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BEHAVIORAL EFFECTS OF STIMULATION BY UHF RADIO FIELDS[1]

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Summary.—20 male albino rats were used as *Ss* in determining behavioral effects of ultra high frequency radiation. Experimental *Ss* were exposed to low intensity (50,000 mV), low frequency (300 mc to 920 mc) UHF radio waves for 47 consecutive days. Radiated rats were more active than non-radiated rats during the early part of the experiment, but became less active as the days of radiation increased. The UHF group was more emotional than the non-UHF group and showed a gradual increase in the latency of recovery from electroshock convulsion. No differences were found for weight, audiogenic seizures, and water consumption. Results suggest that (a) some time is required for UHF to have a consistent effect on behavior, and (b) the effects on behavior may be non-thermal and related to neurophysiological substrates.

Increasing numbers of applications of microwaves have focused attention on these radio waves in the microwave region. Defined in terms of frequency, the microwave, or ultra high frequency (UHF) region, extends from 300 megacycles (mc) to 3,000 mc.

Research has been limited to the somatic effects of high intensity, high frequency UHF fields (Peyton, 1961). Results indicate extensive tissue damage at these high power levels. In addition, experiments have been carried out on a short-term basis. The necessity for experiments using low intensity and low frequency fields is apparent when one considers that the central nervous system (CNS) is most sensitive to microwave energy at low power densities (Turner, 1962), and that lower microwave frequencies both penetrate and activate portions of the CNS to a greater extent than do higher frequencies (Pinneo, Baus, McAfee, & Fleming, 1962). Eakin and Thompson (1962) studied the behavioral effects of low intensity, low frequency UHF radiation over a relatively long period of time. Results suggested an effect on activity level, this effect requiring repeated exposure before becoming apparent. A more extensive study of the behavioral effects of low power and low frequency UHF radiation over a period of time is indicated by these findings and by the fact of the rapidly increasing use of low power, low frequency UHF generators and their proximity to large segments of the population.

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METHOD

Subjects

Twenty 30-day-old naive male Sprague-Dawley rats, weighing from 100-120 gm. at the start of the experiment, were used as *Ss*. These *Ss* were randomly assigned to the two radiation treatment groups.

Apparatus

A General Radio amplitude-regulating power supply (Type 1263A) and a General Radio oscillator (Type 1209B) with a range of 250 to 920 mc was used as a source of UHF energy. A Discone broadband antenna (Bayer, 1949) resonant on the frequencies being used, directed the waves to the experimental *Ss* in their living cages. The antenna was placed in the center of the circular living cages so that no *S* could be more than 24 in. nor less than 12 in. from the antenna at any time. A similar Discone antenna was placed in the center of the control group living cages but was not connected to a source of radio frequency (RF) energy.

Field strength readings were made daily with a Simpson field strength meter, which was situated in the control group room. A lead from the Discone antenna in the control group room served as the input to the meter. The frequency of 800 mc was used to obtain measurements of the field strength both before and after the radiation room had been sealed. Field strength outside the radiation room was essentially zero, being less than 2 microvolts (mV).

A 36-in. $\times$ 36-in. open-field box divided into 36 6-in. squares was used to measure emotionality. A 100-w light bulb with a reflector (12 in. in diameter) was hung 30 in. over the center of the box. Five photocell activity cages were used to measure spontaneous activity.

Experimental and control groups lived in separate rooms of equal size. The floor, walls, and ceiling of the radiation room were lined with bronze screen, the purpose of this shielding being to contain the RF energy within the radiation room. This shielding was grounded to an earth ground through four copper plated steel rods which were driven 6 ft. into the earth. The living cages inside the experimental and control group rooms were made of plastic, since plastic is a dielectric material that has minimal blocking effect on the UHF radio waves.

Procedure

The experimental group was exposed to radiation for 47 consecutive days. The power level of this radiation, as measured from the inside of the cages, was extremely low, being only 50,000 mV. The oscillator was swept continuously through a range of frequencies (300 to 920 mc) in successive ascending and descending sweeps during this time. The time of sweep from 300 to 920 mc was 82 sec. Although the experimental animals were exposed to UHF waves at

all times other than the times when behavioral tests were being made, the control animals were never exposed to the UHF waves.

Behavioral tests for all *Ss* were carried out in the following manner. For 40 consecutive days, activity level measurements were made in the photocell activity cages for 30 min. a day. Each day *Ss* were randomly selected as to the sequence of activity measurement and as to placement in the activity cages. Each rat was observed in the open-field situation for 3 min. a day for 24 consecutive days. Measurements of emotionality included number of boluses and the squares traversed relative to the bright light which was hanging over the center of the box. The criterion for entering a square was the placement of all four feet into the square. Measures of audiogenic seizures and electroconvulsive shock (ECS) were made from Days 41 through 47. Rats in both the UHF and non-UHF groups were randomly assigned to two groups at the end of the first 40 days. One-half of the UHF group and one-half of the non-UHF group were tested for resistance to audiogenic seizures, while the other half of the UHF group and the other half of the non-UHF group were tested for latency of ECS. *Ss* were placed at random in the apparatus for the induction of audiogenic seizures, measurements consisting of latency of seizure. If no seizure occurred within 3 min., tests were terminated for that day. *Ss* in the ECS group were shocked with a stimulator (60 ma, .5 sec), measurements being made of duration of both tonic and clonic phases of the convulsion. Measures of weight were taken every three days while measures of water consumption were made every five days.

RESULTS

A Type I Mixed Design (Lindquist, 1956) was used in analyzing the data for activity, emotionality (squares traversed), ECS, weight, and water consumption. When significant F ratios were obtained, t tests were used to determine which treatment means differed significantly. When significant interactions were obtained, the simple effects were investigated.[3] The Mann-Whitney U test was used in the analysis of the data from the emotionality test (defecation) and audiogenic seizures.

Analysis of the activity data revealed that the UHF main effect was not significant, but a significant difference between days was obtained as well as a significant interaction (see Table 1). Since a significant interaction was obtained, analysis of simple effects was carried out. The simple effects analysis indicated that the UHF and non-UHF groups differed significantly on 18 of the 40 days (see Figs. 1 and 2). Since only five significant differences were present in the early days of the experiment, while 13 significant differences were present later in the experiment, it appears that UHF effects become more apparent as

[3]Complete analysis of variance tables and results from simple effects analyses have been deposited with the American Documentation Institute. Order Document No. 8545, remitting $1.25 for 35-mm. microfilm or 6- by 8-in. photocopies.

TABLE 1

ANALYSIS OF VARIANCE OF ACTIVITY, DAYS 1 TO 40

Source	*df*	*MS*	*F*	*p*
Between Subjects	19			
UHF (U)	1	4,651.24	.69	>.05
Error (b)	18	6,723.56		
Within Subjects	780			
Days (D)	39	3,504.11	5.26	<.05
U × D	39	2,791.82	4.19	<.05
Error (w)	702	666.56		
Total	799			

days progress. This progressive effect is supported further, although indirectly, by separate analyses on the first 20 days and the last 20 days. The UHF main effect is not significant for the first 20 days ($F = 1.73$, $df = 1/18$, $p > .05$), while it is significant for the last 20 days ($F = 11.99$, $df = 1/18$, $p < .05$). In both cases significant interactions were present (Days 1 to 20, $F = 3.03$, $df = 19/342$, $p < .05$; Days 21 to 40, $F = 2.49$, $df = 19/342$, $p < .05$).

Analysis of the number of boluses showed no significant differences between the radiated and non-radiated groups ($U = 3$, $p = .20$). Analysis showed sig-

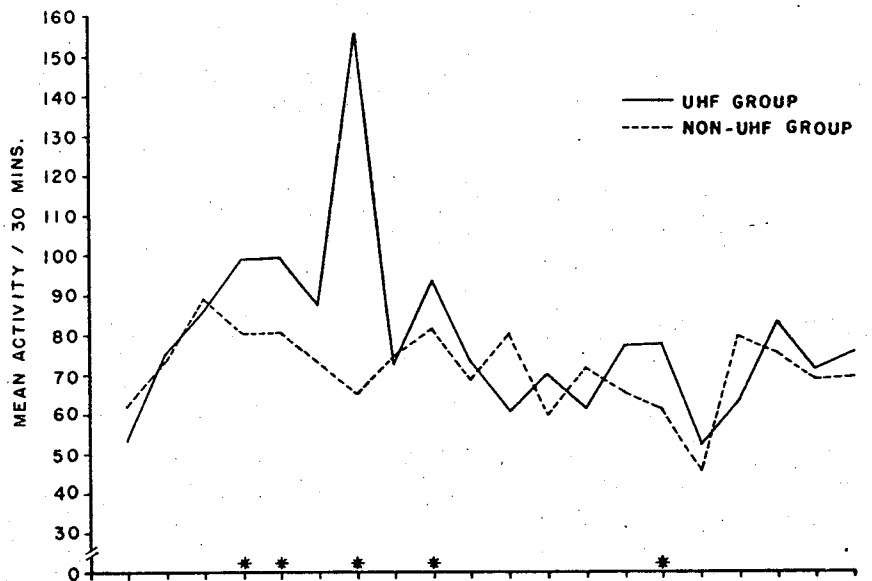

FIG. 1. Mean activity of UHF and non-UHF groups for Days 1 to 20

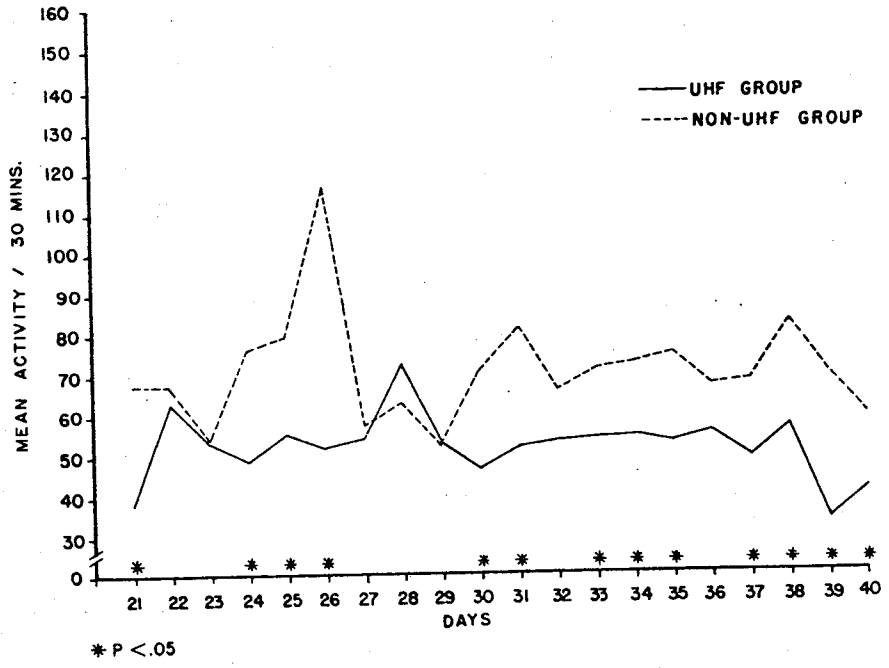

FIG. 2. Mean activity of UHF and non-UHF groups for Days 21 to 40

nificantly fewer inner squares traversed ($F = 4.78$, $df = 1/18$, $p < .05$; $M_{UHF} = 4.15$, non-$M_{UHF} = 6.45$) and medial squares traversed ($F = 4.45$, $df = 1/18$, $p < .05$; $M_{UHF} = 8.32$, non-$M_{UHF} = 13.89$) by experimental animals.

For the tonic portion of ECS, significant differences were found between days ($F = 243$, $df = 6/48$, $p < .05$) and a significant interaction between days and radiation was found ($F = 1285$, $df = 6/48$, $p < .05$). Analyses of simple effects indicated that the groups differed on Days 3, 4, 6, and 7, the experimental group showing a shorter latency on all days except Day 6 (see Table

TABLE 2

MEAN TIME (SEC.) OF TONIC AND CLONIC PHASES OF ECS

Days	Tonic		Clonic	
	UHF	Non-UHF	UHF	Non-UHF
1	12.59	12.60	22.99	27.24
2	12.46	12.31	22.93	40.03
3	11.21	11.73	30.31	40.22
4	10.78	12.21	28.02	29.17
5	12.43	12.43	31.41	26.57
6	12.68	12.07	32.95	21.26
7	12.24	12.93	37.60	27.99

2). Analysis of the clonic portion of ECS showed a significant interaction between days and radiation ($F = 3.57$, $df = 6/48$, $p < .05$). Simple effects analysis indicated that the treatment groups differed on Days 2, 3, 6, and 7. Experimental animals had shorter latencies on Days 2 and 3, but longer latencies on Days 6 and 7 (see Table 2).

UHF and non-UHF groups did not differ in weight ($F = 1.27$, $df = 1/18$, $p > .05$), water consumption ($F = .23$, $df = 1/18$, $p > .05$), or audiogenic seizures ($U = 3$, $p = .056$).

Discussion

It is evident that stimulation by low intensity, low frequency UHF radio waves does have effects on behavior. In general, it appears that UHF radiation has an influence on the following variables investigated in this experiment: activity level, emotionality, and latency of ECS. Upon inspection of activity through the days, it is apparent that some time is required for the UHF waves to have a consistent effect on behavior. At Day 30, the two treatment groups separate and remain separated, the UHF group being consistently less active than the control group. The data also point to a reversal of effects as the days progress. UHF radiation resulted in an initial increase and a subsequent consistent decrease in activity level as the days of radiation progressed.

The results suggest a more emotional behavior on the part of the UHF rats since they avoided the bright light more than did the non-UHF animals. Although the experimental group defecated more than the control group, the difference was not statistically significant. This discrepancy in the two measures of emotionality might be attributed to the fact that the number of boluses is a relatively gross measure of emotionality as compared to subtle movements about a noxious stimulus.

UHF animals show a longer latency of ECS. However, the clonic phase of the convulsion is of greatest interest for two reasons: (a) the experimental group did not differ in time of the clonic phase through the days, while the control group did, and (b) the experimental group showed a gradual increase in the time of the clonic phase, while the control group showed a general decrease. These two findings are of interest in that the control group exhibits the pattern of shorter latency of convulsions as the administration of shock increases. This pattern, which is usually found in ECS experiments, is not applicable to experimental animals.

The results of this experiment suggest that the behavioral effects of UHF radiation may not be attributed to thermal effects. If UHF effects, as some investigators assume, are largely a matter of heating, it seems as if the experimental group would have a higher water consumption level than the control group. This was not the case. A non-thermal hypothesis is favored also by the facts that (a) only extremely low power levels were used, (b) all behavioral

measurements were made when the rats were not being exposed to the UHF fields, and (c) the effects are cumulative in time. Thus, it appears that if heating does occur, it is not the heat *per se* but the effects of heat on some mechanism or process that is the important variable.

One process that might be implicated is the accumulation of acetylcholine (ACh) in time. This interpretation seems tenable since Gordon (1961) found that UHF fields result in the accumulation of ACh along nerve fibers and since the behavioral effects found in this experiment are similar to behaviors found in experiments dealing with the accumulation of ACh. Results from several experiments (Crossman & Mitchell, 1955; Koshtoiants & Kokina, 1957; Russell, 1954) show that ACh in small concentrations leads to cholinergic hyperactivity, while larger concentrations lead to a decrease in activity. Thus, it is possible that UHF radiation results in a gradual accumulation of ACh through time. During the early stages of radiation, ACh could be present only in small amounts which would account for the greater activity during this time. As ACh accumulates with repeated UHF exposures, activity decreases.

The findings from the tests of emotionality and ECS might be related to ACh accumulation as well. Lack of exploratory behavior and increase in responses which might be labeled as emotional are related to ACh accumulation (Rosenzweig, Krech, & Bennett, 1956; Russell, 1954). Latency of ECS is longer and the threshold lower for rats which have high ACh concentrations than for rats which have lower concentrations (Woolley, Rosenzweig, Krech, Bennett, & Timiras, 1960).

This research suggests that further investigations would prove to be of value in discovering relationships between UHF radio waves and behavior. Suggestions include: (a) the investigation of ACh accumulation as being a possible neurophysiological substrate, (b) an extension of the number of days of radiation, (c) studies to determine possible permanent effects, and (d) investigation of behavioral effects using different power levels and frequencies.

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