PHASIC AND PROGRESSIVE EFFECTS OF MICROWAVES ON THE CENTRAL NERVOUS ACTIVITY OF MICE

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Abstract. Many studies emphasised influences of microwaves on the behavior of exposed animals. Various kinds of effects on central nervous activity have been reported for a wide range of microwave frequencies and of exposure levels. Excepting the well-known effects due to high-level exposures, present data are not conclusive concerning the relation between exposure level and specific effects. Our experiment searched for any possible effect on behavior and central nervous activity of mice exposed to low-level microwaves. Ten male Swiss mice were exposed 8 h/day, 5 days per week for 13 weeks to a 400 MHz microwave field of 1 mW/cm^2 power density. The behavior of both exposed and control mice were examined by a battery of three behavioral tests applied every 15 days. The applied tests revealed some behavioral effects suggesting a reduction of the investigative potential of animals during the entire exposure period and, also, some phasic changes in time of their exploratory activity.

Key words: microwaves, animal study, low-level field, long-term exposure, phasic effects.

INTRODUCTION

Although there is also available a substantial body of data describing biological responses to low-level fields from cellular [1, 2], animal [3, 7, 8, 9] or human [5, 12] studies, knowledge of effects due to chronic exposure to weak fields is inadequate to determine whether subtle effects exist and to eemphasizecausal and dose-effect relationships. World Health Organization (WHO) [15] considers that there is still a need of experimental studies regarding biological effects due to exposure to electromagnetic fields, especially in the case of long-term low-level exposures to radiofrequency (RF) or microwave (MW) fields. On the other hand, more recent studies [4, 10, 11] report bioeffects of prolonged exposure to low-level fields and they seem to confirm previous results of some earlier studies. The aim of the present study is to investigate some effects of long-term low-level exposure to MW fields upon central nervous activity of mice.

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MATERIALS AND METHODS

The microwave exposure experiment was carried out on ten Swiss male mice. A control (sham exposed) lot of ten male mice was also used. The mice were selected to be of same age and of 20 ± 2 g initial body weight. Inside a transverse electromagnetic (TEM) cell, ten Swiss male mice were exposed to unmodulated low-level microwave field for a relatively long period of time, comparing to their lifetime. Exposure lasted 8 hours a day, five days a week, for 13 weeks. The operating frequency was 400 MHz and the field level, in terms of electric field strength was about 60 V/m that is equivalent of 1 mW/cm^2 power density of the traveling TEM wave inside the cell.

All the animals were housed individually in separate glass jars. During exposure or sham exposure time intervals, the mice were placed in plexiglas cages. To minimize the field perturbation in a location of a specific mouse due to the presence of other mice in its neighborhood, inside the TEM cell each mouse was placed in its own plexiglas cage. The cages were placed at a maximum distance one from each other.

The behavior of animals was assessed using three tests that investigate the exploring behavior and motor activity: test, evasion test, perforated plate test and open field test. The behavioral test sessions were performed three consecutive days, every 15 days, upon both exposed and control lots

In the *evasion* test the animal is placed in a wood open box [14] on an inclined plane board. The animal motor activity is indicated by the number of the routs made in a period of 3 minutes.

In the *perforated plate* test mice are placed on a wood plate with holes of 2 cm diameter. The natural exploratory behavior is assessed by counting the number of inspected holes during 3 minutes period.

The *open field* test was designed to evaluate the animal behavior in a new environment characterized by large, lighted space. The mouse is placed on a plate divided in 16 squares. The number of squares explored by each animal was recorded. Due to rodent innate fear of openness and height, the mouse develops in such space a phobic reaction of fear and anxiety [6]. After accommodation with the new milieu the animal begins to explore it [13].

RESULTS AND DISCUSSIONS

As revealed by the *evasion* test, the evolutions of performances in both exposed and controls were relatively similar (Fig. 1). Only in the middle period, the mean number of routs made by exposed mice was sensibly higher than the one for controls.

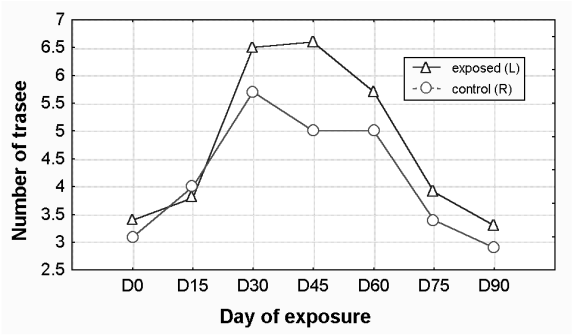

Fig. 1. Mean values of routs in the *evasion* test.

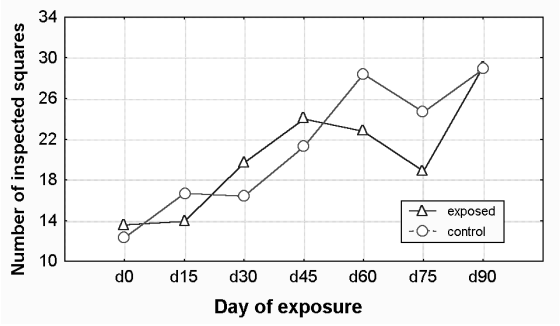

Fig. 2. Mean values of squares inspected in the *open field* test.

In the *open field* test the two lots exhibit relatively similar evolutions ($r = 0.82$, $p = 0.02$ for the exposed and $r = 0.93$, $p = 0.002$ for control) especially in the first part of exposure period (Fig. 2), but in the latter half, excepting the last test session, the performances were lower for exposed. The progressive increasing performances in *open field* test during the experiment can be explained by the alievation of the initial fear and anxiety of the animal placed in the new milieu [14].

The *perforated plate* test results indicated a slight different evolution of the two lots during the entire experiment (Fig. 3). Like in the previous two tests, the performance evolution of the two lots was very similar in the first third of the exposure period and quite similar in its first half. However, in the first half of the experiment, the mean number of inspected holes was sensibly higher for the exposed mice. But, after that period, exposed mice performances decreased very much. Only in the last weeks of exposure, the level of performance for the two lots was similar again.

The regression analysis showed a decreasing tendency in both lots, but more evident and significant in the exposed lot ($r = –0.81$, $p = 0.02$) compared to a non-

significant one in the control lot (r = –0.74, p = 0.058). The well-defined decreasing tendency of exposed mice performances seems to indicate a decrease in time of the exploratory activity in relation with microwave exposure.

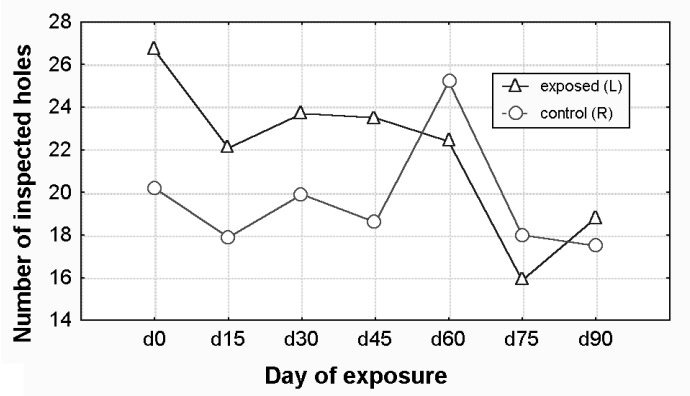

Fig. 3. Mean values of holes inspected in the *perforated plate* test.

The results of the *perforated plate* test are in apparent antagonism with those of the *evasion* test. Even if the *evasion* test also assesses, in some extent, the exploratory ability of the mouse, this activity may be overlapped by a possible motor disability due to long housing in rather reduced space.

GENERAL AND SEQUENTIAL EVOLUTION OF MICE PERFORMANCES

In the second half of the experiment, the lower performances of exposed mice compared to controls were revealed by all tests. In the *perforated plate* while controls have a very slight decrease of performances in time, exposed mice exhibited a well-defined tendency of reducing their performances in this test. In the case of *open field* test the overall ascending evolution of exposed mice is lower than the one of control mice. Moreover, in the *evasion* test the decrease of the performances is higher during the second half of the experiment. Consequently, long-term microwave exposure seems to induce a slight loss in time of the exploratory activity.

Detailed analysis of performance evolution of mice performances between consecutive test sessions revealed some stages in mice exploratory activity.

In the first part of the experiment, all behavioral tests showed an exciting effect that becomes evident in the middle exposure period (between days 30 – 45), when higher performances of exposed mice were recorded, compared to control ones.

After the excitement period, a state of tiredness appears in the exposed mice and their performance decrease (between days 45 – 60). In the mean time controls performances does not decrease.

In the last test session, while controls performances moderately increase only in *open field* test, the exposed mice performances revealed a fast ascending profile of evolution in two of the tests (*open field* and *perforated plate* tests). This different evolution of performances in the two lots suggests a new stage of excitation in exposed mice. Although it is not evident in our experiment since the exposure period is limited to 90 days, the exposed mice might exhibit a cyclic behavior during a longer exposure period consisting in alternative periods of activation and inhibition.

Table 1.

Relevant stages of performance evolution in the exposed mice compared to control ones.

DAY OF EXPOSURE	EFFECTS – COMMENTS
0 – 15	Slight inhibitory effect
15 – 30	Slight exciting effect
30 – 45	Exciting effect
45 – 60	Inhibitory effect – state of tiredness
60 – 75	Apparent inhibitory effect – beginning of winter
75 – 90	New stage of excitation – new cycle activation-inhibition

Taking into account the entire evolution of performances in the two lots, we suppose that the electromagnetic energy, interacting with nervous system, acts as an exciting factor. Consequently, microwave exposure can temporary enhance mice performances, but in time, as a result of enhanced energy consumption during excitation stages, it induces a state of tiredness that conduces to a decrease in animal exploratory activity. Long-term microwave exposure could affect the nervous activity of mice, leading to the reduction of the investigative potential of animals and by inducing a certain psychological stress causing a state of indifference, apathy.

CONCLUSIONS

The study emphasizes some changes in mice exploratory activity due to long-term low-level microwave exposure. Two kinds of modifications were noticed: a decrease in time and a phasic evolution of the exploratory ability, due probably to the interference of microwave with the central nervous system. This phasic behavior is related to the presence of two stages of psychomotor activation and inhibition of mice. In our experiment, this phasic evolution appears to be repeatable, becoming a cyclic evolution. Thus, microwave exposure acts as an additional exiting factor which inducing tiredness after repeated periods of

excitation, and can conduce in time to a chronicle tiredness that reduces the performances and general resistance of the individual.

Anyhow, it is very difficult to quantify the manner and the extent to which microwave fields may influence the central nervous activity. There are necessary new and various exposure experiments to test this possible cyclic evolution of excitation–inhibition due to long-term exposure to various electromagnetic fields of frequencies and levels.

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