BEHAVIORAL CHANGES OF RATS EXPOSED TO MICROWAVE RADIATION

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Abstract

Fixed ratio performance changes of rats exposed to near zone 918 MHz radiation have been observed to occur at incident power levels of 40 mW/cm^2 corresponding to peak absorbed power densities of 32-36 W/kg. No change in behavior was indicated for incident and peak absorbed power densities of up to 20 mW/cm^2 and 18 W/kg, respectively.

Introduction

Several reports [1,2,3] have suggested microwave radiation to be responsible for changes in the behavior of small animals exposed to low incident power densities. Many of these studies, however, are complicated by the fact that behavioral observations of animals have required free movement. This free movement seriously compromises the problems of dosimetry and control of power absorption critical to testing these experimental questions. The present experiment utilizes a specially designed apparatus which permitted simultaneous exposure and monitoring of performances. The incident and absorbed power levels at which disturbances occur to a food-maintained fixed ratio head raising response were investigated.

Method

A total of nine white rats, averaging 180 gm, were used in this investigation. Animals maintained at a food deprivation level equal to 80 percent of their free-feeding weight were placed in a movement restriction holder and trained to perform a head raising response for food reward. The criterion was for the animals to rapidly and regularly execute thirty head movements for each food pellet (fixed ratio 30), to pause briefly and repeat the sequence during each 30 minute session. After stabilizing baseline performance, animals were exposed to increasing amounts of radiation.

A square aperture radiator operating at 918 MHz was used. The maximum intensity of the radiated energy was directed toward the longitudinal midpoint of the rat's body with the tail immobilized. The immobilization was a necessary measure to minimize the hot spot which developed at the tail during the preliminary studies. The distance between the body surface of the animal to the radiator is 8 cm. Two principal methods have been used for the dosimetry: (1) the incident power density at the same position as the axis of the rat's body inside the holder in the empty exposure chamber and directly under the center of the radiator was calibrated in terms of input power by a National Bureau of Standards electric energy density meter (EDM-IC), and (2) a thermograph was used to measure the internal power absorption patterns in exposed rat carcasses in a manner similar to that described previously [4]. The animal was sacrificed, subsequently frozen in the holder, cast in a polyfoam block, and bisected along with the holder. The re-assembled rat carcass and the holder was then returned to the exposure chamber and irradiated with a short duration (30 sec), high power (600 watt) source under the same arrangement as during the behavioral test session. The thermographically recorded temperature patterns over the mid-sagittal plane of the rat were processed digitally using a Honeywell DDP 516 computer to obtain isopower density contours. The power delivered to the radiator was monitored continuously using a directional coupler and Hewlett-Packard microwave power meter (430C).

Results

The isopower density patterns inside the rat and the mid-sagittal plane are shown in Figure 1. It can be seen clearly that absorption peaks occurred in both the body and the tail. The peak absorption at the tail corresponds to 0.9 W/kg per 1 mW/cm^2 incident while the number for the body is 0.8 W/kg. The position of the tail had considerable influence on the absorbed power levels. Dosimetry studies on phantom models of the rat indicated that absorbed power at the base of the tail could increase by an order of magnitude when it was extended straight back [5]. This enhanced absorption was due to increased current density resulting from sharp changes in tissue cross-section and a standing wave maximum resulting from a body resonance condition, since the rat model was approximately one wavelength long. Figure 1 indicates that it is impossible to survey the true temperature change in the animals using rectal thermometers. Moreover, the assumption that keeping the tail or any portion of the rat away from direct illumination ensures non-exposure and minimal absorption may often be erroneous. This illustrates the point that it is most important to know the internal absorption and its distribution.

Examples of the fixed ratio baseline performance of each animal are presented in Figure 2. Cumulative records of response rates show a highly stable performance characterized by runs of 30 responses followed by a brief pause. Oblique marks on the cumulative record indicate food delivery. Figures 3, 4, and 5 show the performances of these same animals under identical experimental conditions during exposure to respectively 10, 20 and 40 mW/cm^2. Visual inspection of the cumulative records and monitoring of overall session response rates show no noticeable effects of exposure until 40 mW/cm^2 power levels were applied. At this level the animal showed physiological changes, i.e., panting, fatigue and foaming of the mouth which are indicative of general hyperthermia (heat stress).

One animal, No. 5, was exposed to irradiation during five consecutive days, in order to observe gross cumulative effects of irradiation and to provide some control for unobserved sources of variability. Another animal, No. 6, was exposed to radiation on alternate days, Monday, Wednesday and Friday; and rat No. 7 received no exposure. Overall response rates, intersession rates, and the comparative performances (Figures 2, 3, and 4) of all three animals do not seem to indicate any cumulative effects. Figure 6 shows recovery of baseline performance for both exposed animals on the first day following 40 mW/cm^2 exposure.

Summary

These preliminary studies with accurate control of incident and absorbed power densities, suggest that incident power levels up to 20 mW/cm^2 do not have significant effects on the fixed ratio behavior of these experimental animals. Performances one day following exposure to fairly high power levels (40 mW/cm^2) indicated that the observed behavioral and/or physiologic changes are reversible. Further investigations are under way to delineate more precisely the point at which EM exposure begins to disturb these behavioral baselines.

It is interesting to note that the body of the rat is a resonant structure at 918 MHz. In fact, based on mass equivalent muscle spheres, our theoretical calculations show maximum peak absorption occurring in a rat size body with peak and average absorbed power densities equal to 0.85 and 0.21 W/kg, respectively, per 1 mW/cm^2 incident. This indicates that an incident power density of 40 mW/cm^2 produces peak absorption of 34 W/kg and average absorption of 8.4 W/kg. The measured peak absorption for the rats exposed to 40 mW/cm^2 was 32-36 W/kg. The 8.4 W/kg absorbed power density is particularly significant in light of the reported [6] depressions in general activity of rats immediately following exposure to 2450 MHz microwaves with an average absorbed power density of 8 W/kg.

References

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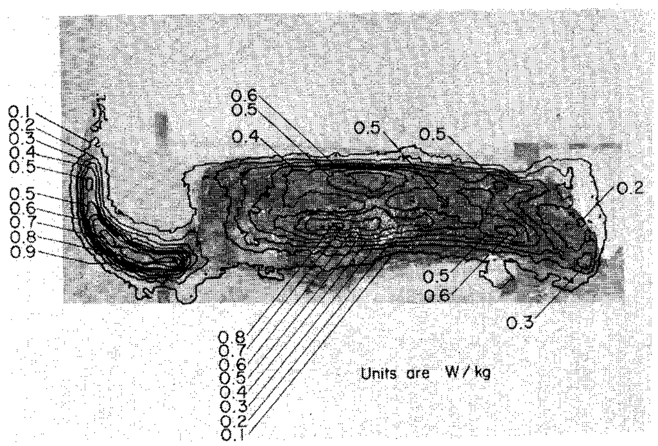

Fig. 1 Absorbed power density pattern in a rat exposed to 918 MHz near zone radiation for 1 mW/cm^2 incident.

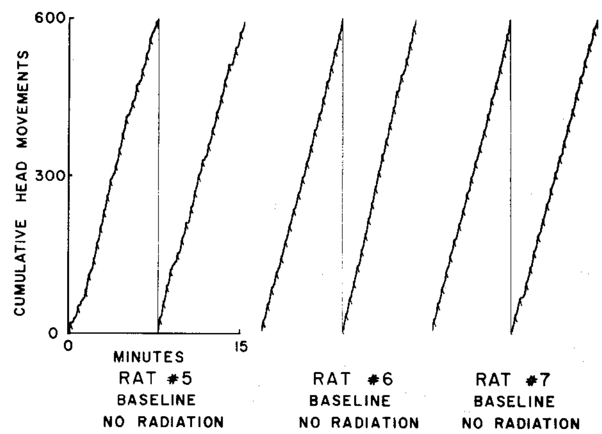

Fig. 2 Cumulative records of fixed ratio performance produced by each of 3 animals during a pre-irradiation session.

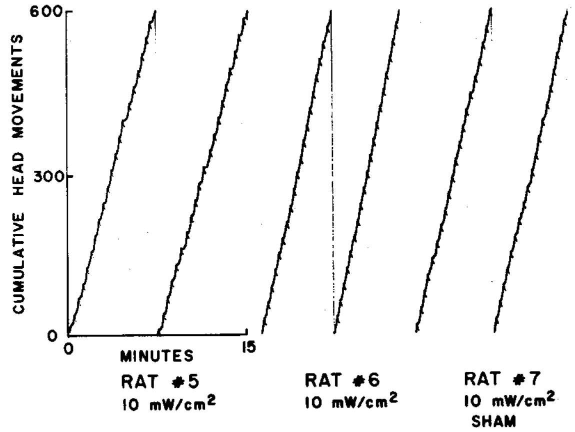

Fig. 3 Cumulative records during a 10 mW/cm^2 exposure session. The peak absorbed power density is 9 W/kg. Rat #7 is sham irradiated.

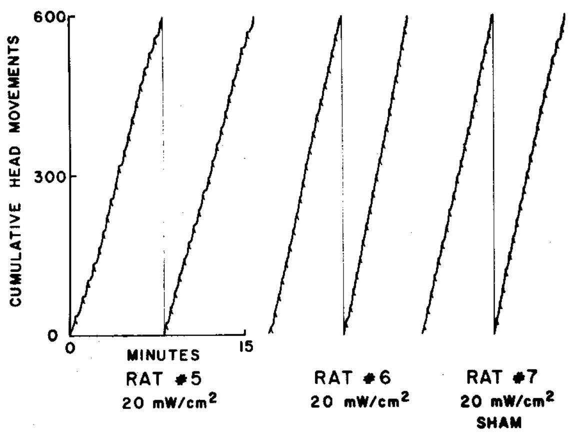

Fig. 4 Cumulative records during a 20 mW/cm^2 exposure session. The peak absorbed power density is 18 W/kg. Rat #7 is sham irradiated.

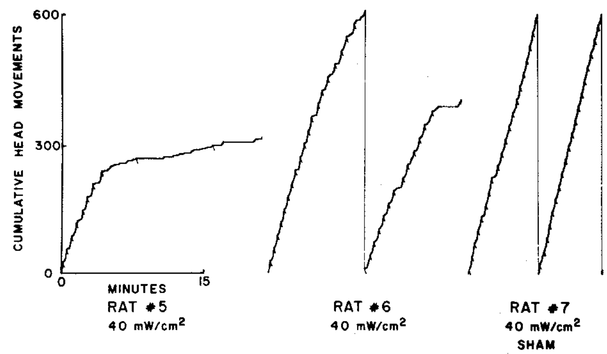

Fig. 5 Cumulative records during a 40 mW/cm^2 exposure session. The peak absorbed power density is 36 W/kg. Rat #7 is sham irradiated.

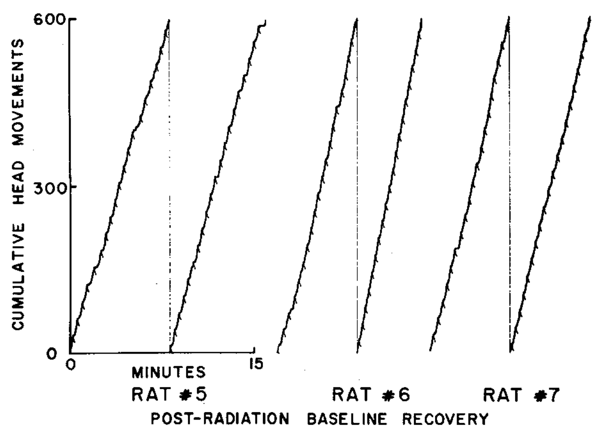

Fig. 6 Cumulative records produced one day post-irradiation showing performance recovery.