EFFECTS ON BEHAVIOR OF LONG TERM EXPOSURE TO LOW LEVEL MWR

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The aim of our effort is to develop a consistent set of conclusions regarding dose/response relationships between MWR exposure and detectable behavioral alterations, and to determine in what sense any such observed alterations constitute evidence for a harmful interaction. The computer controlled facility developed for these experiments provides for simultaneous irradiation and behavioral testing of 16 control and 16 irradiated rats. Pulse modulated MWR is provided via a 750 KW peak pulse power RADAR source operating at 1.3 GHz and feeding a divide-by-sixteen power divider which in turn launches circularly polarized MW energy in each of the active irradiation chambers. Dose rates are derived from a combination of chamber port measurements and whole body thermal measurements.

As to gross behavioral parameters, no differences were noted at the SAR's utilized to date (0-2.6 mW/g). In a group of rats irradiated at .96 mW/g, animal activity and position was assessed in detail. No major differences were noted between the experimental and control groups. In the long term studies of schedule controlled behavior, animals were exposed for 3 hours per day, for 9 weeks. The results to date indicate that MWR at dose rates of up to 2.6 mW/g had little effect on rewarded bar press behavior. There was only a slight indication that, at the higher dose rates, irradiated animals tended to show reduced operant behavior as satiation became a factor. There was, however, a much more apparent difference between experimental and control groups in terms of their error rates. That is, the irradiated rats had a significantly reduced error rate, especially as their rate of bar pressing for reward declined. The data support the conclusion that chronic MWR exposure differently effects rewarded versus non-rewarded instrumental behavior.

It is clear enough that microwave radiation (MWR) can be harmful to organisms. This form of energy has wide usage in food preparation and in tissue fixation for biological analysis. The question is one of limits. Since MWR induced heating can be detrimental to living systems, a major component of the current concern regarding MWR is the level of incident MW energy (or absorbed, if one is to provide reproducible dosimetry) at which harmful sequelae are to be expected.

Relevant ongoing projects in this laboratory include the investigation of MWR interactions with the nervous system on a single cell level, on the biochemical level (that is, on neurotransmitter mechanisms and interactions with centrally acting drugs), and on the behavioral level.

So that the neurophysiological, neurotransmitter and behavioral work underway here and in other laboratories can be put in some meaningful perspective, the aim of our effort is to develop a consistent set of conclusions regarding the dose/response relationships between MWR exposure and behavioral alterations. Our experiments take the form of chronic MWR exposure with behavioral evaluations ongoing during the irradiation. The design of the experiments is such as to focus on levels of irradiation that are below those associated with significant temperature changes and thus concentrate on the so-called "nonthermal" modes of interaction. However, the dose/response curves include dose levels that extend into the range at which significant thermal changes do arise and go beyond the animal equivalent of the current official safety standard (often expressed in terms of incident power density, 10 mW/cm sq for adult human personnel).

The facility developed for these experiments provides for simultaneous irradiation and behavioral testing of 32 rats in parallel with each animal in its own combination wavequide MWR exposure and behavioral testing chamber. MWR dosimetry has been carried out using absorbed MWR dose (using field probes, net power transfer and internal body temperature changes to deduce local absorbed dose rates) and incident field (E-field measurements) techniques.

The array of MWR exposure waveguides has been designed and assembled so as to provide housing, lever press manipulanda, and food reward capabilities for 16 control and 16 irradiated rats. The behavioral apparatus, data acquisition and data summary is managed on-line by means of a special purpose computer designed and built in our laboratory. Pulse modulated MWR is provided via a 750 KW peak pulse power RADAR source operating at 1.3 GHz and feeding a divide-by-sixteen power divider which in turn launches circularly polarized MW energy in each of the 16 active irradiation chambers. The array of irradiation chambers has been extensively tested for internal field distribution, dose rates versus waveguide feed power, microwave match and other electrical parameters. By means of a built-in attenuator system, the power applied to each of the sixteen exposure waveguides can be adjusted in parallel by a single adjustment over a broad range of incident power densities (average). As now utilized, this corresponds roughly to an upper limit dose capability of 30 mW/g for 200 to 400 gram rats.

Obviously, if the microwave irradiation facility were not such as to provide reliable and easily monitored levels of irradiation to the test animal, then there would be little value to the experiments. Several experiments have been undertaken, therefore, to insure that the microwave dose rate and field profiles are as expected. These included, firstly, electrical measurements of the field strength and VSWR. The effects of the animal housing and the behavioral apparatus (both constructed of thin plastic) were found to be minimal. Electric field probe studies have verified that the major source of perturbation of the field distribution is the rat itself. There appears to be no significant variation in net absorption profile in the rat with longitudinal placement in the chamber (posture and orientation held constant). With the circularly polarized EH wave launched from the "front" (i.e., manipulanda) end of the cage (K- or propagation vector parallel to long axis of cylinder) the presence of the animal gave rise to an increase in the measured E field in front of the animal. Down-field from the animal there was a marked reduction in field strength compared with when no rat was present. This simply indicates that the rat is both a reflector and significant absorber of the incident MW energy. Four-port measurements on the waveguide chamber itself indicated that the rat was in fact absorbing 35-50% of the incident MW energy. This is somewhat higher than the percentage reported by Guy and Chou. However, it can be noted that, with respect to the Guy et al., system, the higher operating frequency of our system required a slightly smaller waveguide. Hence, the rat occupies a larger fraction of the cross sectional area.

As a preliminary check on the absorbed dose rate, a water load of known mass was placed within the waveguide and calorimetric checks of the rate of power absorption were run. These data were then compared with the measurements of power absorption provided from the four-port data. These data agree to within approximately 20% at this time. Studies have been carried out using rate of temperature rise to determine regional absorption rates (head and torso) for rats in the typical active, operant posture. In summary, with head forward (the usual operant posture) head SAR was a factor of 4 higher than the whole body average. Rump (torso) SAR was approximately 1/2 of the whole body average SAR.

All animals tolerate the behavioral apparatus quite well. There is every indication that the size, ventilation, isolation, and so forth, of the individual chambers within the behavioral array are appropriate for behavioral studies. One of the first groups run has received irradiation for approximately eight weeks at an average SAR of Ø.5 mW/g. These animals bar pressed in their daily sessions at FR-5 with no notable differences in behavior between the control and experimental groups. Since food intake was controlled consistent with the food reward paradigm in this experiment, weight measurements are not necessarily indicative of food drive or other changes in consummatory behavior outside of the waveguide. Both groups of animals gained weight along an apparently normal growth curve, with perhaps some reduction because of the restricted food intake. There were no differences in the mean weights of control versus experimental rats.

As to gross behavioral parameters, no particular differences were noted at the SAR's utilized to date (Ø-2.6 mW/g). In a group of rats irradiated at .96 mW/g, we regularly (every half hour during the experimental period for this group) assessed animal activity and position. No differences were noted between the experimental and control groups. Both groups spent most of their time in a curled, resting posture, except when actively bar pressing. Exploration extinguished within a few weeks. Both groups spent most of their time at the manipulandum-food reward end of this chamber. Grooming intervals were essentially as expected and there was no indication that the behavioral cage was itself a problem because of size or other factors. After about two weeks of irradiation, the irradiated group seemed to spend slightly more time in a flat, inactive posture. This difference may not be significant, however.

For the long term studies of schedule controlled behavior groups of fifty Long-Evans rats were obtained from an inbred vendor colony at 1ØØ-13Ø gram initial weights. The rats were individually numbered and housed within one week after arrival whereupon a growth curve was initiated. Within two weeks after arrival the animals were food deprived and shaped to bar press for food reward on a fixed ratio schedule (one reward for each preselected number of bar presses). After one week of stable performance at FR-1Ø, 32 animals were selected as the experimental group and randomly assigned to the control (16) or irradiated (16) subgroups.

Each experiment began with a two week "baseline" phase which was then followed by a "experimental" (irradiation) phase and a post-irradiation "recovery" phase. The same behavioral format was used throughout all phases. Our procedure was to break up each three hour irradiation-test "day" into 6 "sessions", each 25 minutes long. A 15 minute interval preceded and followed the contiguous blocks of sessions. Each session, in turn, consisted of a 15 minute operant reward interval (defined for the rat by cue light on) during which bar presses were rewarded by a 45 mg food pellet at FR-25, and a subsequent 10 minute error interval (cue light off) during which bar presses were not rewarded but tabulated as errors.

In the 32 chamber behavioral array, the chambers instrumented to receive MWR are arranged in random fashion over the array. Both irradiation and control chambers are identical in every way except that the power input ports of the latter are not connected to the microwave apparatus. However, to preclude any positional bias on performance, the animals were scheduled into the appropriate chambers in a random fashion. Room temperature and relative humidity were logged daily.

The irradiation phase lasted for 9 weeks during which each irradiated rat was exposed to a constant level of MWR for three hours per day, five days per week. This was at an average SAR of 2.6 mW/g. Following the 9 weeks of irradiation and coincident behavioral testing, a three week recovery phase ensued. That is, the behavioral protocol remained unchanged, however, the rats were run with no MWR applied.

Our results will be summarized only, since no figures are submitted. There was little change in the bar pressing behavior that could be attributed to the MWR at the dose rates used up to this time. By the last session, the operant response behavior became more erratic (the animals nearing satiation) but remained at a reasonably high level (80% of that during session 1). No consistent differences between control and experimental groups could be discerned. Perhaps there was some suggestion that irradiated animals had a greater tendency to show reduced operant behavior as satiation became a factor (session 5 and session 6).

There was a much more apparent difference between the two groups' behavior in terms of their error rates. That is, there was a strong indication that the irradiated rats had a signficantly reduced error rate, especially for the later sessions of the day.

Examination of average operant response rates over the entire session day confirmed that there was little change in the bar press rate for food reward over the course of the experiment. The differences between error rates of the experimental and control groups showed up quite clearly in the overall session averages.

Another mode of interaction of MWR with the nervous system is implied by the studies in other laboratories that have shown signficant changes in the blood brain barrier (BBB) following irradiation at non-thermal levels. To test this possibility groups of animals were exposed at several dose rates for eight weeks and were tested for their rate of absorption of the anesthetic sodium barbital. The general anesthetic properties of this drug are similar to the other barbiturate anesthetics in general use (e.g., pentobarbital), however, barbital sodium has a relatively slow onset. Studies in other laboratories have shown that this slow onset is due to slow passage through the BBB. If MWR had altered this barrier,then we would expect the irradiated animals to show a more rapid onset of the anesthetic. Each of the experimental and control animals were given an interperitoneal injection of barbital sodium, at a dose of 200 mg/kg (in saline solution). The parameter measured was the time taken for loss of the righting reflex following this anesthetic dose.

Experiments were run utilizing SAR's of 0.42, 0.96 and 2.6 mW/g. No significant differences could be detected. We conclude that we detected no alteration in the BBB due to the irradiation. These results need be taken as preliminary only. Considerable additional study of the BBB alteration hypothesis is in order. There is some merit to the argument that measurement of BBB penetration using the method as described above is not suitable to test the current hypothesis of BBB alteration, which notes that selected sites are affected.