Microwave Radiation and Chlordiazepoxide: Synergistic Effects on Fixed-Interval Behavior

Abstract. *In the presence of low-intensity pulsed microwave radiation, at an average power density of 1 milliwatt per square centimeter, the response-rate-increasing effects of chlordiazepoxide were potentiated in rats. The behavioral effects of a drug can be modified by brief exposure to a low-level microwave field even when the radiation level alone has no apparent effects on the behavior.*

Recent electromagnetic radiation research concerned with microwave field intensities of 10 mW/cm^2 or less, intensities previously thought to be ineffectual in producing biological effects, has suggested that such low levels may under some conditions interact with or affect biological systems (*1*). We report here that low-intensity, pulsed microwave radiation, with signal parameters typical of many radar sources, alters the effects of a pharmacological agent on behavior. Microwave radiation at an average power level of 1 mW/cm^2 was observed to modify the behavioral effects produced by the drug chlordiazepoxide, widely used as a minor tranquilizer.

Four male Long-Evans hooded rats, maintained at 80 percent of their free-feeding weights of 325 to 375 g, performed daily in a rodent test chamber enclosed in a sound-attenuated housing. The animals were trained on a fixed-interval reinforcement schedule (*2*) that required responding on a small lever to produce a food pellet. In the fixed-interval (FI) schedule the first lever response that occurred after 1 minute produced a food pellet (FI 1). Delivery of each pellet initiated the subsequent interval. Responses that occurred during the timing of each 1-minute interval had no programmed consequences, but were recorded. The programming and recording of daily 1-hour sessions were accomplished automatically by a system of solid-state digital logic modules. Four months of exposure to daily sessions on the FI 1 schedule established a stable pattern of performance that consisted of a positively accelerated rate of responding throughout each FI period until a food pellet was obtained. A sample of such baseline performance is shown in Fig. 1F.

Before exposure to microwave radiation, a dose-effect function was obtained for chlordiazepoxide hydrochloride over a dose range of 1 to 40 mg/kg. A different dose was given twice per week and behavior was compared immediately preceding and following baseline sessions. The drug was dissolved in saline and administered intraperitoneally 30 minutes before the session. The volume of each injection was 0.1 ml per 100 g of body weight; all doses are expressed as the salt. Occasional saline control injections were given throughout the study. A dose-effect function was obtained, with at least three replications at each dose.

The dose-effect function was then similarly obtained except the animals were exposed to microwave radiation immediately after drug administration during the 30-minute period before the session. At least three replications at each dose were obtained with microwaves. Behavioral effects were measured during the 1-hour session immediately after termination of the 30-minute radiation. All exposures were at a frequency of 2.45 GHz with pulsed radiation (*3*). The pulse width was 2 μsec and the pulse-repetition frequency was 500 Hz. All irradiations were conducted in a 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 wooden holder, and was oriented perpendicularly to the direction of propagation of the radiation. All exposures were conducted under near-field conditions with the subjects located 3.75 wavelengths from the antenna. Radiation field

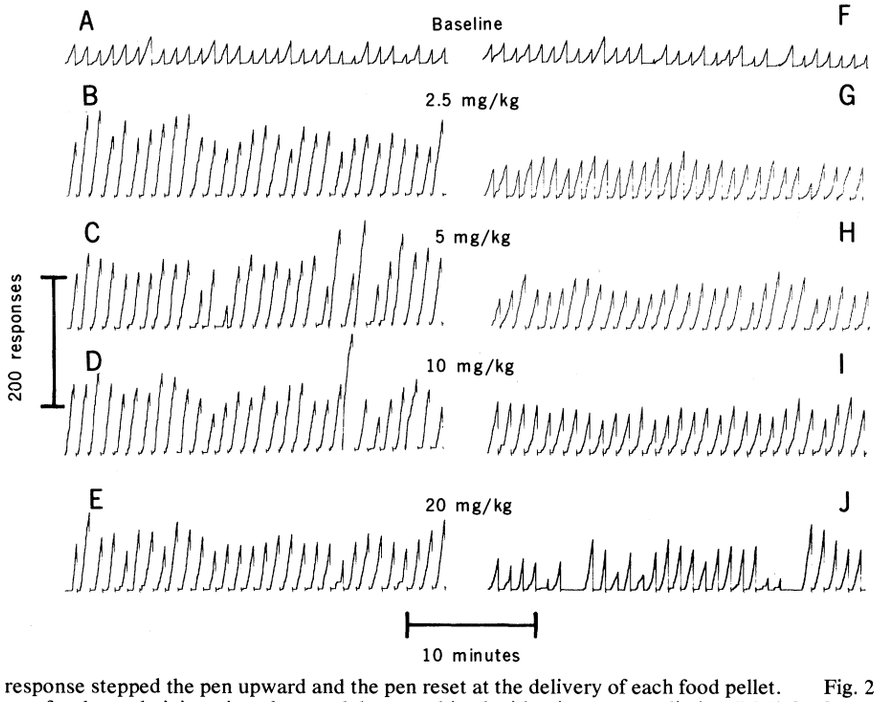

Fig. 1 (left). Cumulative response records of one animal for baseline (F), radiation (A), drug sessions (G through J), and drug-with-radiation sessions (B through E). Each recorded response stepped the pen upward and the pen reset at the delivery of each food pellet.

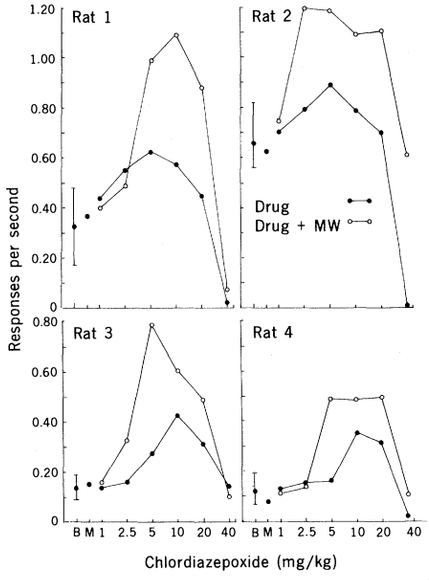

Fig. 2 (right). Effects of chlordiazepoxide on response rate for drug administration alone and drug combined with microwave radiation (*MW*) for four subjects. The points plotted for baseline sessions (*B*) are the means of all sessions that preceded an experimental session and the brackets indicate the ranges. Each drug data point is the mean of all determinations at each dose. The point plotted for microwave-alone sessions (*M*) is the mean of all sessions during which the subjects were irradiated without a drug dose or with saline injections.

0036-8075/79/0330-1357$00.50/0

intensity at the animal's head was adjusted to an average power density of 1 mW/cm² as determined before irradiation by a broadband radiation monitor placed at the position occupied by the animal's head. Ambient chamber temperature was 23° ± 2°C. Doses of the drug without radiation were given throughout the radiation exposure series to assure that behavioral effects of the drug alone had not changed. A complete dose-effect function was redetermined after the microwave series.

Before the effects of radiation on performance were studied, the animals were adapted over several weeks to the sleeve holder by being placed in it daily for 30 minutes before the session until baseline performance with and without the constraint was the same. An animal accustomed to the sleeve holder showed the same behavioral changes on the FI schedule when given a drug dose whether or not it had been constrained in the holder for 30 minutes before the session.

The effects of chlordiazepoxide on the FI performance were modified in the presence of low-intensity microwave radiation. Changes in the rate of responding (total number of responses in a session divided by the duration of the session) on the FI reinforcement schedule as a function of drug dose are shown for both radiation and nonradiation conditions for the four subjects in Fig. 2. The drug-alone response rates are based on preradiation and postradiation sessions as well as drug-alone sessions during the radiation series. Increasing doses of chlordiazepoxide, in the absence of radiation, produced increases in FI response rates up to a maximum; further increases in dose decreased response rate. These changes in behavior on the FI schedule as a function of chlordiazepoxide are in accord with previous results (*4*). When the same doses of chlordiazepoxide were combined with 1 mW/cm² of microwave radiation, greater behavioral effects were obtained. The general shape of the dose-effect functions remained relatively constant under the microwave condition; however, the magnitude of the effect was enhanced. Behavior always returned to baseline values by the session after the drug-alone or drug-radiation session.

A number of cumulative-response records of drug and drug-radiation sessions for one animal are shown in Fig. 1. The cumulative records G through J show the rate-increasing effects obtained with increasing doses of chlordiazepoxide, as seen by the increasing number of responses within each FI 1 interval. Comparison of records A (radiation alone) and F shows that performance on the FI schedule following 30 minutes of exposure to microwaves alone differed little from baseline performance. [This may also be seen in Fig. 2 by comparing the baseline response rate (B) with microwave response rate (M).] Records B through E in Fig. 1 show the enhanced rate-increasing effects obtained with chlordiazepoxide combined with radiation. A comparison of the records for each dose alone and the same dose with radiation shows in what manner the microwave radiation increased the response rate.

The dose-response function for chlordiazepoxide was modified under low-intensity microwave radiation exposure in that the magnitude of the behavioral effect produced by the drug was potentiated in the presence of microwaves. This finding is in accord with studies measuring a variety of biological effects that indicate an interaction between drugs and microwaves at higher intensities or under continuous-wave conditions (*5*). The present results demonstrate that brief exposure to low-intensity pulsed microwave radiation can act synergistically with another agent in affecting the behavior of an organism, although the mechanism of interaction is not clear (*6*).

JOHN R. THOMAS, LINDA S. BURCH
Behavioral Sciences Department, Naval Medical Research Institute, Bethesda, Maryland 20014

STEPHEN S. YEANDLE
Environmental Biosciences Department, Naval Medical Research Institute

References and Notes

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6. In animals similar in weight and size to those used in the present study, we have monitored the rectal temperature during a 30-minute exposure at 5 mW/cm² with a special temperature probe, sensitive to changes of 0.2°C, constructed from a birefringent crystal insensitive to microwave radiation. The frequency, pulse duration, and pulse repetition rate were the same as in the present study. No temperature rise was observed. This result does not prove, but makes unlikely, that any measurable core heating occurred during 30-minute exposure to 1 mW/cm².
7. Supported by Naval Medical Research and Development Command, Work Unit No. ZF51.524.015.0042. The opinions and assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large. The experiments reported herein were conducted according to the principles set forth in *Guide for the Care and Use of Laboratory Animals* (Institute of Laboratory Resources, National Research Council, DHEW Publication No. NIH 74-23, 1977). We thank Hoffman-LaRoche, Inc., for the donation of chlordiazepoxide (Librium).

10 February 1978; revised 30 October 1978

A Brain Event Related to the Making of a Sensory Discrimination

Abstract. *Event-related potentials associated with detected targets in a vigilance task were analyzed in two ways: (i) by sorting the potentials in terms of sequential reaction time bins of 50 milliseconds and (ii) by examining the single trial waveforms. A negative component (N2) covaried in latency with reaction time. These results support the hypothesis that N2 reflects a decision process which controls behavioral responses in sensory discrimination tasks.*

The timing of stimulus evaluation related to discrimination between two or more stimuli is a central issue in human event-related potential (ERP) research and in cognitive psychology. At some time after task-related stimuli are processed, certain brain events related to a decision process controlling appropriate behavioral responses must occur. A long-latency, positive component of

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