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CHANGES IN TEMPORAL ASPECTS OF BEHAVIOR
BY LOW LEVELS OF PULSED MICROWAVES

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The effects of low levels of pulsed microwaves on timing behavior in rats were analyzed. Rats were trained to emit a particular interresponse time (IRT) that was in turn programmed on a differential-reinforcement-of-low-rate (DRL) schedule. Pulsed microwave radiation at a frequency of 2.8 GHz was found to disrupt the precise temporal discrimination generated by the reinforcement schedule. Behavioral changes were observed following 30-min exposures at average power levels of 4, 8, and 16 mW/cm^2 (SARs of 0.8, 1.8, and 3.4 W/kg, respectively), and the changes were power related. With the same IRT in effect, the DRL value was increased from DRL 8-sec with a 4-sec limited hold (LH) to a DRL 14-sec without the LH, and the animals were again exposed to the same radiation parameters. No microwave-induced changes in behavior were observed at the same three power levels with the larger DRL value in effect. When the animals were returned to the original DRL value with a LH and re-exposed to microwaves, decrements in behavior were again observed. Shifting back and forth between the two DRL schedules and exposing the animals to the same three power levels established that the ongoing temporal behavior was or was not affected by microwaves depending on the value of the DRL schedule.

Summary

This research concerns the measurement of the effects of low levels of pulsed microwave radiation on timing behavior in rats and the direct interaction of microwaves with the behavior. The timing behavior involves performance on a schedule of reinforcement that requires a precise temporal discrimination. Rats (300-gram, male) were trained on an operant schedule in which food reinforcement was contingent upon the emission of a 1- to 2-sec interresponse time (IRT). Only lever presses that followed a preceding lever press by more than 1 sec but not more than 2 sec were reinforced. Thus, the reinforced operant was an IRT 1.5 ± 0.5 sec. The IRT requirement was in turn scheduled according to another temporal contingency, a differential-reinforcement-of-low-rate (DRL) schedule. The DRL schedule differentially reinforced a low rate of emitting the 1- to 2-sec IRTs. The DRL value was initially 8 sec with a limited hold of 4 sec. The 1- to 2-sec IRTs were reinforced only if the time since the preceding 1- to 2-sec IRT was greater than 8 sec but not more than 12 sec. The animals were exposed to this complex temporal contingency for 3 months before any experimental manipulations were performed in order to allow for the development and stabilization of the precise temporal behavior.

The baseline behavior consisted of a modal IRT of 1- to 2-sec. The greatest frequency of times between successive IRTs was around 10 sec indicating control by the DRL 8 LH 4 schedule. The schedule generated a low and steady rate of responding, which could be used as a baseline to examine the effects of microwave radiation. The animals performed the temporal schedule for 1-hour daily experimental sessions. Schedule control, recording, and data analysis were accomplished by a digital computer interfaced to the animal cage.

The animals were exposed to pulsed microwave radiation once per week for 1/2 hour. Behavioral effects were measured during a 1-hour session immediately after termination of the 1/2-hour radiation. All exposures were at a frequency of 2.8 GHz. Pulse width was 2 μsec and the pulse-repetition frequency was 500 Hz. All irradiations were conducted in a 512 ft^3 chamber lined with 20 dB microwave absorbing material. Radiation emanated from a standard gain horn antenna oriented so that the electric field was vertically polarized at the animal. The animal was placed in a sleeve made of plastic mesh, suspended from a styrofoam holder, and was oriented perpendicularly to the direction of propagation of the radiation. The animals were initially adapted to the sleeve before microwave exposures and were intermittently sham irradiated in the sleeve as a control procedure throughout the study. All exposures were conducted with the subjects located about 6 wavelengths from the antenna. The animals were exposed to three different field intensities of 4, 8, and 16 mW/cm^2 in a random order with at least three determinations at each intensity. Specific absorption rates

associated with the respective field intensities were 0.8, 1.8, and 3.4 W/kg, as estimated from core temperature measurements with a fiberoptic liquid crystal probe. Radiation field intensity at the animal's head was adjusted to the appropriate average power density by measurement with a broad-band radiation monitor. Ambient chamber temperature was 23°C ± 2° and air flow through the chamber was 10 fpm.

All three radiation levels were found to affect the temporally controlled behavior. Changes in behavior were generally related to power levels. After microwave irradiation the frequency of correctly emitted IRTs declined and most of those that did occur were not appropriately spaced to produce food reinforcements according to the DRL schedule. Rates of emitting behavior were lower and more variable after microwave exposure.

Following the above regimen, the baseline procedure was changed such that 1- to 2-sec IRTs were reinforced on a DRL 14-sec schedule (with no limited hold [LH]). When baselines had stabilized, the animals were again exposed to the previous radiation conditions. No changes were observed in behavior at any of the three power levels. When the original DRL 8 LH 4 schedule was reinstated as the baseline and the animals again were exposed to the three power levels, decrements in performance, as before, were obtained. Switching back and forth between the two DRL baselines several times and exposing the animals to microwave radiations each time established that microwave-induced changes only occurred on the DRL 8 LH 4 schedule. With the DRL 14 schedule in effect the behavior was insensitive to the effects of microwaves, although the overall rate of responding was nearly comparable on the two schedules.

The major finding of this research is that precisely controlled timing behavior in rats can be affected by low levels of pulsed microwaves and that the effects are power-level related. However, seemingly minor parametric changes in the temporal baseline allow the timing behavior to become insensitive to microwave effects. These results are similar to those that have been reported with other environmental influences on behavior, particularly pharmacological, in that critical aspects of the behavior itself determine the nature and magnitude of effects. In this case the behavioral measurement is not just an arbitrary dependent variable but is also an independent variable modulating microwave bioeffects. These findings may account for many of the conflicting behavioral results found in the microwave literature.