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OPERANT BEHAVIOR OF RHESUS MONKEYS IN THE PRESENCE
OF EXTREMELY LOW FREQUENCY-LOW INTENSITY
MAGNETIC AND ELECTRIC FIELDS: EXPERIMENT 2

John de Lorge



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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

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Approved by

Ashton Graybiel, M. D.
Assistant for Scientific Programs

Released by

Captain N. W. Allebach, MC USN
Officer in Charge

15 March 1973

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

SUMMARY PAGE

THE PROBLEM

Low intensity extremely low frequency (ELF) communication systems have been the subject of recent Navy interest. The present study continues a series of investigations aimed at determining the biological effects of electromagnetic radiation in the ELF region.

FINDINGS

No significant alterations in reaction time, in operant responding, or in a match-to-sample task were observed in two rhesus monkeys exposed to 45-Hz magnetic and electric fields. These results concur with earlier studies. When the animals were exposed to 10-Hz fields, statistically significant effects were observed, but they were not clinically significant because the effects did not occur in both subjects nor in either subject when the experiment was repeated. The present study failed to establish that ELF magnetic and electric fields at low intensity unequivocally produce behavioral changes in nonhuman primates.

ACKNOWLEDGMENTS

The services provided by NAMRL Electronics Services and Veterinary Sciences Division were greatly appreciated. Appreciation is also extended to D. A. Miller of the IIT Research Institute, Chicago, Illinois, for measuring the electric fields.

Experiments reported herein were conducted according to the principles enunciated in "Guide for Laboratory Animal Facilities and Care" prepared by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences--National Research Council.

INTRODUCTION

Extremely low frequency (ELF) magnetic and electric fields are the topic of an increasing number of investigations. Many of these investigations are concerned with the fields introduced by climatic changes, solar eruptions, and geomagnetic conditions (11, 15), whereas other studies are concerned with specific fields produced by high-voltage power installations and associated transmission lines (9). In addition, some investigators, interested in biological communication, are studying the fields produced by living organisms (18). The growing concern with ELF magnetic and electric fields was recently demonstrated by an internationally-attended symposium in the United States wherein the biological effect of such fields was the major topic (16).

Generally, the biological effects of ELF fields are not easily discerned. For example, in several studies Persinger (12,13) exposed rats prenatally to ELF (0.5 Hz) magnetic fields of 3-30 gauss. As adults, these rats tended to show less activity than the control group. However, he later exposed adult rats to similar fields and afterwards they displayed greater activity than control animals (14). Because of the variable intensity of the magnetic field used, it is impossible to specify the effective gauss level in Persinger's studies.

Regardless of these apparent inconsistencies, Persinger's work has prompted some hypotheses about the underlying mechanisms mediating effects of ELF magnetic fields (10). The mechanisms are probably independent of reactions to induced electric fields alone because it has been demonstrated that even an electric fish, *Sternarchus albifrons*, reacts differently to a magnetic field (600 to 1200 Hz, 10 and 20 gauss) than it does to an electric field (18).

ELF electric fields (640 Hz, 2 V/m) do influence brain activity (EEG) in rats, and it has been hypothesized that the posterior hypothalamus is involved in the mediation of "electrosensitivity" (9). In preliminary findings, Ludwig (personal communication) discovered that ELF electric fields (5-20 Hz) alter human behavior which could be considered indicative of motivation. He found that some institutionalized patients reported changes in "mood" when these fields were turned off. Because the hypothalamus is intricately involved in motivated behavior, these studies imply that experiments with ELF fields should explore "motivated" behavior in animals. Although reports of positive findings continue to appear, the experiments are difficult to duplicate and attempts to demonstrate ELF effects are not always successful (1,4,5). The present investigation studied a number of different behaviors indicative of motivation level and presents three experiments of a continuing series in an attempt to identify the behaviorally effective frequency of low intensity ELF fields.

METHOD

SUBJECTS

Two male rhesus monkeys (*Macaca mulatta*), approximately 7 years old, were the subjects. These animals, AR4 and AP6, were also in the first experiment of this study in

which they were subjected to 75-Hz magnetic and electric fields (1). Medical histories of the subjects indicated they were physically normal.

APPARATUS

Two animal chambers made of wood and fiberboard, isolated from extraneous light, noise, and vibration, were each placed in large Helmholtz coils. The front of the chambers faced east. Each chamber was outfitted with standard lighting, grid floors, and a work panel containing manipulanda for the animal's responses. A detailed description of the apparatus is given in a previous report (1).

The magnetic fields were 10 gauss and varied ± 0.5 gauss within the chambers. Measurements were made with a Bell 620 gaussmeter. An electric field probe developed by IIT Research Institute, Chicago, Illinois, was used to measure the electric fields. ELF electric fields of 60 Hz generated by the houselights and exhaust fans existed along with the purposely generated 45-Hz and later the 10-Hz electric fields. The extraneous 60-Hz electric fields were a vertical field of 4.4 V/m, an axial (front-to-rear) field of 5.8 V/m, and a transverse (side-to-side) field of 1.8 V/m. These were all rms values of 60-Hz fields and were present throughout the experiment. With the houselight off extraneous fields averaged 0.8 V/m. The 45-Hz E fields were a vertical field of 3.0 V/m, an axial field of 3.5 V/m and a transverse field of 7.4 V/m. Measurements of the 10-Hz electric fields were not made but it was assumed that these E fields would be somewhat less intense than the 45-Hz fields. The presence of the 60-Hz fields combined with the 45- or the 10-Hz fields produced complex waves. Because the extraneous fields were always present during the animals' work periods, and the maximum field was 7.4 V/m when it was applied at 45 Hz, the independent variable was considered to be the 45-Hz B field in phase with a 7.4 V/m (rms) electric field at 45 Hz and later a less intense 10-Hz E field with a 10-Hz B field.

PROCEDURE

The subjects were trained to perform three distinct tasks--Fixed Interval (FI), Reaction Time (RT), and Match-to-Sample (MS)--to obtain food and water. Reinforcement for correct performance was an 0.86 gm Purina Monkey Chow Tablet or 2.0 cc of water. Supplemental portions of fruit prior to each session and weekend food were the only other food sources. The subjects were initially trained to press buttons next to the food and water apertures whenever these apertures were illuminated. Then, the subjects were trained on one of the specific tasks to illuminate the food and water apertures, and, hence, make reinforcement available. Following training on this task, the two other tasks were imposed, and the subjects were trained to work each in succession. When the animals were responding well and prior to the start of this experiment, the reinforcement schedule was altered so that 50 percent of the reinforcement opportunities were replaced with a 0.7-second flash of the food and water lights. These brief flashes were programmed to occur randomly and effectively reduced the frequency of food and water reinforcement by 50 percent. In the present study and others (6), such brief presentations of a reinforcement light were treated as conditioned reinforcers.

FI. In the presence of a green light on the lower center of the work panel, the subjects momentarily lifted a lever directly below the green light. A lever lift after 20 seconds had elapsed resulted in reinforcement availability or a reinforcement light flash.

RT. In the presence of a red light beneath the FI light on the work panel, the subjects lifted the same lever as in FI until a tone occurred. In the presence of the tone the subjects released the lever which resulted in tone and red light extinction and reinforcement availability or reinforcement light flash. If the lever were held up more than 1.0 second while the tone was present, the red light and tone extinguished and a 10-second interval (intertrial interval) intervened between the lever release and the next onset of the red light. The interval between reinforcement and red light presentations, the intertrial interval (ITI), was always 10 seconds. The period between lever lift during the red light and tone onset was the foreperiod, which varied between 0.5 and 10 seconds. Lever releases during the foreperiod (anticipatory responses) and lever lifts in the absence of the red light (ITI responses) reset the interval before the next red light.

MS. The animals were trained to press a disc (standard) centered on the work panel when it was transilluminated with one of ten different stimuli (colors and symbols, Grason-Stadler pattern No. 153). Below the top disc were two similar discs (comparison). A response on the top disc was followed by removal of its stimulus and 1.0 second later the same stimulus appeared on either the right or left comparison disc. A different stimulus was on the opposing comparison disc. When the disc with the matching stimulus was pressed, all stimuli were removed and reinforcement became available or the reinforcement light flashed. When the disc with the non-matching stimulus was pressed, all stimuli were removed and 15 seconds later the same stimulus appeared on the top disc again. Ten seconds after reinforcement was obtained (ITI), another stimulus appeared on the top disc. The presentations of the stimuli on the top disc following reinforcement and light flash were random and their presentation on the right and left comparison discs was also randomly determined.

Each task was available during a single 15-minute component each hour. A component was followed by a 5-minute extinction (ext) period in which no tasks were available. The sequence of tasks during each hour was FI, ext, RT, ext, MS, ext. Each experimental session was of 8 hours duration except on Friday when a 6-hour session occurred. The subjects were confined to the chambers from 0930 on one day to 0730 on the following day. Between 0730 and 0930 the subjects were weighed, the cages cleaned, and the equipment checked. On Friday they were removed to holding cages at 1430 except during the final phase of the experiment when sessions occurred without weekend breaks.

The study was conducted in three discrete sections, A, B, and C. Sections A and B utilized the above procedure. Section C contained a larger FI (30 seconds) and the MS ITI was increased to 15 seconds. Section A, which contained 66 sessions, subjected the animals to a 45-Hz, 10-gauss magnetic field combined with the electric field for 13 sessions starting at session 46, when both subjects' behavior had been stable for a sufficient period (7 sessions). In Section B the fields were a 10-Hz, 10-gauss magnetic field combined with the 10-Hz electric field and began five days after Section A had been

concluded. Section B lasted for 29 sessions. The fields were turned on at the start of session 12 and continued 12 sessions. Section C began six days after B had been concluded. The fields remained the same during Section C and the sessions occurred continuously for 24 sessions. In C there were no weekend interruptions and each experimental session lasted the entire 8 hours. Also, in C the field was on during the middle 8 sessions. The procedures are summarized in Table 1.

At the conclusion of Section C the animals were removed from their chambers and given complete physical examinations.

Table 1
Summary of Experimental Conditions

Section	FI (sec)	RT (ITI)	MS (ITI)	Hz	Field On Sessions	Total Sessions
A	20	10	10	45	13	66
B	20	10	10	10	12	29
C	30	10	15	10	8	24

RESULTS AND DISCUSSION

No physical abnormalities were seen in either animal as a result of the ELF fields at either frequency.

SECTION A

Behavioral indices for the 45-Hz phase of this experiment were extraordinarily stable. Figure 1 illustrates daily performance during FI behavior. The measures were reinforcement time, the time between reinforcement being made available and a reinforcement response; pause time, the time following a reinforcement response and the next FI lever response; and response rate, the number of FI lever responses per minute. As seen in Figure 1 FI behavior showed no significant deviations correlated with the 45-Hz fields. Reinforcement time was very stable for AP6 and quite variable for AR4, but no changes occurred when the fields were introduced at session 46 or removed after session 58. Pause time and response rate showed considerable daily variation but, again, no changes occurred when the fields were introduced or removed. Figure 2 illustrates more definitely the lack of

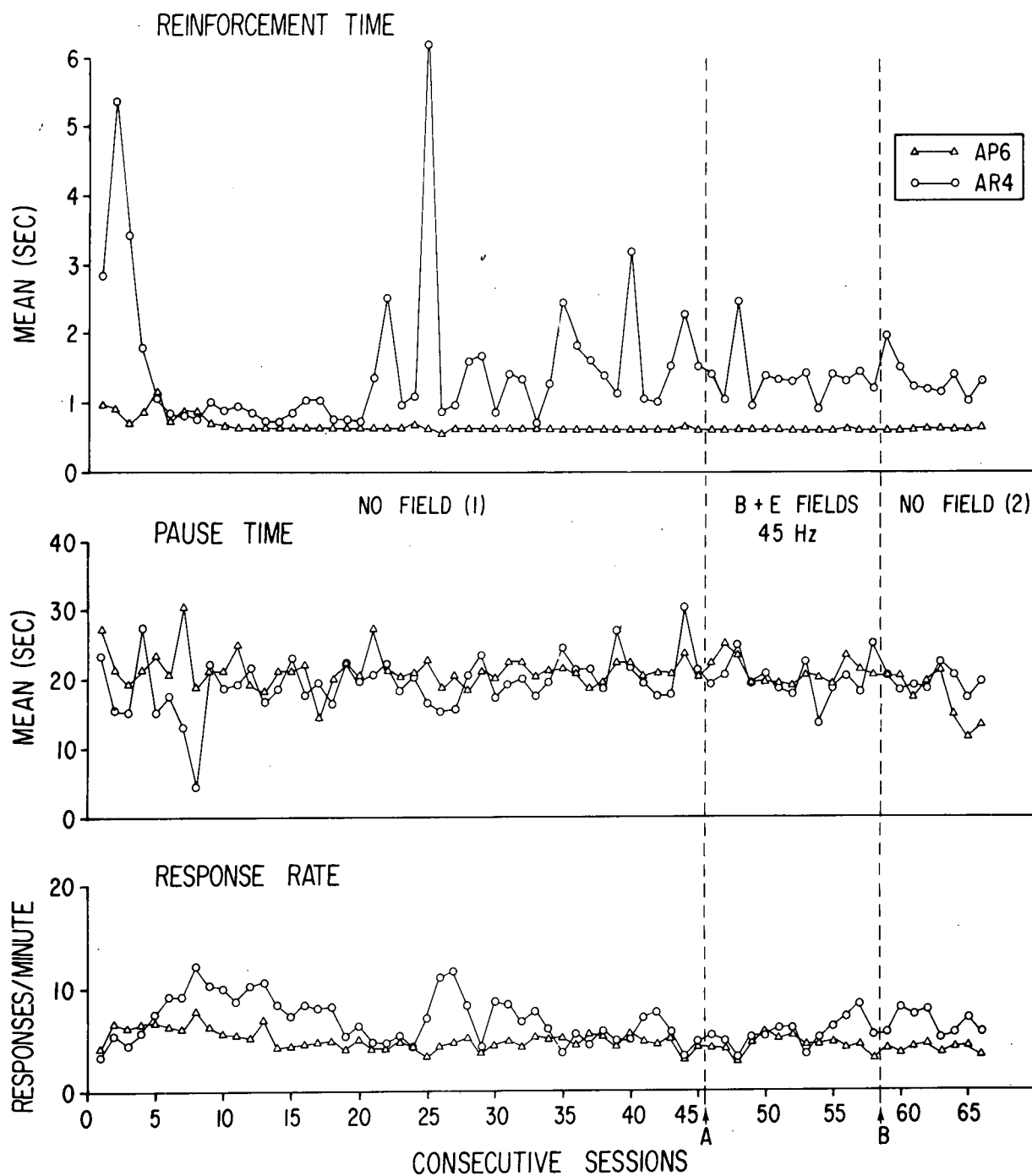


Figure 1

Fixed Interval behavior of AP6 (triangles) and AR4 (circles). A and B on the abscissa indicate respectively when the 45-Hz fields were introduced and then removed.

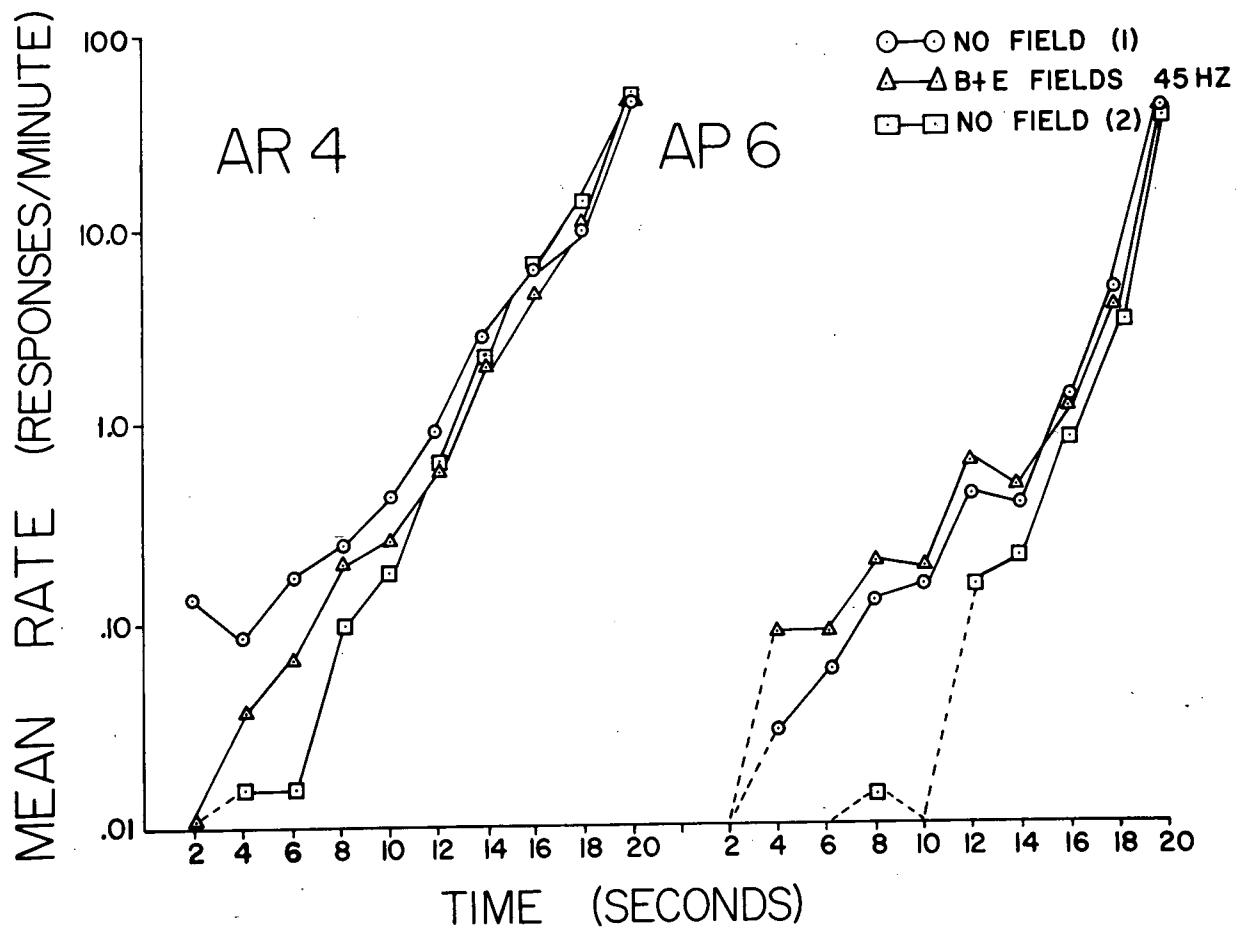


Figure 2

The mean response rate per 2.0-second segment as a function of the 45-Hz fields. Responses were sorted according to the successive 2.0-second segment following the start of an FI 20-second component wherein the response occurred. The ordinate is a log scale.

changes in response rate associated with the fields.* The data are from the 7 days prior to, 13 days during, and 7 days after the fields were present. In Figure 2 the mean rate of responding per minute in each 2.0-second segment of the FI 20-second component is plotted on a logarithmic scale. The only differences appeared at extremely low response rates (less than one per minute) and tended to be related to the chronological course of the experiment but not to the ELF fields. That is, as the number of sessions increased, the response rate in the initial segments of the FI 20-second components decreased.

Reaction time behavior is shown in Figure 3. Measures obtained during RT behavior were ITI responses, anticipatory responses, and reaction time. ITI and anticipatory responses were calculated as the percentage of total responses and are seen in the top and middle portions of Figure 3. Reaction time was recorded as the median latency of a RT response and is seen in the lower portion of Figure 3. Sessions 21 through 24 experienced an equipment malfunction and data were off scale for animal AR4. RT latency was completely unchanged for AP6 and a small decrease in latency was seen for AR4 when the fields were present. However, when the fields were removed, AR4 did not show a concomitant increase in RT. Instead, AR4 continued to respond faster to the tone. Figure 4 demonstrates further the lack of RT change for AP6 and the gradual change in the latency of AR4. In Figure 4 histograms representing the frequency of reaction time responses as a function of their latency are shown in relation to the absence and presence of the fields. Although AP6 displayed no substantial changes in these histograms, AR4 did. The 0.2-second category in each set of AR4's histograms gradually increased from 16 percent to 49 percent over the course of the experiment, and the increases were independent of the ELF fields. In other words, AR4 learned to respond faster as the experiment progressed. The percentage of ITI and anticipatory responses was relatively small and changes associated with the fields were evident only in AR4's anticipatory responses as seen in Figure 3. These changes, however, were smaller than the changes which occurred from session to session and were not statistically significant. AP6 did not display similar changes in his behavior.

MS measures were errors as the percentage of total responses and the median latency to press one of the comparison discs after the top disc had been pressed. The activity measure was actuations per hour of a switch located at one end of a rod in the grid floor of each experimental chamber.

MS performance also was not related to the presence of the ELF fields as seen in Figure 5. AP6 continued to decrease his error rate as did AR4 to a lesser degree. However, during the last 30 sessions no substantial changes occurred in either animal's error rate. Response latency was very stable for AP6 and highly variable for AR4 but in neither case was it related to the ELF fields.

*The points corresponding to the 20-second marks on the abscissa do not truly reflect rate because these points include all responses falling in the last 2.0 seconds of the FI plus responses occurring after the FI timed out.

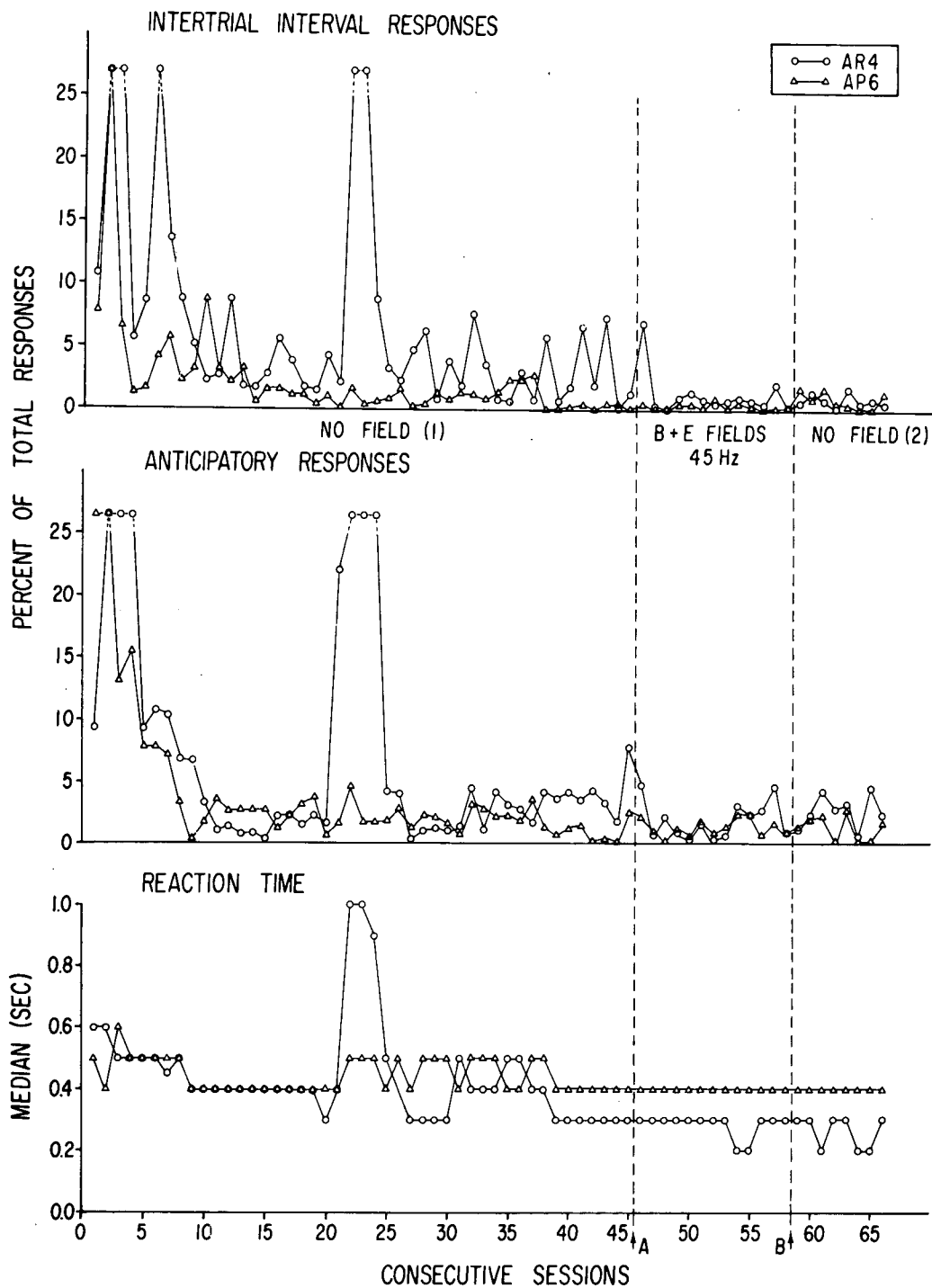


Figure 3

Reaction time measures. Intertrial interval responses were those lever lifts occurring before the reaction time light appeared, and anticipatory responses were those lever releases occurring after the light appeared but before the tone was presented.

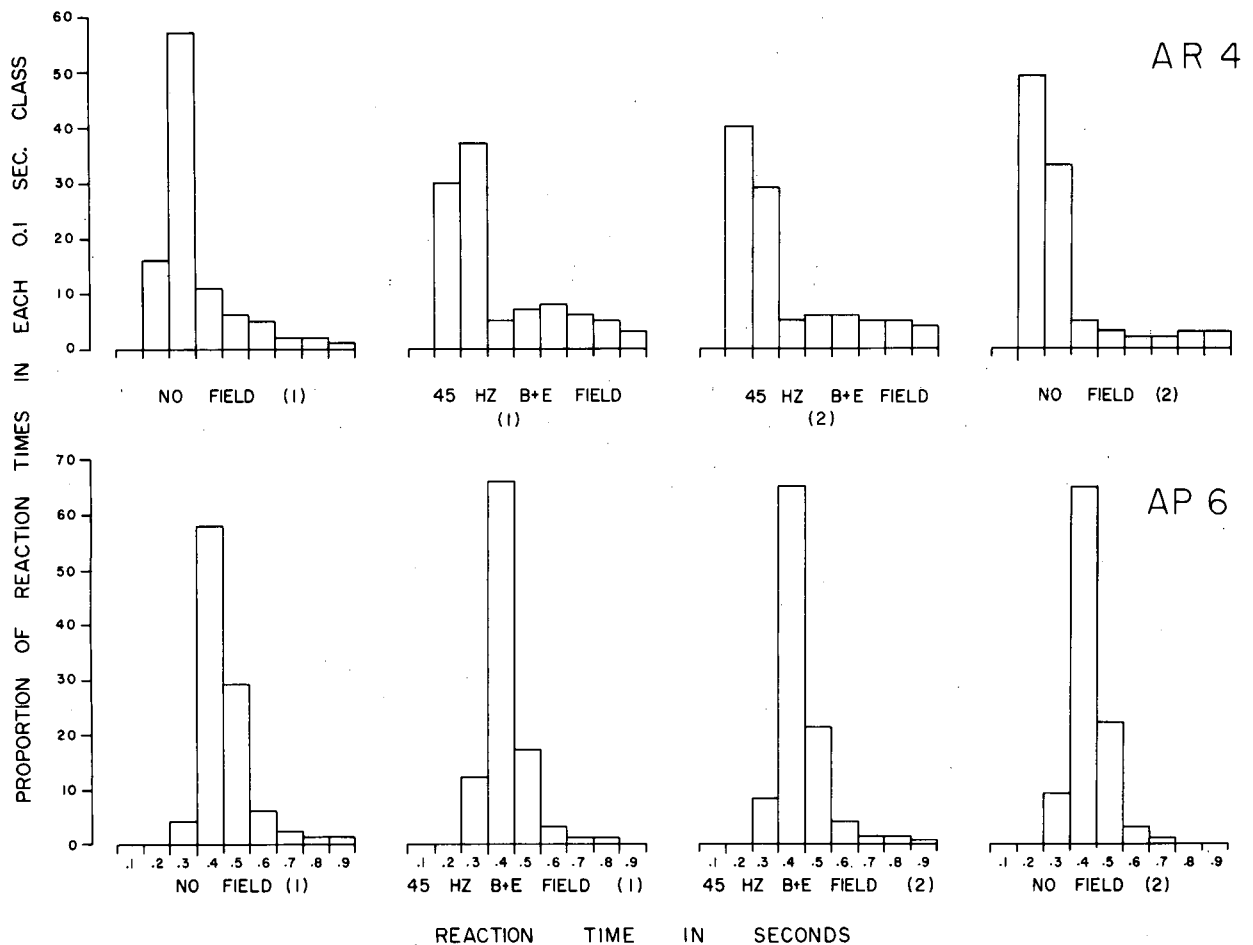


Figure 4

Histograms representing average proportions of reaction times that occurred during the first second following the reaction time tone. The data were obtained from the seven sessions preceding the introduction of the 45-Hz fields (NO FIELD 1), the seven sessions after the fields were turned on (45 Hz B & E FIELD 1), the seven sessions before the fields were turned off (45-Hz B & E FIELD 2), and the seven sessions after the fields were removed (NO FIELD 2).

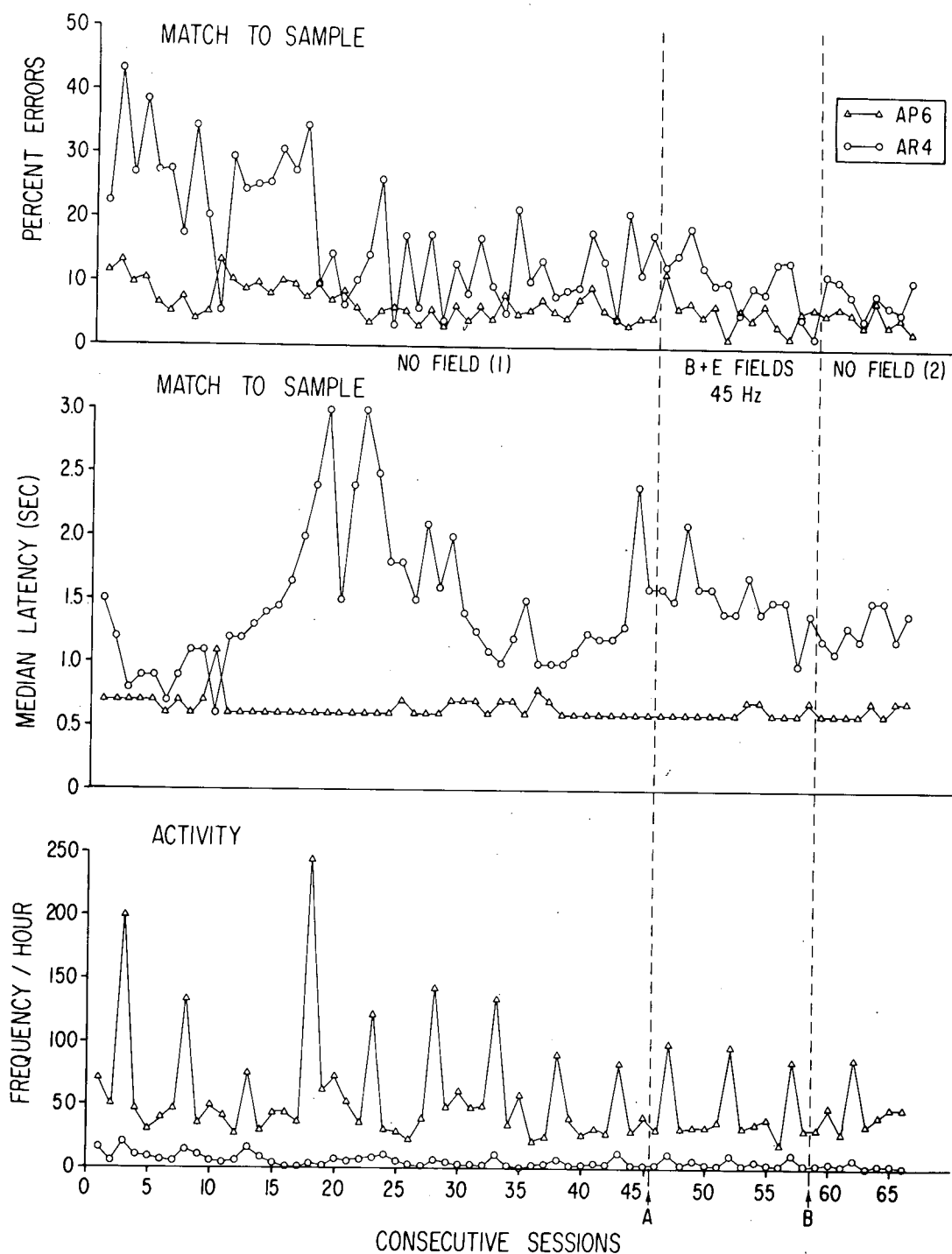


Figure 5

Match-to-sample and general activity. Errors were calculated as the proportion of errors to the total responses. The higher points in the activity graph occurred on Mondays.

General motor activity gradually decreased for both animals during the course of the experiment and no relationship to the ELF fields was evident as seen in the lower part of Figure 5. Both animals did display a 5-day activity cycle in which they exhibited greatest amounts of activity in the first session following the weekend layoff.

The Mann-Whitney U Test (17) was used to assess statistical significance whenever mean differences were observed. Probabilities at the .05 level or less were considered to be significant and were reported; however, none were reported in Section A because the 45-Hz fields had no statistically significant effect on the behaviors observed. The lack of changes was not merely a function of using averaged data. None of the measures demonstrated any substantial changes between sessions at the time the fields were introduced or removed.

SECTION B

Behavior of the animals reasonably stabilized during the first 11 sessions of this portion of the experiment and the 10-Hz fields were turned on at the start of session 12. Performance was essentially the same as in Section A on most measures, as seen in Figure 6. The data for Figure 6 are means from the six sessions preceding the introduction of the fields, the 12 sessions while the fields were on, and the 6 sessions following the removal of the fields. The standard error of the means for the same data are shown on the left of Table II. These figures give an indication of the session to session variability of the means. FI performance, although not influenced by the fields, did show some indication of a change in motivation. Both animals took increasing amounts of time to obtain available reinforcement and gradually decreased their response rates as the number of sessions increased. AR4 slightly increased his response rate when the fields were on but this increment was not significant. Again, there were no substantial changes in post reinforcement pause time except for a small gradual increase for AR4 as the sessions progressed. Figure 7 demonstrates average responding in each 2.0-second segment of the FI. There was obviously no strong influence of the fields on FI responding since each point for the field presence is almost the same as the analogous point for the field absence, with some exceptions in the case of AP6.

In the RT task AP6 showed a slight, statistically insignificant, increase in latency as a function of the fields; however, AR4 did not. The behavior of AP6 was drastically reduced for one session when the fields were on and produced extreme latencies in both RT and MS. AR4 did show a non-significant drop in the percentage of ITI responses during the RT task. These changes were not similar to changes occurring with the 45-Hz fields. A closer examination of RT responses is made in Figure 8. The histograms of RT responses show that each animal varied his reaction times about the same with the fields as without them and that modal response values did not vary.

MS performance demonstrated a tendency for one animal to be influenced in one direction by the fields and the other animal to be influenced in the opposite direction. Neither of these changes were statistically significant. Where AP6 increased his mean matching errors and his latency to press a comparison stimulus when the fields were on,

Table II

Standard Error of the Mean for Data Shown in Figures 6 and 9*

Measure	Section B				Section C		
		No Field (1)	B & E Field	No Field (2)	No Field (1)	B & E Field	No Field (2)
Reinf. Time	AR4	.14	.72	.60	.39	.96	.91
	AP6	.01	.43	.97	.11	.04	.31
Pause Time	AR4	1.09	.55	1.19	1.77	1.36	2.11
	AP6	.50	1.29	3.23	4.98	4.44	3.24
Response Rate	AR4	2.30	2.83	.84	1.63	2.23	.93
	AP6	.93	1.55	.90	.53	.53	.65
ITI Responses	AR4	3.14	2.40	3.05	1.20	1.04	.45
	AP6	.74	.50	.43	.16	.41	.34
Antic. Responses	AR4	1.40	1.61	1.51	.85	1.86	1.07
	AP6	.36	1.02	1.20	.47	.61	.96
Median RT	AR4	.05	.05	.04	.05	.07	.05
	AP6	.04	.03	.04	0	.05	.03
MS Error	AR4	5.33	9.16	6.51	2.07	2.03	2.78
	AP6	1.88	4.27	5.14	1.83	2.86	3.77
MS Latency	AR4	.13	.20	.17	.10	.39	.07
	AP6	0	.53	.04	.06	.08	.14
Activity	AR4	2.43	1.62	3.91	6.05	1.25	2.54
	AP6	25.72	28.84	15.16	5.80	4.57	3.50

*The initial 10-Hz study is on the left and the replication on the right.

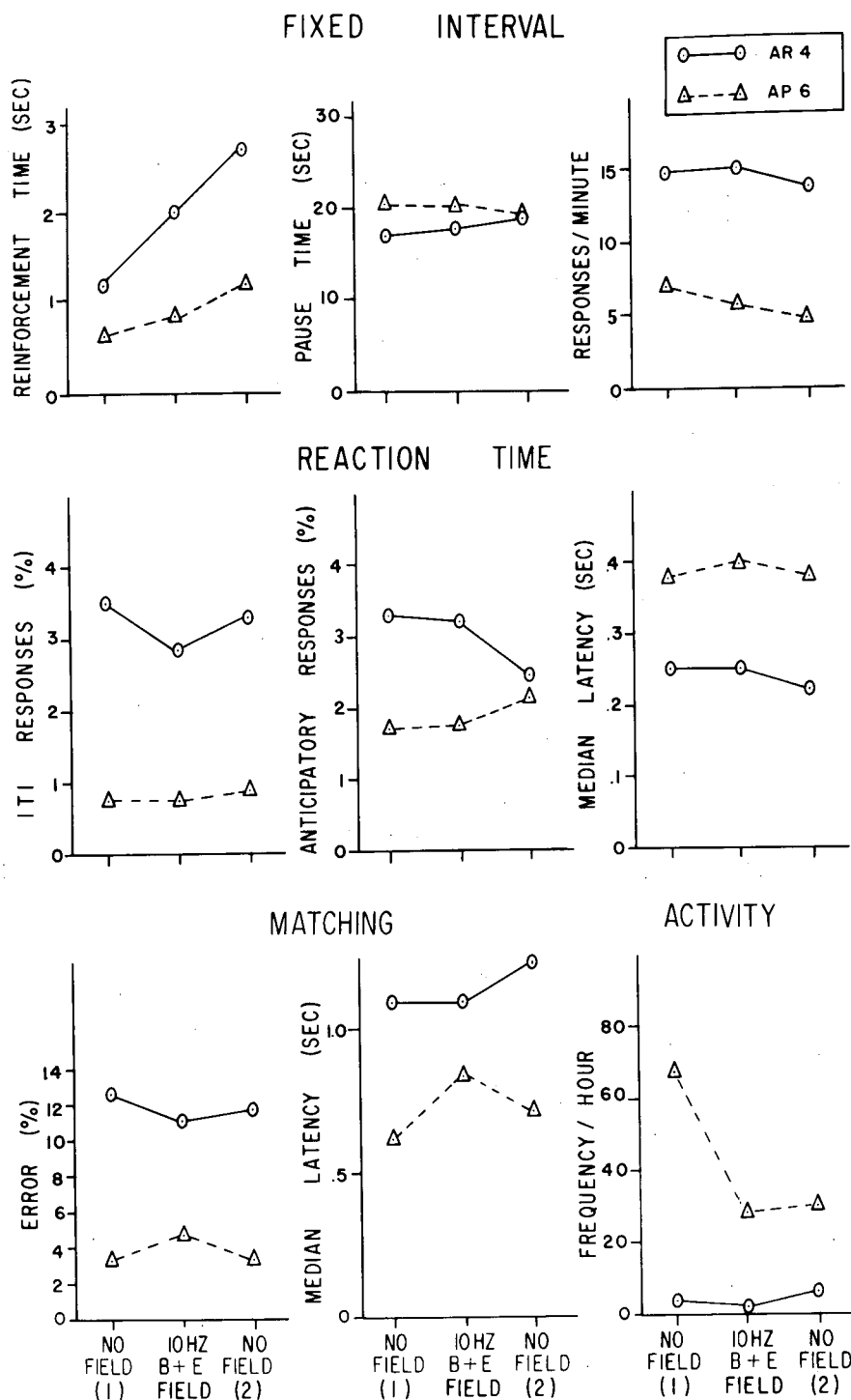


Figure 6

Summary of mean behavior before (NO FIELD 1), during (10-Hz B & E FIELD), and after (NO FIELD 2) the 10-Hz magnetic and electric fields were introduced. Fixed interval data are shown in the top three graphs. Reaction time data are in the center three graphs and match-to-sample and activity data are in the lower three graphs. The ordinate on each graph describes the particular datum and its quantity.

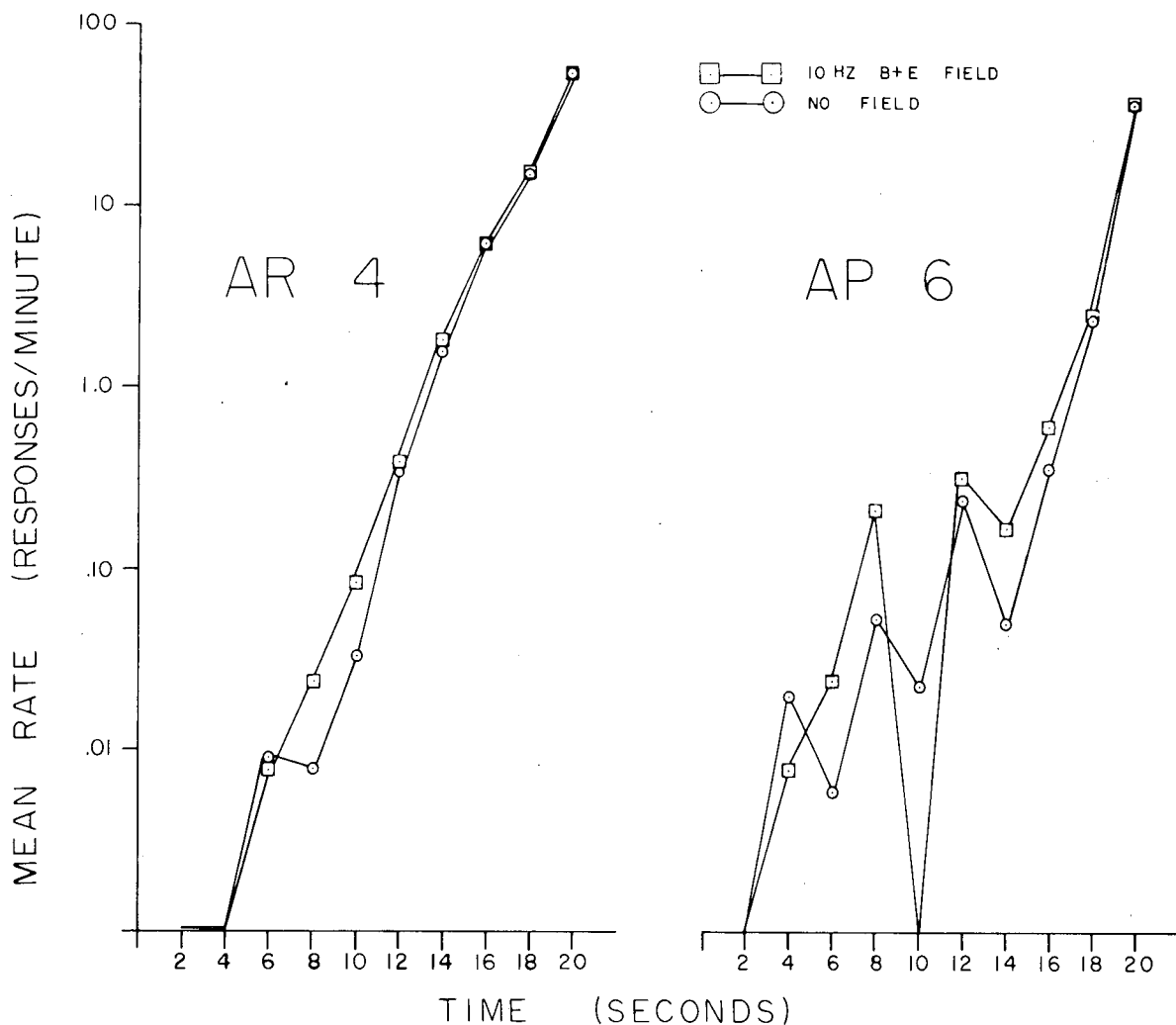


Figure 7

Mean response rate per 2.0-second segment as a function of the 10-Hz fields. The figure is similar to Figure 2 except that the data representing the absence of the fields (NO FIELD) were obtained by combining the data from the six days preceding the introduction of the fields with the six days following the removal of the fields. The entire 12 days while the fields were on contributed data for the curves (10-Hz B & E FIELD).

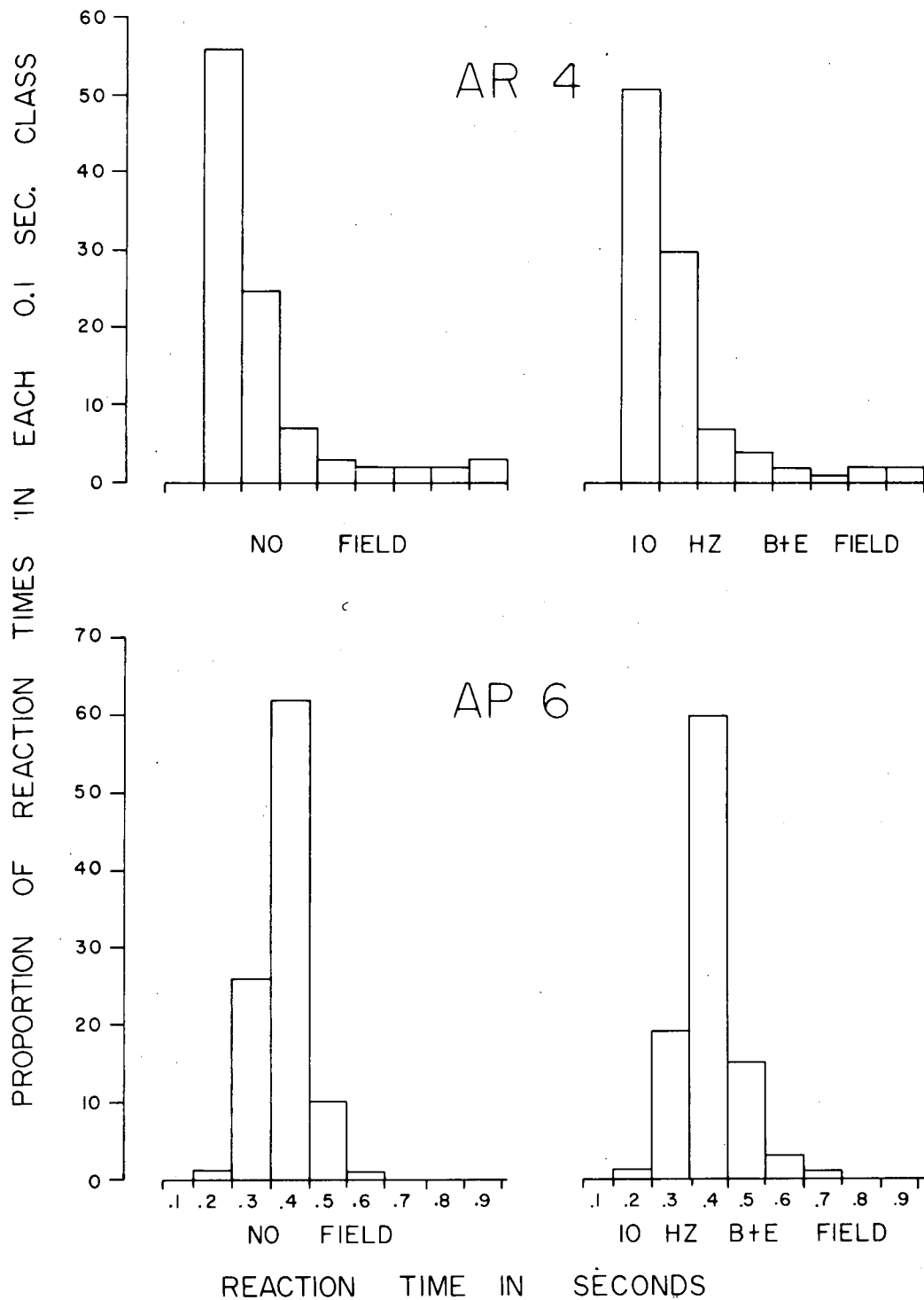


Figure 8

Histograms of the proportion of reaction time responses which occurred during the 0.9 seconds following the reaction time tone. Data were obtained from the same sessions as in Figure 7.

AR4 decreased his errors and showed no decrement in his latency. AP6 responded only 16 times one session and produced this outcome.

The activity data continued to show a general decrease and both animals produced significantly less activity during the presence of the fields ($p < .02$ for both animals). These changes were the first to occur concurrently in both subjects as a function of the fields.

Because more changes, significant and non-significant, occurred as a function of the 10-Hz fields than occurred under the 45-Hz fields, it was decided to repeat the 10-Hz stimuli and not interrupt data collection over the weekends; hence, Section C, which contained 24 continuous sessions, was imposed.

SECTION C

Figure 9 summarizes the means of various measures obtained when the 10-Hz fields were repeated. Data were averaged over the 16 sessions without the fields (8 before and 8 after) and the 8 sessions with the fields on. The standard errors of these means are shown on the right of Table II. In Figure 9 it is seen that both animals gradually reduced their response rate and increased their pause time in the FI 30-second task. These changes were not correlated with the introduction of the fields. AP6 did show a significant decrement in reinforcement time when the fields were present ($p < .002$). This change had not been seen previously. The fact that there was no substantial influence of the fields on FI behavior is seen in Figure 10 where the average response rate per 2.0-second segment of the FI 30-second schedule is plotted. Most of the data points representing field and no field overlap or else are very close. This is particularly true where the rates are greater than one response per minute. Although these data represent responding on a FI 30-second schedule, they are very similar to those in Figures 2 and 7 representing responding on a FI 20-second schedule. The similarity illustrates the high stability of FI behavior during the three sections of the experiment and the general insensitivity to ELF effects.

There were some changes in RT performance as a function of the 10-Hz fields. When the fields were on, AR4 increased his ITI responses, significantly increased his anticipatory responses ($p < .05$), and only slightly decreased his reaction time. Previously, when the 10-Hz fields were introduced (Section B), AR4 decreased his ITI responses, and in Section A, when the 45-Hz fields were on, AR4 decreased his anticipatory responses. AP6 significantly increased his ITI responses ($p < .05$) when the fields were on, but his other RT performance illustrated changes related to increased number of sessions only. Figure 11 shows that there were no substantial changes in AR4's reaction time responses since the distributions were essentially the same under all three conditions. A close examination of the three sets of histograms for AP6 reveals that he gradually increased the proportion of responses in the 0.3-second category and reduced those in the 0.4-second category as the sessions increased.

Performance on the MS task also tended to be influenced by the ELF fields during Section C. Both animals responded faster when the fields were on, AR4 significantly so

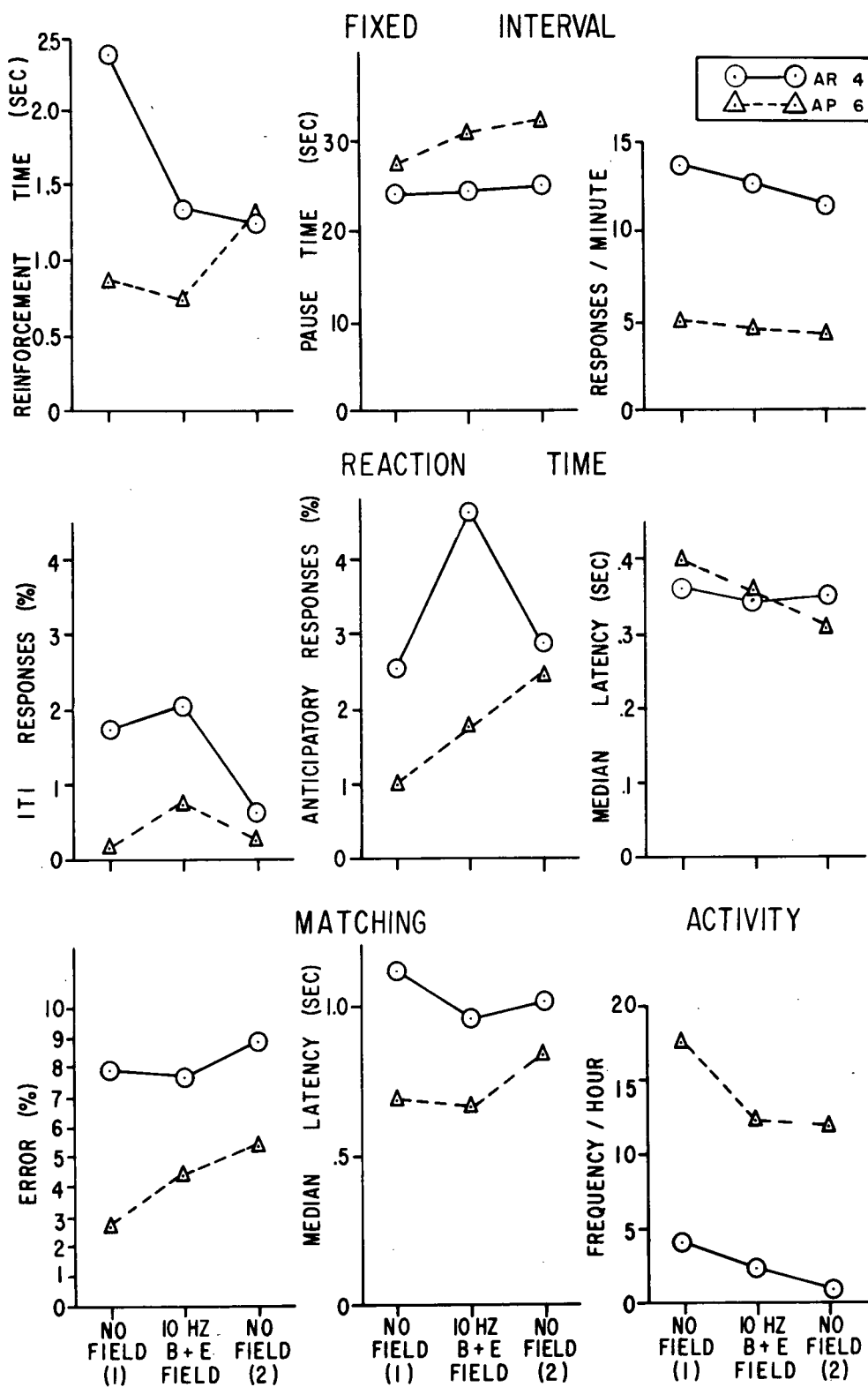


Figure 9

Summary of mean behavior when the 10-Hz magnetic and electric fields were presented during continuous sessions. The graphs are similar to those in Figure 6.

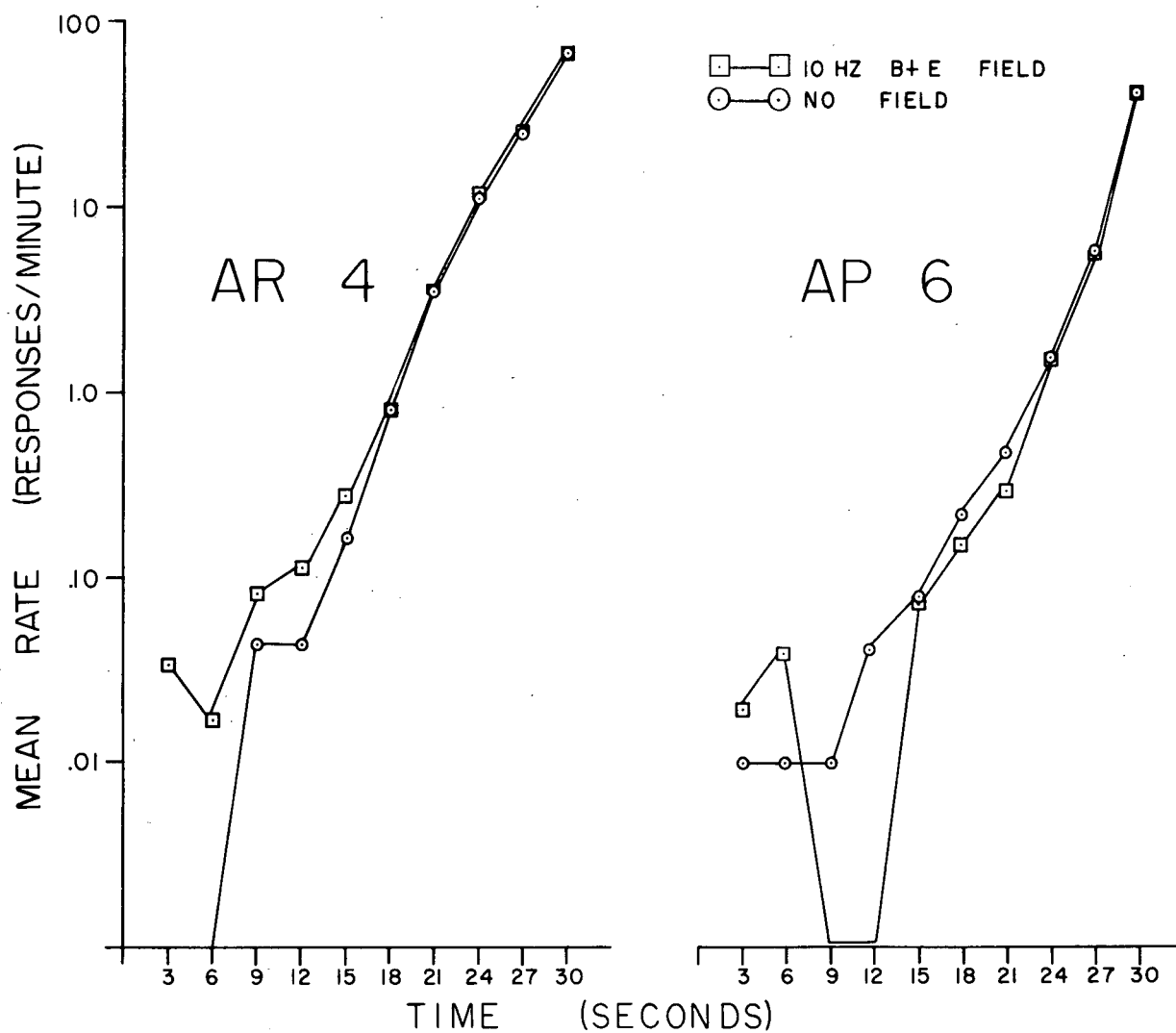


Figure 10

Mean response rate per 3.0-second segment as a function of the 10-Hz fields during Section C.

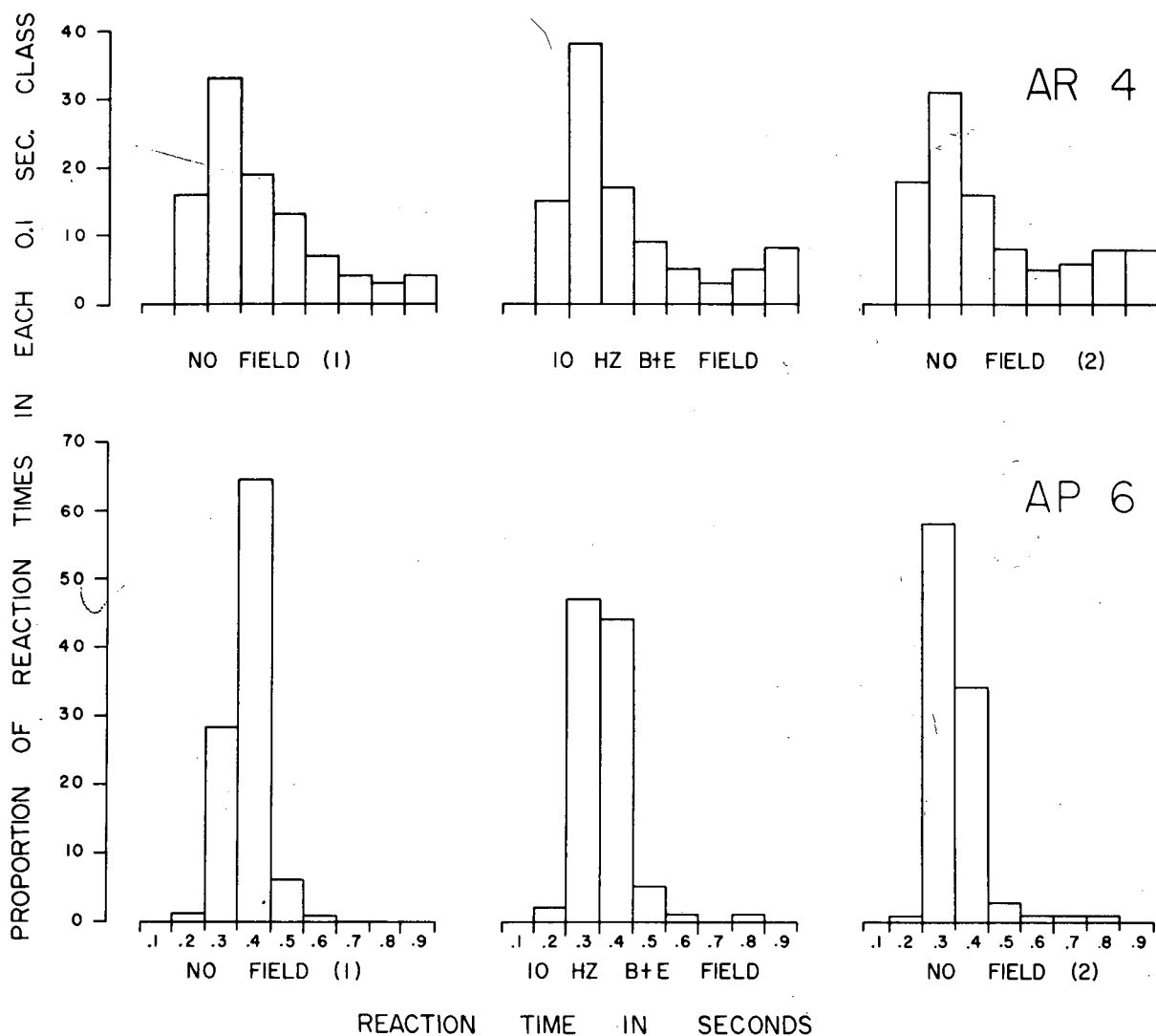


Figure 11

Histograms representing reaction time distributions before, during, and after the 10-Hz fields were introduced and removed in Section C.

($p < .05$), than they did when the fields were off, and AR4 made fewer errors in the presence of the fields. These changes, however, were similar to those in the previous 10-Hz fields only in the case of AR4's percentage of error. Previously AP6 increased his response time, whereas, in Section C, AP6 decreased his response time when the fields were on.

General motor activity continued to decrease and was at very low rates at the end of the experiment. Such decrements in activity often occur with continued confinement. In Section C there were no significant effects or trends in the activity data and Section B's results were not confirmed.

A summary of the three sections of this study reveals that few consistent patterns of behavioral change occurred as a function of the ELF fields either between or within subjects, and only in the case of one animal, AR4, was a repeatable effect observed. However, this effect, a reduction in MS errors when the 10-Hz fields were on, was not statistically significant in any case.

In general, the overall performance of the animals was the same as in Experiment 1 (1) demonstrating that the 50 percent reduction in reinforcement rate did not influence behavior.

CONCLUSIONS

Even though a number of trends in the data occurred in the presence of the 45-Hz fields, similar tendencies were not observed when the 10-Hz fields were introduced and, in some cases, the exact opposite occurred. For example, AR4 had a lower FI response rate in the presence of the 45-Hz fields but a higher FI response rate in the presence of the 10-Hz fields. Similarly, predictions made because of differences and trends in the first 10-Hz section (B) were confirmed in only one instance in the second 10-Hz section (C) and in some cases the opposite outcome occurred. For example, AP6 had a larger response latency on the MS task when the initial 10-Hz fields were on (Section B) but a smaller latency the second time the 10-Hz fields were on (Section C). Such inconsistencies are not unusual (3,7,8), but they do require explanations. One explanation of these results would be that the ELF fields have no effect and that the significant differences which appeared were due to chance alone. Such chance occurrences were quite likely since 18 measures were obtained, and the probability that one of these would have shown significant differences by chance is almost the same as the significance level used (.056 versus .05). On the other hand, both animals significantly reduced their activity in the presence of the 10-Hz fields in Section B which was highly unlikely as a chance phenomenon. A reason they failed to show a similar effect the second time (Section C) may have been because of the overall reduction in activity that occurred as a function of increased confinement. That is, activity was reduced to such a low level that the ELF fields or even a very strong stimulus would have had no discernible effect. Other studies have consistently obtained differences in activity as a function of ELF fields (12,13,14), and this investigator believes that the activity change in the current study was probably the only behavior presently explored that could have been an effect of the 10-Hz fields.

In general, the results failed to support the assumption that ELF fields will affect motivated behavior. In only one instance was a superficial indicator of motivation (time to obtain reinforcement once it was available) significantly changed in one animal and only once did the activity level of both animals seem to be lowered by the fields.

Because there was so little consistency in the results from one section of the experiment to another, or between subjects, and since the effects (except on activity) were not related to those reported in other studies, such as a simple reaction time effect (2), this investigator believes that substantial replication will have to be accomplished if effects of ELF non-ionizing radiation are to be unequivocally identified. The present study does not support the assumption that ELF fields always affect animal behavior. Such effects, if they are real, will most certainly be dependent upon the specific frequency of the field. This specific frequency has yet to be identified.

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<p>Consonant with the U. S. Navy's exploration of the biological effects of extremely low frequency electromagnetic radiation, the present studies exposed two rhesus monkeys to 10-gauss 45-Hz and 10-Hz fields. Low intensity electric fields occurred simultaneously. No effects of the 45-Hz fields on immediate memory, operant responding, reaction time, or activity were observed. Statistically significant effects were produced by 10-Hz fields, but not in both animals nor in a replication of the experiment. The study failed to provide unequivocal evidence that ELF magnetic and electric fields affect behavior, although weak support for effects of 10-Hz fields on general motor activity was given.</p>			

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