AD/A-000 078

A PSYCHOBIOLOGICAL STUDY OF RHESUS MONKEYS EXPOSED TO EXTREMELY LOW FREQUENCY-LOW INSTENSITY MAGNETIC FIELDS

John de Lorge

Naval Aerospace Medical Research Laboratory
Pensacola, Florida

16 May 1974

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

Unclassified
Security Classification

AD/A-000078

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Aerospace Medical Research Laboratory Pensacola, Florida 32512	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP N/A
3. REPORT TITLE A Psychobiological Study of Rhesus Monkeys Exposed to Extremely Low Frequency-Low Intensity Magnetic Fields	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) N/A	
5. AUTHOR(S) (First name, middle initial, last name) John de Lorge	

6. REPORT DATE 16 May 1974	7a. TOTAL NO. OF PAGES ~~25~~ 31	7b. NO. OF REFS 14
8a. CONTRACT OR GRANT NO. b. PROJECT NO. BuMed MF51.524.015-0014BX7X c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NAMRL-1203 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) .4	
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.		
11. SUPPLEMENTARY NOTES N/A	12. SPONSORING MILITARY ACTIVITY N/A	

13. ABSTRACT

Four rhesus monkeys were exposed to magnetic fields between 8.2 and 9.3×10^{-4} T alternating at 45 Hz and 15 Hz in a series of four studies. Associated electric fields were minimal. The monkeys displayed no reliable changes in performance analogous to timing behavior, nor were there indications that the animals could detect the fields. No consistent hematological changes were found to relate to the fields.

31

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0102-014-6600

Unclassified
Security Classification

Unclassified

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Magnetic fields						
Nonionizing radiation						
Extremely low frequency						
Operant behavior						
Blood chemistry						
Rhesus monkeys						

DD FORM 1 NOV 65 1473 (BACK)

(PAGE 2)

Unclassified

Security Classification

A PSYCHOBIOLOGICAL STUDY OF RHESUS MONKEYS EXPOSED TO EXTREMELY LOW FREQUENCY-LOW INTENSITY MAGNETIC FIELDS

John de Lorge

Bureau of Medicine and Surgery
MF51.524.015-0014BX7X

Approved by	Released by
Ashton Graybiel, M.D. Assistant for Scientific Programs	Captain N. W. Allebach, MC USN Officer in Charge

16 May 1974

Naval Aerospace Medical Research Laboratory
Naval Aerospace Medical Institute
Naval Aerospace and Regional Medical Center
Pensacola, Florida 32512

SUMMARY PAGE

THE PROBLEM

Communications systems have been shown to produce extremely low frequency (ELF) nonionizing radiation at low intensities. Several studies indicate that radiation within these ranges might have biological effects. The present study contained a number of experiments designed to reveal various behavioral and biochemical changes potentially induced by ELF magnetic fields.

FINDINGS

Magnetic fields between 8.2 and 9.3×10^{-4} T alternating at 45 or 15 Hz had no consistent effects on operant behavior in four rhesus monkeys. No hematological changes were found to relate to the presence or absence of the fields although such changes were related to food deprivation.

ACKNOWLEDGMENTS

Appreciation is extended to the Veterinary Sciences Division for their laboratory analyses and to Electronics Services of NAMRL for their assistance in this study. The author is especially thankful to Mr. C. Ezell for maintaining the experiment and to Ms. B. Boss for her daily devotion to the data.

INTRODUCTION

Many heretofore unsuspected biophysical agents have been discovered in contemporary investigations of environmental influences on plants and animals. Among these agents is nonionizing radiation. Such radiation includes electromagnetic fields generated by local climatic or geological conditions and fields produced by high tension power lines. Low intensity fields are also associated with many household appliances and conveniences. Although the majority of studies have been concerned with higher frequency electromagnetic fields such as in the microwave region (300 - 300,000 MHz), the present study was particularly interested in low intensity, extremely low frequency (ELF) magnetic fields below 300 Hz.

The literature on the biological influence of magnetic fields was extensively reviewed by Barnothy (1) and Presman (12), these reviews illustrate that very little research has been conducted with low intensity ELF magnetic fields. However, since these reports, a plethora of investigations concerned with low intensity ELF magnetic and electric fields has emerged. Contemporary research in the area is especially concerned with frequencies associated with communications and power-generating facilities although a number of investigators are also exploring the relationship between geomagnetic/climatic phenomena and biological effects. (See Persinger et al. [10] for a review of recent ELF research.) Because of the difficulty in separating magnetic and electric fields, many of the recent studies do not differentiate between the two. In addition, whereas earlier research with animals concentrated on broad measures such as general motor activity, current work tends to obtain data on specialized behavior such as reaction time and conditioned responses.

In their review of recent work, Persinger et al. (10) conclude, among other things, that ELF electromagnetic research has shown effects in timing behavior and oxygen uptake. However, investigations in our laboratory failed to discover any reliable behavioral influences of ELF fields (3, 4, 5, 8, 9) although there were indications of increases in serum triglycerides in man after one day of exposure to a low intensity ELF magnetic field (2). The present study was designed to explore the purported changes in time-dependent behavior and blood chemistry using rhesus monkeys as subjects.

METHOD

SUBJECTS

Four rhesus monkeys (Macaca mulatta) previously used in similar experiments (4,5) were the subjects. 3Z5 and 4Z7 were 7 and 5-year old females respectively; AP6 and AR4 were males and approximately 8 years old at the start of experiment 1. The animals were on ad libitum feeding in their home cages for at least 3 months prior to the present study.

APPARATUS

The apparatus, essentially the same as reported in previous studies (4, 5) but located in a different building, consisted of two conventional operant animal boxes each surrounded by a pair of large Helmholtz coils aligned in a north-south direction with the X-axis oriented east-west. The boxes were partially shielded from the coils by standard aluminum window screening connected to an earth ground. The room in which the boxes were located had a static geomagnetic field of approximately 0.4×10^{-4} T in a northerly direction with an inclination of about 55° below the horizon. Magnetic (B) field measurements were obtained with a Bell 620 gaussmeter. When the coils were energized, relatively homogeneous alternating magnetic fields were produced in the boxes. Table I shows the magnetic flux density, expressed in teslas, in the two boxes under various experimental conditions. Although most B-field measurements were generally obtained at 15 different points within the animal boxes, the B-fields of experiment 2C were measured directly in front of the animal's work panel during a 1-second energization of the coils. B-field differences between experiments 1 and 2A were due to unavoidable changes in the apparatus supplying power for the coils.

Table I

Magnetic Flux Density in Animal Boxes Under

Different Experimental Conditions

		B-Field ($\times 10^{-4}$ T)	
Experiment	Hz	Box 1	Box 2
1	45	9.2 ± 0.53	9.3 ± 0.50
2A	45	8.4 ± 0.56	8.4 ± 0.61
2B	15	9.2 ± 0.61	9.0 ± 0.73
2C	45	8.2	8.2

As shown in Table II, the electric (E) field strength measured in the center of the boxes was less than 1.2 V/m regardless of whether the coils were energized during experiment 1. The frequency of the E-fields was 60 Hz when the B-field was off. E-fields were not measured at 15 Hz. Electric field measurements were made with a probe constructed by NAMRL Electronic Services Division.

Table II

Electric Field Strength in Animal Boxes With and

Without the 45-Hz Magnetic Field

Box	B-Field Condition	E-Field (V/m) Axis X	Y	Z
1	off	1.0	< 0.4	< 0.4
	on	1.2	1.00	0.5
2	off	1.0	< 0.44	< 0.44
	on	1.2	0.90	0.90

Room temperature, humidity, and barometric pressure were recorded continuously. Temperature of air leaving the boxes was also continuously recorded. Masking of extraneous noises and vibrations was partially accomplished by a 75-dB white noise within each box and by mounting the boxes on rubber vibration isolators. The boxes were not in physical contact with the surrounding coils, yet, even with this isolation a slight vibration of approximately 1.5 dB (SPL) occurred in the boxes when the field was turned on.

PROCEDURE

Blood Chemistry

Prior to partial food deprivation in preparation for experiment 1, blood samples were drawn and a number of laboratory tests were conducted. The samples were obtained in the following manner. All food was removed from the animals at 1600 hours on the day preceding sampling. The following day at approximately 0900 the animals were given 0.65 mg/lb of Thorazine intramuscularly in the thigh, and approximately 20 minutes later 10 cc of blood were drawn from the femoral vein. Two months later, when the animals were at approximately 90% of their ad libitum weights, blood was drawn again. The latter samples were obtained at 1300 after all animals had finished their daily experimental session. Again, 0.65 mg/lb of Thorazine was administered and only 5 cc of blood were drawn from the femoral vein. Samples were obtained biweekly during an 8-week period while the animals were at their 90% body weights (one animal was sampled at a much lower weight). Two weeks after the fourth sample under deprived feeding conditions, another sample was obtained in the same manner as the original sample while the animals were in their home cages under ad libitum feeding conditions. The animals remained on ad libitum feeding in their home cages for 16 additional days to establish new baseline body weights after which they were again partially deprived of food. On the eighteenth day of deprivation and every seventh day thereafter (experiments 2A and 2B), a series of blood samples was again obtained following the same procedure as in experiment 1 under deprived conditions. Six samples were drawn during the final series.

Behavior

Experiment 1. The subjects had previously learned to operate the manipulanda in the boxes to obtain food and water (4, 5). All subjects were now trained to work two different and separate tasks--an interresponse-time (IRT) schedule and a fixed ratio (FR) schedule. The reinforcer for appropriate responses was an 0.86 gm Purina Monkey Chow Tablet or 2.0 ml of water. (Water was later omitted from experiment 1 and subsequent experiments because the animals never took water when it was available). A supplemental portion (1/4) of an apple or an orange was given following an experimental session and food tablets were given in the home cages during the weekends. Weekend feeding varied in an attempt to maintain 90% body weights. One animal (4Z7) gradually decreased her body weight until it was maintained at approximately 71% of ad libitum weight during the last month of the experiment.

The subjects were trained first on the IRT schedule. When a green light appeared above a lever on the front wall of the box, the animal was required to wait 5.0 seconds and then lift the lever. A lever lift before 5.0 seconds and after 6.0 seconds had elapsed produced no reinforcement and recycled the timer, thereby requiring another 5.0-second wait. The 5.0-second interresponse time was constant, but the limited hold following the 5.0 seconds was initially 30 seconds and was reduced gradually after 2 weeks of training to 1.0 second. Lever lifts between 5.0 and 6.0 seconds resulted in illumination of the food and water apertures and produced the opportunity to respond for food or water. A press response on the buttons beside the food and water apertures while they were illuminated produced a food tablet or water allotment.

Next, the subjects were trained to lift the same lever 10 times (FR 10) in the presence of the red light. The tenth lever response resulted in reinforcement availability. As the sessions progressed two subjects, 3Z5 and AP6, were required to lift the lever on an FR 20. Beginning with session 36 a correct response on either task produced reinforcement availability on 40% of the occasions. Following 60% of the correct responses, only a brief (0.75 second) flash of the food and water lights was presented.

A 5-minute time out period during which neither task could be performed followed each 15-minute exposure to a task. Each task occurred three times during an experimental session, thereby producing sessions of 2 hours' duration. Sessions for one pair of animals began at approximately 0800 and for the other pair at approximately 1030. Experimental sessions occurred daily except weekends. Following an experimental session animals were removed from the chambers and returned to the colony room to await the next daily session. Most behavioral indices were stable and showed no consistent trends after 54 sessions, and the 45-Hz magnetic field was then imposed for 8 sessions. Following this exposure, 8 additional sessions occurred in the absence of the field resulting in 70 sessions for experiment 1.

Experiment 2A. The animals were on ad libitum feeding for 30 days following the first experiment and then placed on deprivation feeding for 6 days prior to starting the second experiment. No preliminary training was required, and the animals were placed on the IRT schedule for daily 2-hour sessions. The IRT schedule was in effect for 15 minutes followed by a 5-minute time out period as in experiment 1, but in this case no other tasks were programmed, and the IRT schedule occurred six times during a session. Correct interresponse times, between 5.0 and 6.0 seconds, were reinforced 30% of the time with food availability and 70% of the correct responses were reinforced by only the 0.75-second flash of the food and water lights.

Sessions occurred daily except weekends, and beginning with session 16 a 45-Hz magnetic field was introduced for five sessions. At session 21 the field was removed for five sessions.

Experiment 2B. All conditions were the same as in experiment 2A except that at session 26 a 15-Hz magnetic field was turned on for five sessions and, then, it too was removed for five additional sessions.

Experiment 2C. In this portion of the study conditions in sessions 36 and 40 were the same as in the preceding five sessions but, during sessions 37-39, the 1.0-second limited hold period between 5.0 and 6.0 seconds was associated with a 1.0-second actuation of the magnetic field. The coils for a particular box were individually energized dependent on an animal's behavior, and were not necessarily on simultaneously as in the earlier three experiments.

RESULTS AND DISCUSSION

Blood Chemistry

Blood was initially sampled on 8-31-73 under ad libitum feeding conditions and, at this time, analyzed for only a few constituents--triglycerides, creatine, hemoglobin, cholesterol, and SGOT. The data are shown in Figures 1, 2 and 3. The rationale for

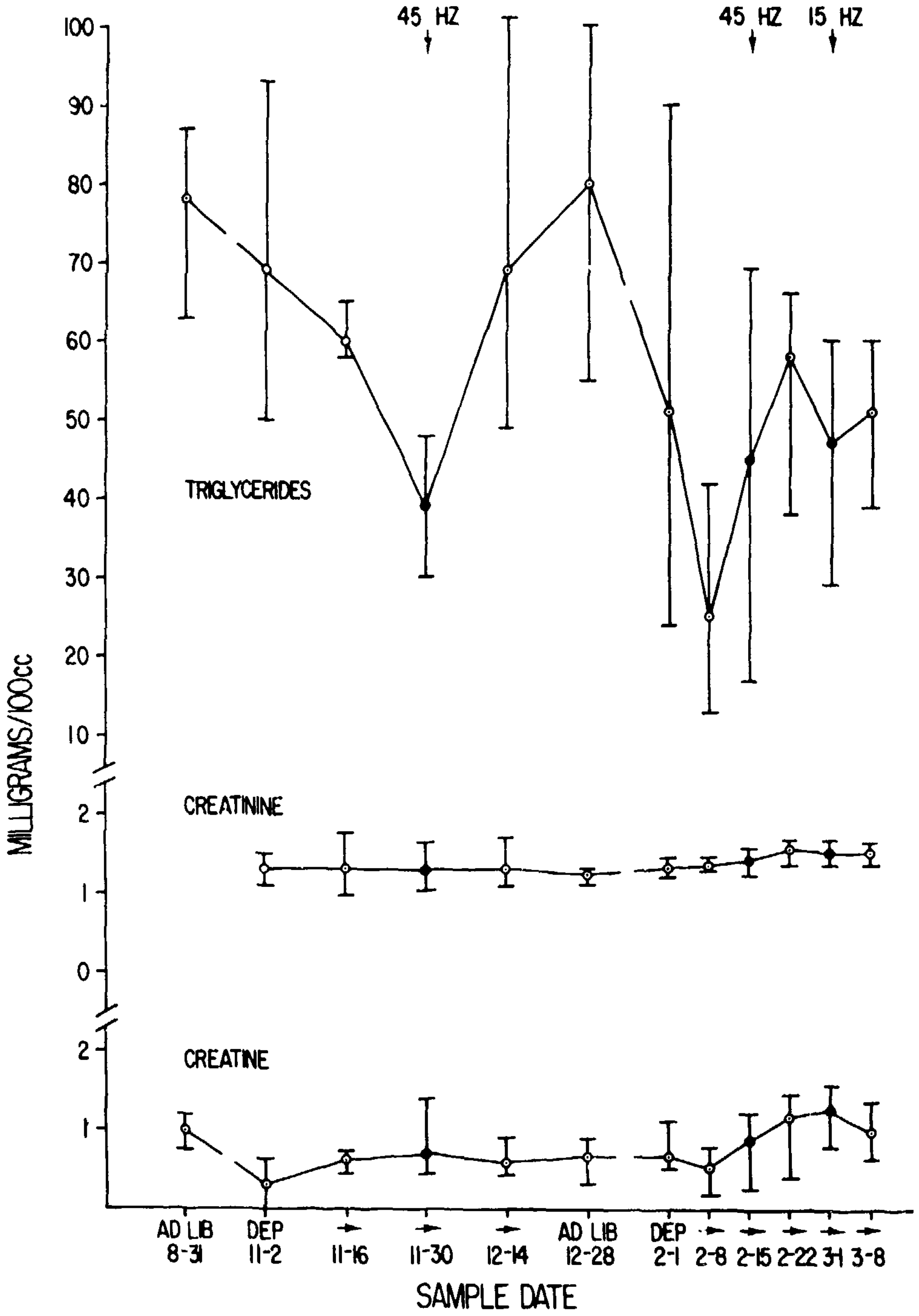

Figure 1

Means and ranges of three serum determinations from the four rhesus monkeys. The solid circles represent values obtained after 5 days' exposure to the magnetic fields indicated with arrows at the top of the figure.

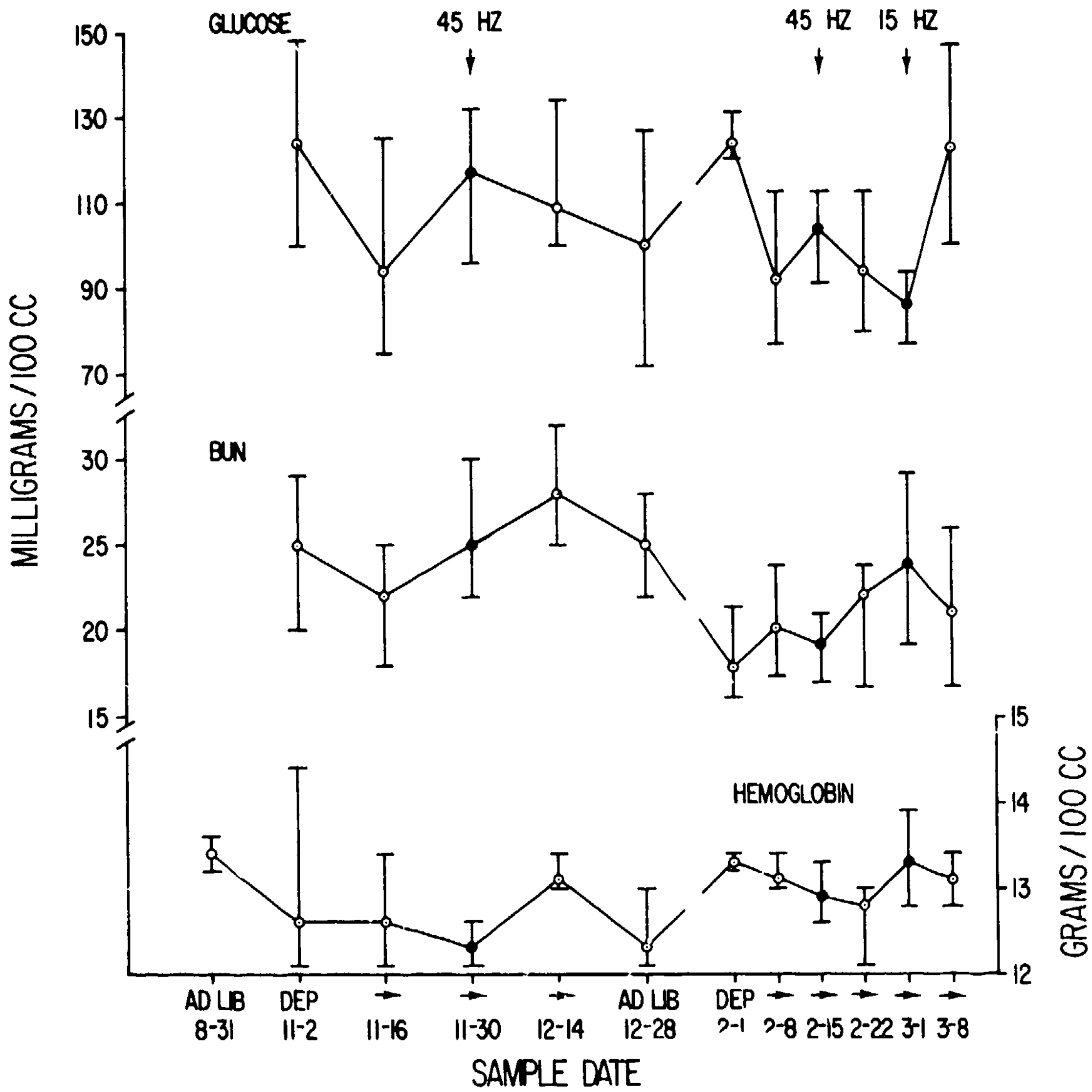

Figure 2

Additional means and ranges of serum determinations. BUN is blood urea nitrogen. Hemoglobin is represented on the right hand scale. Broken lines indicate more than a 14-day interval between samples. The animals were on free-feeding schedules during AD LIB and were on deprived schedules, as described in the text, during DEP.

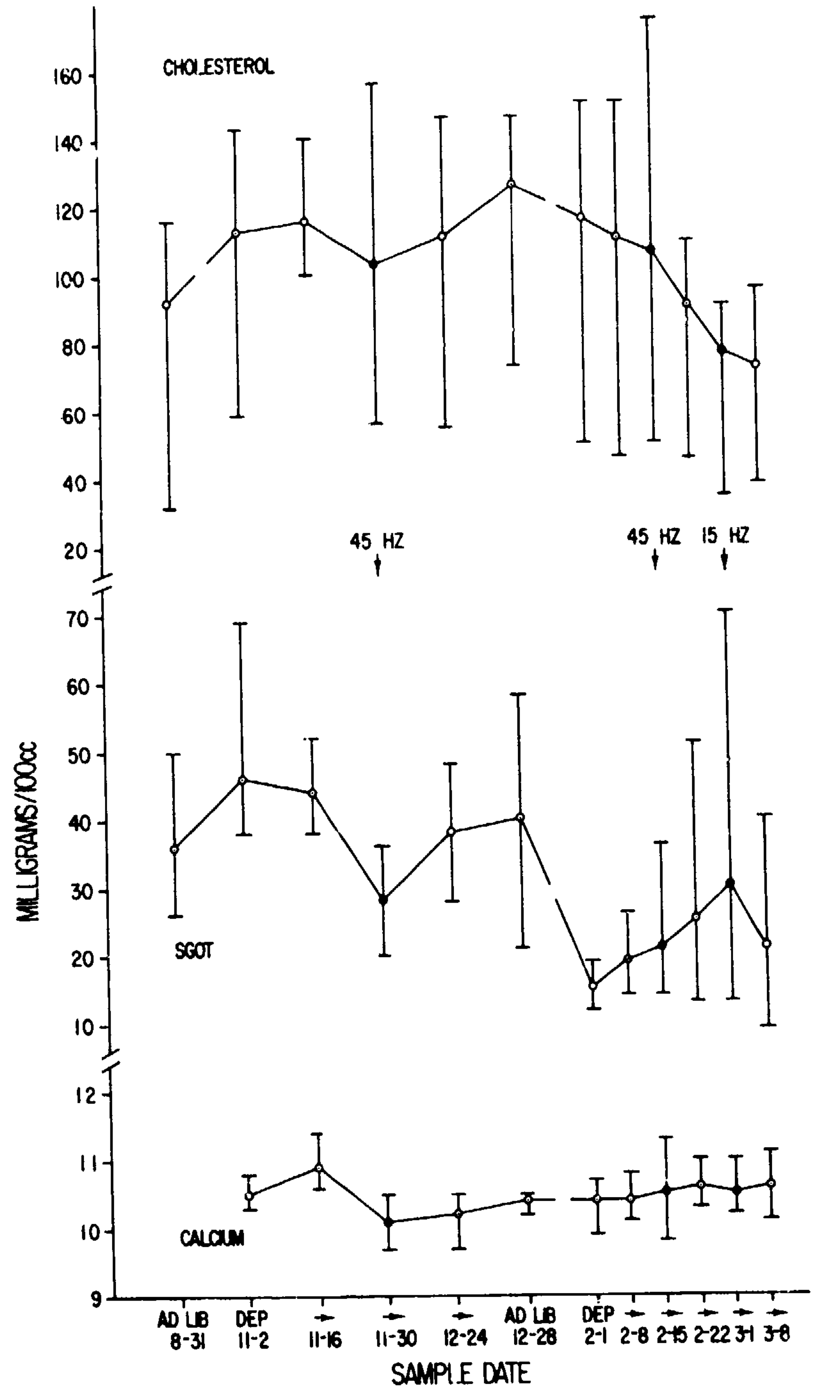

Figure 3

Additional means and ranges of serum determinations. SGOT is serum glutamic oxaloacetic transaminase.

the various determinations was varied. Triglycerides have been previously found to increase following ELF exposure in man (2). However, in the present study triglycerides showed a decrease after 5 sessions' (10 hours) exposure and no significant changes during subsequent similar exposures as seen in Figure 1. Although the decrease was significant ($F = 3.62$, $p < .05$, 3, 12 d.f.) if the data under exposed conditions (11-30) were compared with pre- and post-conditions (11-2, 11-16, 12-14), such significance did not occur when all deprived conditions throughout the entire study were compared. Figure 1 shows the mean and range of these determinations and the great variability of these measures. Since the data indicate that food deprivation leads to decreased amounts of triglycerides, it is quite probably that the large decrease was nothing more than a reaction to deprivation that reached a temporary minimum after 6 weeks (11-30) and recovered during the next 2 weeks. The last 6 weeks of data under deprived conditions, shown in Figure 1, tend to support this argument.

Other determinations were suggested in personal communications with Dr. Michael A. Persinger (Laurentian University). He obtained tentative results indicating that ELF fields could be used to drive a drug-induced, failing heart in the rat. Hence, a number of indications of myocardial infarction were obtained including creatine phosphokinase (CPK), cholesterol, lactic dehydrogenase (LDH), potassium, and serum glutamic oxaloacetic transaminase. Figures 1-7 show that none of these indices were related to the presence of the magnetic fields. There were some relationships between food deprivation and a few measures. For example, as body weight decreased so did SGOT. LDH tended to increase as body weight decreased. During the last 6 weeks, cholesterol decreased along with body weight in 3Z5 and 4Z7. CPK was at its highest level when the 45-Hz field was introduced the second time, and LDH reached high points when the second 45-Hz and 15-Hz fields were applied. None of these differences approached significance.

A few determinations were obtained because of the purported relationship between respiration, oxygen uptake and ELF electromagnetic fields. These were calcium, red cell count, hemoglobin and hematocrit (PVC). Figures 2, 3, 6 and 7 illustrate the lack of any influence of the magnetic fields.

The white cell differential count, WBC, monocytes, eosinophiles (Figure 4), polycytes, lymphocytes and bands (Figure 5) were obtained to indicate stress or general infectious disorders. Figures 4 and 5 also illustrate the absence of magnetic field effects on these determinations.

Finally, the other determinations in Figures 1, 2, 6 and 7 were obtained to provide a general indication of kidney and liver functions. None of these measures reflected a magnetic field effect on either kidney or liver. Summarizing the present findings in blood chemistry, no effects were consistently related to the presence of the magnetic fields. Other than the triglyceride result, which was only significant in an immediate comparison of the adjoining tests, there were trends that encourage the further measurement of LDH and CPK although neither of these were significantly influenced by the fields. Incidentally, the values reported fall within the range established on 12 rhesus monkeys in our laboratory.

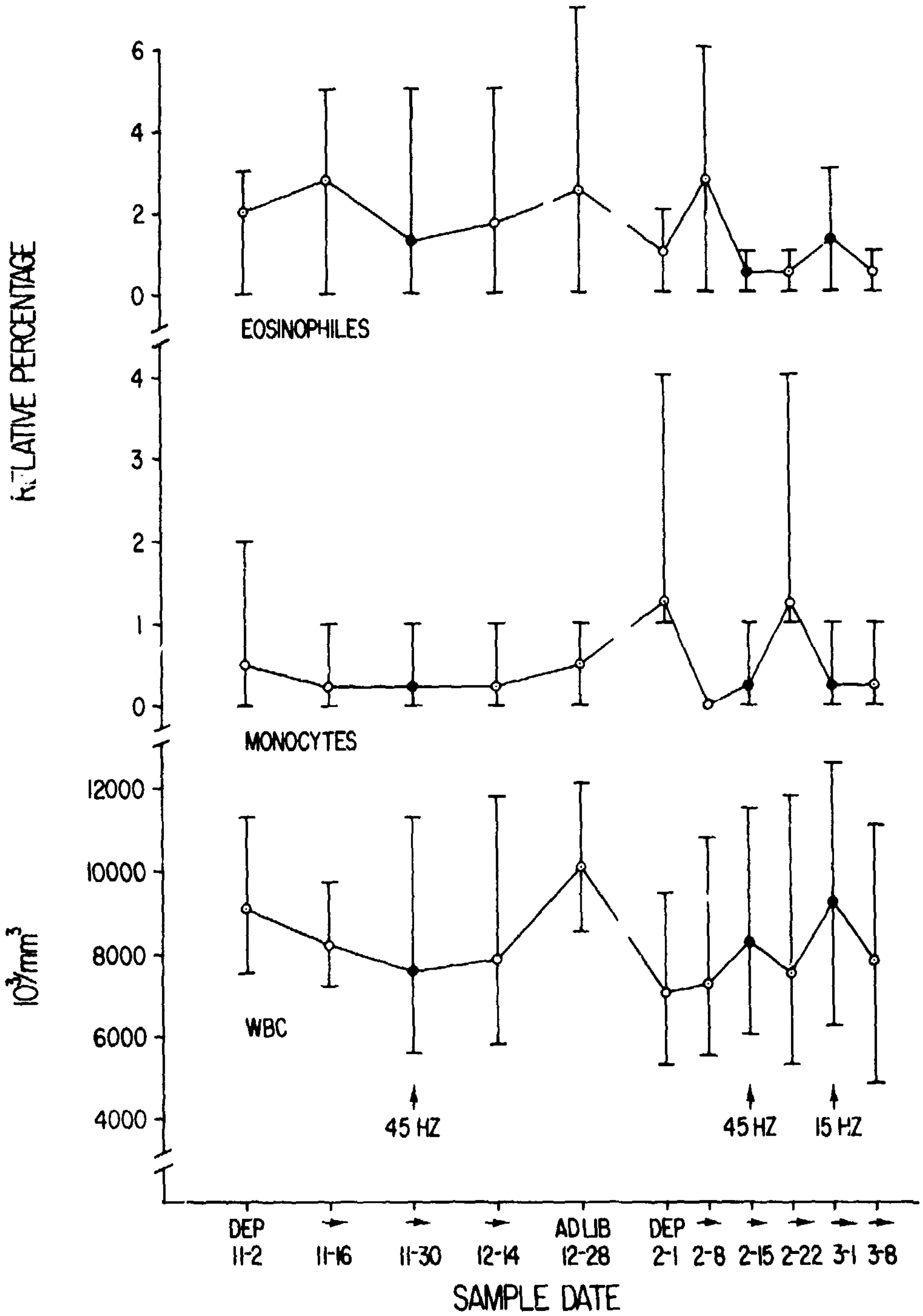

Figure 4

Leucocytes (WBC) and proportions of the white cell differential count.

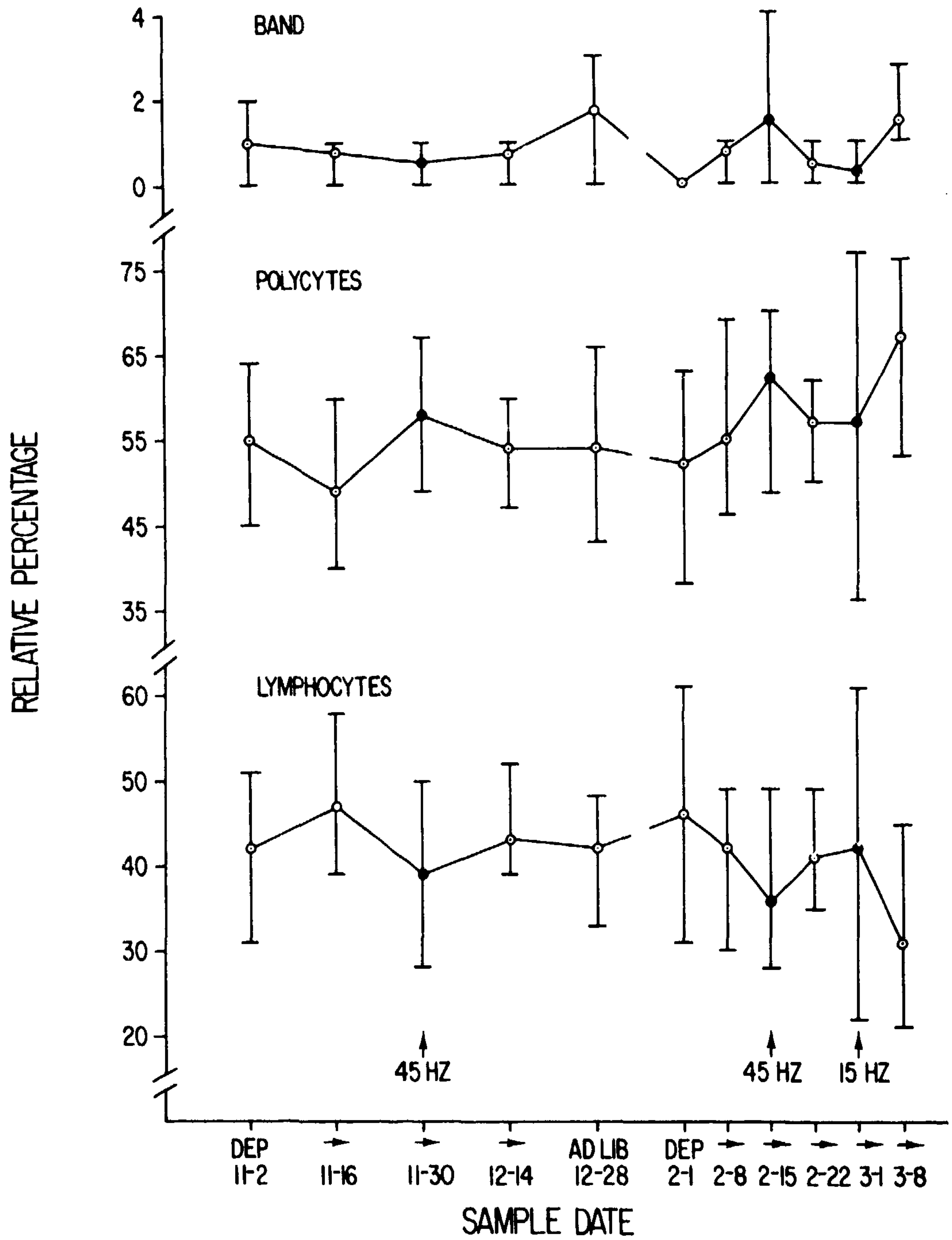

Figure 5

Additional values of the white cell differential count.

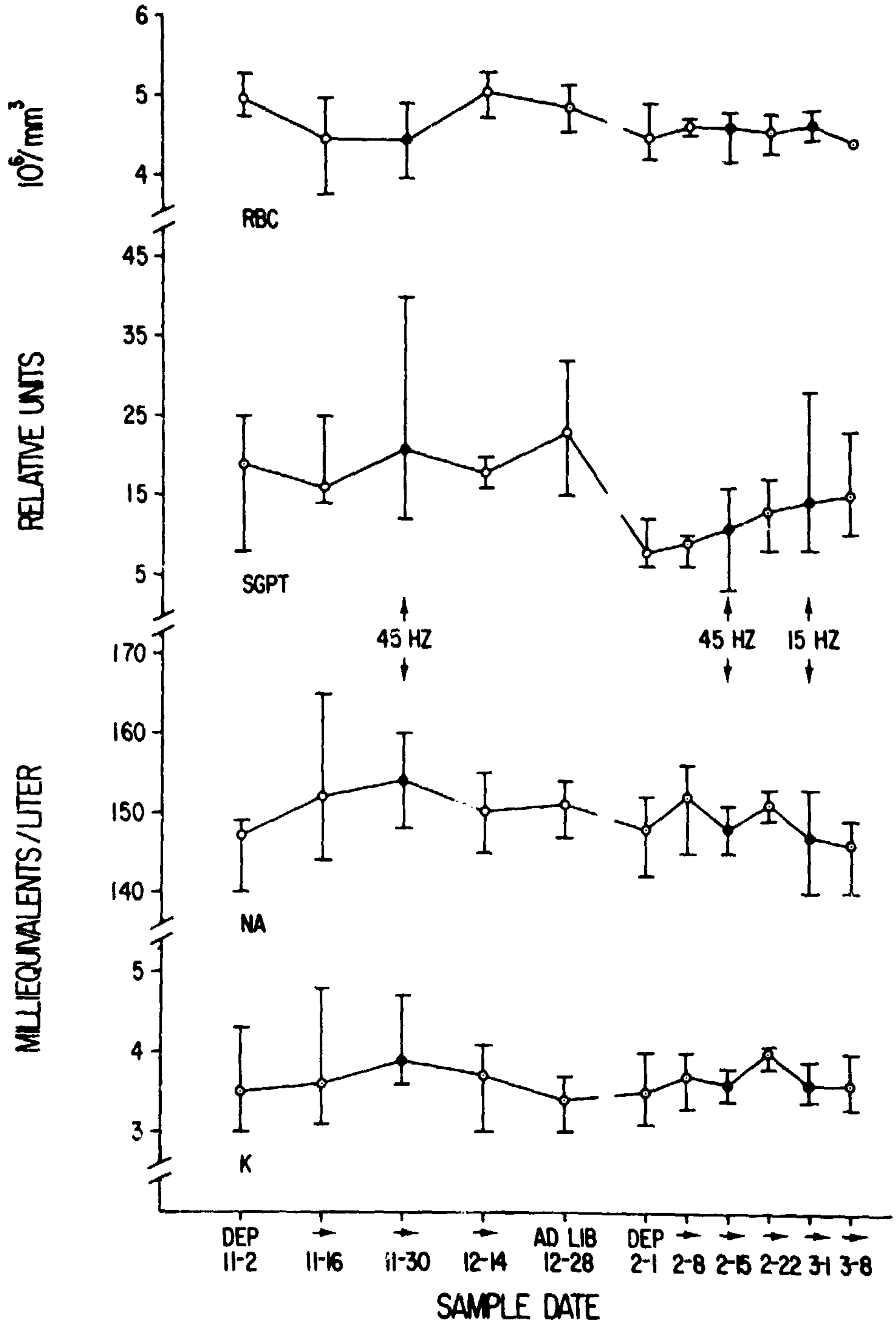

Figure 6

More serum determinations. RBC is the red blood cell count. SGPT is serum glutamic pyruvic transaminase.

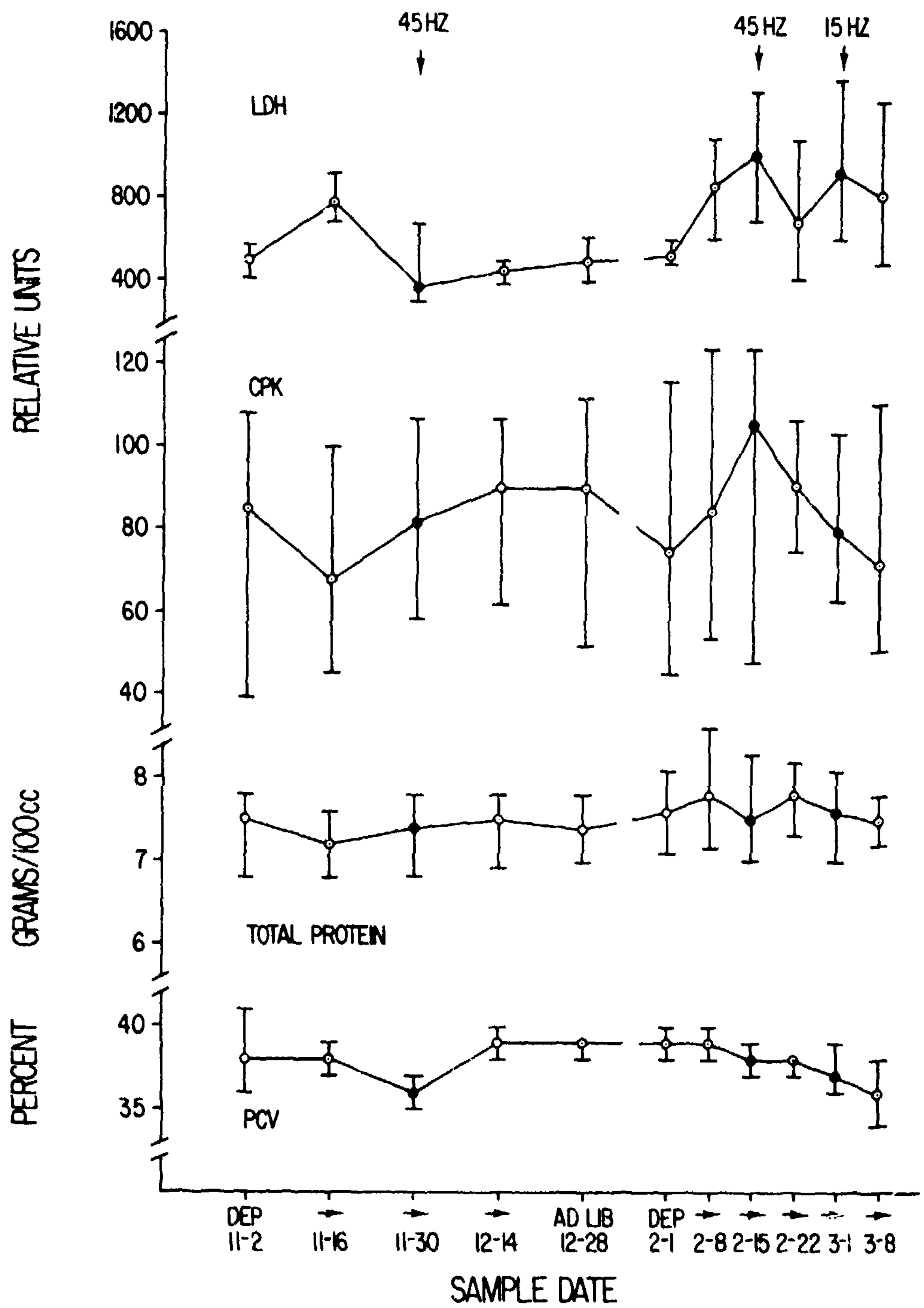

Figure 7

More serum determinations. LDH is lactic dehydrogenase. CPK is creatine phosphokinase. PCV is packed cell volume or hematocrit.

Behavior

Experiment 1. Figure 8 illustrates FR behavioral data of all four animals during the final 22 sessions of the first experiment. The 45-Hz magnetic field was introduced during sessions 55-62. The top four graphs show the percentage body weight. Three subjects were maintained at approximately 90% while 4Z7 was maintained at approximately 71%. 4Z7 seldom worked at weights greater than this. As a matter of fact, 4Z7 was highly erratic in most of her behavior on both FR and IRT schedules but is included in the data to illustrate that, even with poorly performing animals, ELF magnetic fields have no obvious behavioral influence.

FR response rates were variable and, although AR4 and 3Z5 reached their highest rates during the presence of the fields, the mean rates were not significantly influenced by the fields. 3Z5 and AP6 were responding on FR 20 schedules, hence their rates were higher than those of 4Z7 and AR4 who were working on FR 10 schedules. All animals except 4Z7 tended to increase their response rates and decrease their pause time during the study. These changes are shown in the lower half of Figure 8. Pause time on the FR schedule was not related to the magnetic field nor was reinforcement time, as seen in the upper half of Figure 8. Reinforcement time tended to be the most stable data for all animals under all conditions.

Even though previous reports found differences in general motor activity due to magnetic fields (3, 11), no such effects were found in the present experiment, as seen in the upper portion of Figure 9.

IRT schedules, especially those with a limited hold, have more control over behavior than FR schedules. The lower three sets of graphs in Figure 9 illustrate this control. Time to obtain reinforcement and pauses after reinforcement were very stable and showed no relationship to the ELF field although pause time decreased throughout these sessions as on the FR schedule. The response rate was more variable, yet less so than under the FR schedule, and again no influence of the ELF field is seen. As expected on an IRT 5-second schedule, the pause time centered around 5 seconds and the response rate centered around 10-12 responses per minute. The fact that reinforcement time tended to be about 0.8 seconds is probably related to the 0.75-second light that occurred in the absence of food with 60% of the correct responses. That is, the animals probably attempted to respond on the food available button prior to the extinction of the brief light.

A finer analysis of IRT data entailed classifying various interresponse times into 1.0-second categories before, during and after the magnetic field was present. Figure 10 illustrates these IRT frequency distributions for all four animals. The off distribution was composed of data before and after field exposure. Each of these polygons was composed of more than 3000 interresponse times. The differences between on and off distributions for AP6 and 4Z7 were statistically highly significant (Kolmogorov-Smirnov test [14], $p < .001$) while the distribution differences for the other two animals were not. Because

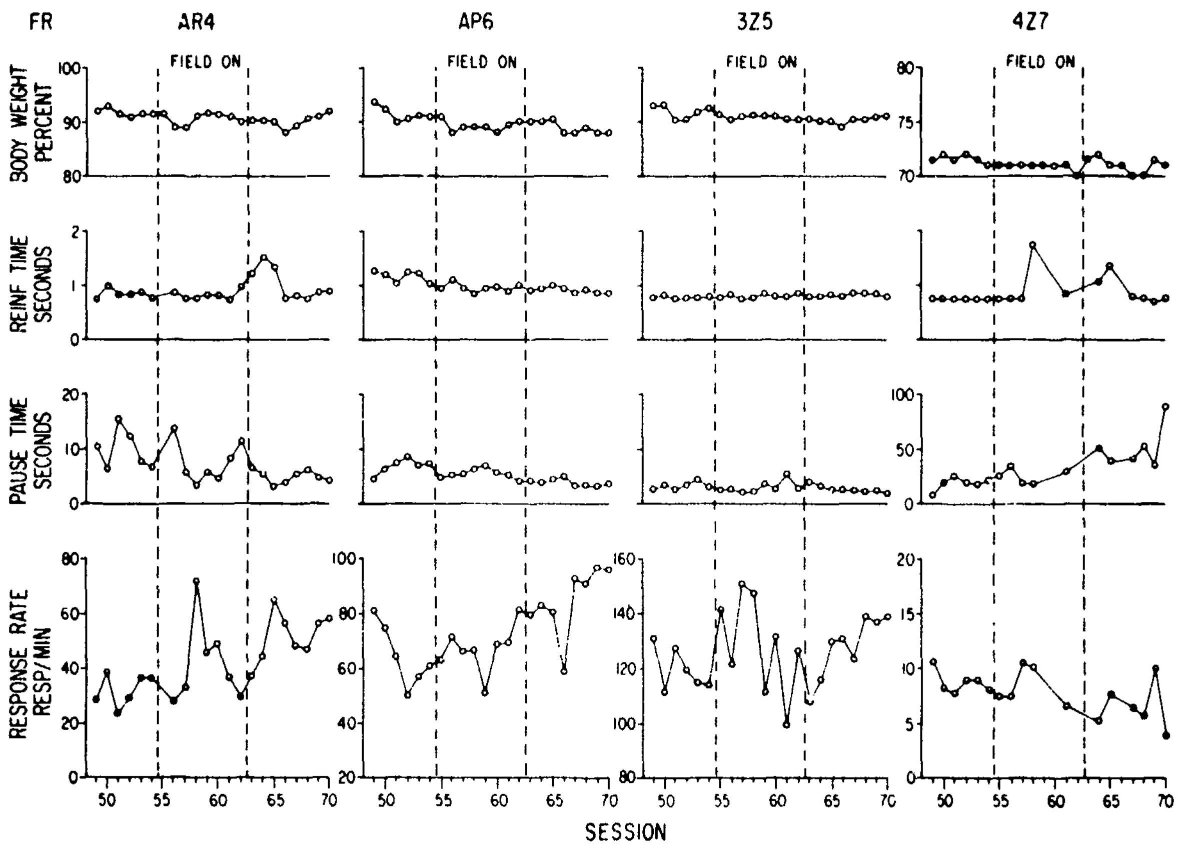

Figure 8

Percentage body weight and FR data from experiment 1. Data obtained during malfunctions and when 4Z7 failed to work were omitted. The 48 sessions prior to behavioral stability were omitted. Reinforcement time refers to the mean latency to respond on the food lever when food became available. Pause time refers to the mean latency to make the first FR response after taking a food tablet. The broken vertical lines enclose sessions when the 45-Hz field was present. Where measures were disparate individual changes in ordinates were made.

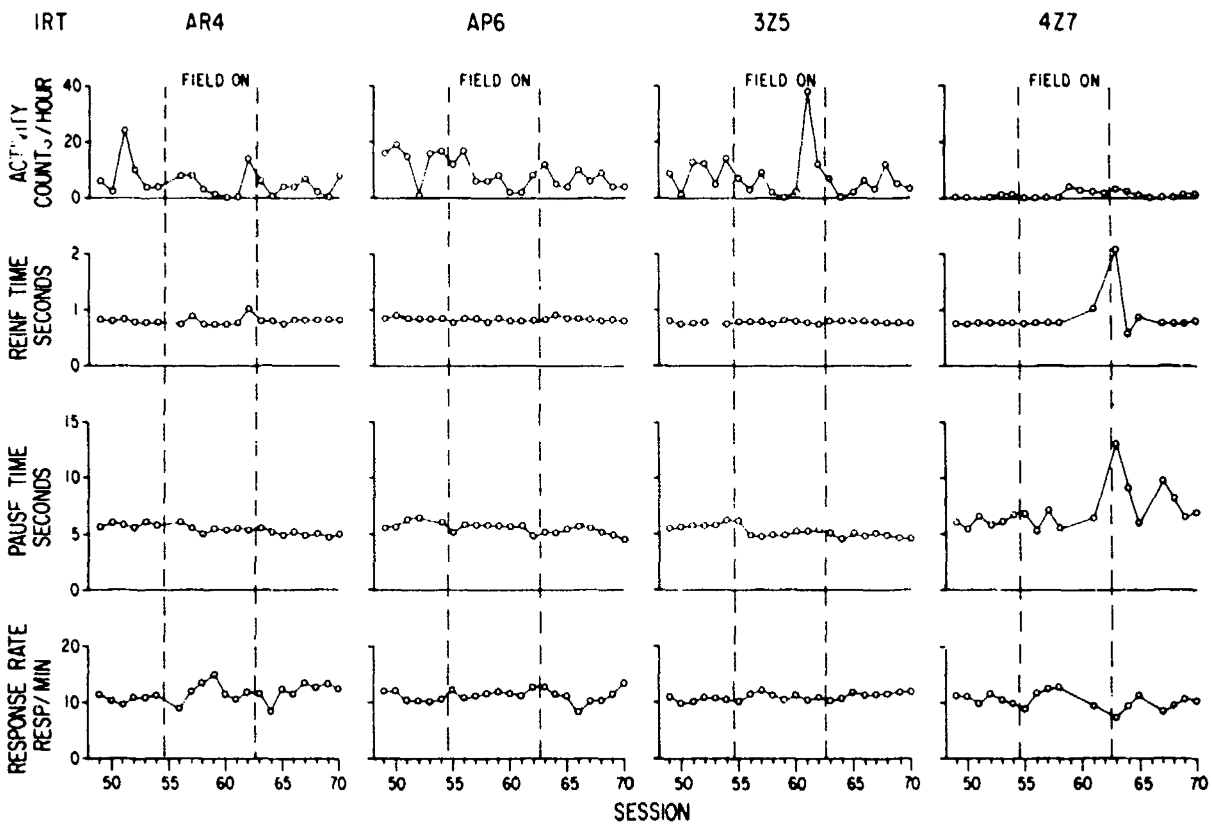

Figure 9

General motor activity and IRT data from experiment 1. Animals are identified at the top of their respective graphs.

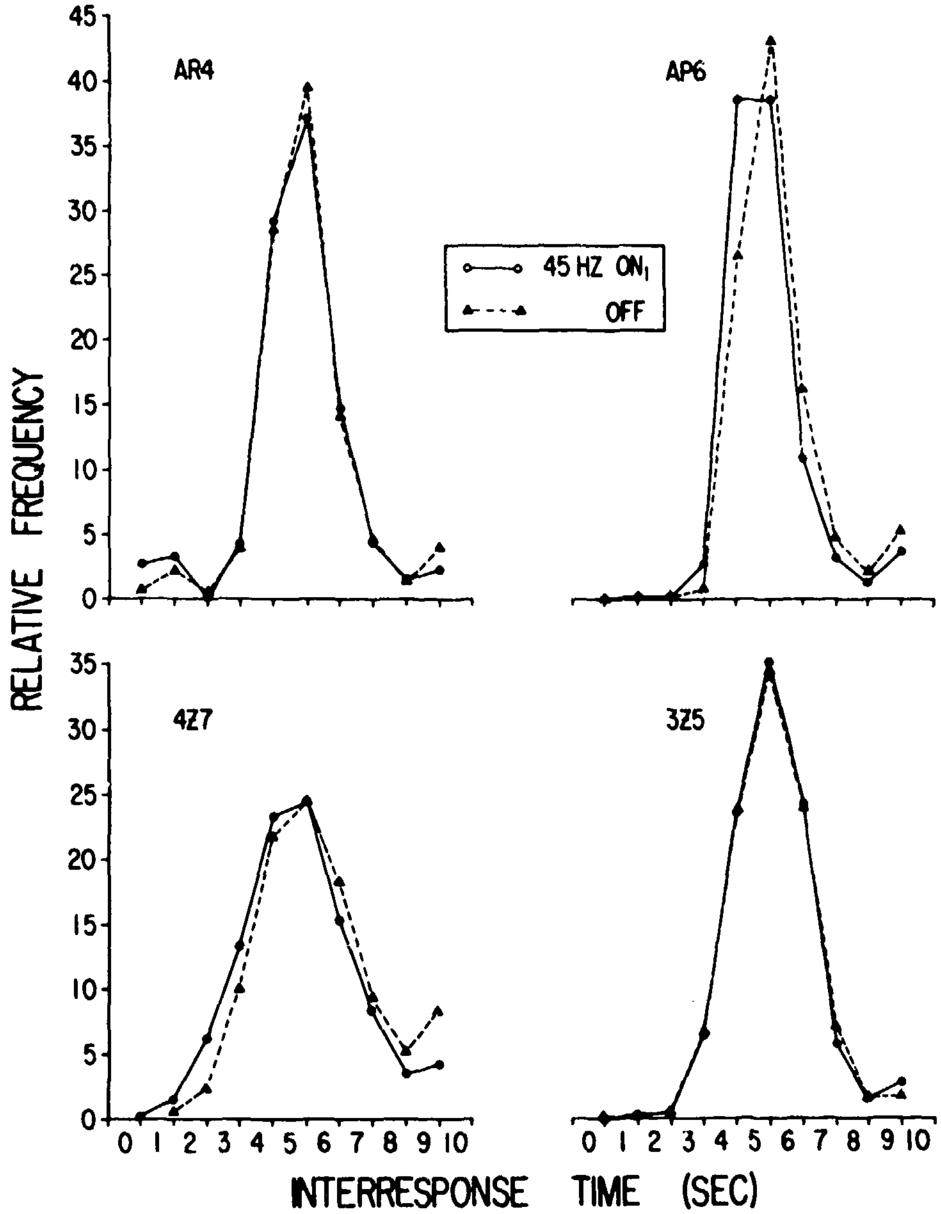

Figure 10

Interresponse time distributions of responses during the IRT schedule in experiment 1. Responses between 5 and 6 seconds on the abscissa were reinforced. Data during the field off (triangles) were collected from the four sessions before and four sessions after the field exposure. Data during field exposure were collected from the eight sessions when the 45-Hz magnetic field was activated.

of the inconsistencies in this data, the means of the IRT distributions from 6 sessions before, 8 sessions during, and 8 sessions after field exposure were statistically analyzed for differences. None of the four animals displayed significant changes as a result of field exposure (Mann Whitney U test) (14). Hence, while it is true, according to the distributions, that AP6 and 4Z7 shifted to faster IRT's in the presence of the fields, their mean IRT's did not change significantly. An examination of the daily IRT distributions of all animals, especially 4Z7 and AP6, failed to reveal any time course or other relationship between field exposure and shifts in IRT's.

Experiments 2A and 2B. Few sessions were needed to again obtain stable behavior when the animals were retrained for the rest of the experiments although the behavior of 4Z7 continued to deteriorate throughout the rest of the study. Figure 11 contains IRT data from experiments 2A, 2B and 2C for all four subjects. The two male monkeys maintained their body weights reasonably well at approximately 98%, while the two females, 4Z7 and 3Z5, gradually decreased from 95 to 72% of their ad libitum weights. These changes are shown in the upper portion of Figure 11. The graphs in the adjoining portion show the percentage of IRT responses falling in the 5- to 6-second category (correct responses). No consistent or significant changes in correct responses as a result of 45- or 15-Hz fields were found. Except for the data of 4Z7 the other measures, reinforcement time, pause time, and response rate, were very stable. And although 4Z7 occasionally produced extreme scores in the presence of the magnetic fields along with increases in mean pause time (0.03 second at 45 Hz, 1.85 second at 15 Hz), it is certain that this behavior was not related to the fields. 4Z7 was just a highly variable animal in her behavior. The other three subjects produced slight reductions in mean pause time (0.09 to 0.23 second) during the 45-Hz field while one animal increased mean pause time during the 15-Hz field (0.10 second) and the other two animals decreased their mean pause time during the 15-Hz field (0.19 and 0.04 second). None of these changes were statistically significant. General activity was on the same order as previously seen and, although not illustrated, was also not influenced by the magnetic fields.

One interesting phenomenon seen in Figure 11 occurred with response rate. Overall response rate tended to be lowest at the first and last sessions of the week. The cyclicity is especially evident in the data of AR4 and 4Z7 although the other monkeys behaved similarly.

IRT distributions during the 45-Hz and 15-Hz magnetic field exposures are shown in Figures 12 and 13 respectively. Although these polygons are almost duplicates, in each case minor differences for some of the animals were statistically significant (N in each single polygon was more than 4000). For example, in Figure 12 the distributions of field on versus field off for AR4, 3Z5, and AP6 were significantly different (Kolmogorov-Smirnov test, $p < .001$) while the data of 4Z7 were not. These differences were in the direction of faster interresponse times. On the other hand, the distributions obtained during the 15-Hz field exposure as seen in Figure 13 illustrate significantly faster responding with 3Z5 ($p < .05$), significantly slower responding with AP6 ($p < .001$) and no significant differences with the other two monkeys. Again, these inconsistencies required

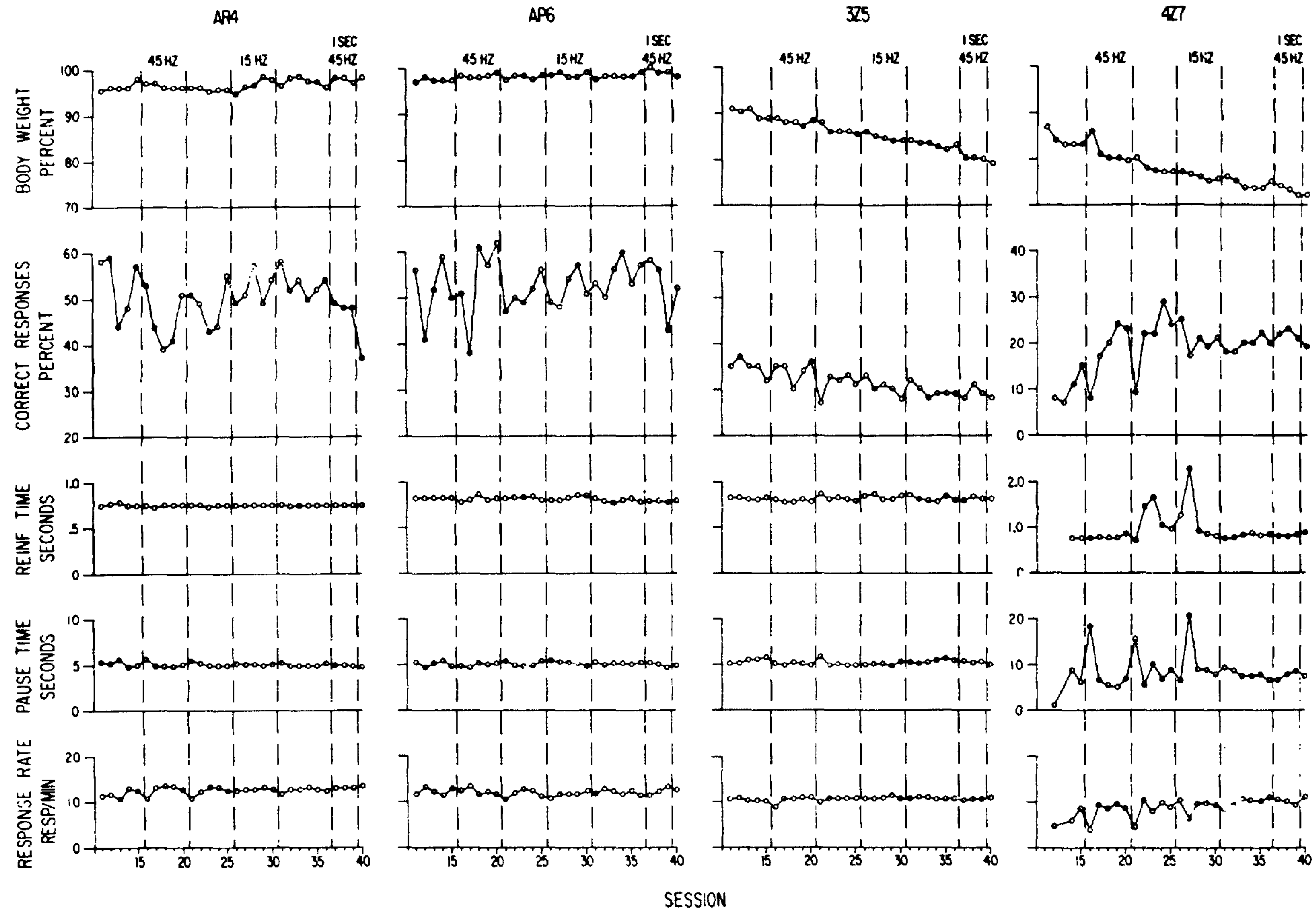

Figure 11. Percent body weight and IRT data from experiments 2A, 2B and 2C. The first 10 sessions' data were omitted. The ordinates for the graphs of 4Z7 reflect her poorer performance. Correct responses occurred between 5 and 6 seconds. Broken vertical lines enclose data during field exposure in experiments 2A (45 Hz), 2B (15 Hz) and 2C (1 second 45 Hz).

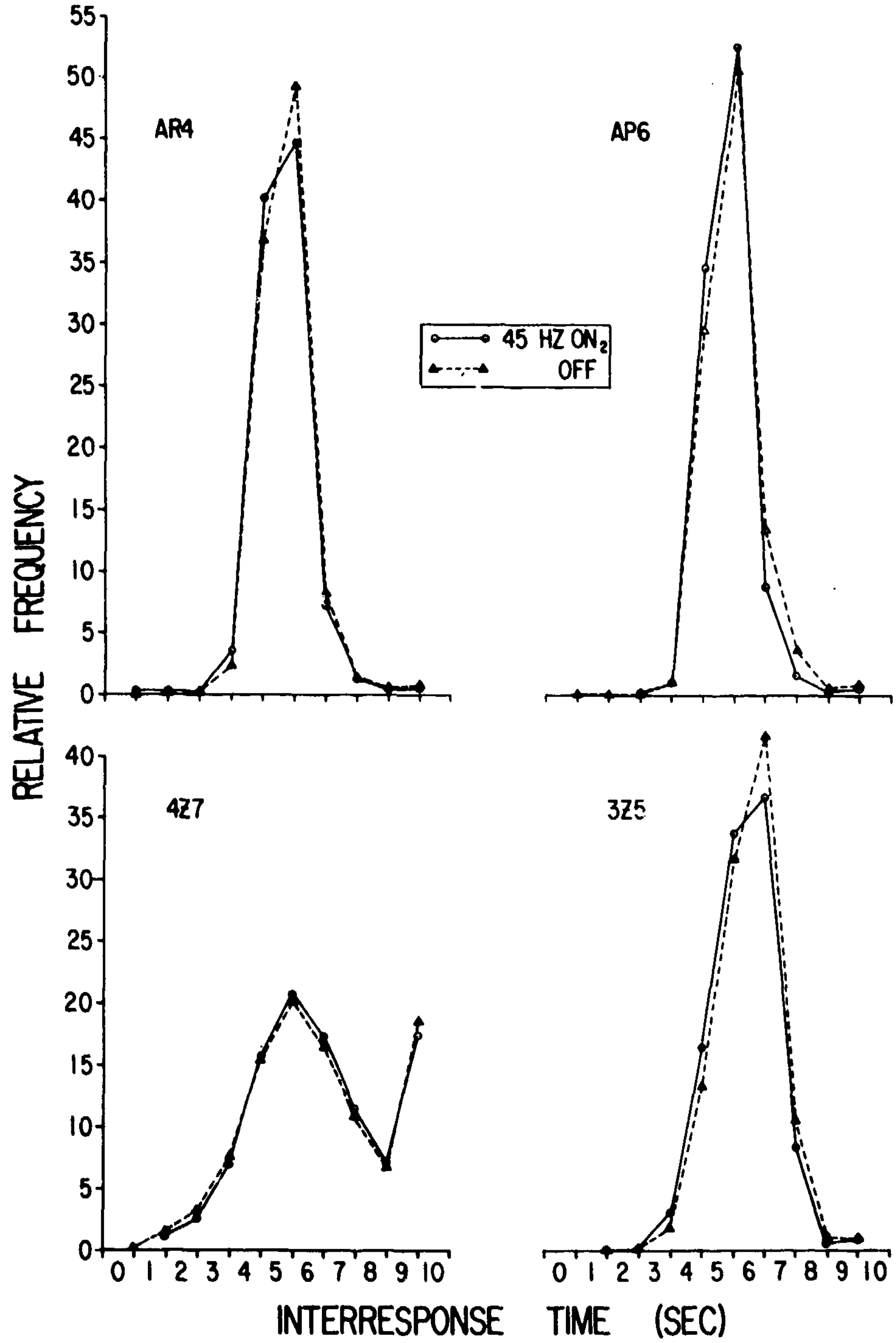

Figure 12

Interresponse time distributions during (circles) and before and after (triangles) exposure to a 45-Hz field in experiment 2A. Data were obtained from the 5 sessions during field exposure and 2 sessions prior to combined with 3 sessions immediately following field exposure.

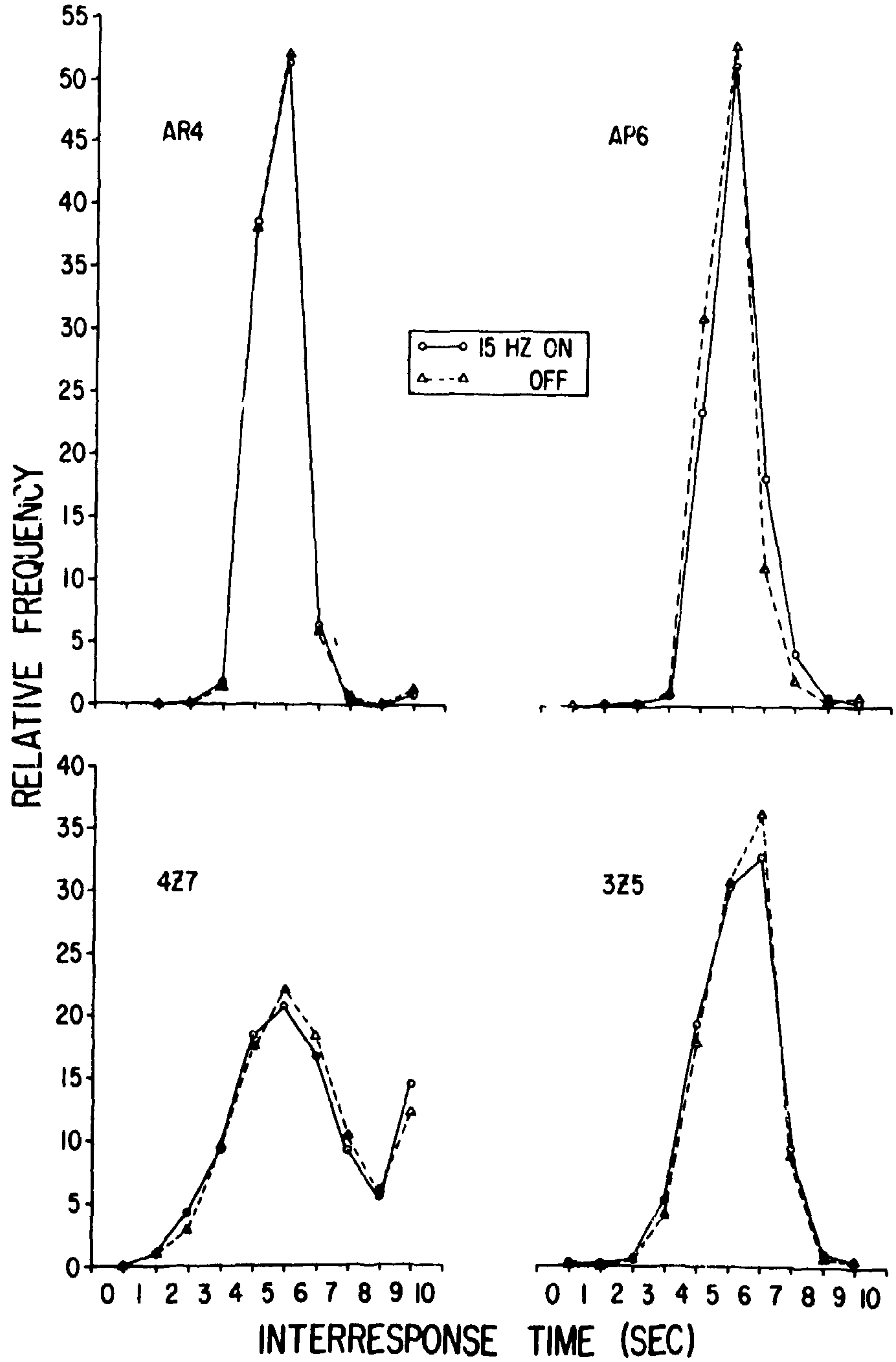

Figure 13

Interresponse time distributions from experiment 2B in which the animals were exposed for 5 days to a 15-Hz magnetic field. The off data were obtained from 2 sessions prior to and 3 sessions following exposure to the magnetic field.

that other measures be examined. The mean IRT's of the five days preceding and following 45-Hz field exposure were compared with the mean IRT's during exposure for each animal individually and as a group and no statistically significant differences were obtained (Mann Whitney U test). The 15-Hz field data were similarly examined and no significant differences were found.

Experiment 2C. If the 45-Hz magnetic field were detectable between 5.0 and 6.0 seconds, the monkeys would be expected to use this cue and increase the relative number of correct responses. Three monkeys slightly increase their mean percentage of correct responses when the field was activated between 5.0 and 6.0 seconds (2.1 to 0.3%) while AP6 decreased his mean correct responses at this time (-1.0%). Overall these differences were not significant ($t < 1$). Figure 11 illustrates these differences. It is also evident that correct responses were not at their highest levels at this time in any animal. Figure 14 provides a better illustration of these changes. AP6 and 3Z5 had almost identical distributions with and without the 1.0-second field, whereas the other two showed slight increases during the fifth to sixth second. Actually, AP6 had significantly faster IRT's and 3Z5 and 4Z7 had significantly slower IRT's during the sessions with the field (Kolmogorov-Smirnov test, $p < .001$). The IRT distributions of AR4 were not statistically different.

CONCLUSIONS

While it is apparent that the ELF magnetic fields used in the present study had no large or consistent biological influences on the four monkeys, some changes were observed. These changes did not recur when the fields were reintroduced; for example, serum triglycerides were not reduced when the animals were exposed the second time to the 45-Hz field. Behavioral changes also failed to consistently occur within an animal; for example, AR4, 3Z5 and 4Z7 had faster IRT's under one 45-Hz exposure but not the other. AP6 responded faster under both 45-Hz exposures but slower during the 15-Hz exposure. Concurrently, more traditional measures such as the mean interresponse time failed to reveal these differences. IRT distributions were analyzed because a previous study that employed monkeys on an IRT schedule with a limited hold, utilized a similar analysis and found significant effects of 7-Hz electric fields (7). While the statistical assumptions regarding normality, its violations, and the use of the t test for assessing differences in percentage polygons (IRT distributions) might lead one to debate the analysis in the previous study (7), differences in the mean IRT's were large in most cases (0.36 to 4.46 seconds). Such large differences were not found in the present study as a result of magnetic field exposure although shifts towards faster responding were observed.

The present findings might be chance phenomena, an assumption supported by the inconsistencies between animals and experiments, or they might be due to a misinterpretation because of the particular statistical analysis (polygon comparisons with very large N's). In either case the differences were not impressive or long lasting. Friedman et al. (6) report the transient nature of magnetic field exposure (low intensity-static fields) and assume that their animals (squirrel monkeys) adapted to the presence of the fields. A

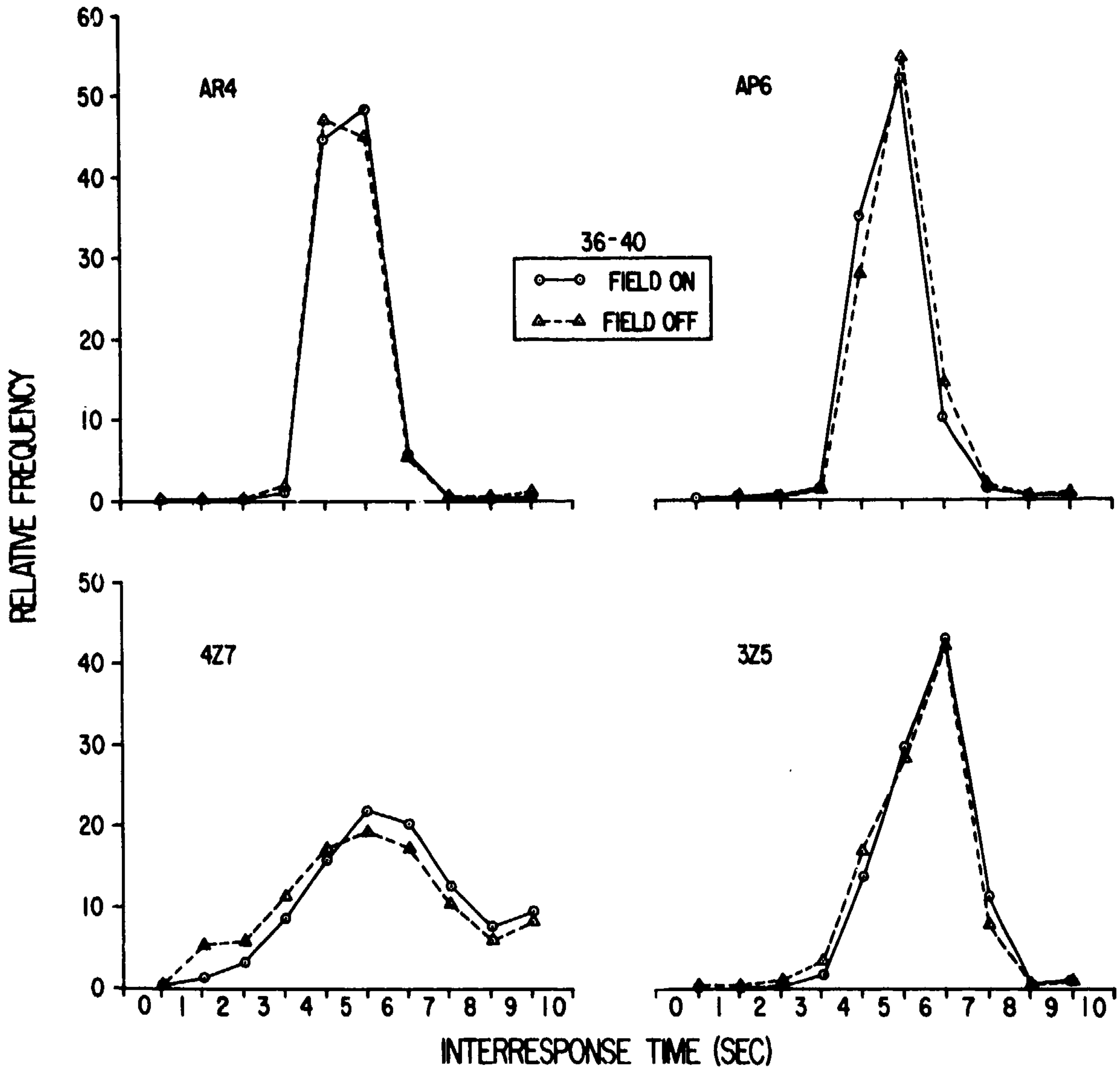

Figure 14

Interresponse time distributions from experiment 2C. Field on data were averaged over sessions 37, 38 and 39 when a 1.0-second activation of the 45-Hz field accompanied the correct response interval between 5 and 6 seconds. Field off data were averaged over sessions 36 and 40.

session-by-session review of the present data failed to reveal any initiating effects of the fields and there was no evidence that any of the animals adapted to the field. The present subjects had extensive histories of magnetic field exposure, and it is possible that adaptation had previously occurred.

The ephemeral nature of low intensity-low frequency magnetic field effects might be due to lack of experimental control. Schmitt and Tucker (13) observed that man becomes increasingly less capable of perceiving magnetic fields (60 Hz, low intensity) as the control of extraneous variables is improved. In a series of experiments, where isolation of the subjects was increased from one study to the next, they eventually observed that perception of magnetic fields occurred at a chance level. Perhaps the small changes seen in the present study would not have occurred had the boxes been completely isolated from the vibration accompanying the fields.

Finally, this investigator believes that the magnetic fields do not affect the behavior of rhesus monkeys, as presently measured, to any practical extent, but this does not preclude the possibility that an individual animal may be capable of detecting or being influenced by either the magnetic field or artifacts contiguous with that field.

REFERENCES

1. Barnothy, M. F., Biological Effects of Magnetic Fields, Volume 2. New York: Plenum Press, 1969.

2. Beischer, D. E., Grissett, J. D., and Mitchell, R. E., Exposure of man to magnetic fields alternating at extremely low frequency. NAMRL-1180. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, 1973.

3. de Lorge, J., Operant behavior of rhesus monkeys in the presence of extremely low frequency-low intensity magnetic and electric fields: Experiment 1. NAMRL-1155. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, 1972.

4. de Lorge, J., Operant behavior of rhesus monkeys in the presence of extremely low frequency-low intensity magnetic and electric fields: Experiment 2. NAMRL-1179. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, 1973.

5. de Lorge, J., Operant behavior of rhesus monkeys in the presence of extremely low frequency-low intensity magnetic and electric fields: Experiment 3. NAMRL-1196. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, 1973.

6. Friedman, H., and Carey, R. J., Biomagnetic stressor effects in primates. Physiol. and Behav., 9:171-173, 1972.

7. Gavalas, R. J., Walter, D. O., Hamer, J., and Adey, W. R., Effect of low-level, low-frequency electric fields on EEG and behavior in Macaca nemestrina. Brain Res., 18:491-501, 1970.

8. Grissett, J. D., Exposure of squirrel monkeys for long periods to extremely low-frequency magnetic fields: Central-Nervous-System effects as measured by reaction time. NAMRL-1146. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, 1971.

9. Grissett, J. D., and de Lorge, J., Central-Nervous-System effects as measured by reaction time in squirrel monkeys exposed for short periods to extremely low-frequency magnetic fields. NAMRL-1157. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, 1971.

10. Persinger, M. A., Ludwig, H. W., and Ossenkopp, K-P., Psychophysiological effects of extremely low frequency electromagnetic fields: A review. Percep. and Motor Skills, 36:1131-1159, 1973.

11. Persinger, M. A., Persinger, M. A., Ossenkopp, K-P, and Glavin, G. B., Behavioral changes in adult rats exposed to ELF magnetic fields. Int. J. Biometeor., 16:155-162, 1972.

12. Presman, A. S. Electromagnetic Fields and Life. New York: Plenum Press, 1970.

13. Schmitt, O. H., and Tucker, R. D., Human perception of moderate strength low frequency fields. Washington, D.C.: International Magnetics Conference, sponsored by Magnetics Society, IEEE, April, 1973. Pp. 65-70.

14. Siegel, S., Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill, 1956.