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Original Article

EFFECT OF ROTATORY VESTIBULAR STIMULATION ON LEARNING AND MEMORY IN RATS-STANDARDIZATION OF A NOVEL METHOD

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ABSTRACT

Objective: To find out the effect of rotatory vestibular stimulation in cognition in rats through examining the behavioural patterns, the alterations in dendritic arborization and changes in AChE activity.

Methods: Rotatory vestibular stimulation was provided in a rotatory vestibular apparatus at a rate of 50 rpm for 5 min, for 30 d for rats. 0.3 mg/kg of physostigmine also administered to rats of another group as a standard drug. No rotatory vestibular stimulation or physostigmine is provided to the control rats. Behavioural analysis, Neuromorphological and biochemical studies were done after vestibular stimulation.

Results: No. of trails for acquisition and retention reduced significantly in treated rats when compared with the control rats. In all the treated rats the dendritic arborization increased significantly, and activity of AChE decreased significantly when compare with the control.

Conclusion: Rotatory vestibular stimulation enhances learning and memory *via* increasing dendritic arborization and inhibiting acetyl-cholinesterase activity in rats.

Keywords: Rotatory vestibular stimulation, Learning, memory, Hippocampal pyramidal neurones

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INTRODUCTION

A lot of work has been done to find out the best method to improve cognitive functions in normal individuals as well as in age-related cognitive impairments and also memory lose in diseased states like dementia and Alzheimer's diseases. The present study was an attempt to find out an easy and safest method of cognitive enhancement in rats through a novel method of rotatory vestibular stimulation.

Sensory stimulation alters hippocampal LTP as the vestibular system linked with various brain regions involved in cognitive processes like hippocampus, raphe nucleus, locus ceruleans, thalamus, amygdala, insular cortex, anterior cingulated cortex, prefrontal cortex, cerebellum, occipital cortex, putamen, parietal lobe [1]. The contribution of vestibular stimulation is widespread in various aspects like, regulating posture and equilibrium and also relieves stress, cancer pain, promotes sleep, improves immunity, remedy for endocrine disorders and also improves cognition [2]. Vestibular stimulation can be regarded as a very effective and reliable approach for treating attention deficit or hyperactivity disorder, particularly when combined with other training [3]. Hence the present study is an investigation through the behavioural, neuromorphological and biochemical changes in rats treated with Rotatory Vestibular Stimulation.

Vestibular under stimulation causes no effect and overstimulation may results in nausea, vomiting and radical fluctuations in pulse and respiration [4]. If the input of rotatory vestibular stimulation is excessive, it can cause an overload of stimulus to the brain causes poor autonomic nervous system adaptation and leads to an inability to concentrate, and unstable mood, dizziness, nausea, vomiting, paleness, hypotension and postural imbalance [5]. Hence the present study also aims to find out a comfortable rotation per minute in rotatory vestibular apparatus.

MATERIALS AND METHODS

Animals used for the present study

The present study was approved by Institutional Animal ethical committee of Little Flower Medical Research Centre in 2012. Wistar albino rats were purchased from Kerala Agricultural University, Mannuthy, Thrissur. Breeding was carried out in our own animal house. The present research experiments were carried out in 45 d old male Wistar rats weighing in the range of 121.2±66.74g.

Care and maintenance of rat colony

The rats were bred and maintained at the central animal research facility (Rodent house Register number: 496/01/a/CPCSEA) of the Little Flower Medical Research Centre (LFMRC), Angamaly. Rats were housed in polypropylene cages (30 x 22 x 14 cm). Paddy husk was used as bedding material, which was changed on alternate days. The colony was maintained in a well-aerated room with exhaust and ceiling fans. The rats were maintained at 12 h light-dark cycle.

The room temperature was 28±4 °C. Three to four rats were housed in each cage. The rat diet included rat chow obtained from the local market, and multivitamin syrup (polybion) was provided along with drinking water (1 ml syrup/100 ml water). All animals received food and water *ad libitum*.

Rotatory vestibular apparatus

A new instrument has been designed in our laboratory for providing vestibular stimulation by rotations to find out whether learning and memory can be enhanced in rats through rotatory vestibular stimulation. This instrument was designed out of fibre frame as the basement with three plastic cages attached on it to place rats. The cages were off about 15 cm length and 10 cm width. Only one animal can occupy comfortably in one cage without any entrapment stress. The device works on electricity and the movement provided by this device gives vestibular stimulation in rotation mode. The speed of rotation was 50 revolutions per minute were fixed by trial and error method with 25 rpm and 75 rpm.

Standardisation of the speed of rotation per minute in vestibular apparatus

Grouping of animals for standardisation of the speed rotation

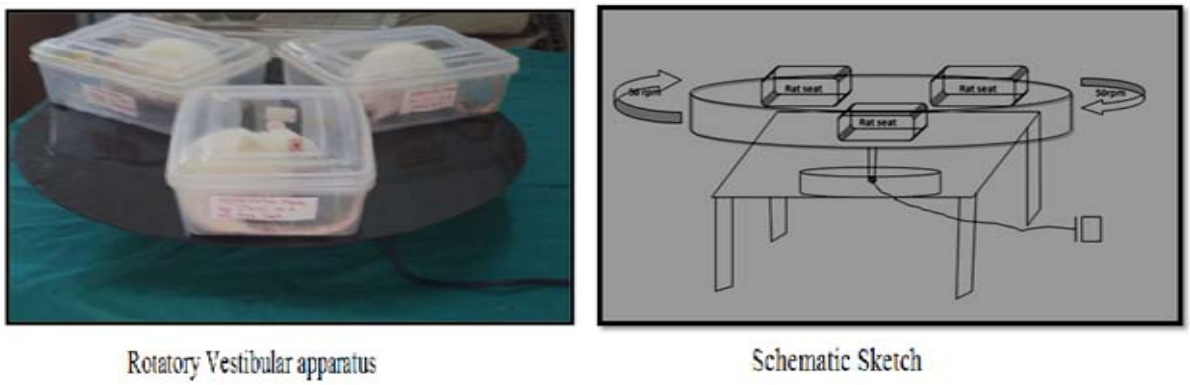
Each group consists of 18 no. of rats.

Group A: Control group (Neither Vestibular Stimulation, nor the drug was administered).

Group RVS 25: Rotatory Vestibular Stimulation was given at a speed of 25 rpm.

Group RVS 50: Rotatory Vestibular Stimulation was given at a speed of 50 rpm.

Group RVS 75: Rotatory Vestibular Stimulation was given at a speed of 75 rpm.



Rotatory Vestibular apparatus Schematic Sketch

Fig. 1: Rotatory vestibular apparatus

For standardising the speed of rotation, the rats were subjected to 5 min of rotation in rotatory vestibular apparatus at a rate of 25 rpm, 50 rpm and 75 rpm in a clockwise direction except for the control group for 30 d. After 30 d of vestibular stimulation, the rats were subjected for behavioural studies to find out, among the three speeds of rotation which improves learning better. In 25 rpm the rats show no significant difference in acquisition when compare to the control, and in 75 rpm the rats took significantly increased no. of trails in acquisition when compared to the control. In 50 rpm the rats shows a significant decrease in no. of trails for an acquisition than control and shows a better learning. The same effect is repeated for retention also.

Low vestibular stimulation has no effect and overstimulation may cause nausea, vomiting and radical rise and fall in pulse and respiration [6]. If the input of rotatory vestibular stimulation is extreme, it can cause a surplus of stimulus to the brain causes poor adaptation of the autonomic nervous system. This may result in failure to concentrate, unsteady mood, giddiness, nausea, vomiting, pallor, hypotension and postural imbalance [5]. The no. of rotation cause a high impact on animals [6].

Hence the present study standardised and fixed the rotation to 50 rpm as the comfortable speed of rotation, with slight modifications from a previous study [7] where the speed of passive rotation was fixed at one rotation every 2 seconds. The safety and tolerability of rotatory vestibular stimulation in this study were based on the behavioural response of rats. There was no discomfort or dizziness was noticed during rotation.

Grouping of animals for standardisation of the method

Rats were randomly divided into different groups comprising 18 no. of rats.

Group A: Control group (Neither Vestibular Stimulation, nor the drug was administered).

Group B: Standard drug Physostigmine (Phy) Treated Group (No Vestibular Stimulation).

Group C: Rotatory Vestibular Stimulated Group (RVS).

Experimental design for behavioral analysis and administration of rotatory vestibular stimulation and physostigmine

All the rats of group C were subjected to rotatory vestibular stimulation for 5 min in a rotatory vestibular apparatus, at a rate of 50 revolutions per minute in a clockwise direction for 30 d.

After 30 d of vestibular stimulation, the rats were subjected for Behavioural studies in Radial arm Maze. The behavioural experiments were carried out in three phases, viz; Orientation and Training Session, Learning Performance Test (Acquisition Test), and Memory Performance Test (Retention test). The rats were semi-starved for 48 h before the start of behavioural experiments, conducted in the same room, with the same allocentric cues such as doors, windows, posters, and the experimenter. Experimenter always maintained the same position throughout the whole of the experiment. During the three days of orientation, the semi-starved rats were allowed to familiarise themselves with the radial maze. After the orientation phase, the behavioural task was performed, where all the eight arms of the maze were baited with food pellets (Kellogg's chocolate wheat scoops), and then the rat was placed in the centre of the maze and allowed to explore the maze freely. The rats were required or trained to take the food pellet from each arm without making a reentry into the already visited arm. The training or trial was terminated when the animal learned to take the food reward from the all eight arms or after 10 min if all the eight arms were not visited. Six trials per day were given with an inter-trial interval of 1hour. To avoid olfactory cues, the maze was wiped with 70% ethanol prior to each session [8]. After acquisition phase, all the trained rats were kept for consolidation of the learned task for 10 d. After 10 d of acquisition, the retention test was carried out until the rats attaining the learning criteria [9, 10]. For the assessment of learning and memory, the no. of trails taken for attaining the task were recorded. For analysing the Long Term Potentiation (LTP), the retention test was repeated for 7 times with 10 d of gap in between each test [11].

Control rats (Group A) were undergone the same procedure of behavioural task without providing any drug or vestibular stimulation. The rats of Group B were administered with the drug physostigmine (0.3 mg/kg, orally) [12, 13] for 30 d without any vestibular stimulation and kept as standard drug group.

Statistical analysis

Statistics were done using Graph pad prism (5.0) software. Results are shown in mean±SD. ANOVA followed by Tukey's multiple comparison post hoc is done in the study. $p<0.05$ was considered to be statistically significant.

RESULTS

I. Standardisation of the speed of rotatory vestibular stimulation for learning and memory:

i) Acquisition in various rpm in rotatory vestibular apparatus

The result of acquisition in three different rpm in Rotatory vestibular apparatus, Control (30.44±1.15), RVS 25 rpm

(29.56±0.98), RVS 50 rpm (8.17±1.69) and RVS 75 rpm (39.89±1.18), clearly indicates that RVS 50 rpm showed a significant reduction (p<0.001) in no. of trails to learn the radial arm maze task when compare with Control, 25 rpm and 75 rpm. Whereas the no. of trails under 75 rpm significantly (p<0.001) increased when compared with Control, 25 rpm and 50 rpm indicating that the rats require more time to learn the task than the normal control and 25 and 50 rpm. There is no significant difference between control and 25 rpm. Hence 50 rpm was preferred throughout the study. Results showed in table 1.

Table 1: No. of trails taken by rats for acquisition in various rpm in rotatory vestibular apparatus

No. of trails in for Acquisition (mean±SD)	Control group	Rotatory vestibular stimulated (RVS) group		
		25 rpm	50 rpm	75 rpm
	30.44±1.15	29.56±0.98^{ns}	8.17±1.69^{a,d}	39.89±1.18^{a,d,h}

^{a}p<0.001, ^{b}p<0.01, ^{c}p<0.05, ns, representation for 25 rpm, 50 rpm and 75 rpm when compared with Control, ^{d}p<0.001, ^{e}p<0.01, ^{f}p<0.05, and ns, is the representation for 50 rpm and 75 rpm when compared with 25 rpm, ^{h}p<0.001, ^{i}p<0.01, ^{j}p<0.05, and ns, representation for 50 rpm when compared with 75 rpm, ns = Non Significant

ii) Retention

Memory from the 10th-70th day

The result of retention in three different rpm in Rotatory vestibular apparatus, from 10th–70th day clearly indicates that RVS 50 rpm showed a significant reduction (p<0.001) in no. of trails to recall the learned task when compared with Control, 25 rpm and 75 rpm. Whereas the no. of trails under 75 rpm significantly (p<0.001) increased when compared with Control, 25 rpm and 50 rpm indicating that the rats require more time to memorise the learned task than the normal control and 25 and 50 rpm.

There was no significant difference between control and 25 rpm. Hence 50 rpm was preferred throughout the study. Results showed in table 2.

Table 2: No. of trails taken by rats for retention in various rpm in rotatory vestibular apparatus

Groups	Retention from 10th–70th day (mean±SD)						
	10th	20th	30th	40th	50th	60th	70th
Control	11.56± 1.10	11.50± 0.92	11.56± 1.10	11.17± 0.86	10.94± 0.64	11.17± 0.92	11.11± 0.90
25 rpm	11.50± 1.20^{ns}	11.06± 0.87^{ns}	12.0± 1.09^{ns}	10.39± 0.98^{ns}	10.06± 1.06^{ns}	10.39± 0.85^{c}	10.33± 0.97^{ns}
50 rpm	4.28± 0.75^{a,d}	4.00± 0.69^{a,d}	3.83± 0.71^{a,d}	3.83± 0.62^{a,d}	3.44± 0.51^{a,d}	3.39± 0.50^{a,d}	3.00± 0.00^{a,d}
75 rpm	22.28± 1.78^{a,d,h}	22.50± 1.69^{a,d,h}	22.50± 1.30^{a,d,h}	22.28± 1.32^{a,d,h}	22.06± 1.63^{a,d,h}	22.89± 1.28^{a,d,h}	23.56± 1.62^{a,d,h}

^{a}p<0.001, ^{b}p<0.01,^{c}p<0.05,ns, representation for 25 rpm, 50 rpm and 75 rpm when compared with Control, ^{d}p<0.001,^{e}p<0.01, ^{f}p<0.05, and ns, is the representation for 50 rpm and 75 rpm when compared with 25 rpm, ^{h}p<0.001,^{i}p<0.01, ^{j}p<0.05, and ns, representation for 50 rpm when compared with75 rpm, ns=Non Significant

II. Standardisation of the method rotatory vestibular stimulation in cognition

i) Behavioral analysis

The effect of Rotatory Vestibular Stimulation on learning and memory was investigated in rats using Radial Arm Maze task. The acquisition and retention of the three groups were statistically analysed using one-way ANOVA followed by Turkey's multiple comparison tests.

a. Acquisition

The mean no. of trails for acquisition in Group B (8.83±0.86, p<0.001) and Group C (8.17±1.69, p<0.001) showed a significant reduction when compared with Group A (30.44±1.15). But there was no significant difference between Group B and Group C indicates that Rotatory vestibular stimulation and physostigmine are equally good at enhancing learning capacity. Results showed in table 3.

Table 3: No. of trails for acquisition in different groups of rats

Groups	No. of trails (mean±SD)
Group A (Control)	30.44±1.15
Group B (Phy)	8.83±0.86^{a}
Group C (RVS)	8.17±1.69^{a,ns}

^{a}p<0.001,^{b}p<0.01,^{c}p<0.05, ns, representation for Group B and C, when compared with Group A, ^{d}p<0.001,^{e}p<0.01, ^{f}p<0.05, and ns, representation for Group C when compared with Group B, ns = Non significant

b. Retention: memory from the 10th-70st day after acquisition

Memory on 10th day: The treated Groups B (4.78±0.88) and C (4.28±0.75) showed a significant decrease (p<0.001) in a number of trials taken for retention when compared with Group A (11.56±1.09).

Memory on 20th day: The treated Groups B (4.61±1.09) and C (4.0±0.69) showed a significant decrease (p<0.001) in a number of trials taken for retention when compared with Group A (11.50±0.92).

Memory on 30th day: The treated Groups B (4.33±0.97) and C (3.83±0.71) showed a significant decrease (p<0.001) in a number of trials taken for retention when compared with Group A (11.56±1.09).

Memory on 40th day: The treated Groups B (4.39±1.20) and C (3.83±0.62) showed a significant decrease (p<0.001) in a number of trials taken for retention when compared with Group A (11.17±0.86).

Memory on 50th day: The treated Groups B (3.78±0.43) and C (3.44±0.51) showed a significant decrease (p<0.001) in a number of trials taken for retention when compared with Group A (10.94±0.64).

Memory on 60th day: The treated Groups B (3.67±0.59) and C (3.39±0.50) showed a significant decrease (p<0.001) in a number of trials taken for retention when compared with Group A (11.17±0.92).

Memory on 70th day: The treated Groups B (3.56±0.51) and C (3.0±0.00) showed a significant decrease (p<0.001) in a number of trials taken for retention when compared with Group A (11.11±0.90). Results showed in table 4.

Table 4: No. of trails taken by each group of rats in each days of retention

Groups	Retention from 10th–70th day (mean±SD)						
	10th	20th	30th	40th	50th	60th	70th
Group A (Control)	11.56± 1.09	11.50± 0.92	11.56± 1.09	11.17± 0.86	10.94± 0.64	11.17± 0.92	11.11± 0.90
Group B (Phy)	4.78± 0.88[a]	4.61± 1.09[a]	4.33± 0.97[a]	4.39± 1.20[a]	3.78± 0.43[a]	3.67± 0.59[a]	3.56± 0.51[a]
Group C (RVS)	4.28± 0.75 [a,ns]	4.0± 0.69 [a,ns]	3.83± 0.71 [a,ns]	3.83± 0.62 [a,ns]	3.44± 0.51[a,ns]	3.39± 0.50[a,ns]	3.00± 0.00[a,ns]

[a]p<0.001,[b]p<0.01,[c]p<0.05 representation for Group B and C, when compared with Group A, [d]p<0.001,[e]p<0.01, [f]p<0.05 and [ns](Non-Significant), representation for Group C when compared with Group B.

From the analysis, it is observed that the treated Groups (B and C) showed a significant decrease in a number of trials taken for both acquisition and retention when compared with the Control (Group A), but no significant difference was observed between the Group B (Physostigmine) and Group C (RVS). In retention from the 50th day of retention onwards a considerable reduction in no. of trails were seen within each treated groups. This indicates that Rotatory Vestibular stimulation and physo-stigmine equally responsible for LTP.

ii) Neuromorphological analysis

a. Dendritic branching points

0-20 µm concentric circle: The treated Groups B (10.30±0.63, p<0.01) and C (13.63±0.99, p<0.001) showed a significant increase in a number of branching points when compared with Group A (7.33±0.92). A significant increase in dendritic branching points in Group C (p<0.01) when compared with Group B.

20-40 µm concentric circle: The treated Groups B (20.33±1.15) and C (25.50±1.48) showed a significant increase (p<0.001) in a number of branching points when compared with Group A (9.33±0.58). A significant increase in dendritic branching points in Group C (p<0.001) when compared with Group **40-60 µm concentric circle:** The treated Groups B (18.77±3.20) and C (23.53±0.52) showed a significant increase (p<0.001) in a number of branching points when compared with Group A (9.27±0.37). A significant increase in dendritic branching points in Group C (p<0.001) when compared with Group B.

60-80 µm concentric circle: The treated Groups B (16.50±1.52) and C (20.90±1.38) showed a significant increase (p<0.001) in a number of branching points when compared with Group A (8.80±0.85). A significant increase in dendritic branching points in Group C (p<0.001) when compared with Group B.

80-100 µm concentric circle: The treated Groups B (14.13±1.21) and C (18.47±1.54) showed a significant increase (p<0.001) in a number of branching points when compared with Group A (8.72±0.44). A significant increase in dendritic branching points in Group C (p<0.001) when compared with Group B.

100-120 µm concentric circle: The treated Groups B (6.83±0.50, p<0.01) and C (10.07±1.18, p<0.001) showed a significant increase in a number of branching points when compared with Group A (3.55±0.39). A significant increase in dendritic branching points in Group C (p<0.01) when compared with Group B.

From the analysis it is clear that dendritic branching points are significantly increased in 20-40 µm to 80-100 µm concentric circles, when compare with the control and among these 20-40 µm concentric circle showed a highly increased branching points in comparison with others. A significant increase in Group C than Group B indicates that Rotatory Vestibular Stimulation enhances the dendritic branching points. Results showed in table 5.

Table 5: No. of dendritic branching points of hippocampal pyramidal neurones of rats, results in (mean±SD)

Groups	Concentric circles					
	0-20 µm	20-40 µm	40-60 µm	60-80 µm	80-100 µm	100-120 µm
Group A (Control)	7.33±0.92	9.33±0.58	9.27±0.38	8.80±0.85	8.72±0.44	3.55±0.39
Group B (Phy)	10.30±0.63[b]	20.33±1.15[a]	18.77±3.20[a]	16.50±1.52[a]	14.13±1.21[a]	6.83±0.50[b]
Group C (RVS)	13.63±0.99[a,e]	25.50±1.48[a,d]	23.53±0.52[a,d]	20.90±1.38 [a,d]	18.47±1.54 [a,d]	10.07±1.18 [a,e]

[a]p<0.001,[b]p<0.01,[c]p<0.05 representation for Group B and C, when compared with Group A, [d]p<0.001,[e]p<0.01, [f]p<0.05, [ns] (Non-Significant), representation for Group C when compared with Group B.

Dendritic Intersections

20 µm concentric circle: The treated Group B (13.23±1.27) showed a non-significant and Group C (15.83±0.48, p<0.01) showed a significant increase in a number of the dendritic intersection when compared with Group A (8.77±0.19). No significant difference observed between Group B and C.

40 µm concentric circle: The treated Groups B (21.60±0.96) and C (30.27±5.47) showed a significant increase (p<0.001) in a number of the dendritic intersection when compared with Group A (13.08±0.43). A significant increase observed in Group C (p<0.001) when to compare to Group B.

60 µm concentric circle: The treated Groups B (39.23±4.11) and C (35.67±4.61) showed a significant increase (p<0.001) in a number of the dendritic intersection when compared with Group A (20.60±0.40). No significant difference observed between Group B and C.

80 µm concentric circle: The treated Groups B (43.0±1.96) and C (43.57±2.16) showed a significant increase (p<0.001) in a number of

dendritic intersection when compared with Group A (21.93±0.53). No significant difference observed between Group B and C.

100 µm concentric circle: The treated Groups B (36.70±1.99) and C (38.13±4.70) showed a significant increase (p<0.001) in a number of the dendritic intersection when compared with Group A (9.33±0.51). No significant difference observed between Group B and C.

120 µm concentric circle: The treated Group B (14.10±3.14) showed a non-significant and Group C (16.53±2.15, p<0.001) showed a significant increase in a number of the dendritic intersection when compared with Group A (8.95±0.54). No significant difference observed between Group B and C.

From the analysis, it is clear that the dendritic intersection increased from 40 µm concentric circle to 80 µm concentric circle, in each group but dendritic intersection gradually decreased in 100 µm and 120 µm. The dendritic intersection at its peak was observed in 80 µm. Results showed in table 6.

Biochemical analysis

The rate of Acetylcholinesterase of Group B (5.17±0.71**)** and C (5.24±0.55**)** is significantly decreased when compare with the Group A (6.87±0.65, p<0.001). There is no significant difference between group B and C. From the result it is clear that rate of AChE activity is reduced in treated groups of rats and this, in turn, resulted in improved learning and memory. Results showed in table 7.

Table 6: No. of dendritic intersections of hippocampal pyramidal neurons of rats. Results in (mean±SD)

Groups	Concentric circles					
	20 µm	40 µm	60 µm	80 µm	100 µm	120 µm
Group A (Control)	8.77±0.19	13.08±0.43	20.60±0.40	21.93±0.53	9.33±0.51	8.95±0.54
Group B (Phy)	13.23±1.27^{ns}	21.60±0.96^{a}	39.23±4.11^{a}	43.0±1.96^{a}	36.70±1.99^{a}	14.10±3.14^{ns}
Group C (RVS)	15.83±0.48^{b,ns}	30.27±5.47^{a,d}	35.67±4.61^{a,ns}	43.5±2.16^{a,ns}	38.13±4.70^{a,ns}	16.53±2.15^{a,ns}

^{a}p<0.001,^{b}p<0.01,^{c}p<0.05, ns, representation for Group B and C, when compared with Group A, ^{d}p<0.001,^{e}p<0.01, ^{f}p<0.05, ns, representation for Group C when compared with Group B, ns = Non-Significant, It is clear from the geomorphological analysis that dendritic arborization is increased in Group B and C when compares to the Control Group, but Group B and C showed a rather similar result in dendritic intersection.

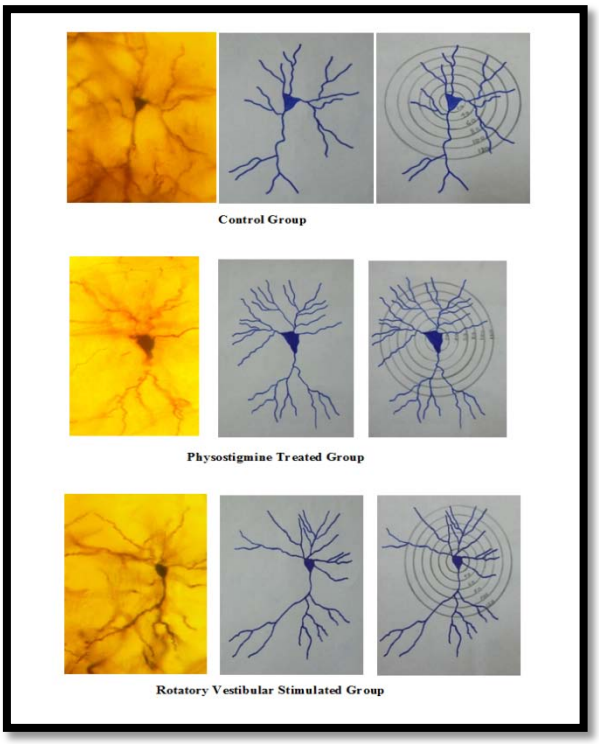


Fig. 2: Microphotograph and camera lucida tracing of hippocampal pyramidal neurones in different groups of rats

Table 7: AChE activity in hippocampus of rats

Groups	AChE activity in µmoles/g tissue/min (mean±SD)
Group A (Control)	6.87±0.65
Group B (Phy)	5.17±0.71^{a}
Group C (RVS)	5.24±0.55^{a,ns}

^{a}p<0.001,^{b}p<0.01,^{c}p<0.05,ns, representation for Group B and C, when compared with Group A, ^{d}p<0.001,^{e}p<0.01, ^{f}p<0.05, ns, representation for Group C when compared with Group B, ns = Non-Significant.

DISCUSSION

In the present study rats provided with RVS enhanced learning, memory through increasing dendritic arborization and decreasing AChE activity. Similar results were observed with the standard drug also. This indicates that Rotatory Vestibular Stimulation enhances long-term potentiation (LTP) as physostigmine improves memory. This is in par with several previous reports [14]. Different types of rotations provide vestibular stimulation are, spinning, dancing, rolling, jumping, running, soccer and basketball games, rotating circular, or turning types of motion. Stimulation at the maximum happens when the movement is started or stopped or where there is a change in the speed of the motion. Slight stimulation has occurred in between starting and stopping. Head rotations result in stimulation of the semicircular canals by the movement of the fluid in the semicircular canal [14]. Stimulation of hippocampal neurones holds back glucocorticoids secretion, a hormone which impairs learning and memory [15]. Still, a common denigration to spinning motion [16] and centrifugation studies [17] is that both engross combined semicircular canal and otolith stimulation. Consequently, the exact input of the semicircular canal to the acuity of verticality cannot be clearly deduced. But in the present study vestibular stimulation in a comfortable speed diminishes stress and also stimulates the semicircular canal and made learning and memory easy.

Vestibular nuclei and hippocampus have anatomical connections [18] and vestibular stimulation hinder both the stress axes (HPA-hypothalamic-pituitary-adrenocortical) and sympathetic adrenomedullary (SAM) axis, and consequently reduces glucocorticoids and cortisol level and also maintains heart rate and blood pressure within normal range, promotes sleep, and thus improves cognition [2,6, 20]. This may be because of the firing of two types of hippocampal neurones (place cells and HD cells) crucial for spatial behaviour through vestibular stimulation [21]. Vestibular stimulation is a very effectual and dependable loom for treating attention deficit or hyperactivity disorder particularly when combined with other training [3] because vestibular stimulation activates the hippocampal formation, parietal cortex and retrosplenial cortex in humans [22] and rats [23]. In addition, vestibular stimulation alters primate neuronal activity [24] and rat hippocampal place cell activity [25]. The hippocampal theta rhythm and HD cell activity also augmented through vestibular input [26, 27]. In a spatial discrimination task study using cross maze normal rats received rotational stimulation for 20 d with ten full revolutions showed improvement. This indicates that adaptation to vestibular

system stimulation is needed for the perfection of cognition even in normal rats [28]. The horizontal semicircular canals activated and stimulated by rotation. Rotatory chairs activate the horizontal semicircular canals, particularly when the participant is in upright sitting position. Behavioural reactions may be multifarious in the centrifugal rotation. The centrifugal rotations induce a combined tilt-translation sensation such as being on a gondola [29]. These results suggest to the use of linear motion simulators allowing the motion and positioning in space to stimulate the otolithic organ, and also frequency and displacement range is rationally limited when compared to rotatory chairs. Certain herbal extracts like *Centella asiatica*, *Myristica fragrans and Curcuma longa* forms growth factors such as brain-derived neurotrophic factor (BDNF) which will bring alteration in dendritic structure and will induce the formation of new synapses [30-34]. The hippocampus is the fundamental integrative centre which regulates the exploratory activities and also for incorporating spatial information [35]. The hippocampal area is engaged in long-term potentiation (LTP) by using nootropic drugs [36]. An increase in the dendritic arborization and synapses in the hippocampal pyramidal neurones results in the facilitation of cognition (learning/acquisition) and performance in the spatial learning tasks. The increase in dendritic arborization also increases the number of synaptic connections with the neurones. This can be considered as the root of the neural basis for the improved cognitive functions in the treated rats. In the present study, we used rotatory vestibular stimulation and noticed a significant improvement in learning and memory as the horizontal semicircular canals activated by rotation and also the hippocampal formation acquired activation and increased dendritic arborization and decreased AChE activity without any discomfort or physical illness in rats.

CONCLUSION

Learning and memory enhanced in rotatory vestibular stimulation *via* increased dendritic arborization and decreased AChE activity. Rotatory vestibular stimulation can be recommended as a secure and simple way of improving learning and memory power in normal rats. Further studies have to be done to find out the BDNF level in vestibular stimulated rats.

ABBREVIATION

Physostigmine: Phy, Acetylcholinesterase: AChE, Brain-derived neurotrophic growth factor: BDNF, Long-term potentiation: LTP, Head direction cells: HD cells, Rotatory vestibular stimulation: RVS, Revolutions per minute: rpm.

CONFLICT OF INTERESTS

Declared none

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