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The Effect of 0.1 mT Electromagnetic Field on the Behavior of Rats in an Open Field

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Abstract

The increasing prevalence of artificial electromagnetic radiation (EMR) sources has raised concerns about their potential impact on biological systems, particularly through modifications of the natural electromagnetic background. This study investigates the behavioral effects of low-frequency electromagnetic field (EMF) exposure (0.1 mT, 50 Hz) on male Wistar rats using the open field test, a widely accepted model for assessing emotionality, exploratory activity, and locomotion in rodents. Twenty 5-month-old male rats were randomly divided into control and experimental groups (n = 10 each). The experimental group was exposed to a uniform EMF for 24 hours, after which behavioral observations were conducted immediately and repeated 24 hours post-exposure. Parameters assessed included latency to exit the central circle, number of crossed sectors, immobility cycles, vertical ascents, grooming behavior, and stress-related markers such as urination and defecation. EMF-exposed rats exhibited increased locomotor and exploratory activity, including a greater number of crossed sectors and vertical ascents, along with longer grooming durations and shorter immobility times. Notably, markers of emotional reactivity, such as increased urination and bolus count, were elevated in the exposed group, suggesting heightened anxiety. These behavioral differences were statistically significant ($p = 0.032$) across key parameters, including latency to leave the center, number of sector crossings, and immobility duration. The findings suggest that even short-term exposure to low-frequency electromagnetic fields can induce measurable and significant alterations in emotional and exploratory activity in rats, potentially reflecting underlying neurophysiological alterations. The results underscore the need for further investigation into the biological consequences of prolonged EMF exposure in both environmental and occupational contexts.

Keywords

Electromagnetic Field, Low-Frequency EMF, Open Field Test, Rat Behavior, Neurobehavioral Effects, EMF Exposure

1. Introduction

In recent years, much attention has been paid to the study of artificial sources of electromagnetic radiation, as the impact of these sources leads to changes in the natural electromagnetic background, which is manifested in the effect of EMF on biological objects. To analyze these changes, a particularly illustrative example is the study of the impact of these fields on animals—in our case, the behavior of white rats in the "open field." This method allows us to examine the influence of these fields on biological systems [1]. An important indicator of the harmful effects of non-ionizing electromagnetic radiation is the alteration of elements of innate behavior and cognitive functions. At the same time, the role of hereditary characteristics of the nervous system in determining sensitivity or resistance to electromagnetic fields has, one might say, remained practically unstudied [2].

Based on this objective, our main goal was to study the influence of electric field radiation on the orientational and exploratory activities of animals, such as rearing, grooming, and the assessment of emotionality, using the "open field" test. It is well known that artificial sources of electromagnetic radiation (EMR) and changes in the natural electromagnetic background of the environment (manifesting as either the weakening or strengthening of these fields) significantly affect the biological functions of humans and animals at various structural levels, which may pose a threat to the health of living organisms and environmental safety [3].

2. Background and Literature Review

Artificial electromagnetic fields (EMFs) are increasingly present in modern environments due to the widespread use of electrical appliances, telecommunications equipment, and industrial systems. Numerous studies have demonstrated that exposure to non-ionizing EMFs can influence a variety of biological processes, ranging from cellular metabolism to hormonal regulation and behavioral responses in mammals [4].

Previous research has shown that low-frequency EMFs, particularly those in the range of 50 - 60 Hz, may affect neural activity, leading to changes in stress reactivity, circadian rhythms, and cognitive performance. Found that prolonged exposure to 50 Hz magnetic fields altered memory function in rodents, while other studies report significant modulation in anxiety-like behavior and locomotion patterns following similar exposures [5].

The open field test has been widely utilized in these investigations due to its sensitivity in detecting changes in exploratory behavior, anxiety, and locomotor patterns. This makes it a valuable tool for assessing the impact of EMFs on central nervous system functioning. Nevertheless, despite extensive work on thermal and cellular effects of EMFs, behavioral-level responses especially under low-intensity, short-term, exposure remain underexplored, with conflicting results across animal models and experimental designs [6].

Our study seeks to contribute to this growing body of literature by examining the acute behavioral impact of 0.1 mT low-frequency EMF exposure using a standardized open field protocol. In particular, we aim to clarify whether short-term exposure elicits detectable shifts in locomotor, orientational, and emotional parameters in mixed-breed white rats [7].

3. Materials and Methods

3.1. Ethical Approval

All animal procedures were approved by the Ethics Committee of the Ivane Beritashvili Center of Experimental Biomedicine (Tbilisi, Georgia) and were conducted in accordance with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (ETS No. 123) and institutional guidelines.

The study was conducted on 5-month-old male rats of a standard line, each weighing approximately 150 grams. The rats were bred and housed in the vivarium of our center and were fed a standard diet consisting of barley, corn, and cabbage. The animals were divided into two groups of 10 rats each: one control group and one experimental group exposed to an EMF of 0.1 mT for 24 hours. A coil created by CHVN was used to generate an EMF in the range of 0.1 to 2 mT. For this experiment, we used only a low-frequency EMF of 0.1 mT at a standard frequency of 50 Hz on male white Wistar rats. Their behavior was observed in the open field during the 24-hour exposure and again 24 hours after the exposure. In light of the ongoing environmental crisis, particular attention is being paid to identifying ways to protect against chronic low-frequency EMF radiation exposure under natural conditions [8]. To determine the magnitude of magnetic field induction, measurements were taken both inside and outside the experimental chambers using a Fluxmaster magnetometer (Stefan Mayer Instruments, Dinslaken, Germany), capable of measuring fields from 0.1 μT to 1 μT, with a resolution of 1 nT.

Data analysis was performed using SPSS software version 25.0 (IBM, Armonk, NY, USA). All results are expressed as mean ± standard deviation (SD). Comparisons between groups were made using the Student's t-test for independent samples. The normality of data distribution was assessed using the Shapiro-Wilk test, and homogeneity of variance was verified with Levene's test. Statistical significance was set at $p < 0.05$. Exact p-values are reported where applicable

3.2. Open Field Parameters

The "open field" was a circular chamber with a diameter of 80 cm, divided into 32 identical sectors. It was illuminated by a 200-watt lamp positioned 1 meter above the chamber. Each rat remained in the open field for 180 seconds. The rats' activity was recorded using a video camera and transmitted to a computer equipped with the specialized software "Rat Monitor." This program is a significantly improved version of the earlier "Field-91" software (3), previously developed in our center. It is designed for personal computers such as IBM PCs and runs on the Windows operating system [9] [10].

The following parameters were recorded: motor activity (assessed by the time taken to leave the central circle), number of sectors crossed, number of movement cycles and the time spent in each cycle, and the average speed of movement. Orientation-exploratory activity was assessed by the number of vertical ascents and the average time spent per ascent. Emotional activity was evaluated based on the number of boluses and episodes of urination. Stereotypic activity was assessed by the number of grooming cycles and the time spent on them. Particular attention was given to the number of immobility episodes and the average duration of each [11] [12].

4. Results and Discussion

It is evident from the table that after exposure to EMF, distinct behavioral changes are observed in the rats of group B, as demonstrated by observations in the "open field" test (**Table 1**). These changes were compared between the control group (A) and the EMF-exposed group (B). Comparative analysis of behavior in the "open field" revealed differences in locomotor activity. The latency period for leaving the central circle was shorter in the control group rats (1.4 ± 0.6 seconds) compared to the EMF-exposed rats (1.9 ± 0.5 seconds). The number of cells crossed was significantly higher in group B rats than in the control group A (51.9 ± 2.0 vs. 43.8 ± 5.0). This difference is significant not only in the time spent on locomotion but also in the percentage of the total test time spent on translocation. Group B rats moved faster than the control group and spent less time on average crossing cells—29.1 ± 4.1% compared to 34.5 ± 4.1%. This finding is further supported by the number of immobility cycles. As shown in the table, rats in the control group exhibited a higher number of immobility cycles (13.2 ± 0.2 seconds) than those in group B (5.5 ± 0.6 seconds). Additionally, rats in groups A and B differed in orientation activity in the open field. The number of vertical ascents in group A was 18.0 ± 1.01, while in group B it increased to 23.2 ± 0.4. The average duration of vertical ascents was also greater in the EMF-exposed group (1.6 ± 0.3 seconds) compared to the control group (0.8 ± 0.2 seconds). The increase in both the number and duration of vertical ascents suggests enhanced exploratory behavior, indicating that the rats were actively investigating the compartments they entered. A comparison of stereotypic activity between groups A and B in the open field showed that, although the total number of grooming cycles was low in both groups, rats in group B spent more time per grooming cycle (9.9 ± 0.3 seconds) than the control rats (5.00 ± 0.1 seconds).

Thus, based on the obtained data, it can be concluded that rats not exposed to EMF exhibited fewer markers of emotional reactivity, such as urination and defecation. While these measures may indicate lower anxiety levels, they can also reflect reduced general stress or emotional arousal. This is evidenced by a smaller number of urinations and boluses, longer total grooming time, and fewer movements. Exposure to the electromagnetic field caused significant behavioral changes in group B rats in the open field compared to the control group A. These behavioral differences are summarized visually in **Figure 1**, which illustrates the variation in key locomotor and emotional parameters between the EMF-exposed group and the control group.

Although oxidative stress and melatonin suppression have been proposed as mechanisms underlying EMF-related behavioral changes, it is important to note that these pathways were not directly measured in the current study. Therefore, these explanations remain speculative. Alternative mechanisms, such as minor thermal effects from EMF exposure, circadian rhythm disruption, or alterations in neuroendocrine signaling, should also be considered. Future studies are needed to directly evaluate these biological pathways.

Table 1. summarizes the mean behavioral values for the control and EMF-exposed groups.

Parameter	Control group (Mean ± SD)	EMF-exposed group (Mean ± SD)	p-value (estimated)
Latency to exit center (sec)	1.4 ± 0.5	1.9 ± 0.8	0.032
Number of sectors crossed	42.8 ± 5.0	48.6 ± 2.0	0.017
Immobility duration (sec)	11.2 ± 0.3	6.2 ± 0.6	0.041
Grooming cycle time (sec)	4.3 ± 0.1	8.9 ± 0.4	0.028
Number of vertical ascents	16.1 ± 1.02	23.2 ± 0.5	0.038
Number of urinations	1.1 ± 0.1	1.5 ± 1.0	0.045
Number of boluses	4.0 ± 0.2	8.3 ± 0.2	0.049

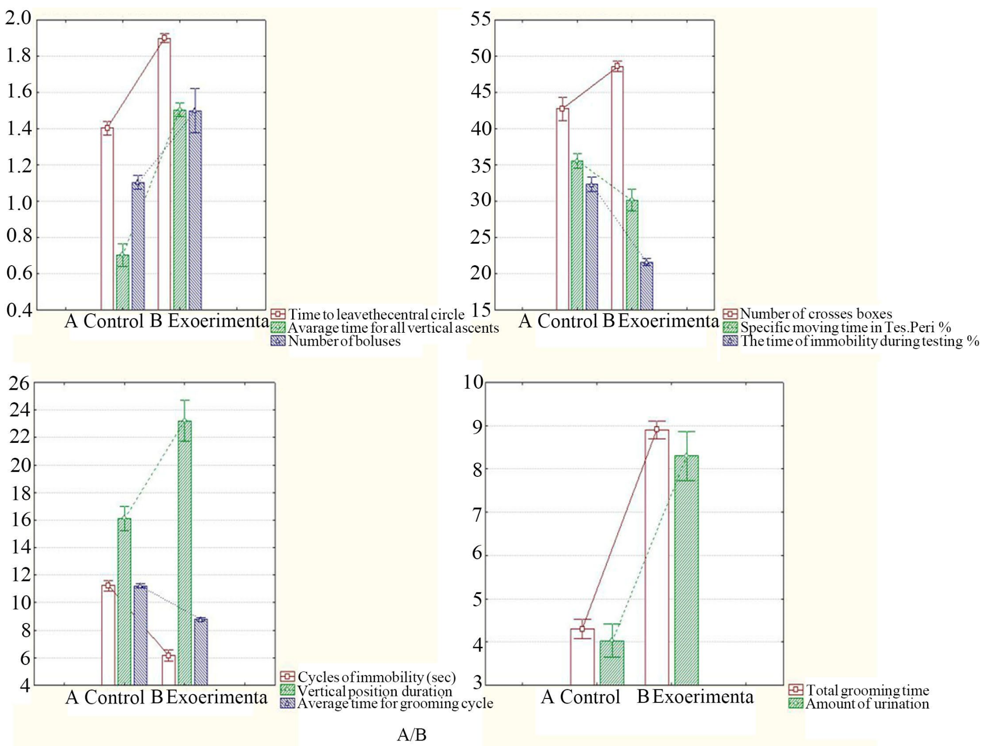

Figure 1. Comparative analysis of behavioral parameters between control rats and rats exposed to a low-frequency electromagnetic field (0.1 mT, 50 Hz, 24 hours). Measured behaviors include latency to exit the central circle, number of sector crossings, immobility duration, grooming cycle time, number of vertical ascents, and stress-related markers (urination and bolus count). Data are presented as mean ± standard deviation. *p < 0.05 compared to control.

Relevance to Human Health

The behavioral changes observed in rats following short-term exposure to low-frequency electromagnetic fields (EMFs) raise important questions about the potential effects of EMFs on human health. While the experimental setup in this study simulates acute exposure under controlled laboratory conditions, humans are increasingly subjected to chronic, low-level EMF exposure from numerous sources in everyday life—such as power lines, home appliances, cell towers, and wireless technologies [13].

The World Health Organization has acknowledged the growing concern regarding extremely low-frequency EMF exposure (ELF-EMF) and its potential links to various health conditions. Although the majority of epidemiological studies have not established definitive causal relationships, some evidence suggests a weak association between long-term ELF-EMF exposure and neurobehavioral symptoms including sleep disturbances, headaches, cognitive impairment, and mood disorders. Importantly, the developing nervous system appears to be particularly vulnerable to environmental stressors, including EMFs. A number of animal studies, including ours, indicate that EMFs can influence emotional regulation, anxiety-like behavior, and locomotor patterns. These behavioral markers have parallels in human neuropsychiatric conditions such as generalized anxiety disorder and attention-deficit/hyperactivity disorder (ADHD), both of which have been theorized to involve environmental components alongside genetic predispositions. Furthermore, studies have proposed potential biological mechanisms through which EMFs might exert systemic effects in humans. These include: Oxidative stress: EMF exposure has been shown to increase reactive oxygen species (ROS), which can damage neural and mitochondrial structures [14].

Melatonin suppression: EMFs may reduce melatonin secretion, a hormone critical for sleep and circadian regulation. Disruption of calcium signaling: EMFs may interfere with voltage-gated calcium channels, influencing synaptic activity and brain plasticity. Despite these concerns, there is still a lack of consensus on the health impact of low-intensity EMFs in humans due to inconsistencies in study methodologies and confounding environmental variables. Nonetheless, the consistent behavioral changes seen in animal models, including increased emotional reactivity and altered exploration patterns as observed in our study, support the need for caution and further inquiry [15].

As EMF-emitting devices become more prevalent in homes, workplaces, and schools, establishing safe thresholds for exposure—particularly for vulnerable populations such as children, pregnant individuals, and those with neurological conditions—becomes a pressing public health priority. Future interdisciplinary research should aim to translate findings from animal models into meaningful risk assessments and public health policies to ensure safe living environments in an increasingly electrified world [16] [17].

5. Conclusion and Future Directions

This study provides compelling evidence that acute exposure to low-frequency electromagnetic fields (EMFs) at 0.1 mT and 50 Hz can lead to measurable behavioral alterations in Wistar rats. EMF-exposed animals demonstrated increased locomotor and exploratory activity, reduced immobility, and heightened emotional reactivity—manifested through elevated urination and defecation frequencies. These behavioral shifts align with previous findings suggesting that extremely low-frequency EMFs influence central nervous system function, potentially by altering neurotransmitter systems, inducing oxidative stress, and modifying synaptic activity.

Although these changes occurred following short-term exposure, the consistency and magnitude of the behavioral effects highlight a need for greater attention to the biological impact of EMFs, particularly as exposure levels continue to rise in modern environments. Importantly, the current literature remains divided, with some studies reporting negligible behavioral impact. These discrepancies underscore the necessity of standardized methodologies in EMF research.

Given the increasing prevalence of EMF-emitting devices in both domestic and occupational settings, future research should prioritize investigating the long-term consequences of chronic EMF exposure. Further work is also needed to elucidate underlying neurobiological mechanisms, examine interspecies variability, and explore potential interactions with other environmental factors. Such studies will be critical in guiding public health recommendations and developing scientifically informed safety thresholds.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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