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Research Article

Impairment of Spatial Performance by Environmental Noise

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We examined the effects of noise on acquisition and retention of the spatial memory task in equal and unequal context in adult male rats. The natural noise in Azadi football stadium was recorded and measured by sound level meter instrument and set in high (HI), moderate (MI), and low (LI) intensities, 86, 64, and 47 decibels A (dbA), respectively. Rats were trained in Morris water maze (MWM) for 3-consecutive-day program and at day 4 visible and probe tests were done under one of the above noise intensities. The retention was evaluated at day 7 on the basis of equal and unequal noise exposure situation. Escape latency, traveled distance, and swimming speed were recorded and used for subsequent analysis. Our results showed significant increases in the escape latency and traveled distance by increasing the noise intensity during acquisition period, and also retention test in equal noise situation. Furthermore, retention test in the group that was under HI noise during both training period and retention test escape latency and traveled distance compared to the groups which was under HI noise during training period and LI or MI noise during retention test (HI-LI or HI-MI).

1. Introduction

Noise is one of the problems which affects some aspects of human life. For example, noise impairs human task performance most likely in the case of unexpected bursts of noise presented during tasks, whether it involves the continuous intake of new information [1, 2], and also the psychomotor task impaired by brief experimentally imposed noise in human [3]. In contrast of these studies, It has been shown that addition of an appropriate amount of noise can improve signal detection in a nonlinear system called stochastic resonance [4]; human hearing and the ability of encoding temporal information can increase by noise [5–7]. Nevill et al. [8] found that crowd noise influenced referee's decisions at favor of the home team. In marine life (e.g., in cetaceans), the general increase in underwater noise and the use of sonar have been associated with behavioral and pathological changes in diving mammalians exposed to such an environment [9, 10].

Studies on the short-term effects of imposed noise on school-age children's performance in classroom environments have found no effects of a range of noise levels on writing task performance [11], and different kinds of sound on performance of easy and difficult arithmetic problems [12], and also imposed experimental noise on oddity task performance. Adverse effects of 55–78 dbA noise have been found on recognition memory task [13]. Several studies found long-term effects of traffic noise on auditory discrimination [14], reading, and attention [15].

Some theories explaining the effects of noise are primarily based on the researcher's perception of the role of adaptation [13], but Glass and Singer [16] have reported that autonomic reactivity does not always adapt with brief noise stimulation (continuous 80 dbA). Prevalent theoretical approaches often account for noise effects using the concepts of arousal or distraction [17–20]. Positive and negative effects are suggested to be as a reason of distraction-arousal arising from extra-auditory systemic responses (physiological and intellectual) to stimulate nervous system through auditory channels [21].

However, different kinds and levels of noise can have various effects on retention test. The present study was performed to investigate this idea that whether various intensities of noise can act as differential positive and negative impacts on acquisition and retention of a spatial memory task in equal; when the intensity of noise during training period is the same as exposed noise intensity during retention performance task, and unequal noise contextual situations in rats.

2. Materials and Methods

2.1. Animals. Adult male albino Wister rats (12 weeks old), weighting 250–300 gr, were obtained from the breeding colony of the Pasteur Institute of Iran. They were housed four per cage in a temperature and light-controlled room under 12 hours: 12 hours light-dark cycle (light at 07:00 am) with free access to water and food. Experiments were carried out in a room where only the MWM was placed in standard conditions and took place at 13:00–16:00.

2.2. Noise Regulation. We measured intensity of noise obtained from a football stadium with sound level meter (B&K 2250, UK) instrument, when the stadium was full of spectators (about 100 000 people). The intensity of noise was about 105 dbA in an extremely noisy situation, and about 95 dbA in moderate situation, and also 69 dbA in silence times. At first, we recorded this natural sound from football stadium and compared to the hearing system of rats, then we set the intensity of noise for high and moderate situations in 86 dbA and 64 dbA. We regulated the acoustic system in these intensities by Cool-Edit 2000 Software (designed by Gold soft company, UK) at a stable frequency.

2.3. Apparatus. The MWM task was consisted of a dark circular pool (140 cm in diameter, 55 cm height) filled with water ($20 \pm 1^{\circ}$C) to a depth of 25 cm. A transparent Plexiglas platform (11 cm in diameter) was located 1 cm below the water surface in the center of one of arbitrarily designed north-east (NE), south-east (SE), south-west (SW), or north-west (NW) orthogonal quadrants. The platform provided the escape from the water. The room, where water maze was placed, was surrounded by extra maze cues such as racks, a door, a watch, and pictures on the walls which were kept in fixed positions, respectively, around the swimming pool. So rats were allowed to locate the escape platform hidden below the water by using these cues. A video tracking system and a PC computer with software developed for monitoring and storing the position of the rat in the water maze was used. Thus, the required time to reach the platform (escape latency) and the swimming path (travelled distance) were recorded.

2.4. Procedure. The spatial memory task was defined as finding the hidden platform in the MWM. All rats were given a daily session of two blocks (each block consisted of 4 trials) with 5 minutes interval between blocks for 3 days in the training period. During all experiments, the platform was located in a fixed position in the middle of SW quadrant. Each trial involved placing the rat in the pool, close to and facing the wall in one of the four equal quadrants (North, South, East, or West). Rats were allowed to swim freely until they found the platform. If a rat failed to find the platform within 90 seconds, the experimenter placed the rat on it. The intertrial interval was 30 seconds, during which the rat remained on the platform. The rat was taken directly from the platform to the new starting point which was changed from trial to trial in a quasirandom order. So each starting point was used once in each session of 4 trials. All animals were exposed to the defined noise in their group (as described below) during training period and also probe, visible, and retention tests.

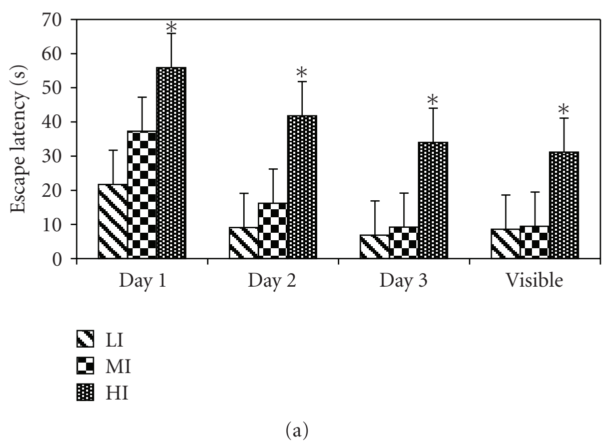
We divided rats into 3 groups: low-intensity noise group (LI = control) was trained under natural noise (47 dbA) (n = 8), while moderate-intensity noise (MI) and high-intensity noise (HI) groups were trained under 64 dbA and 86 dbA (n = 7 per group) noise intensities, respectively. For the first 3 consecutive days, rats were trained in MWM along with noise exposure. At the day 4, probe and visible tests were done. For the Probe test, the platform was removed away in the MWM and let the rats to swim and look for platform and SW quadrant. 60 minutes after doing the probe test, the platform was covered by aluminum foil and placed 1 cm above the water surface in the SE quadrant and visible test was done. This procedure is believed to provide information on the possible nonspecific effects involving motor, visual, or motivational abilities. At day 7, the retention test was done when the platform was placed in the SW quadrant and it was similar to the training day program in blocks and trial numbers of sessions while noise was exposed. If the exposed noise during retention test was similar to ones in the training period, then the test is called "equal;" if it wasn't similar, then it is called "unequal" retention test.

2.5. Statistical Analysis. The data analyzed by one-way analysis of variance (ANOVA), followed by post hoc Tuky's test and also we used t-repeated measure. All results have shown as mean ±SEM. In all statistical comparisons, $P < .05$ was considered as significant difference.

2.6. Experiments

Experiment 1. The aim of this experiment was to determine the effect of low-intensity (LI) noise exposure during acquisition period and retention test on MWM performance. In this experiment, rats were trained in LI noise for 3 training days according to the procedure. Visible and probe tests were held in day 4. Retention test was performed under equal (LI) and two unequal (MI and HI) noise conditions. It should note since environmental sounds in the experimental room were similar to LI noise intensity (approximately 47 dbA), so we used the group under LI-exposed noise during both training period and retention test (LI-LI) as the control group.

Experiment 2. The aim of this experiment was to determine the effect of MI noise exposure during acquisition period and



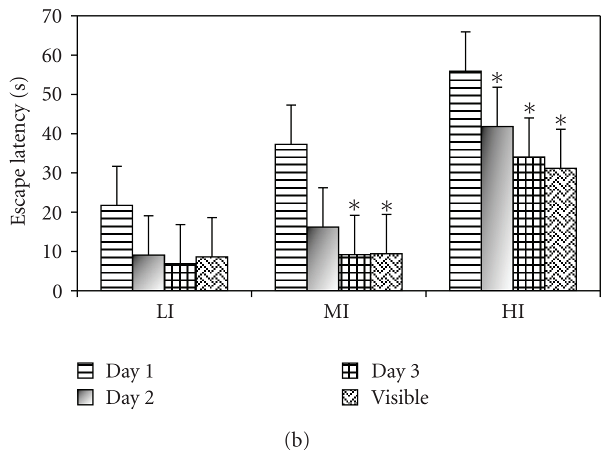


FIGURE 1: Effects of various intensities of noise during training period on escape latency in day 1–3 and visible test (day 4). $^*P < .05$ shows a significant difference between different intensities and LI.

retention test on MWM performance. In this experiment, rats were trained in MI noise for 3 training days according to the procedure. Visible and probe tests held in day 4. Retention test was performed under equal (MI) and two unequal (LI and HI) noise conditions.

Experiment 3. The aim of this experiment was to determine the effect of HI noise exposure during acquisition period and retention test on MWM performance. In this experiment, rats were trained in HI noise for 3 training days according to the procedure. Visible test and probe tests held in day 4. Retention test was performed under equal (HI) and two unequal (LI and MI) noise conditions.

3. Results

Our results were based on the data which was acquired in acquisition period and retention tests in equal and unequal noise situations. The escape latency, traveled distance, and swimming speed were recorded. In all experiments, the swimming speed had no significant differences. So we do not report details of speed results here.

3.1. Training Period

3.1.1. Hidden Platform Trials (Day 1 to 3 between Groups). Figure 1(a) shows the results of training in the three levels of noise during training period and visible test. There were significant differences in escape latency at day 1 [F (2, 20) = 14.48, $P < .05$], day 2 [F (2, 20) = 27.62, $P < .05$], and day 3 [F (2, 20) = 10.53, $P < .05$] between three groups. These significant differences in the escape latency were between LI group with HI group in day 1 ($P = .00$), day 2 ($P < .05$), and also day 3 ($P < .05$).

For traveled distance, there were significant differences at day 1 [F (2, 20) = 22.43, $P < .05$], day 2 [F (2, 20) = 83.7, $P < .05$], and day 3 [F (2, 20) = 19.44, $P < .05$] between groups. At day 1 (Figure 2(a)), there were significant differences between LI group with MI group ($P < .05$) and also HI group ($P < .05$). At day 2 and 3, it showed a significant difference between LI group with HI group ($P < .05$).

Experiment 1: Performances in Exposure of LI Noise during Training Period, Equal and Unequal Retention Tests. There were no significant differences between the results of day 1 to 3 in LI noise (Figures 1(b) and 2(b)). Figures 3(a) and 4(b) show there were significant differences between equal and unequal retention tests (for escape latency F (2, 20) = 14.1, $P < .05$ and also for traveled distance, F (2, 20) = 16.7, $P < .05$); it was between equal (LI-LI) and unequal (LI-HI) retention tests ($P < .05$ for both escape latency and traveled distance). In the visible and probe tests, there were no significant differences for escape latency and traveled distance.

Experiment 2: Performances in Exposure of MI Noise during Training Period, Equal and Unequal Retention Tests. There were significant differences between the results of day 1 to 3 in exposed MI noise (Figures 1(b) and 2(b)). Figures 3(b) and 4(b) show there were significant differences between equal and unequal retention tests (for escape latency, F (2, 20) = 17.3, $P < .05$ and for traveled distance, F (2, 20) = 18.7, $P < .05$); which it was between equal (MI-MI) and unequal (MI-LI) retention tests ($P < .05$ for both escape latency and traveled distance). In the visible and probe tests, there were no significant differences for escape latency and traveled distance.

Experiment 3: Performances in Exposure of HI Noise during Training Period, Equal and Unequal Retention Tests. There were significant differences between the results of day 1 to 3 in exposed HI noise (Figures 1(b) and 2(b)). Figures 3(c) and 4(c) show there were significant differences between equal and unequal retention tests (for escape latency, F (2, 20) = 22.7, $P < .05$, and for traveled distance, F (2,20) = 23.08, $P < .05$); which it was between equal (HI-HI) and unequal (HI-MI) retention ($P < .05$ for both escape latency

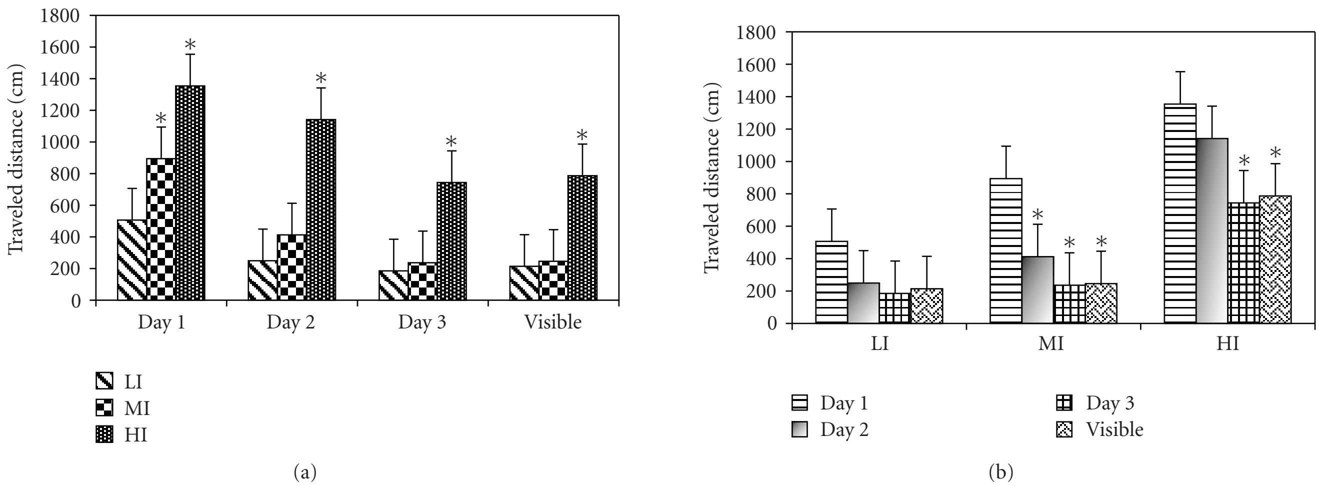


Figure 2: Effects of various intensities of noise during training period on traveled distance in day 1–3 and visible test (day 4). $^*P < .05$ shows a significant difference between different intensities and LI.

and traveled distance). In the visible and probe tests, there were no significant differences for escape latency and traveled distance.

Performances in Equal Retention Tests. Figures 3(d) and 4(d), there were significant differences between LI-LI and MI-MI groups with HI-HI group in escape latency and traveled distance ($P < .05$ for both) during retention tests. But this difference was not significant between LI-LI and MI-MI groups.

4. Discussion

In this study, adult male rats treated with different intensities of exposed noise displayed memory performance impairments by increase in intensity of noise (47, 64, and 86 dbA). In training period, it was significant difference between performance of groups in day 1 and day 2. Also this difference was shown in days 2 and 3 between HI with MI and LI in escape latency and traveled distance. The longest time and traveled distance to find the platform during acquisition period was seen at HI group. It is possible that learning process might be impaired by high-intensity noise [22]. Also it showed that the time and distance to find the platform was improved according to progression in training period, caused by learning process. In visible test, there was no significant difference between LI and HI. This finding is similar to Hamberick–Dixon's [13] interpretation that they did not find different effects of noisy and quiet day care center in separation of relevant visual cues, because of directing the subjects to pay more attention to visual rather than auditory resources [13, 23]. Also this is in agreement with Glass and Singer's [16] findings that found the psychological and behavioral adaptation to brief noise exposure. Also, this is in contrast with Broadbent [3] finding which revealed the psychomotor task impaired by brief experimentally imposed noise. Our results in experiment 2 support this notion that a moderate-intensity noise (MI) in training period can promote retention in high-intensity noise (MI-HI) than retention in low-intensity noise (MI-LI). Several possible underlying explanations may explain this finding. Maes & De Groot [5] have described that discrimination performance at under noise situation is better than under silence situation supported with Zeng et al. [4] findings. So we suggest that this promotion in performance at this intensity might be associated with elevation of the arousal to an appropriate level [24]. So silent conditions (LI in this experiment) may be associated with under-arousal so that noise may elevate arousal to a more optimal level; thereby increasing task performance [24]. Another suggestion of this improvement is about adaptation with moderate levels so that rats can have an appropriate attention and good performance [6, 13, 25, 26].

The present results in experiment 3 showed that retention test in equal situation after exposure to high-intensity noise (HI-HI) in training period caused less latency and traveled distance rather than unequal retention in moderate noise (HI-MI). This finding supports the "test-training context law" described that retention can be better in equal contexts [27]. Also this is similar to this hypothesis that the identical retention test of noise levels consequences has better performance than do dissimilar noise levels [25]. The best time and distance showed in retention tests of unequal low-intensity noise that supports with external investigations [3, 5, 13, 20]. From our data, it could be reasonable that the learning process might get disruption with high-intensity noise [2, 22, 25]. Another possible explanation of this disruption is that high-intensity noise may result in over-arousal that can produce "panic effect" and also disturbs attention [5, 8, 17, 18, 21, 24, 26, 28].

In experiment 4, it did not show significant difference between LI-LI and MI-MI groups in equal retention test. It may be associated with "power of training law" [2, 27] or it associated with the possibility of interaction between the noise condition during training and retrieval of information [5]. But in unequal retention at high-intensity imposed

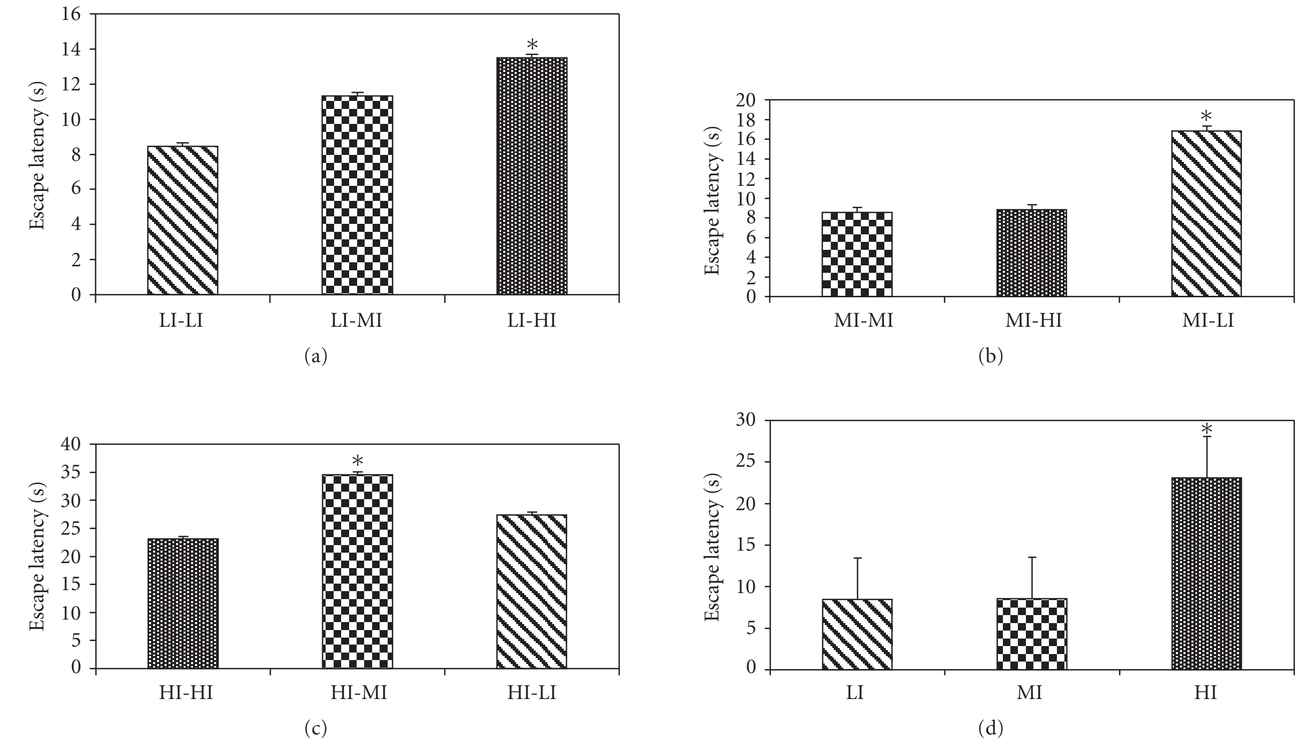


Figure 3: Different effects of noise exposure on escape latency. (a) Equal (LI-LI) and unequal, moderate (LI-MI) and high (LI-HI) intensities, and retention tests in LI training group; (b) equal (MI-MI) and unequal, low (MI-LI) and high (MI-HI) intensities, and retention tests in MI training group; (c) equal (HI-HI) and unequal, low (HI-LI) and moderate (HI-MI) intensities, and retention tests in HI training group; (d) equal retention tests for LI, MI, and HI training groups. $^*P < .05$ shows a significant difference between different intensities with equal group in a to c and LI group in d.

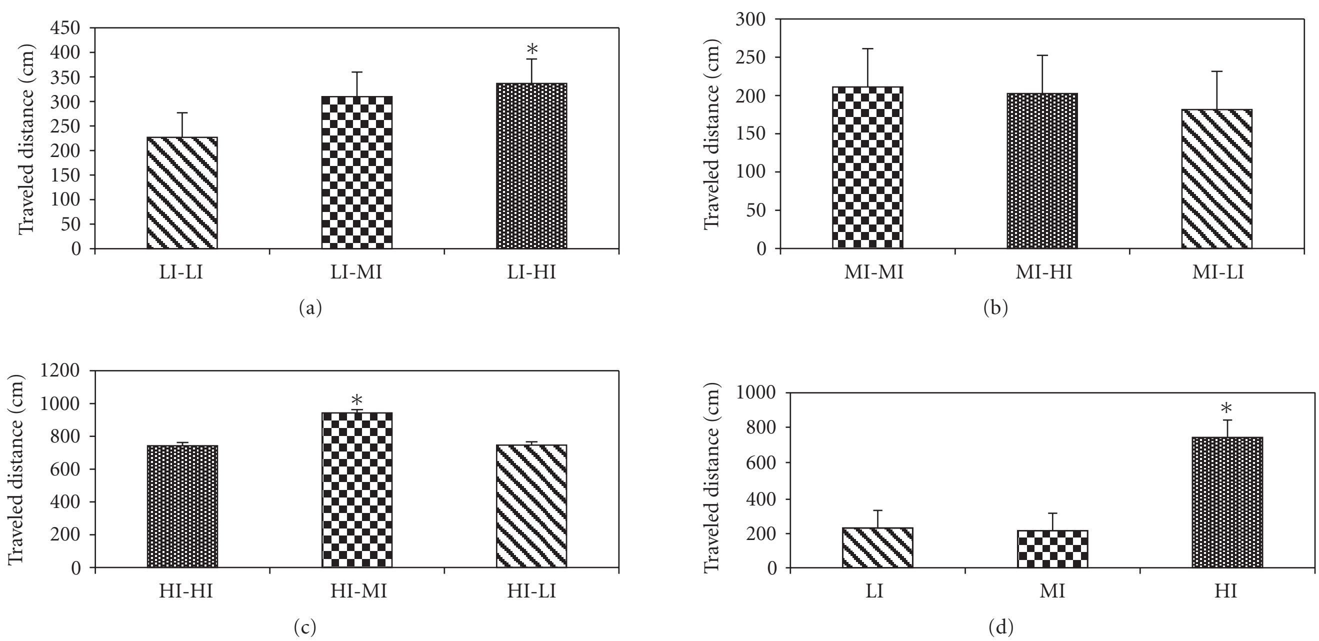


Figure 4: Different effects of noise exposure on traveled distance. (a) Equal (LI-LI) and unequal, moderate (LI-MI) and high (LI-HI) intensities, and retention tests in LI training group; (b) equal (MI-MI) and unequal, low (MI-LI) and high (MI-HI) intensities, and retention tests in MI training group; (c) equal (HI-HI) and unequal, low (HI-LI) and moderate (HI-MI) intensities, and retention tests in HI training group; (d) equal retention tests for LI, MI, and HI training groups. $^*P < 0.05$ shows a significant difference between different intensities with equal group in a to c and LI group in d.

noise, it presented the big difference in the results as it has been reported the role of high-intensity noise in memory processes [1, 5, 8, 10, 12–15, 21, 26]. We did not find significant difference between speeds of these groups. It could be resulted that the motor system of rats did not influence by noise.

In general, it seems that the interaction between training period and noise intensity might interfere with the level of performance in special retention test. We concluded that when a group trains at the special noise intensity in training period, it will get adaptation with the situation, and then it will have lower performance in other intensities at the retention tests, even at the lower intensities. So, it might be better to train at the equal noise intensity, maybe adapt with this external disruptive operant and decrease its influences.

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References

[1] A. Smith, "A review of the effects of noise on human performance," *Scandinavian Journal of Psychology*, vol. 30, no. 3, pp. 185–206, 1989.

[2] P. K. Smith, H. Cowie, and M. Blades, *Understanding Children's Development*, Blackwell, Ofxford, UK, 4th edition, 2003.

[3] D. E. Broadbent, "Human performance and noise," in *Handbook of Noise Control*, C. S. Harris, Ed., pp. 2066–2085, McGrow-Hill, New York, NY, USA, 1979.

[4] F.-G. Zeng, Q.-J. Fu, and R. Morse, "Human hearing enhanced by noise," *Brain Research*, vol. 869, no. 1-2, pp. 251–255, 2000.

[5] J. H. R. Maes and G. de Groot, "Effects of noise on the performance of rats in an operant discrimination task," *Behavioural Processes*, vol. 61, no. 1-2, pp. 57–68, 2003.

[6] C. D. Takahashi, D. Nemet, C. M. Rose-Gottron, J. K. Larson, D. M. Cooper, and D. J. Reinkensmeyer, "Neuromotor noise limits motor performance, but not motor adaptation, in children," *Journal of Neurophysiology*, vol. 90, no. 2, pp. 703–711, 2003.

[7] G. Waye, "Effects of low frequency noise on cortisol levels," *Behavioural Brain Research*, vol. 112, pp. 22–34, 2002.

[8] A. M. Nevill, N. J. Balmer, and A. Mark Williams, "The influence of crowd noise and experience upon referring decisions in football," *Psychology of Sport and Exercise*, vol. 3, no. 4, pp. 261–272, 2002.

[9] D. Malakoff, "A roaring debate over ocean noise," *Science*, vol. 291, no. 5504, pp. 576–578, 2001.

[10] P. D. Jepson, M. Arbelo, R. Deaville, et al., "Gas-bubble lesions in stranded cetaceans," *Nature*, vol. 425, no. 6958, pp. 575–576, 2003.

[11] B. Slater, "Effects of noise pupil performance," *Journal of Educational Psychology*, vol. 59, no. 4, pp. 239–243, 1968.

[12] H. Kassinove, "Effects of meaningful auditory stimulation on children's scholastic performance," *Journal of Educational Psychology*, vol. 63, no. 6, pp. 526–530, 1972.

[13] P. J. Hamberick-Dixon, "Effects of experimentally imposed noise on task performance of black children attending day care center near elevated trains," *Developmental Psychology*, vol. 22, no. 2, pp. 259–264, 1986.

[14] S. Cohen, G. W. Evans, D. S. Krantz, and D. Stokols, "Physiological, motivational, and cognitive effects of aircraft noise on children: moving from the laboratory to the field," *American Psychologist*, vol. 35, no. 3, pp. 231–243, 1980.

[15] S. Cohen and N. Weinstein, "Nonauditory effects of noise on behavior and health," *Journal of Social Issues*, vol. 37, no. 1, pp. 36–70, 1981.

[16] D. C. Glass and J. E. Singer, *Urban Stress: Experiments on Noise and Social Stressors*, Academic Press, New York, NY, USA, 1972.

[17] V. A. Benignus, D. A. Otto, and J. H. Knelson, "Effect of low-frequency random noises on performance of a numeric monitoring task," *Perceptual and Motor Skills*, vol. 40, no. 1, pp. 231–239, 1975.

[18] T. C. Auburn, D. M. Jones, and A. J. Chapman, "Arousal and the Bakan vigilance task: the effects of noise intensity and the presence of others," *Current Psychology*, vol. 6, no. 3, pp. 196–206, 1987.

[19] A. Furnham and L. Strbac, "Music is as distracting as noise: the differential distraction of background music and noise on the cognitive test performance of introverts and extraverts," *Ergonomics*, vol. 45, no. 3, pp. 203–217, 2002.

[20] S. A. Stansfeld, B. Berglund, C. Clark, et al., "Aircraft and road traffic noise and children's cognition and health: a cross-national study," *The Lancet*, vol. 365, no. 9475, pp. 1942–1949, 2005.

[21] K. D. Kryter, *The Effects of Noise on Man*, Academic Press, New York, NY, USA, 1970.

[22] D. G. Nunez, "Cause and effects of noise pollution," Student Papers, University of California, Irvine, Calif, USA, 1998.

[23] M. M. Haines, S. A. Stansfeld, R. F. S. Job, B. Berglund, and J. Head, "Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children," *Psychological Medicine*, vol. 31, no. 2, pp. 265–277, 2001.

[24] R. M. Yerkes and J. D. Dodson, "The relation of strength of stimulus to rapidity of habit-formation," *Journal of Comparative Neurology and Psychology*, vol. 18, pp. 459–482, 1908.

[25] P. A. Bell, S. Hess, E. Hill, S. L. Kukas, R. W. Richards, and D. Sargent, "Noise and context-dependent memory," *Bulletin of the Psychonomic Society*, vol. 22, pp. 99–100, 1984.

[26] A. E. Talpalar and Y. Grossman, "Sonar versus whales: noise may disrupt neural activity in deep-diving cetaceans," *Undersea & Hyperbaric Medicine*, vol. 32, no. 2, pp. 135–137, 2005.

[27] R. A. Magill, *Motor Learning Concepts and Applications*, McGraw Hill, Boston, Mass, USA, 6th edition, 2001.

[28] G. W. Overbeck and M. W. Church, "Effects of tone burst frequency and intensity on the auditory brainstem response (ABR) from albino and pigmented rats," *Hearing Research*, vol. 59, no. 2, pp. 129–137, 1992.