ORIGINAL RESEARCH

Acquisition and retention of a complex task is ameliorated when learned in alternation with a simple task

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Abstract

A novel alternated dual task (ADT) was designed to clarify whether increasing novelty and alternation factors in a task will increase or decrease the short term and long term memory in rats. Rats were made to learn T-maze (TM) spontaneous alternation task and radial arm maze (RAM) task alternatively. Administration of anticholinergic drug scopolamine (SC) and a cholinesterase inhibitor, rivastigmine (RVM) was used to see whether adopting ADT procedure could withstand the deterioration in spatial memory caused by anticholinergic drug and is it comparable to a cognitive enhancement caused by cholinesterase inhibitor. The results showed that ADT help to learn a complex task faster than learning it in isolation from other tasks. An anticholinergic drug, SC showed similar decrement in both TM and RAM tasks. But this decrement can be decreased by adopting ADT procedure, especially for complex task (RAM). The influence of ADT on SC treated rats was similar to the effects of rivastigmine. But this similarity was restricted to RAM task and TM task was less influenced by ADT procedure. The improvement in spatial learning and memory due to ADT are discussed on the basis alternation and novelty drive hypothesis.

Introduction

Animals who are moving in space may compute their current position by path integration, that is, by detecting movement-generated or idiothetic cues; or they may use allothetic cues generated by combinations of environmental land marks.[1] It has been suggested that allocentric spatial impairments reflect the role of the hippocampus system in detecting and controlling the animal's movements through space[1]. Also it was shown that hippocampal – system lesions typically disrupt allocentric (defined with respect to external land marks) spatial learning but leave egocentric (defined with respect to rat's body axis) learning intact.[1] Spatial memory is the part of memory responsible for recording information about rat's environment and its spatial orientation. Spatial working memory in this article specifically refers to the memory for intermediate results that must be held during performance of a spatial task by the rat.

Allocentric spatial learning can be assessed using T-maze spontaneous alternation (TM) task and also using Radial arm maze (RAM) task.[2, 3] In general there is a tendency to go to the part of the environment that has been least recently explored.[4] In its simplest form, spontaneous alternation behavior was first described nearly 85 years ago[5], the phenomenon has been ascribed to the operation of a variety of mechanisms including Hullian reactive inhibition[6], stimulus satiation[7], action decrement [8], curiosity [9], habituation to novelty [10], foraging strategies [11] and spatial working memory.[12]

A more complex dual alternated task was designed to clarify whether increasing novelty and alternation factors in a task will increase or decrease the short term and long term memory in rats. In this study both T-maze spontaneous alternation task and RAM task was used. The evaluation of allocentric spatial learning was done by making rats to learn both the task alternatively as well as learning them separately. The influence of one behavioural task on another one depending on its complexity was investigated. A simple task like T-maze task was made to learn by the rats in alternation to a complex task like RAM task. We named this particular task as 'alternated dual task' (ADT). In the present study the aim was to determine whether learning a simple task (T-maze) along with a complex task (RAM), elongates or reduces the acquisition time for either of the task, and whether any influence on retention (memory) can be observed.

It has been suggested that allocentric spatial impairments reflect the role of the hippocampus system in detecting and controlling the animal's movements through space.[13,14] Also it has been shown that hippocampal – system lesions typically disrupt allocentric (defined with respect to external land marks) spatial learning but leave egocentric (defined with respect to rat's body axis) learning intact.[15,16,17] A number of cholinesterase inhibitors have been shown to improve cognitive functions.[18-21] On the other hand, anticholinergic drugs, like scopolamine (SC), can disrupt short-term or working memory in humans and animals.[22,23,24] Peripheral injections of anticholinergic

drugs like scopolamine and hippocampal lesions produce similar effects in rats in a number of behavioral tasks. [25- 29]

For assessing the involvement of hippocampus in 'alternated dual task' the administration of anticholinergic drug SC was used. The main aim was to see whether adopting ADT procedure could withstand the deterioration in spatial memory caused by anticholinergic drugs. SC was administered separately during acquisition and during retention phases in different groups. The lack of a post-acquisition impairment after hippocampectomy[30] or scopolamine injection[30,31] might reflect the use by the animal of non-spatial strategies in some types of maze. A large number of studies support the role for acetylcholine in short-term memory and the acquisition of new information.[32] It was also shown that radial arm maze performance might be more susceptible to impairment than performance on the Morris water maze.[33] In present study the scopolamine was used to see the participation of cholinergic systems in performance of a novel 'alternated dual task'.

Rivastigmine (RVM) is a carbamate inhibitor of acetylcholinesterase (AChE) with a relatively selective action on the enzyme in brain compared with that in the heart and skeletal muscle.[34, 35] RVM causes long inhibition on AChE of up to 10 hours.[36] Bejar, Wang, & Weinstock, in 1999 [37] showed that RVM (1.5 mg/Kg) antagonized the memory deficits induced by scopolamine (1 mg/Kg). They also showed that RVM at a dose of 1.5 mg/Kg have least adverse effects like diarrhea and tremor. In this study similar to SC, RVM was also used to see the participation of cholinergic systems in performance of a novel 'alternated dual task'.

The present study also compared the effects of a cholinesterase inhibitor, RVM, with that of 'alternated dual task', against SC induced learning and memory impairments in RAM and T maze tasks.

Materials and methods

Subjects: A total of 168 male Wistar albino rats were used for this study. They were housed in groups, in propylene cages in an acclimatized (25 - 27⌾C) room and were maintained on a 12 hr light / dark cycle. Food and water was given *ad libitum* until they aged 60 days at the beginning of the experiment. Average weight of the rats was 180 ± 30 g.

Rats were grouped into four based on the behavioural task, with 42 rats in each group. First group performed only T maze task and designated as TM alone group, and second group had only radial arm maze task and designated as RAM alone group. Third and fourth groups performed both the behavioural tasks. Third group did both the tasks alternatively, hence designated as alternated dual task (ADT) group, but the fourth group did one task first and after completing one phase of it, the second task was done, and designated as non alternated dual task (NADT) group.

Each of the above mentioned four groups were further subdivided into seven groups based on drug administration, with 6 rats in

each group. The seven groups were; control group with only saline injection, scopolamine (SC) administered during acquisition group, SC administered during retention group, rivastigmine (RVM) administered during acquisition group, RVM administered during retention group, RVM & SC administered during acquisition group and RVM & SC administered during retention group.

Apparatus

T-maze: The T-maze used for the study was made of wood with smooth polished surface, consisted of a stem (35◈12 cm), a choice area (12◈12 cm) and two arms (35◈12 cm). The end of each arm contained a food well. The sidewalls are 40 cm high. The choice area is separated from the arms by a sliding door. [2]

Radial arm maze: Radial arm maze was made of Plexiglass, consisted of eight equally spaced arms radiating from an octagonal central platform. Each arm was having a length of 56.2 cm, width of 7.9 cm and height of 10 cm. The entire maze is elevated 80 cm above the floor for easy location of spatial cues by rats.[3]

Drugs: Buscopan® tablets manufactured by Cadila Healthcare limited and Rivamer 1.5 capsules manufactured by Sun pharmaceutical India limited were used. Each Buscopan tablet contained Hyoscine (scopolamine) Butylbromide I P 10 mg and excipients (q.s.). The tablets were powdered and mixed with sterile 0.9% w/v normal saline. It was administered to the rats as intraperitoneal injection at a dose of 1 mg / Kg.[38] Each Rivamer 1.5 capsule contained rivastigmine tartrate equivalent to rivastigmine 1.5 mg and excipients (q. s.). The capsule shell was removed and the powder mixed with sterile 0.9% w/v normal saline. It was administered to the rats as intraperitoneal injection at a dose of 1.5 mg / Kg. [37]

Experimental design

All 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 hrs before the start of behavioural experiments. The body weight was maintained at 85% of the original body weight, through out one session of behavioural experiment.

During various phases of behavioural procedure all the rats received either saline, or any drug (scopolamine (SC) or rivastigmine (RVM)) injection, intraperitonealy, once every day, 30 minutes prior to the start of behavioural experiments. Neither saline nor any drug was administered during the gap days between the phases. Saline injection was given at the rate of 5 ml / Kg body weight of rat, to all the control groups and to all other groups during the phases where drug was not injected. SC was injected at a dose of 1 mg / Kg body weight of rat, only during the phases where it was assigned. Similarly RVM was injected at a dose of 1.5 mg / Kg body weight of rat, only during the phases where it was assigned. In those groups were both the drugs were administered, RVM was

injected 10 minutes before SC injection, and SC was injected 30 minutes before beginning the behavioural trials, every day, either during acquisition or retention depending on the group.

Behavioural experiments were conducted in the same room, with the same allocentric cues, such as doors, windows, posters and the experimenter. Experimenter always maintained same position throughout the whole of the experiment.

The following behavioural experiments were included.

T-maze spontaneous alternation task (TM group)

This was analogous to non-matching to sample task [39], where the rat was rewarded only if the current choice doesn't match the previous one. As reward is used it can also be considered as a learned alternation procedure.[40] In the orientation phase, the starved rats were allowed to spend 10 minutes / day for three days in the T-maze and trained to collect food pellet from the food wells.

During the acquisition test, all the rats were given six trials / day with an inter trial interval of one hour. Each trial consists of four sample and choice run. In the sample run, the rat was placed at the start end of the T-maze stem. Allowed to move towards one arm and collect the food pellet, while keeping the sliding door of other arm closed. In the choice run, the rat was placed at the start end of stem and both arms were kept open. If the rat visits the same arm as that of sample run, it was recorded as error and the rat was not rewarded with food. Instead, if the rat visits the alternate arm, it was recorded as correct score and the rat was allowed to eat food pellet (reward) in the food well. There was an interval of 30s between each run.

Score was given for alternate selection of arm during choice run and a maximum score of '4' can be obtained per trial. The acquisition test was continued until the rats attained the learning criteria of obtaining '4' correct score without any error for three consecutive trials.

Ten days after the last day of acquisition of the task, the rats were subjected to retention test. The test was conducted similar to acquisition test and was continued until the rats attained the learning criteria.

Radial arm maze task (RAM group)

Orientation phase was for three days, where the starved rats were allowed to familiarize themselves with the radial maze. Prior to each acquisition trial, all the eight arms were baited with food pellets. The rat was placed in the center of the maze and allowed to freely explore the maze. The rats were required to take the food pellet from each arm without making a reentry into the arm already visited. The trial was terminated when the animal takes the food reward from all the eight arms or after 10 minutes if all the eight arms were not visited. A correct score was given when the rat visits an arm and collect the food reward, and a maximum score of '8' can be attained per trial. When a rat reenters an already visited

arm or doesn't enter an arm, it was taken as error. The acquisition test was continued until the rats attained learning criteria of obtaining a correct score ¤ 7, and an error ✪ 1, for three consecutive trials. Six trials / day was given with an inter trial interval of one hour.

Ten days after the last day of acquisition of the task, the rats were subjected to retention test. It was continued until the learning criteria were attained.

Alternated dual task (ADT)

Rats were trained to learn two tasks viz; T-maze spontaneous alternation (TM) task and radial arm maze (RAM) task. In the alternated dual task the rat was given the TM trial first then followed by RAM trial with an interval of one minute between them. The task was alternatively given with six trials (3 T-maze trials and 3 RAM trials) per day. The interval between one coupled TM–RAM trial to the next one was one hour. Studies in our lab showed that in ADT when RAM trial was given first followed by TM trial there was no difference in the results compared to the present protocol where TM trial was given first then followed by RAM trial.[1, 41, 42] These comparative results are not given in the present article.

In the orientation phase, the starved rats were given 10 minutes / maze / day for three days and trained to collect food pellet from food wells. The acquisition phase was begun soon after the orientation and score was calculated. It was continued until the learning criteria were obtained for both the tasks separately. Ten days of gap was given in between acquisition phase and retention phase. Retention phase was also continued until the learning criteria were attained for both tasks separately.

Non alternated dual task (NADT)

This group of rats were also given dual task, but the tasks were learned separately without alternating, i.e. the rats learned TM task first by giving six trials / day with an inter trial interval of one hour, and after attaining the learning criteria, the RAM task was learned also by giving six trials / day with an inter trial interval of one hour. 10 days after acquisition of both tasks retention test was carried out until attaining learning criteria.

Statistical analysis was performed using SPSS version 10.0.1 for Windows. Significance was accepted at $p < 0.05$. Means and standard deviations are reported. Number of animals used in all groups are 6.

Results

Saline treated groups

Number of trials to criteria for T maze (TM) task and radial arm maze (RAM) task by different saline treated groups are shown in figure 1. One way ANOVA with least significant difference (LSD) post test for number of trials to criteria for acquiring TM task by different saline treated groups revealed that there was no significant difference between them, $F(2, 15) = 0.190$, $p = 0.829$. That is to say that TM alone group, alternated dual task (ADT) group, and non alternated dual task (NADT) group

took similar number of trials to criteria for acquisition of TM task, indicating that neither ADT nor NADT procedures have influenced the acquisition of TM task. During retention of TM task number of trials to criteria showed a slight significant difference in one way ANOVA between the three saline treated groups, F (2, 15) = 5.098, p = 0.02. The significant difference was observed in LSD post test between TM alone and TM task of ADT groups (p = 0.007) and between TM task of ADT and NADT groups (p = 0.041), but not between TM alone and TM task of NADT groups (p = 0.404). This indicates that only ADT procedure and not NADT procedure have got slight influence on retention of TM task.

In the case of RAM task one way ANOVA during acquisition (F (2, 15) = 11.756, p = 0.001) and during retention (F (2, 15) = 35, p < 0.001) showed significant difference. A LSD post test during acquisition showed significant difference between RAM alone and RAM task of ADT groups (p = 0.002) and between RAM task of ADT and NADT groups (p < 0.001), but not between RAM alone and RAM task of NADT groups (p = 0.519). Similar results were observed during retention also. This indicates that by adopting ADT procedure both acquisition and retention of RAM task was enhanced, but NADT procedure has not enhanced it. NADT group of rats behaved similar to TM alone and RAM alone groups.

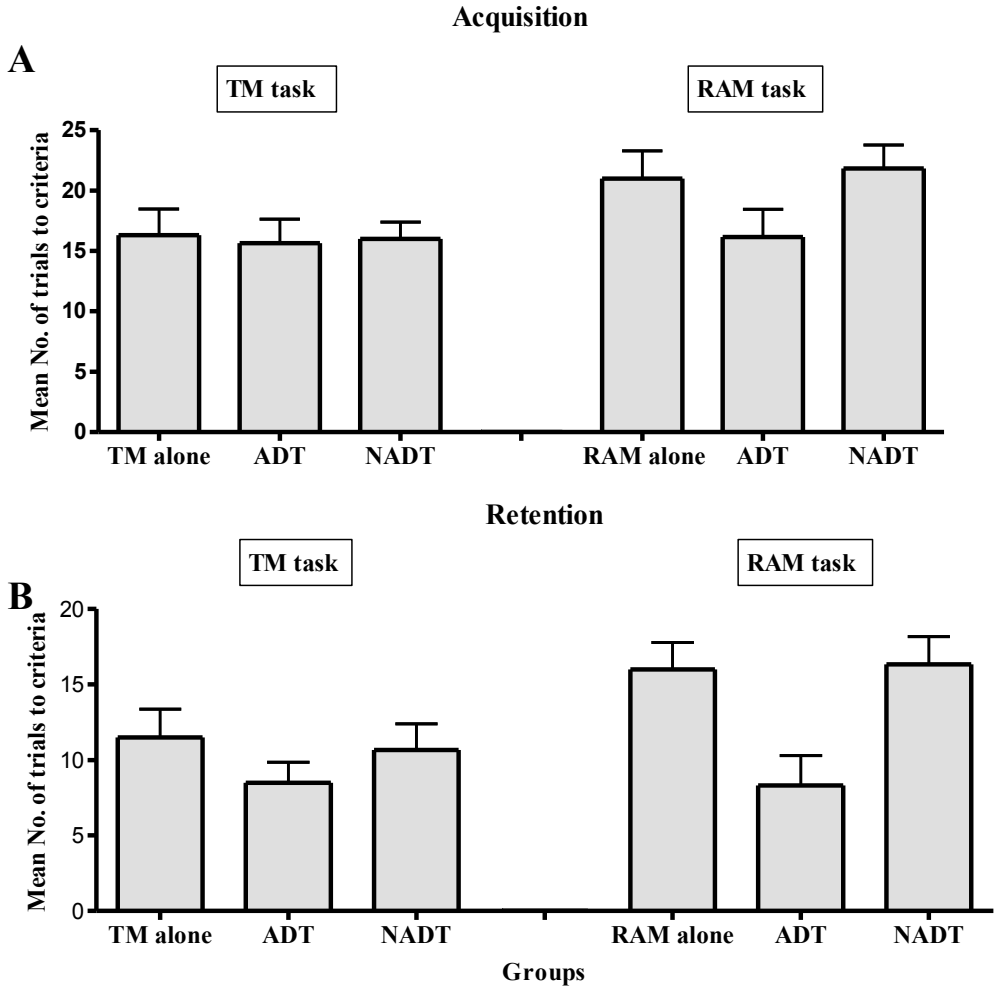

Figure 1: Number of trials to criteria for TM and RAM tasks by different saline treated groups. A: Left panel indicates similar number of trials to criteria required for acquisition of TM task by the three groups. But on right panel for RAM task ADT group took significantly less number of trials to criteria than other groups. B: During retention in both TM and RAM task ADT group took significantly less number of trials to criteria than other groups. TM = T maze, RAM = radial arm maze, ADT = alternated dual task group, NADT = non alternated dual task group, TM alone = single task group with TM task and RAM alone = single task group with RAM task. Error bars indicate standard deviation.

The fact that the RAM task is more complex than the TM task was indicated by '*t*' test done separately during acquisition and retention between TM alone and RAM alone groups. The results showed that RAM alone group took more number of trials to criteria for both acquisition, t (10) = 3.639, p = 0.005, and retention, t (10) = 4.258, p =

0.002, than TM alone group. By adopting ADT procedure number of trials to criteria for acquisition and retention of RAM task was brought down to the level of TM task. This fact was revealed in a repeated measure ANOVA within saline treated ADT group. Even though a significant difference was obtained, F (1, 5) = 175, $p < 0.001$, LSD comparisons revealed that there was no significant difference between acquisition of TM task and acquisition of RAM task within ADT group ($p = 0.363$) and also between retention of TM task and retention of RAM task within ADT group ($p = 0.741$). Significant difference was observed only between acquisition and retention of TM task within ADT group ($p < 0.001$) and between acquisition and retention of RAM task within ADT group ($p < 0.001$). But by adopting NADT procedure RAM task took more number of trials to criteria than TM task, which was similar to RAM alone and TM alone groups. This fact was indicated in a repeated measure ANOVA done within saline treated NADT group, which showed a significant difference, F (1, 5) = 212.962, $p < 0.001$. In LSD comparisons significant difference was observed between acquisition of TM task and acquisition of RAM task within NADT group ($p < 0.001$) and also between retention of TM task and retention of RAM task within NADT group ($p < 0.001$).

The above results indicate that the number of trials to criteria for acquisition and retention of RAM task was brought down to the level of TM task by the ADT procedure; hence only in ADT group there was no significant difference between them. A 2 (behavioural tasks, viz; TM and RAM) × 2 (behavioral procedure, viz; single task and alternated dual task) two way ANOVA done separately during acquisition and retention showed a significant interaction between behavioral task × procedure, indicating that ADT procedure influence RAM task more than TM task during acquisition, F (1, 20) = 5.454, $p = 0.03$, and during retention, F (1, 20) = 10.481, $p = 0.004$, (figure 2).

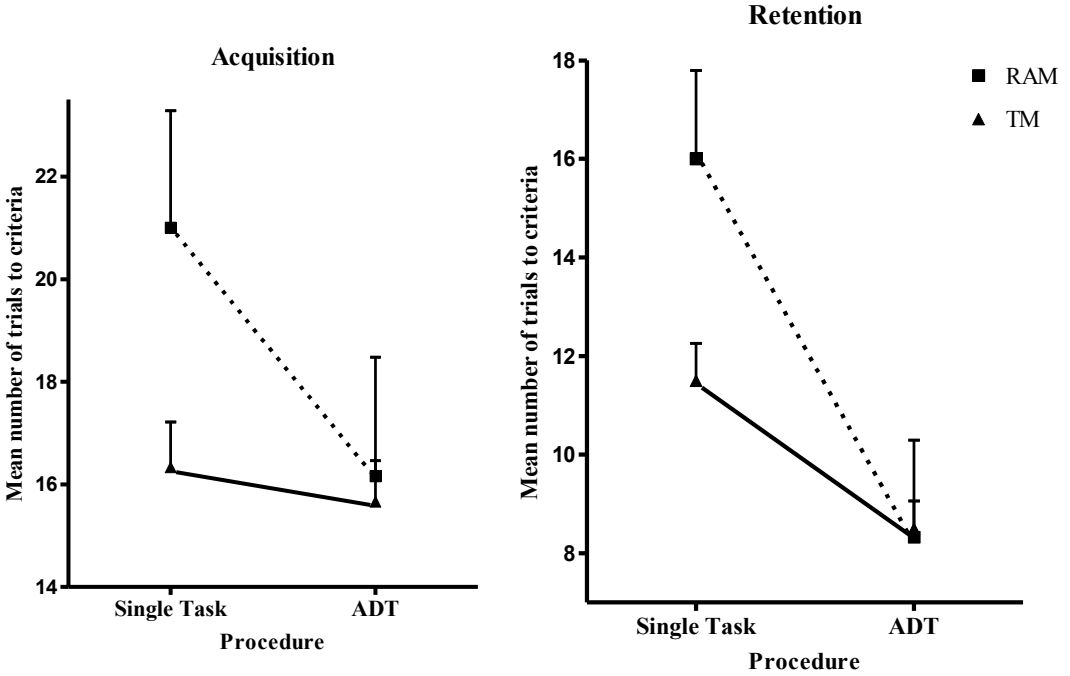

Figure 2: Differential effect of alternated dual task (ADT) procedure on T maze (TM) and radial arm maze (RAM) tasks. During both acquisition and retention ADT procedure reduced the number of trials to criteria for RAM task to the level of TM task. Also note that during retention TM task showed significant difference between single task and ADT, but not in the acquisition phase. Error bars indicate standard deviation.

Paired t test revealed a significant difference between number of trials to criteria for acquisition with that of retention in TM alone group, t (5) = 15.727, p < 0.001, RAM alone group, t (5) = 13.693, p < 0.001, ADT group TM task, t (5) = 23.32, p < 0.001, ADT group RAM task, t (5) = 25.489, p < 0.001, NADT group TM task, t (5) = 25.298, p < 0.001, and NADT group RAM task, t (5) = 11, p < 0.001. These results indicate that in saline treated groups' retention always took less number of trials than acquisition. A 2 (time, viz; acquisition and retention) × 2 (behavioral procedure, viz; single task and alternated dual task) mixed model ANOVA done separately for TM task and RAM task showed a significant interaction between time × behavioral procedure, indicating that ADT procedure influence retention more than acquisition in both TM task, F (1, 10) = 28.824, p < 0.001, and RAM task, F (1, 10) = 35.244, p < 0.001.

Effects of scopolamine

Effect of scopolamine (SC) on TM alone and RAM alone groups are shown in figure 3. A 2 (behavioural task, viz; TM and RAM) × 2 (drug, viz; saline and SC) factorial ANOVA done during acquisition revealed a significant main effect for behavioral tasks, indicating that acquisition of TM task took less number of trials to criteria than RAM task, F (1, 20) = 68.638, p < 0.001. Also the main effect for drug was significant, F (1,

20) = 428.988, $p < 0.001$, indicating that in acquisition of both TM and RAM tasks SC treated rats took more number of trials to criteria than saline treated rats. An interaction between behavioural task × drug showed significant difference, F (1, 20) = 7.626, p = 0.012. But a low Eta squared value of 0.276, gives the conclusion that SC have similar effect on acquisition of both TM and RAM tasks.

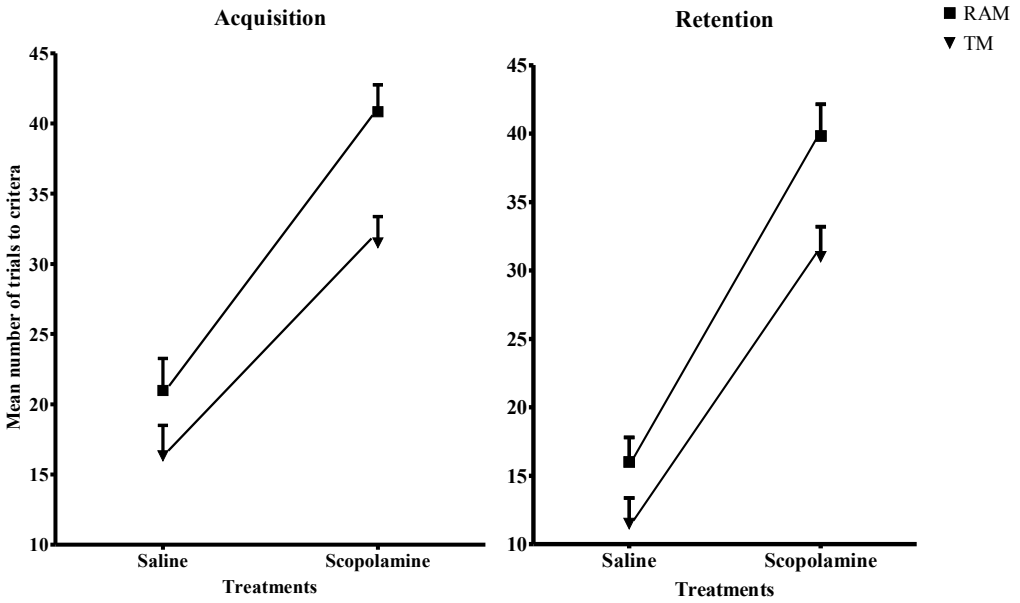

Figure 3: Effect of scopolamine on acquisition and retention in T maze (TM) alone and radial arm maze (RAM) alone groups. Scopolamine caused similar increase in number of trials to criteria for both TM and RAM tasks during acquisition and retention. Error bars indicate standard deviation.

Similar to acquisition, in retention of TM and RAM tasks also the interaction between behavior × drug was less significant F (1, 20) = 6.68, p = 0.018, with a low Eta squared value of 0.25. The main effect of drug was also significant during retention, F (1, 20) = 667.984, p <0.001. This indicates that similar to acquisition, in retention also SC treated rats took more number of trials to criteria than saline treated rats.

Whether SC induced memory deficits can be tolerated by adopting ADT procedure was examined further, by treating ADT and NADT groups of rats with SC during acquisition and retention separately. The results are shown in table 1. Saline treated ADT group and SC treated ADT group was compared using independent sample t test, separately for TM and RAM tasks. A significant difference was obtained during acquisition of TM task, t (10) = 15.996, $p <$ 0.001, and during acquisition of RAM task, t (10) = 15.124, $p < 0.001$. This indicates that even in ADT group SC caused impairment during acquisition. Also during retention of TM task, t (10) = 12.403, $p <$ 0.001, and during retention of RAM task, t (10) = 11.798, $p < 0.001$, significant difference was observed. So SC causes

impairment in ADT group during both acquisition and retention of both TM and RAM tasks.

Table 1. Effect of scopolamine treatment on alternated dual task and non alternated dual task groups. TM = T maze, RAM = radial arm maze, SC = scopolamine, ADT = alternated dual task group, NADT = non alternated dual task group and SD = standard deviation.

		ADT with saline		ADT with SC during acquisition		ADT with SC during retention		NADT with saline		NADT with SC during acquisition		NADT with SC during retention	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Acquisition	TM task	15.66	1.966	31.16	1.329	15.33	1.211	16	1.414	32.16	1.722	16	1.673
	RAM task	16.16	2.317	33.66	1.633	16.16	2.137	21.83	1.941	40.33	1.633	21.33	1.211
Retention	TM task	8.5	1.378	8.33	1.366	19	1.549	10.66	1.751	10.33	1.033	31.33	1.862
	RAM task	8.33	1.97	8.33	1.211	20	1.414	16.33	1.862	16.5	1.049	39.33	1.75

When acquisition of RAM task by RAM alone group with SC treatment during acquisition (M = 40.83, SD = 1.941) was compared to acquisition of RAM task by ADT group with SC treatment during acquisition (M = 33.66, SD = 1.633), there was a significant difference, t (10) = 6.921, p < 0.001. This indicates that impairment of SC on acquisition of RAM task was reduced by adopting ADT procedure. Similarly in retention of RAM task also a significant difference was observed, t (10) = 17.899, p < 0.001. But when acquisition of TM task by TM alone group with SC treatment during acquisition (M = 31.5, SD = 1.871) was compared with acquisition of TM task by ADT group with SC treatment during acquisition (M = 31.16, SD = 1.329), there was no significant difference, t (10) = 0.356, p = 0.729. For retention of TM task significant difference was observed, t (10) = 10.954, p < 0.001. These results indicate that by adopting ADT procedure, acquisition and retention of RAM task was restricted from impairment of SC. But in TM task only retention was restricted and not the acquisition.

Effects of rivastigmine

Mean number of trials to criteria for TM and RAM tasks by different saline treated groups and respective rivastigmine (RVM) treated groups are shown in figure 4. One way ANOVA comparison between these groups showed a significant difference, F (23, 120) = 44.77, p < 0.001. LSD post test results indicate that in all the groups RVM influenced positively the spatial learning and memory.

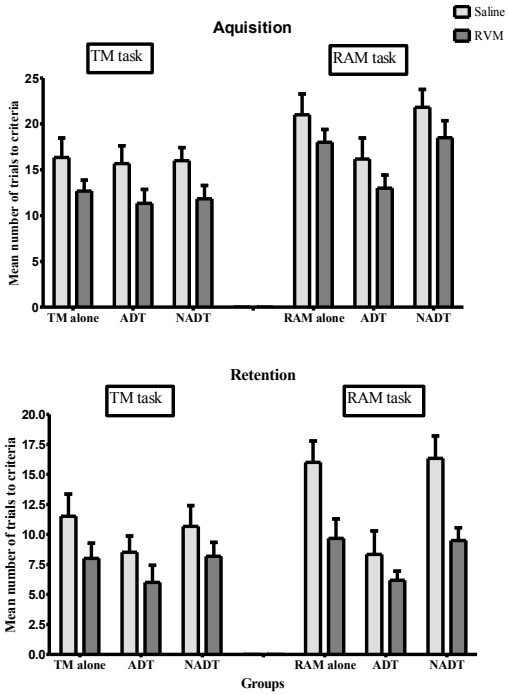

Figure 4: Effect of rivastigmine: During acquisition and retention in all the groups RVM caused significant decrease in number of trials to criteria. RVM = rivastigmine, TM = T maze, RAM = radial arm maze, ADT = alternated dual task group, NADT = non alternated dual task group, TM alone = single task group with TM task and RAM alone = single task group with RAM task. Error bars indicate standard deviation

To see whether the influence of RVM on all groups are uniform or not, a 6 (behavioural tasks, viz; TM alone, TM task of ADT, TM task of NADT, RAM alone, RAM task of ADT and RAM task of NADT) × 2 (drug, viz; saline and RVM) factorial ANOVA was done separately during acquisition and retention.

The non significant interaction between behavioral task × drug during acquisition F (5, 60) = 0.279, p = 0.923, and a significant interaction during retention F (5, 60) = 5.490, p < 0.001, but with a very low Eta squared value of 0.314, indicates that RVM have similar effect in all cases. That is to say that either by adopting ADT or NADT procedures the influence of RVM have no change.

Combined effects of scopolamine and rivastigmine

Mean number of trials to criteria for TM and RAM tasks by different SC treated groups and respective RVM + SC treated groups are shown in figure 5. One way ANOVA comparison between these groups showed a significant difference, F (23, 120) = 152.159, p < 0.001. LSD post test results indicate that in all the groups RVM + SC treatment reduced the impairment caused by SC.

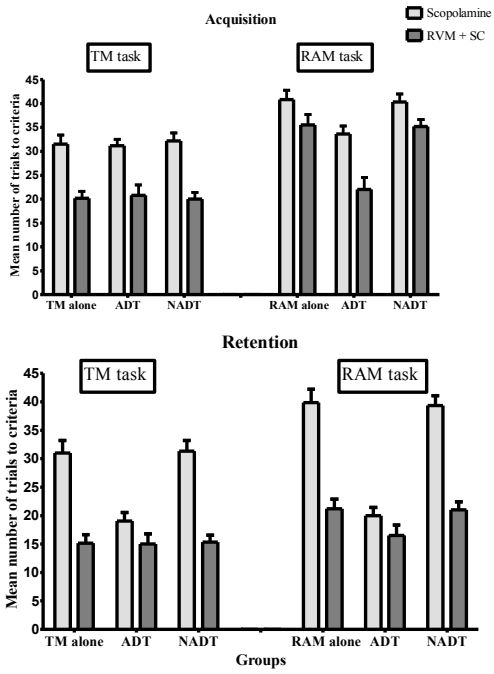

Figure 5: Effect of rivastigmine on scopolamine treated rats: During acquisition and retention in all the groups RVM caused significant decrease in impairment caused by SC. SC = scopolamine, RVM = rivastigmine, TM = T maze, RAM = radial arm maze, ADT = alternated dual task group, NADT = non alternated dual task group, TM alone = single task group with TM task and RAM alone = single task group with RAM task. Error bars indicate standard deviation.

No significant difference was observed between number of trials to criteria for retention of TM task (M = 11.5, SD = 1.871) in TM alone group with saline treatment and retention of TM task (M = 11.33, SD = 1.366) in TM alone group with RVM + SC treatment during acquisition only, t (10) = 0.176, p = 0.864. Similarly for retention of RAM task also no significant difference was observed t (10) = 0.307, p = 0.765. This indicates that a combination of RVM and SC given only during acquisition has not influenced the retention of the task. But this observation was of less importance, because even when only SC was given during acquisition no significant difference was observed between number of trials to criteria for retention of TM task (M = 11.5, SD = 1.871) in saline treated TM alone group and retention of TM task (M = 11.17, SD = 1.169) of TM alone group with SC treatment during acquisition, t (10) = 0.37, p = 0.719. Similarly in retention of RAM task also no significant difference was observed, t (10) = 0.191, p = 0.852. So, when SC alone or a combination of RVM and SC given only during acquisition has not influenced the retention in those rats.

Figure 6 reveals differential influence of RVM and ADT on SC induced deficits. A one way ANOVA comparison between acquisitions of TM task among the three groups viz; TM alone group with SC treatment during acquisition, TM alone group with RVM + SC treatment during acquisition and TM task of ADT group with SC treatment during acquisition, showed a significant difference, F (2, 15) = 100.717, p < 0.001. But LSD post test revealed that significant difference was present only between SC treated and RVM + SC treated TM alone groups, and not between SC treated TM alone group and SC treated ADT group. Also significant difference was present between RVM + SC treated TM alone group and SC treated ADT group. This result indicates that during acquisition of TM task the impairment caused by SC was reduced only by RVM and not by ADT procedure. During retention of TM task a similar one way ANOVA comparison showed a significant difference, F (2,15) = 131.121, p < 0.001. LSD post test showed a significant difference among all the three groups. This indicates that both RVM and ADT reduced the impairment caused by SC, also RVM was found to be more effective than ADT. In the case of RAM task similar comparison also showed significant difference during acquisition, F (2, 15) = 22.41, p < 0.001, and retention, F (2, 15) = 215.758, p < 0.001. But interestingly in LSD post test there was no significant difference between RVM + SC treated RAM alone group and SC treated ADT group during acquisition (p = 0.12) and retention (p = 0.293). These results indicate that for RAM task the reduction in the SC induced impairment caused by RVM and ADT procedure are similar. That is to say that for acquisition and retention of RAM task ADT procedure was very effective in reducing the impairment caused by SC, but in the case of TM task it was not at all effective during

acquisition and less effective during retention.

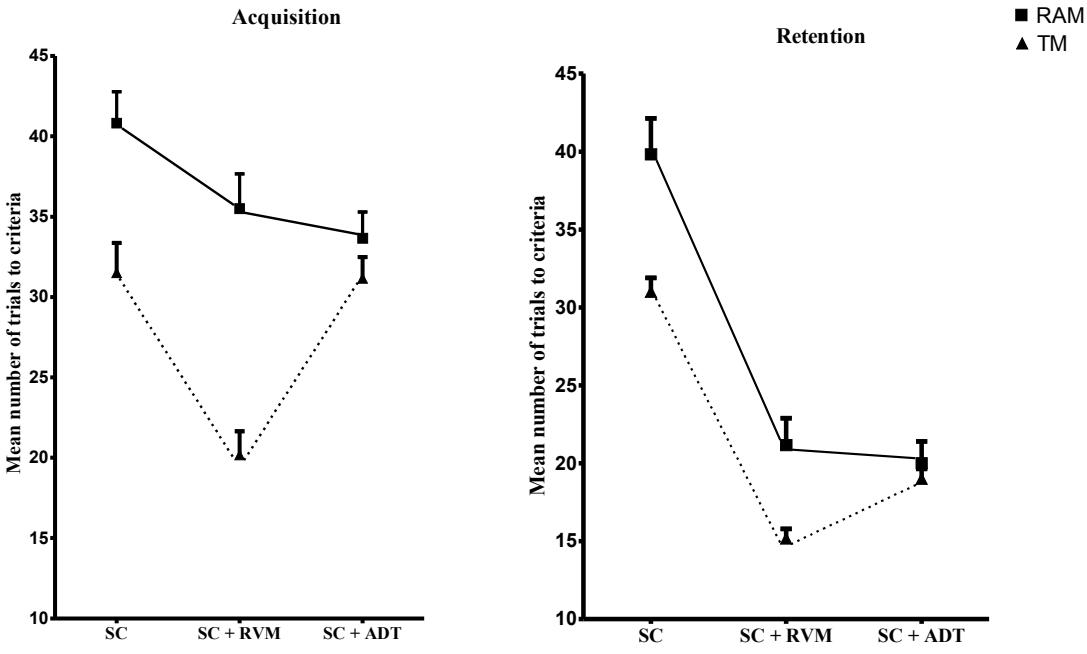

Figure 6: Differential influence of RVM and ADT procedure on SC induced deficits. For RAM task effect of RVM and ADT procedure are almost same in reducing the defects caused by SC during acquisition and retention. But for TM task RVM is more effective than ADT procedure. For TM task ADT procedure have significant influence in reducing the defects caused by SC during retention but still not as much as RVM

Discussion

It is generally agreed that radial arm maze (RAM) task and spontaneous alternation behavioural task in T maze (TM) are hippocampal dependent spatial tasks. The present and other previous experiments revealed that number of trials required for acquisition and retention of TM task is significantly less than RAM task. This gave the basis for considering TM task as a simple task & RAM task as a complex one.

In the saline treated alternated dual task (ADT) groups the number of trials required for acquisition and retention of RAM task was similar to TM task, in contrast to other groups. This indicates that the rats learning ability has increased when the task was alternated. The probable reason for this may be novel learning conditions given alternately. A novel environment represents a stressful condition, and the first exposure to it causes pronounced behavioral activation[43,44], which provides one of the

most elementary forms of learning. As stated by Dember, & Fowler, in 1958,[45] rats tend to choose the environment that has been least recently explored. This could have increased the curiosity, and curiosity tends to increase the ability of alternation behavioural tasks.[8] It was pointed out that rats prefer (over repeated trials) a path leading to a goal box containing complex stimuli over a blind alley or an empty goal box respectively.[46] So when rats were alternated between TM and RAM their learning ability enhanced. Also when rats were learning both the task without alternation, the novelty drive hypothesis [46] was lacking and be the reason why they behaved similar to single tasked groups for having a significant difference between the number of trials required for TM task and RAM task.

When ADT procedure is used, it is seen that a complex task can be learned easily. Moreover the long term memory for the complex task learned is better, and that the task learned faster is not easily forgotten. So this principle of 'alternated dual task' can be made use when a complex task is to be learned by a rat within a short period of time. We have no clear explanation for the finding that learning ability of only complex task is increased due to ADT procedure. Langlais, & Savage, in 1995[47] provided evidence for the fact that high levels of spontaneous alternation are consistent with good spatial memory performance. Here in our experiment also as the complexity in alternation increased by using alternated dual task, the spatial memory performance also enhanced. Since RAM task involve more use of spatial cues than TM task, probably by ADT, spatial memory performance may be enhanced and thus better performance of RAM task.

RAM is more susceptible to impairment by scopolamine (SC) than Morris water maze.[32] But in the present study both TM and RAM task showed almost similar deficit with SC. This is probably because both tasks involve similar rewarded behavioral strategies and neuronal network involved may also be similar. The effects of scopolamine on the retention of well learned maze habits are ambiguous since Domer, & Schueler, in 1960 found it to produce a deficit whereas Pazzagli, & Pepeu, in 1964 failed to demonstrate a scopolamine induced deficit.[48,30] In the present study both acquisition and retention of TM and RAM tasks was impaired by SC, probably because, after acquisition the memory may not be well consolidated in long term memory store. The fact that SC appears to be less disruptive to long term memory storage could not be established here, as retention was equally affected by SC similar to acquisition.

Activation of the forebrain cholinergic system has been demonstrated in many tasks and conditions in which the environment requires the analysis of novel stimuli that may represent a threat or offer a reward.[49] Scopolamine interferes with memory and cognitive function in humans [22] and experimental animals[21, 50] by blocking muscarinic receptors mainly in these brain regions. In ADT also we consider the novel stimuli to be the key factor. This explains the memory ailment, even though less, caused by SC in ADT procedure.

Rivastigmine (RVM) alone clearly reduces the number of trials to criteria in both the tasks by different groups. It was able to antagonize the amnesia produced by SC in all the groups. Also, when the rats were under the influence of a combination of RVM and SC during the acquisition trial, their memory in the retention test was unimpaired. So all these results show that RVM is an effective antagonist of the SC induced deficits in spatial memory and this view is also supported by other works.[36] The present study compared the effects of this relatively novel cholinesterase inhibitor, RVM, with that of ADT procedure against SC induced memory impairments in the RAM task and spontaneous alternation behavioural task in TM. In RAM task both RVM and ADT could restrict the impairment caused by SC, but in TM task only RVM could do it efficiently.

Rats placed in novel environments, showed a 150%–200% increase in acetylcholine (Ach) release from the cortex and hippocampus.[49] Hippocampal ACh release increases during performance of a learned spatial memory task[51,52], and, interestingly, the improvement in RAM performance is positively correlated to the increase in ACh release during 12 days of task learning.[53] These results show that the learning of the spatial task modifies the function of cholinergic neurons projecting to the hippocampus, which become progressively more active. In ADT group of rats probably there is a better positive modification of cholinergic neurons projecting to the hippocampus, compared to other groups, and this may be the explanation for reduced effect of SC in ADT group of rats.

Conclusion

In conclusion it may be stated that "alternated dual task" help to learn a complex task faster than learning it in isolation from other tasks. An anticholinergic drug, scopolamine showed similar decrement in both T maze and radial arm maze tasks. But this decrement can be decreased by adopting procedures like 'alternated dual task', especially for complex task. The influence of "alternated dual task" on scopolamine treated rats were similar to the effects of rivastigmine. But this similarity was restricted to radial arm maze task and T maze task was less influenced by 'alternated dual task' procedure.

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