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MICROWAVES AFFECT THERMOREGULATORY BEHAVIOR IN RATS*

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Rats, with their fur clipped, pressed a lever to turn on an infrared lamp while in a cold chamber. When 2450 Megahertz continuous wave microwaves were presented for 15 minutes, the rate of turning on the infrared lamp decreased as a function of the microwave power density, which ranged between 5 mW/cm^2 and 20 mW/cm^2. This result indicates that behaviorally significant levels of heating occur at exposure durations and intensities that do not produce reliable changes in either colonic temperature or other behavioral measures. Further study of how microwaves affect thermoregulatory behavior may help us understand phenomena such as reported "non-thermal" behavioral effects of microwaves.

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DISCLAIMER

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A debate concerning potential hazards of microwave exposure focuses on the issue of "nonthermal" behavioral effects. A key contribution to this debates is the are the reports, made largely by Soviet and Eastern European investigators, that Western exposure standards are too lax. Soviet standards for exposure to microwaves, which vary depending on the exposure conditions, are 10 to 1000 times more stringent than the U.S. (ANSI/OSHA) standard of 10 mW/cm^2. The experimental basis for this difference stems, in part, from Soviet claims that, although Western standards are based on thermal, or tissue-heating effects, microwaves also can induce non-thermal behavioral effects. In animal studies, the Soviets define "thermal" on the basis of core, especially colonic, temperature, typically measured with a rectal probe.

There is no question that microwaves can affect behavior. Microwaves heat tissue, and heat itself can affect behavior. When microwave exposure elevates colonic temperature, concomitant behavioral change is attributed often to the thermal burden. When microwave exposure produces no change in colonic temperature, concomitant behavioral change is attributed sometimes to "non-thermal" actions of microwaves. Numerous biological processes, however, are affected by temperature changes not reflected by core temperature. Many reactions to temperature change, in fact, help ensure the constancy of the colonic temperature. In cold air, for example, blood vessels near the skin contract and retard the dissipation of body heat. Thermoregulatory behavior, moreover, is a function of skin and hypothalamic temperature, rather than colonic temperature. It seems plausible, then, that microwaves could alter behavior as a consequence of thermal stimulation in the absence of core temperature changes.

In the present experiment, the behavior of the rat serves as a thermometer, so to speak. Thermoregulatory behaviors are those which produce a direct effect on the thermal environment of the subject. Thermoregulatory behavior is sensitive to several classes of variables including duration and intensity of the heat source, ambient temperature, endocrine status, drugs, etc. In the prototypical experiment, the subject is given access to a heat source, such as a heat lamp, that it can activate to counteract the ambient cold. In the present experiment, in a 5 °C environment, a rat, with its fur clipped, could turn on an infrared heat lamp for a fixed duration (2 sec) by pressing a small lever. Responses made during the 2-sec activation period produced no programmed consequences. Generally, after a few sessions, rats pressed the lever at a nearly constant rate for several hours. This performance provided a baseline for studying the effect of 2450 MHz continuous wave (CW) microwaves on thermoregulatory behavior.

Six male Long-Evans hooded rats (325g-450g) were tested two or three times per week. Late in the afternoon, and immediately prior to the session, the fur was clipped closely from most of the torso. The rat was then placed in the 20 cm x 20 cm x40 cm high Styrofoam chamber with 15 cm x 25 cm windows lined with cellulose acetate and located in a dark, refrigerated room. The infrared heat lamp was 44 cm from the front wall. Microwaves illuminated the chamber via a feeder horn with a 6.5 cm x 7.5 cm aperture directed toward the chamber floor 44 cm below. After several sessions, rats usually responded within an hour after being placed in the chamber. When microwave exposures were scheduled, the first control period began the following morning. Alternating control and exposure periods lasted fifteen minutes. Within a single session, across different exposure periods, the microwaves illuminated the chamber in an ascending followed by a descending or a descending followed by an ascending series of power densities (5, 10, or 20 mW/cm^2).

The data are the results of the second series of exposures. (Results from the first series were similar, but more variable, an outcome often seen with drugs.) The proportion of time during which the heat lamp was kept on decreased as the microwave power density increased. On-line cumulative records of responding showed that rates of responding remained fairly constant within individual exposure and control periods, thus demonstrating that the consequences of presentation or removal of microwaves were immediate and constant throughout the respective condition. Altogether, the data indicate that rats respond less frequently to turn on the heat lamp during a 15-minute period of exposure to microwaves; that this effect is a direct function of power density; that the effect appears almost immediately; that it occurs at 5 mW/cm^2; and that recovery is immediate after each exposure.

Statistical analyses confirmed these conclusions. A linear regression model provided a good fit to the data; the overall regression line for the proportion of time the heat lamp remained on had an intercept of 0.324 with a slope of -0.0063 ($p<0.01$, t-test). Power density accounted for 61% of the variation. Significant trends over time (or trials) did not appear. Serial correlation within individual rats was examined using the Durbin-Watson test, which confirmed the absence of an effect from the previous 15-min exposure period and the suitability of the linear regression model. An analysis of covariance demonstrated that the individual regression lines of the heat lamp on time to power density were parallel for the five rats exposed twice to each power density. The common slope indicates that, if one conceives of microwaves as replacing heat from the lamp, then the amount of heat replaced by a given power density is the same for each rat. Randomization tests compared results for all six rats at each power density with all zero exposures, with only the preceding zero exposure, and with the adjacent exposure to a different and non-zero power density. Two-sided p-values were all less than $p=0.003$ except for 5 mW/cm^2 vs all zero exposures ($p=0.023$) and 5 mW/cm^2 vs adjacent 10 mW/cm^2 ($p=0.021$).

The most parsimonious interpretation of these data is that the rat responds to maintain a constant thermal environment. When heat from one source, microwaves, is introduced, the rat continues to maintain thermal constancy by reducing the heat input from another source, the infrared heat lamp. Although one could propose other mechanisms of microwave action leading to reduced responding, the immediate recovery of responding during the succeeding control periods supports the view that the rat is precisely adjusting its behavior to maintain a nearly constant thermal state. The sensitivity of the rat to relatively small changes in power densities to which other behavioral preparations tend to be insensitive also supports this interpretation. The rat, therefore, can serve as a "thermometer", and thermoregulatory behavior may provide an index of the thermal burden contributed by microwaves. Even if measureable colonic temperature change occurs sometimes at 5mW/cm^2, the observed time course of the behavior change does not parallel it. These behavioral changes, however, were immediately related to the thermal input.

Although this experiment measured one thermoregulatory behavior directly, such behaviors occur whether or not one measures them. Furthermore, they do not occur in isolation; rather, they occur concurrently with other behaviors. Changes in the frequencies of these other behaviors could result from changes in the pattern and frequency of thermoregulatory behaviors such as reduced activity, sprawling and saliva spreading. Our interpretations of the other reported behavioral effects of microwaves would be clarified by measuring concurrent thermoregulatory behaviors.