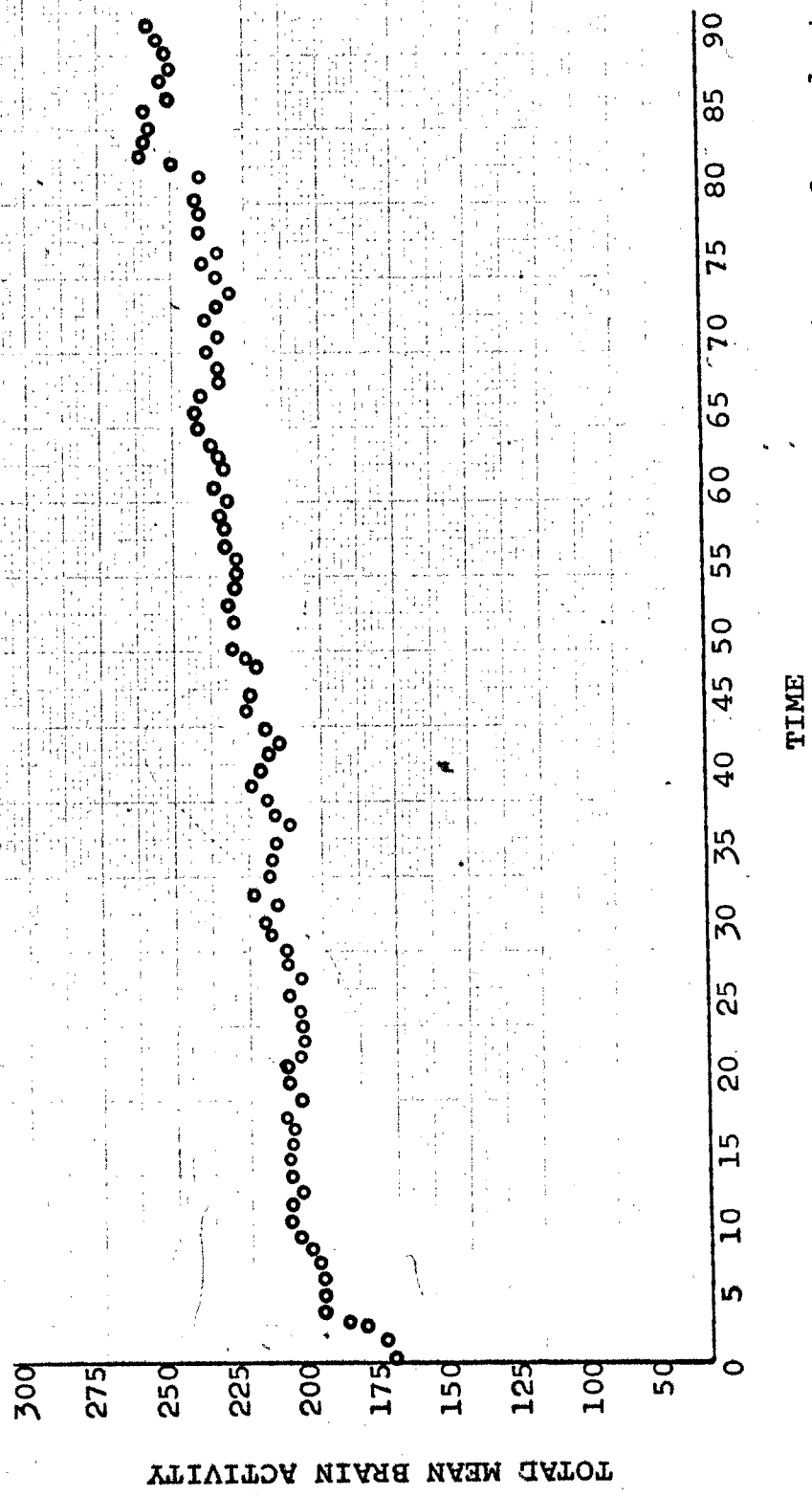
Fig. 8 -- Total brain activity in sham-exposed rats using surface electrodes.
(Each circle represents a mean of 9 experiments analyzed each minute for 90 minutes.)
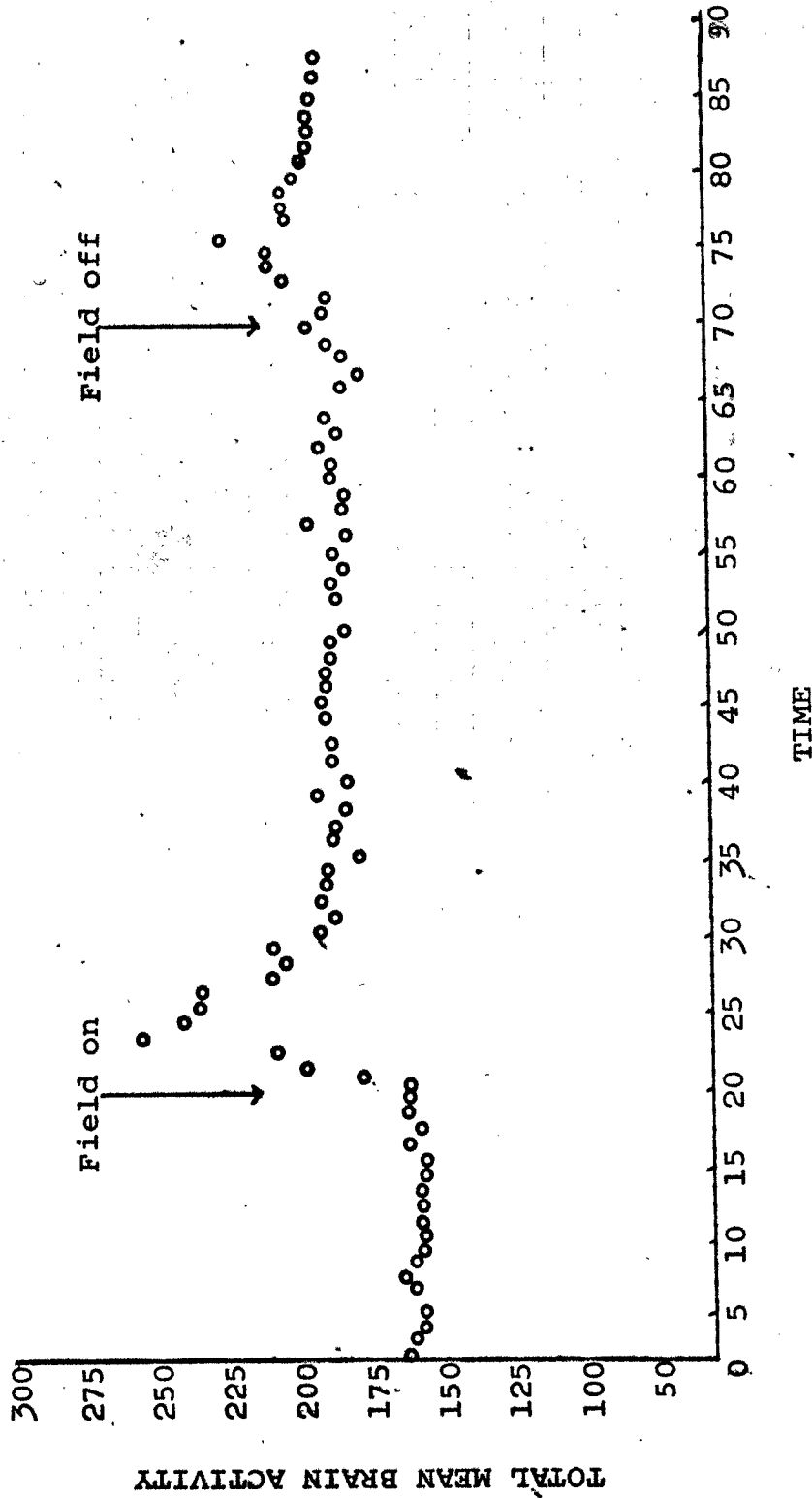
Fig. 9 -- Total brain activity in rats exposed to continous fields, 10^4 KV/M, using surface electrodes. (Each circle represents a mean of nine experiments. Readings were not taken for 6 minutes following application of the field.)
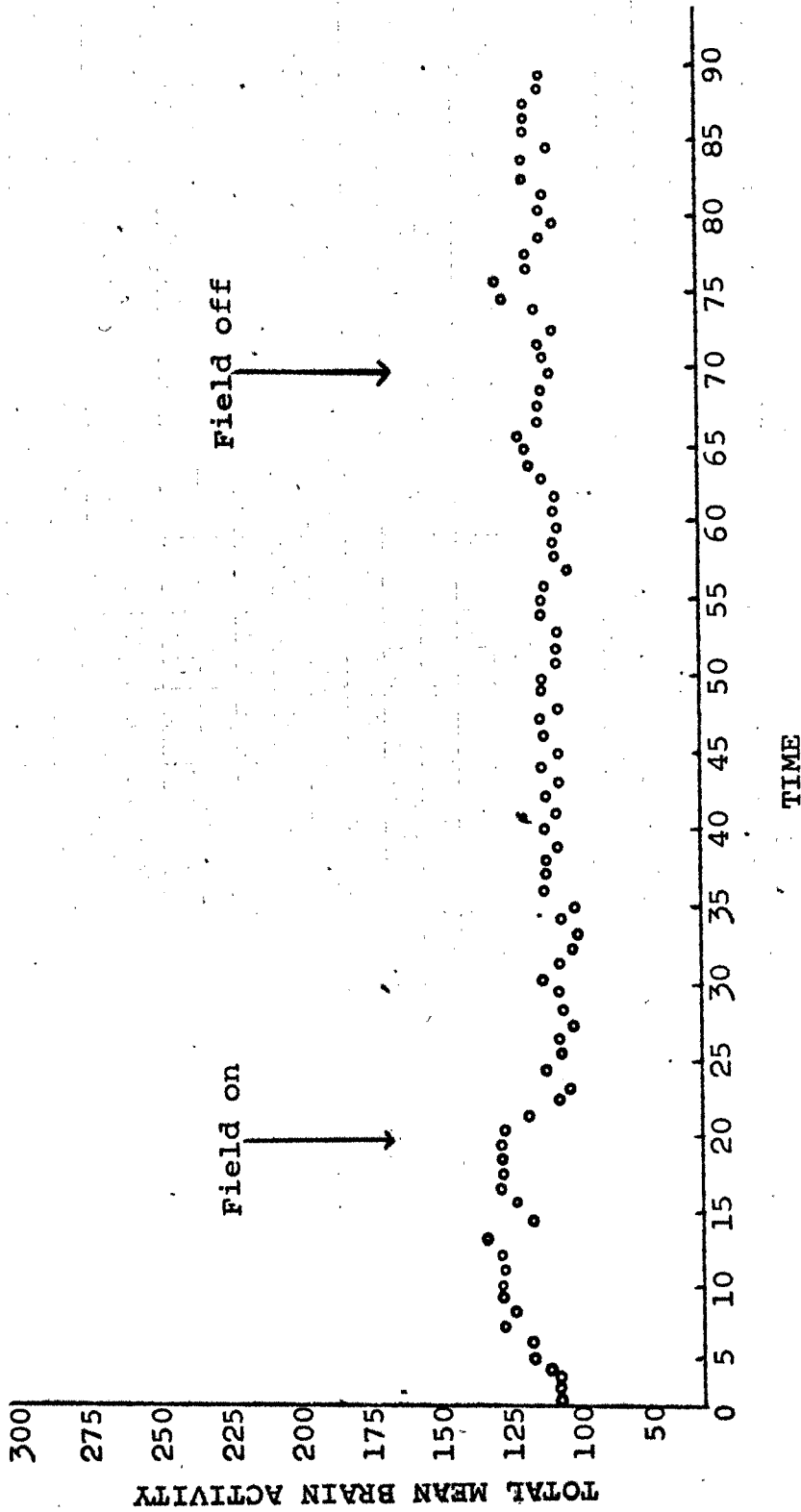
Fig. 10 -- Total brain activity in rats exposed to continous fields, 10^4KV/M, using hypothalamic implanted electrodes. (Each circle represents a mean of nine experiments. Readings were not taken for 6 minutes following application of the field.)
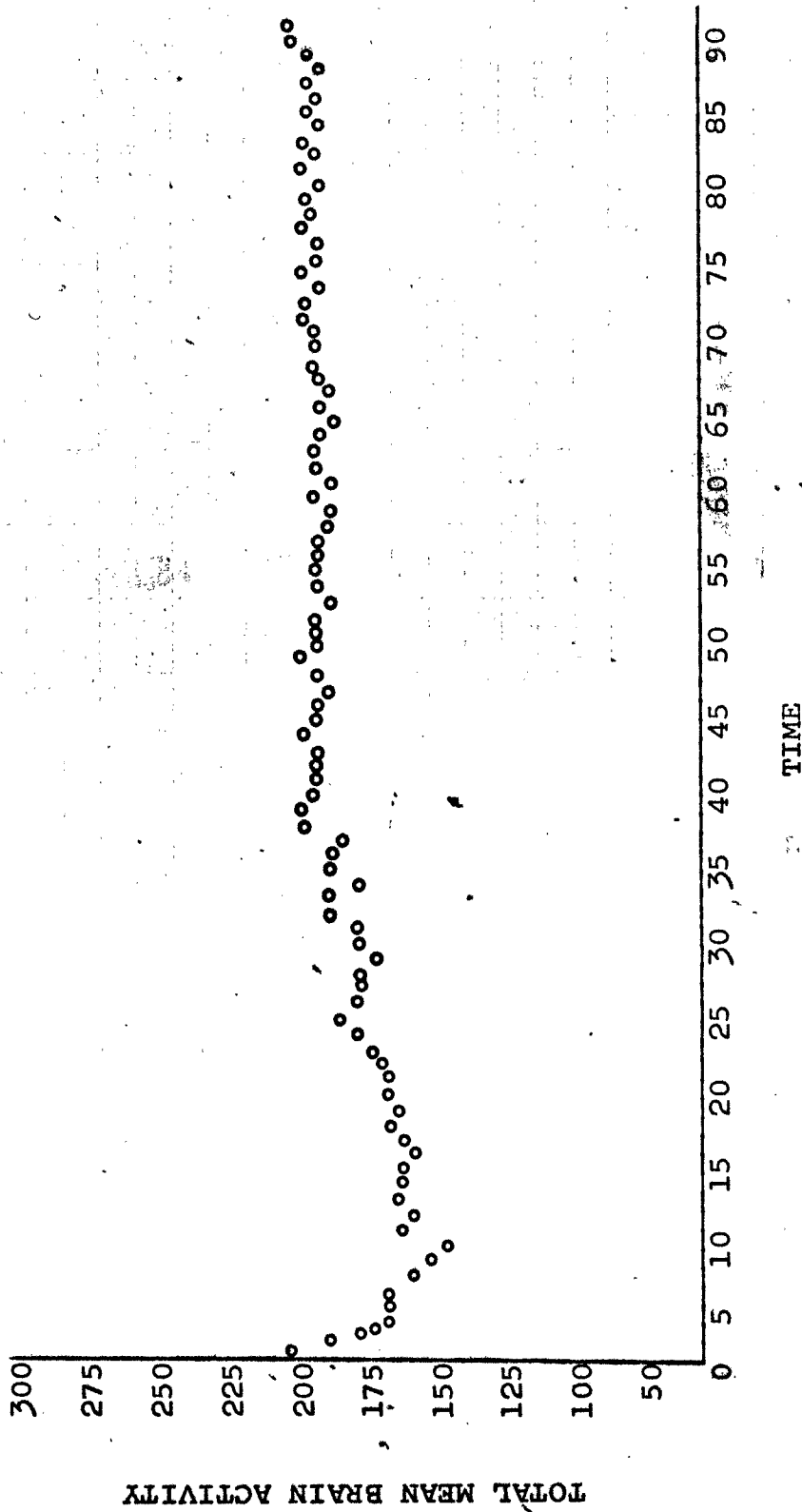
Fig. 11 -- Total brain activity in sham-exposed rats using hypothalamic implanted electrodes. (Each circle represents a mean of 9 experiments analyzed each minute for 90 minutes.)

300
275
250
225
200
175
150
125
100
75
50
0

TOTAL MEAN BRAIN ACTIVITY

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90

TIME

Field on

Field off
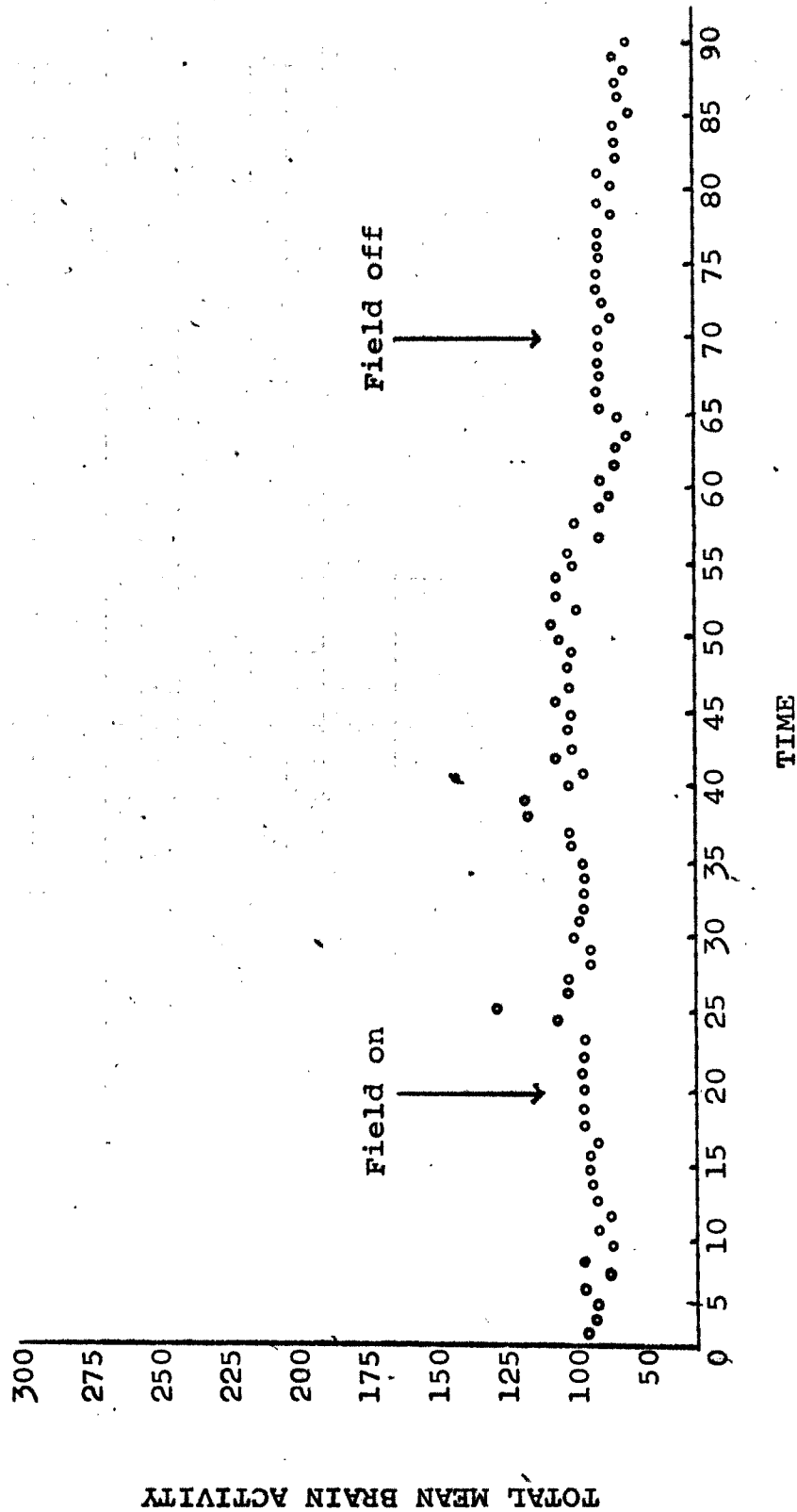
Fig. 12 --Total brain activity in rats exposed to pulsed fields, 20v at 640cps, using surface electrodes. (Each circle represents a mean of 9 experiments. Readings were not taken for 6 minutes following application of the field.)
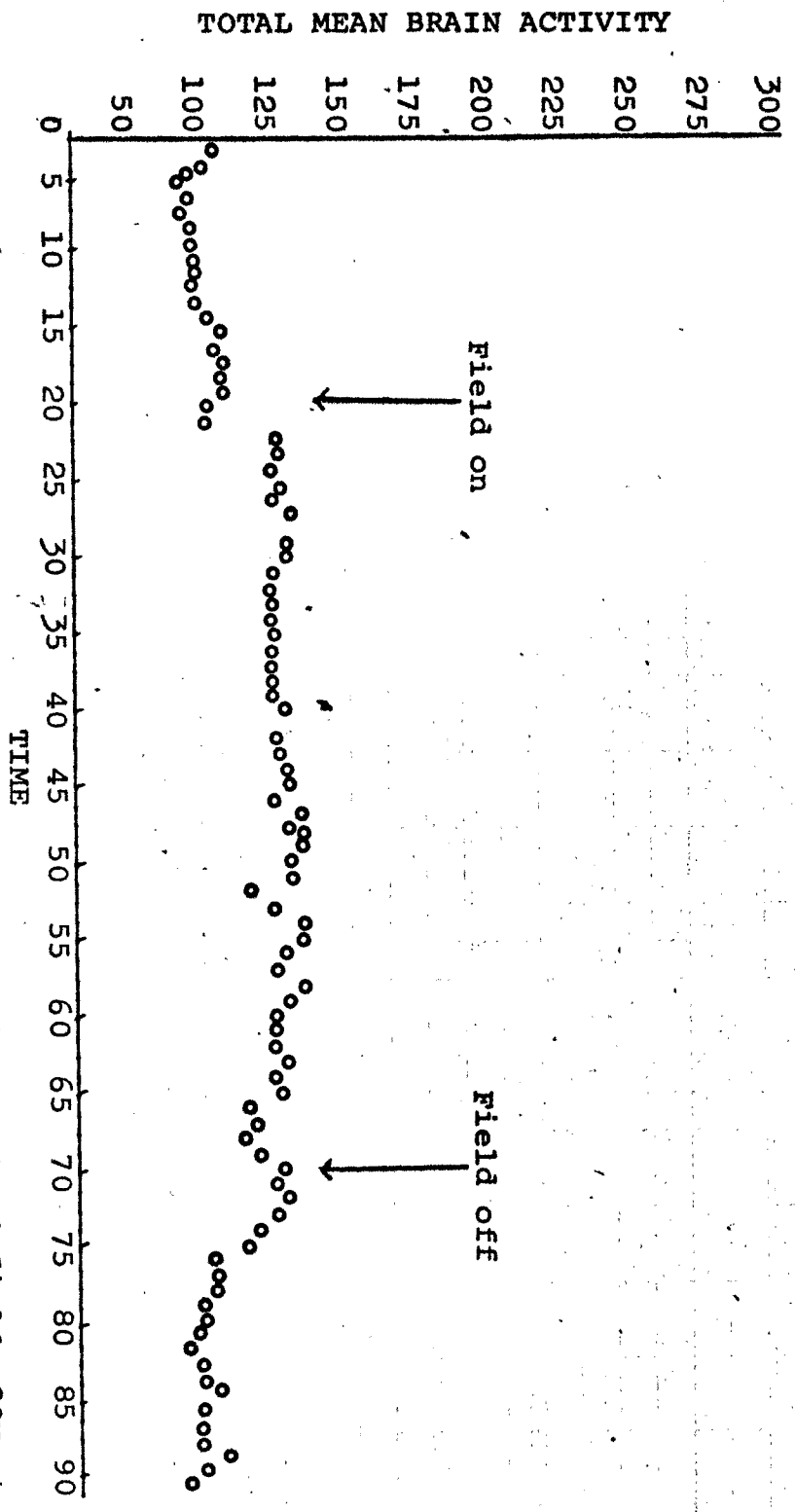
Fig. 13 -- Total brain activity in rats exposed to pulsed fields, 20V at 640cps, using hypothalmic implanted electrodes. (Each circle represents a mean of nine experiments. Readings were not taken for 6 minutes following application of the field.)

of the field (for about 10 minutes). The increase was

noticeably less when the field was turned off. Moreover,

there was a sustained <u>increase</u> in the level of activity

throughout the test period. The activity failed to

return to pre-test levels during the post-test period.

Surprisingly, as shown in Figure 10, the level of

hypothalamic activity in animals exposed to a continuous

electrostatic field was <u>depressed</u> throughout the experiment.

The degree of depression of the hypothalamic activity,

however, was not as striking as that achieved in the

animal from which the activity was recorded from scalp

electrodes. Moreover, there appeared to occur a slight

recovery or return to pre-test levels following the

cessation of the field.

Figure 11 depicts the hypothalamic brain activity

in sham-exposed animals. Following a decrease in activity

during the initial phase of anesthesia a relatively

constant level of activity was reached within 25 minutes

following the anesthesia and was sustained throughout

the remainder of the experiment.

The level of activity obtained from surface electrodes in animals exposed to an electrostatic field was also increased in this condition. However, as shown in Figure 13, the increase was not as great as that observed in the hypothalamic-implanted animals. Another interesting difference was noticed, i.e.,"spiking, activity was observed during the exposure period, particularly at the 25-minute interval and between 35- and 40-minute periods.

Summaries of the data represented by Figures 8-13 are presented in Tables 1 and 2. The data are based on the Comparison of Sample Means: Paired Observation Test (Steele and Torrie, 1960). The numbers presented in the Activity Index Column were calculated by dividing the first minute reading of the digital recorder print-out into itself and into each subsequent reading throughout a particular experiment. Therefore, the first reading represents one total unit of activity, or 100%. Readings following the initial one would fall above or below this reading depending upon the trend set by the experimental animal's brain activity. One can see from this procedure that variability between experiments in terms of actual

TABLE I

A Summary of the Effects of Electric Fields on Rat Brain Activity,
Recordings from Scalp Electrodes.

A.   Continuous Fields (10,000 V/M)

Time Period Compared	Mean Activity Index[+]		% of Change*
	Control S.D.	Test S.D.	
10-20	96.4 ± 1.9	101.9 ± 2.1	5.7
Field on			
20-30	95.7 ± 2.0	134.2 ± 10.7	+40.2***
40-50	103.5 ± 2.0	116.1 ± 2.4	+12.1**
60-70	109.6 ± 1.4	116.6 ± 4.4	+ 6.4
Field off			
70-80	110.8 ± 2.6	131.3 ± 6.3	+18.5***
	103.3 ± 2.0	120.0 ± 5.2	+17.0

B.   Pulsed Fields (20 V at 640 cps)

Time Period Compared	Mean Activity Index		% of Change
	Control S.D.	Test S.D.	
10-20	96.4 ± 1.9	98.4 ± 6.8	2.1
Field on			
20-30	95.7 ± 2.0	111.1 ± 12.4	+17.1***
40-50	103.5 ± 2.0	112.1 ± 4.1	+ 8.8**
60-70	109.6 ± 1.4	91.1 ± 5.8	-16.8***
Field off			
70-80	110.8 ± 2.6	90.3 ± 3.4	-18.5***
	103.2 ± 2.0	100.6 ± 6.5	- 1.4

*$\dfrac{\text{Control value - Test value}}{\text{Control value}}$ x 100

**Statistically significant (p 0.01)

***Statistically significant (p 0.001)

[+]$\dfrac{\text{Activity per Interval}}{\text{Initial Activity}}$

TABLE II

A Summary of the Effects of Electric Fields on Rat Brain Activity,
Recordings Taken from Hypothalamic Implanted Electrodes.

A. Continuous Fields (10,000 V/M)

Time Period Compared	Mean Activity Index[+]		% of Change*
	Control S.D.	Test S.D.	
10-20	100.7±2.7	100.0±2.6	0.99
Field on			
20-30	110.5±2.4	91.1±6.4	-18.1***
40-50	114.9±3.3	89.7±2.4	-21.3***
60-70	116.3±1.8	92.0±1.6	-20.6***
Field off			
70-80	116.2±1.4	93.4±4.4	-19.4***
	111.7±2.3	93.2±3.4	-15.7

B. Pulsed Fields (20 V at 640 cps)

Time Period Compared	Mean Activity Index		% of Change
	Control S.D.	Test S.D.	
10-20	100.7±2.7	106.9±7.0	5.8
Field on			
20-30	110.5±2.4	124.1±4.1	+12.7***
40-50	114.9±3.3	126.4±3.1	+10.5***
60-70	116.3±1.8	120.4±5.8	+ 3.4**
Field off			
70-80	116.2±1.4	105.0±7.3	- 9.5***
	111.7±2.3	116.5±5.4	+4.58

$$*\frac{\text{Control value} - \text{Test value}}{\text{Control value}} \times 100$$
**Statistically significant (p 0.01)
***Statistically significant (p 0.001)
$+\frac{\text{Activity per Interval}}{\text{Initial Activity}}$

brain activity reading is eliminated while the trends

set by these readings are amplified. This allows one

to compare a certain time interval of the test period

with the same time interval of the control experiments.

Table 1 contains data showing the effects of a

continuous (A) and pulsed (B) fields on rat brain activity

recorded from scalp electrodes. All of the changes

observed, when the field was applied and when the field

was turned off, were statistically significant from the

changes observed in the sham-exposed animals. This

included both experimental conditions; i.e., pulsed and

continuous fields. The differences in effects on the

EEG in the animals exposed to pulsed fields and continuous

fields were striking. The latter brought about a sustained

increase in activity, whereas the former produced a distinct

biphasic effect—an initial increase in activity followed

by a distinct decrease in activity upon cessation of the

field. Of course, these differences may be due to the

differences in magnitude of the fields (10,000 V/M vs 20 V

at 640 cps pulsed field).

The data in Table 2 shows the effects of (A) continuous and (B) pulsed fields on hypothalamic activity. They also show statistically significant changes in relation to one another. The pulsed field produced a sustained decrease in hypothalamic activity while the continuous field brought about a slightly biphasic response, i.e., an initial increase in activity followed by a return to control levels following the cessation of the pulsed field.

Even more striking are the differences in effect of the same electric field on the activity recorded from surface electrodes as compared with the hypothalamic activity (Table 1 A and B).

Animals exposed for one hour to 10,000 V/M exhibited a significant and sustained increase in surface activity. On the other hand, a significant decrease in hypothalamic activity was observed during the same time period. Differences in the brain response of the animals to pulsed fields was not as striking as those seen with the continuous fields; however, there were differences. Animals exposed to pulsed fields showed a more distinct biphasic effect on the recordings from the brain surface than on hypothalamic activity. Moreover, the magnitude of the effects were not as apparent in those recordings from the hypothalamus.

DISCUSSION

In assessing the present study one must appreciate
some of the problems that were encountered with the
experiment. Alignment of the experimental apparatus so
as to get accurate results was a problem throughout each
experiment. Proper grounding of the apparatus was essential
so as to not form ground loops and consequently develop
electrical feedback that would interfere with accurate
monitoring of the biological parameters. The apparatus
used in this experiment was especially sensitive to
jarring. The slightest touch to the power inputs to the
Faraday cages was enough to completely obliterate an
EEG tracing for several seconds.

Variation in the animals' physiological states made
direct analysis of data, at times, difficult. Many
animals recovered from the anesthesia 30 minutes into
an experiment for no apparent reason causing that
particular experiment to be aborted. It was learned
during the study that if an animal showed an absence of

the pupil reflex ten minutes after nembutalization, that animal would probably remain anesthesized during the entire experimental period.

Proper implantation of the hypothalamic electrode was another very critical factor. Indeed, several experiments were of no value because the electrode was found, at autopsy, to be improperly positioned. Moreover, once the electrodes were properly implanted it was difficult to make good connections to those electrodes without applying pressure and thereby deflecting the electrode from the region of the hypothalamus. Good connections were achieved by applying very small alligator clips that were filed to allow maximum contact with the electrode jutting from the acrylic cap. Another difficulty lay in establishing a suitable method for creating an identifiable heat lesion in the rat brain. After this was accomplished, the histological determination of the location of the electrode tip was greatly facilitated.

Another problem, semantic as well as scientific in nature, is the fact that not all physicists are in complete agreement on the definition of the term <u>electrostatic field</u> (Reiter, 1953). Therefore, one can only describe

the manner in which one produces such a field and then include the type of apparatus used in measuring or monitoring that field. It was a surprise to learn that very few electric field monitors are on the market at this time.

Generally, it is difficult to compare the data presented here with those of other workers owing to (1) the nature of the problem and instrumentation, (2) the scarcity of similar work in the literature, (3) differences in the methodology used, and (4) poor translation of foreign papers.

In the experiments dealing with fast and slow activity it was not possible to show any changes which occurred when the field was turned on or off. A reason for this might be the method of EEG analysis. The method used in this study was a visual one, employing an EEG analyzer grid. With this method it would have been possible to miss a subtle change in brain wave frequency. Chizhenkova (1966) showed that differences in cortical electrical responses in different types of fields were more marked when the method of automatic analysis of EEG frequencies was used. If a Walter frequency analyzer had been available, perhaps

frequency changes would have been noted in this study.

However, the occurrence of fast and slow activity when

compared across experiments did show some changes.

With continuous fields-surface electrodes there was

an _increase_ in both fast and slow activity. This finding

agrees with those of Kornbleugh (1955), who exposed

animals to varying concentrations of positive ions,

and those of Lukyanova (1965), who used the Students'

criterion for relative variability to show that fast

activity (spindles) and slow activity increased

significantly during exposure to "static magnetic"

fields. On the other hand, a _reduction_ in the hypothalamic

activity was noted in this study in those animals

exposed to both continuous and pulsed fields. Pulsed

fields also reduced the surface activity in the animals,

but not to as great an extent. The reduction in the

hypothalamic activity may be explained on the basis of

Muller's work (1964). He reported that a stimulation

of the posterior hypothalamus attenuated amygdaloid

responses. Since the continuous field was of a greater

magnitude than the pulsed field, one might assume that the

increase in surface activity observed in those animals
might well have depressed other deeper brain centers
including the posterior hypothalamus. This type of
neurological interplay (feedback) is well documented
(Hansell, 1962; Brazier, 1968).

Again one must be careful in comparing the data
involving such a magnitude of differences in the experimental
variable used, i.e., the electric field per se (10,000 V/M)
versus the pulsed field used (20V at 640 cps).

The integrated data depicting the total energy of
the brain activity more clearly define the effects of
electric fields on the nervous system. The increase in
brain surface activity observed in both continuous and
pulsed fields concurs with the findings of Livanov (1962),
who used "electromagnetic fields" of varying frequencies.
The major drawback in attempting to compare the data
reported here with those of Livanov is due to the poor
description of his methodology. The spiking observed
upon cessation of the continuous fields is similar to that
observed in animals exposed to ionizing radiation (Grigor'ev,
1963; Garcia et al., 1963). It appeared that the animal

"knew" when the field came on and went off, thus

indicating the presence of an electrosensory system in

the animal. One cannot rule out a possible indirect field

effect on the animal, where sensors external to the brain

"inform" the brain of changes in the external electric

field, thereby altering the brain activity.

The decrease in posterior hypothalamic activity

observed in those animals exposed to 10^4 KV/M was somewhat

unexpected, since it has been shown that ionizing radiation

brings about <u>increased</u> activity in various lower brain

centers, e.g., hippocampus and hypothalamus (Kimeldorf

and Hunt, 1965), in addition to changes (desynchronization)

in the EEG. This was not observed here. Instead, an

opposite effect of the continuous field on the EEG

(increased activity) and the posterior hypothalamus

(decreased activity) was observed. These findings

may be explained on the basis of some negative feedback

mechanism previously mentioned (Sheer, 1963; Hansell,

1964; Brazier, 1968).

The results observed using pulsed fields at a relatively

low energy (20V at 640 cps) were even more surprising.

In this case, only sporadic "spiking" was noted in the EEG, and a significant and sustained increase in posterior hypothalamic activity occurred. One is tempted to conjecture that there may be various levels or different loci of electro-sensitivity in the brain. In this case the posterior hypothalamus appears to be more suitable in sensing smaller changes in the external electrical environ-ment than the brain in toto. One wonders at what frequency and voltage levels the EEG begins to sense the change in the external electric field.

The findings that continuous fields had no significant effect on such physiological parameters as heart rate, respiration, EKG, and temperature are in agreement with those of Cristof (1965), etc. The similar findings with the pulsed field were in slight discord with those of Puharich (1966), who observed rather drastic changes in humans (nausea, confusion, anxiety) exposed to pulsed fields of a higher magnitude in a Faraday cage. Based on Schau's findings with the golden hamster (nest relocation), one would think that pulsed fields were "harmful" to the animal. Sensing an abnormal and perhaps harmful change in the

external environment, the animal began to move her young and her nest into another area. One would expect a change in at least the heart rate and respiration under these circumstances. Such changes were not observed in this study. This might have been due to the lower frequency and/or voltage of pulsed fields used here, as opposed to the magnitude of pulsed fields used by Puharich and Schua.

Along the same lines is the well known "radarman syndrome" common to many workers who are near large electronic communication systems. These people complain of headache, malaise, nausea, and vertigo — all nervous in nature. Are these symptoms due to the effect of microwaves and/or pulsed electric fields being emitted from the electronic device in the Faraday cage-like rooms in which they work?

Again, one would expect during such a syndrome, changes in heart rate and respiration. The literature is relatively sparse on work reporting measurements of electric fields in radar rooms and around communications equipment.

At this point one might ask why the brain should

respond at all to external electrostatic fields. Lund,

in his book, <u>Bioelectric</u> <u>Fields</u> <u>and</u> <u>Growth</u> (1947),

presents a provocative piece of work which might answer

this question. Lund maintained that each cell, each

organism, has an electrochemical system, an intra- and extra-

cellular electric polarity. Moreover, he states that any

externally applied electrostatic field either opposite

in polarity or opposite in intensity may quite possibly

alter the "behavior" of the cell or organism. This possible

change in behavior based on permeability changes is

stated by Lund:

> The pattern of transfer of ionic
> materials is probably of the same
> order of complexity as the pattern
> of the electrical field. It is
> certain, however, that electrical
> energy is used in transporting ionic
> materials, and a distortion of the
> electric field would distort the
> pattern of transport of materials,
> possibly with observable results
> as for example, in a gross manner
> such as polarization.   PP.288.

Lund has extensive data which prove the existence of

his "electrochemical system." If such a system does

exist, in this study an external electrical field was

applied to it and an effect was noticed.

In summary, the data presented here indicate clearly
that animals are capable of sensing changes in their
external electrical environment. Such findings point to
the need of further experimentation on the effects of
electrical fields, both continuous and pulsed, on all
levels of biological activity. In western Europe, there
are devices now in operation in clinics, offices, printing
companies, schools, and homes that attempt to stimulate
the external electrical field inside enclosures which act
as Faraday cages (Bonnevie, 1960). These devices are nothing
but large pole electrodes suspended from the ceiling and
charged positively. The walls and floor are by their
nature (connected to ground) already charged negatively;
therefore, a field can be established and maintained
at levels found on the outside of buildings. Some clinics
claim that certain pathological states can be treated
with electric fields (Wehner, 1962).

In view of the present, more scientific, findings
of this study, it would appear that we in the western
world might investigate further into the field of

bioelectrics. We should consider electric fields, along
with pressure, temperature, humidity, etc., as an important
component of man's external environment.

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