ACUTE EXPOSURE TO 50 Hz, 8 mT MAGNETIC FIELD CAN IMPAIR RAT SPATIAL MEMORY

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Abstract: This study was planned for evaluating the effect of short exposure to 2 and 8 mT magnetic fields on consolidation of spatial memory. 33 naive male wistar rats (3-4 month old, 235 ±15 gr) were selected randomly and divided in three groups (sham and exposed to 2 and 8 mT magnetic fields). Animals were given 8 trials (one training session) at 2 blocks, with 3 minutes interval between blocks for one day in Morris Water Maze. Immediately after training, head exposure was performed by a 50 Hz, 8 or 2 mT magnetic fields for 20 minute. 48 hours after the exposure to sham or magnetic field, animals were given a 60 second probe trial. Analysis of probe trials data showed that, compared to sham group, animals had been exposed to 8 mT but not 2 mT magnetic fields significantly ($p < 0.05$) spent less time in the platform quadrant during 60 second probe trial and had different swimming pattern so that they showed less tendency for finding the platform. The results of this study show that short time exposure to 50 Hz, 8 mT but not 2 mT magnetic fields can impair consolidation phase of spatial memory.

Introduction

At present, electricity has a critical role in mankind life. Electrical current that is used for supplying of instruments can produce a low frequency magnetic field in their wires. In the last decades, many researches were performed on the effects of exposure to magnetic field on different nervous system functions such as memory in human and animals. The results from researches performed on human cases have indicated that one-hour exposure to low intensity magnetic field can immediately decrease perception, cognition and memory [1]. In one study, it has been shown that electromagnetic fields, produced by systems like computer and video, can increase neurophysiologic disorders in adults that were exposed to these fields for more than 4 hours [2]. The results from researches done on animal cases indicated that exposure to low frequency magnetic fields has effects on memory performance [3]. Lai et al [4] showed that use of 60 Hz magnetic field before learning has effect on memory performance. In one study, Kavaliers et al [5] showed that this effect is sex- dependent, so that magnetic field has more effect on male rats' spatial memory. In addition to sex, it seems that intensity and duration of exposure to magnetic field are important factors in effectiveness of the field on memory and in fact these two factors have interactions [6, 7, 8]. For example the results of experiment done by Lai and Carino [9] showed that immediately after exposure to 2 mT but not lower intensities magnetic fields for 60 minute the frontal cortex and hippocampus cholinergic activity significantly decrease. Similar effect was seen with long duration exposure to lower intensities (0.5, 1 and 1.5 mT) magnetic fields. This decrease in cholinergic activity in the brain can impair spatial memory in rats. On the other hand, in our previous in-vitro experiments we observed that exposure to 8 mT but not 2 mT magnetic fields for 20 minute have effect on neural cell function of snail [10, 11]. These results show the same intensity /duration interaction presented by Lai and Carino [9]. Almost all experiments like the present study, for example that has been done by Lai et al [12], contribute to effects of pre-training exposure to magnetic field (acquisition phase of memory) and few experiments are about post-training exposure (consolidation phase) effects. Therefore the present study was planned for evaluating that whether short exposure to 8 and 2 mT magnetic fields has effects on consolidation of spatial memory and do these effects follow similar intensity/duration relation as the in-vitro condition.

Materials and Methods

Subjects

33 naive male wistar rats (3-4 months old, 235 ±15 g) were used in three groups: sham-exposed (n=11), exposed to 8 mT (n=11) and 2 mT (n=11) magnetic fields. Rats were maintained on a 12-hour light-dark cycle and with an ambient temperature of 21°C.They were housed in a maximum of six rats per breeding cage and allowed access to food and water ad libitum.

Morris Water Maze training

The water maze was a metal, circular pool (diameter: 140 cm, height: 50 cm) filled with water (23± 1°C) to a depth of 35 cm. A circular glass platform (diameter: 11cm) was placed at the center of one quadrant (N-E quadrant) of the maze and submerged 4 cm below the surface of the water. The maze was located in a room containing several visual extra-maze cues. Each animal was released into the water from the wall of the maze at arbitrarily defined east, south, west, and north points. The sequence of points of release into the water followed a random order. The animal was allowed to find the platform and land on it. If it could not find the platform within 1 minute, it was guided manually to the platform. After finding the platform, it was allowed to stay there for 45 second before another trial. Performance in the maze was carried out and saved in a computer by an infrared receiver mounted on the roof. For spatial training, animals were given 8 trials (one training session) at 2 blocks, with 3-minute interval between them for one day in Morris Water Maze. 48 hour after the exposure to sham or magnetic field, each animal was given a probe trial, in which the platform was removed and the animal was released from the opposite quadrant of the platform quadrant and allowed to swim for one minute.

Magnetic Exposure System

To assess the effect of acute exposure to low level magnetic field on consolidation phase of spatial memory, immediately after training, each rat was put in a small pouch so that its head was out and exposed to magnetic field. These pouches were used for avoiding stress induced by restrainer. Animals head was exposed to a transverse, sinusoidal, 50 Hz, 8 or 2 mT magnetic fields for 20 minute. The sinusoidal waveform were generated with a signal generator (GFG-8019G, Good Will instrument Co.) and amplified by an own made audio amplifier (600 Watt). Then amplifier output drove an 850 turned coil with 8 cm internal diameter made from 0.75 mm copper wire. The maximum intensity of magnetic field (2 or 8 mT) calibrated using a digital teslameter (HI-3550, HOLADAY industries, USA) at the center of the coil at each experiment.

Statistical analysis

From the data recording, escape time (i.e., the time between releasing animal in the water and landing on the platform) was measured by computer. The average escape time of the eight trials in each training session was used in data analysis. The distance (cm) and swim speed (cm/s) was calculated for each trial by the system soft ware. For the probe trial, time spent in the quadrant of the maze where the platform was previously located (N-E) was scored. After checking the normality of the distribution of each analyzed variable with Kolmogoroff - Smirnoff test, distance and swimming speed data from training sessions were analyzed by the one-way ANOVA. The difference between groups escape time in the probe trials was compared by the T-test. A difference at $p \leq 0.05$ was considered statistically significant.

Results

The results of escape time during the eight trials are shown in figure 1. Data analysis showed a significant trial effect (i.e., a significant decrease in escape time with training). There was no significant difference in time during the training session between the sham-exposed and exposed animals.

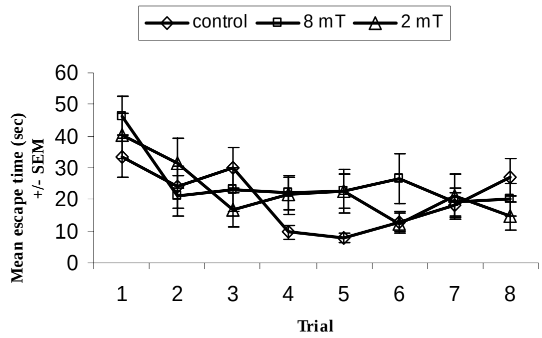

Figure 1: Average escape time (time to reach the platform after release into the water), during the training session.

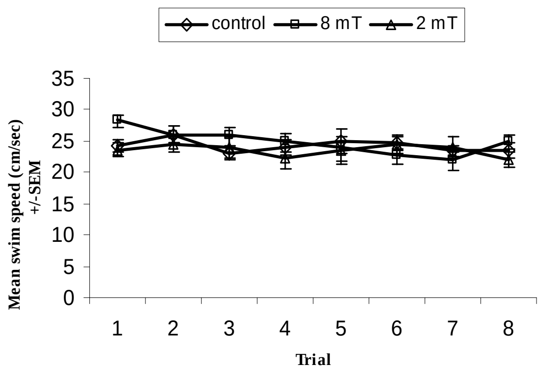

Figure 2: Average swim speed (cm/s) of the rats during training session.

Figure 2 shows the mean swim speed of the two groups of animals during the training session. Analysis of the data showed no significant effect (i.e. there was no significant difference between mean swim speed of three groups).

Results of the probe trial are presented in figure 3, which shows the average duration of time for the three groups of rats during the 1-minute probe trial period in the N-E quadrant.

Analysis of the data by the T-test showed that in comparison to sham-exposed group, 8 mT exposed group spent significantly ($p < 0.05$) less time in the platform quadrant during 60 second probe trial and had different swimming patterns (figure 4), so that they displayed less tendency for finding the platform. Although no statistically significant difference emerged between 2 mT and sham- exposed group, but confused swimming pattern was recorded.

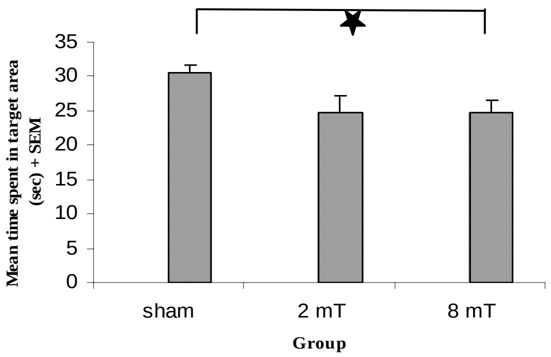

Figure 3: Average time spent in target area during probe trials (*significant).

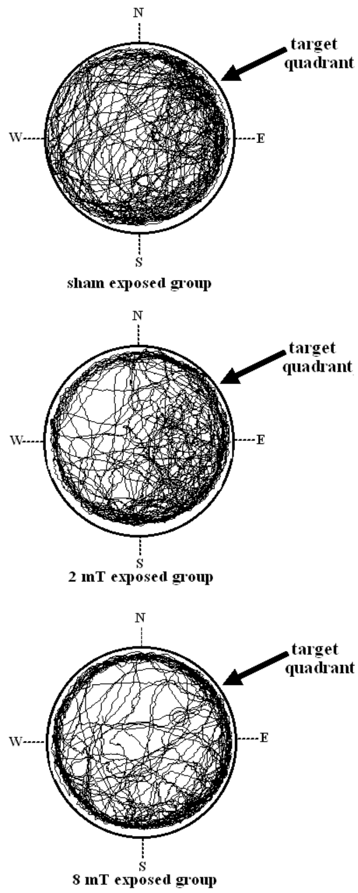

Figure 4: Cumulative swim patterns during the probe trials. The platform was located at the north- east (N-E) quadrant during training session. Rats were released at the south (S) point.

Discussion

The obtained results indicated that short time exposure to 50 Hz, 8 mT magnetic field induced by sinusoidal waveform could impair consolidation phase of spatial memory. These results are in agreement with results of studies done by Kaviani, Lai, Trimmel, Sienkiewicz, Kavaliers and Marino [1, 5, 7, 9, 10, 11, 13]. On the other hand, our results showed that short time exposure to 50 Hz, 2 mT magnetic fields cannot impair consolidation phase of memory. This is in agreement with results of our previous in-vitro studies [10, 11] that showed exposure to 2 mT magnetic field for 20 minute has no effect on neural cell function of snail. Other studies showed similar results for example Kurokawa et al [13] found that 50 Hz, 50μT magnetic fields has no effect on human brain and Sienkiewicz et al [6] did not observe low intensity magnetic field dependent effects on memory in mice. In addition it is indicated that the 50μT to 6mT magnetic fields have low and transient effects and there is no obvious relation between field intensity and following responses [14, 15]. On the other hand, McKay and Persinger [16] showed that 60-minute exposure to 200- 500 nT magnetic fields before training phase can impair spatial memory and exposure before testing phase only decreases responding time of rats in the radial maze.

In another study, Sienkiewicz et al [7, 8] indicated that in intensities more than 75 μT behavioral changes in mice increase due to increase of flux density of field. They concluded that acute exposure to magnetic field can impair spatial learning and memory function, but it seems it has no effect on long-term memory.

The effects of 60 Hz, 1 mT magnetic field on spatial memory were investigated by Lai et al [11]. They found that in comparison to sham group, exposed rats spend less time in target quadrant of Morris water maze and have different swimming pattern. Trimmel and Schweiger's [1] study on 66 human subjects showed results like Lai's study. They found one-hour exposure to 50 Hz, 1 mT magnetic field could immediately decrease perception, cognition and memory.

On the other hand, in another study Lai and Carino [9] showed an interaction between intensity and duration of exposure to magnetic field so that high-intensity/ short-duration exposure and lower-intensity/longer-duration exposure have similar effects on frontal cortex and hippocampus cholinergic activity and memory.

Lovely et al [17] also suggest that duration of exposure is an important factor and exposure less than 15 minute is not enough for the effect of magnetic field on memory of rats in radial maze. But Kavaliers [5] proposed that short-duration exposure has effects on learning in some experiments.

Almost all of experiments done on the effects of magnetic fields on animals' memory contribute to acquisition phase of memory formation and fewer experiments are about consolidation phase. For example McKay et al [16] indicated that exposure to magnetic field can impair memory consolidation of contextual conditioned fear rats. Consolidation is defined as a process by which new labile memories convert to more stable long-term memories. It is showed that consolidation requires RNA and protein synthesis [18, 19]. Sienkiewicz et al [7] suggests that magnetic fields have no effects on the well-established long-term memories. On the other hand, it is showed that magnetic fields can affect on the gene expression, final three-dimensional structure of proteins and DNA [20, 21]. Therefore, the effects of magnetic field on consolidation can emerge from impairment in gene expression and protein synthesis.

Conclusions

We concluded that short time exposure to 50 Hz, 8 mT magnetic field can impair consolidation phase of spatial memory and it follows similar intensity /duration interaction as presented by Lai and Carino [9] and our previous in-vitro experiments [10, 11].

Although this study was used as a model for understanding the effect of magnetic field on consolidation, further studies are needed to test other durations and intensities on this phase of memory and attention to the human occupational magnetic field exposure.

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