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ScienceDirect
Neurobiology of Learning and Memory 88 (2007) 387–392
Neurobiology of Learning and Memory
www.elsevier.com/locate/ynlme

Acute exposure to a 50 Hz magnetic field impairs consolidation of spatial memory in rats

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Received 8 November 2006; revised 22 July 2007; accepted 25 July 2007
Available online 4 September 2007

Abstract

This study was planned to evaluate the effect of an exposure to magnetic fields on consolidation and retrieval of hippocampus dependent spatial memory using a water maze. In Experiments 1 and 2, rats were trained in a hidden version (spatial) of water maze task with two blocks of four trials. The retention of spatial memory was evaluated 48 h later. Exposure to a 50 Hz 8 mT, but not 2 mT magnetic fields for 20 min immediately after training impaired retention performance. The same time exposure shortly before retention testing had no effect. In Experiment 3, rats were trained in a cued version of water maze with two blocks of four trials. Exposure to magnetic field at 8 mT for 20 min immediately after training did not impair retention performance. These findings indicate that acute exposure to a 50 Hz magnetic field at 8 mT for short time can impair consolidation of spatial memory.

Keywords: Magnetic field; Spatial memory; Consolidation; Retrieval; Acute exposure; Water maze

1. Introduction

At present, electricity has a critical role in mankind life. Electrical currents that are used for supplying of instruments can produce a low frequency magnetic field in their wires. In fact, appliances (TV sets, mobile phones, PC monitors, etc.) and power lines emit low frequency magnetic fields. In the last decades, several studies have shown the influences of magnetic fields on behavior, motor activity, and neurotransmitter systems in brain (Chance et al., 1995; Pesic, Janac, Jelenkovic, Vorobyov, & Prolic, 2004; Trzeciak et al., 1993).

The effects of exposure to a weak magnetic field on cognitive functions are not known. The results from human (Trimmel & Schweiger, 1998) and animals (Lai, 1996; Lai & Carino, 1999; Lai, Carino, & Ushijima, 1998; Sienkiewicz, Haylock, Bartrum, & Saunders, 1998a; Sienkiewicz, Haylock, & Saunders, 1998b) studies indicating that exposure to magnetic fields can influence cognitive functions. For example, previous studies have shown that a 60 Hz magnetic field exposure before learning impairs spatial memory in rats (Lai, 1996; Lai et al., 1998). It seems that the amount of impairment is dependent to the gender of animal. Kavaliers et al. (1996) have demonstrated that spatial memory of male rats is more affected than female ones by magnetic field, suggesting a modulatory role of sex hormones in the influences of magnetic fields on memory functions. Moreover, it has been shown that intensity and duration of magnetic fields may interact in influencing cognitive functions. For example, the results of Lai and Carino (1999) study indicated that exposure to 2 mT but not lower intensities magnetic fields for 60 min significantly decreased cholinergic

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1074-7427/$ - see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.nlm.2007.07.010

activities of the frontal cortex and hippocampus. Similar effect was seen with longer (1.5 or 3 h) exposure to lower intensities (0.5, 1 and 1.5 mT) magnetic fields (Lai & Carino, 1999). Since the cholinergic system plays an important role in memory processing (Whishaw, 1989; Whishaw & Tomie, 1987), any decrement in its activity can impair memory processing.

In the recent *in-vitro* studies, we found that exposure to 8 mT, but not 2 mT magnetic fields for 20 min diminished activity of neural cell function of snail (Kaviani Mogadam & Firoozabadi, 2002; Kaviani Mogadam, Firoozabadi, & Janahmadi, 2004). On the other hand, previous studies mainly focused on the effects of magnetic fields on acquisition of memory. As far as we know, only one study evaluated the effects of magnetic fields on post-training consolidation or retrieval processes (McKay & Persinger, 2000). Thus, the present study was planned to evaluate whether acute exposure to 2 or 8 mT magnetic fields would influence consolidation and retrieval of spatial memory in a water maze.

2. Materials and methods

2.1. Subjects and experimental groups

Adult male Wistar rats (3–4 months old, 235 ± 15 g) were housed five per cage in a room with natural light cycle and constant temperature (24 ± 2 °C). Food and water were available ad libitum. All procedures were conducted in agreement with the National Institutes of Health Guide for care and use of laboratory animals. In Experiment 1, three groups were used: sham-exposed ($n = 11$), exposed to 2 mT ($n = 11$) and 8 mT ($n = 11$) magnetic fields. In Experiment 2, two groups were used: sham-exposed ($n = 10$) and exposed to 8 mT ($n = 10$) magnetic field. In Experiment 3, two groups were tested: sham-exposed ($n = 7$) and exposed to 8 mT ($n = 7$) magnetic field.

2.2. Water maze training

2.2.1. Apparatus

The behavioral training and testing was conducted in a water maze. The water maze was a blue circular pool (140 cm in diameter and 50 cm high) filled to a 25 cm depth with 22 ± 2 °C water (Rashidy-Pour, Motamedi, & MotaghedLaijani, 1996). The maze was located in a room containing several visual extra-maze cues for spatial training.

2.2.2. Behavioral training

For training in the spatial water maze, a transparent Plexiglas platform was submerged 2 cm below the surface of the water. The rats were subjected to two blocks and each consisted of four trials. The interval time between blocks was 3 min. Our previous study indicated that with these training procedures, normal rats display a significant bias upon retention test for swimming in the training quadrant, in which the platform was placed (Rashidy-Pour et al., 1996). Twenty-four hours prior to the start of training, rats were allowed to swim 3 min in the pool containing no platform for habituation. On each trial, the rat was placed into the water from one of the four cardinal points of the compass (N, E, S, W), which varied from trial to trial in a quasi-random order. The rat had to swim until it found and climbed onto the escape platform. Rats were guided to the platform if they failed to locate it within 60 s. The rat was allowed to stay on the platform for 45 s as the inter-trial interval and returned to the holding cage after last training. Since the feces defecated during the last trial may served as intra-maze cues, any feces were removed from maze before starting the next trial. After training, all rats transported to their home cage.

For training in the cued task, we used same procedure described by Setlow and McGaugh (2000). A black- and white-striped stone ball (5 cm in diameter) was mounted on a transparent Plexiglas platform. The platform was located in a different quadrant of the maze on each trial. The platform was placed in each the four quadrants twice within the training session and the order of the placements was such that the platform was located to the left or right and distal or proximal relative to the start position within equal frequency . In this task, the rats were allowed 10 s on the platform and then placed in the holding cage for 30 s, which the next trial was begun.

Two days later, the rats were returned to the water maze for a retention test. For the spatial task, the rats were given a 60 s probe trial during which the platform was removed. The parameters measured from probe test were the time spent (%) in each quadrant of the task, swim speed and total swim distance. For the cued task, the platform was located in the SE quadrant. The N start position was used, and the latencies of rats to reach the platform were recorded.

2.3. The magnetic field exposure system

Magnetic fields were applied in a room adjacent to that used for behavioral experiments. A sinusoidal magnetic field was created using a round coil electromagnet (inner diameter: 8 cm, outer diameter: 12 cm, thickness: 2 cm) made from a 850 turned copper wire (0.75 mm). The electromagnet was supplied with a sinusoidal waveform signal generator (GFG-8019G, Good Will instrument Co.). The signals were amplified by an own made audio amplifier (600 W). Then amplifier output droved to coil, producing a magnetic field of 2 or 8 mT at the center of the coil. The desired intensity of magnetic field (2 or 8 mT) calibrated using a digital teslameter (HI-3550, HOLADAY industries, USA) at the center of the coil. The heat generated by coil dissipated due to good ventilation in exposure area. The electrical apparatuses and exposure system adjusted on the laboratory non-metallic table. The average 50 Hz background magnetic filed at the location of the subject was 10 μT.

Immediately after training in the spatial water maze and the cued tasks or 30 min before retention testing in the spatial water maze, rats were exposed to magnetic fields. The rats were left on a table in laboratory room. Each rat was put in a small cotton pouch so that rat's head was out and was held in the center of the coil. The minimum distance between head of animal and inner wall of coil was 2 cm.

2.4. Statistical analysis

Kolmogorov–Smironov test showed normal data distribution. Hence, parametric analysis procedures were used for data analysis. Data from training session (escape latencies and total swim distance) and probe data (the time spent in each quadrant, swim speed and total swim distance) were analyzed with one way or two way ANOVA with the repeated measures. Tukey's post hoc test was performed to determine the source of detected significances. Student's *t*-test was used for comparison of two independent groups. A difference at $p \leqslant 0.05$ was considered statistically significant.

3. Results

3.1. Effect of exposure to magnetic fields for 20 min immediately after training on retention of spatial memory

Analysis of the training latencies (Fig. 1a) with a two way ANOVA (groups × trials) showed no significant effects of groups [$F_{(2,240)} = 1.47$, $P = .27$], a significant effects of trials [$F_{(7,240)} = 6.71$, $P = .001$], and no significant interaction between two factors [$F_{(14,240)} = 0.87$, $P = .58$]. Analysis of total swim distance (Fig. 1b) revealed similar results. Again, two way ANOVA showed no significant