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Spatial memory in a solitary subterranean rodent *Ctenomys talarum (Rodentia : Ctenomyidae)*

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Almost all research on spatial orientation in animals has been conducted on surface-dwelling species (9), however, more recently studies have focused on spatial orientation in subterranean mammals (10,11). Spatial orientation in underground tunnels must be based on restricted sensory input, because of the limited use of auditory and olfactory cues, and the impossibility of using visual cues. This restriction of sensory stimuli necessitates the development of a mechanism for orienting efficiently within the burrows to reduce the energetic costs of digging (12).

Ctenomys talarum (Thomas, 1898) is a small subterranean rodent found in southern parts of South America (13), that inhabits a system of closed galleries parallel to the soil surface. Animals of both sexes and all ages maintain exclusive territories (5). The complex burrow system of *C. talarum* has a branching structure, consisting of a main axial tunnel and a variable number of lateral branches and feeding tunnels, all of them plugged with soil (1). Although individuals of *C. talarum* forage within their tunnels, the majority of foraging bouts occur above ground, and animals must venture away from their tunnels for brief periods to gather vegetation growing on the soil (5). A highly developed spatial orientation capacity and the ability to learn and memorize a tunnel system is crucial for *C. talarum* to achieve successful foraging, reproduction and to defend a home range within their complex subterranean burrows. The objective of this study was to investigate the ability of *C. talarum* to learn and memorize an artificial maze.

Adult tuco-tuco (*Ctenomys talarum*) of both sexes were trapped in Mar de Cobo (Buenos Aires Province, Argentina ; 37°45´S, 57°56´W) using plastic live traps set at fresh surface mounds, carried to the laboratory and housed in individual plastic cages (25 cm x 32 cm x 42 cm) and maintained in an animal room with photoperiod and temperature automatically controlled (12 :12 L : D ; 25 ± 1° C). Relative ambient humidity ranged from 50 to 70 %. Animals were fed a vegetarian diet. Since *C. talarum* do not drink free water, this source was not provided to the animals. The ability of a total of nine individuals (three males and six females) to learn and memorize a pathway through a burrow system was studied. To investigate the phenomenon of spatial orientation, and following KIMCHI & TERKEL (11) methodology, we built a labyrinth with white PVC tubes (10 cm in diameter) that comprised a series of dead-end paths with one correct path to the goal (Fig. 1).

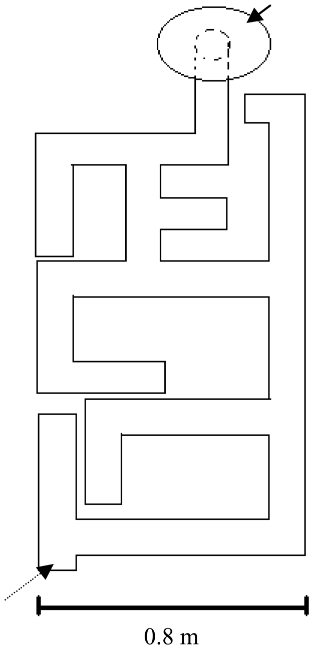

Fig. 1. – Complex labyrinth used for testing spatial memory in *Ctenomys talarum*. The dotted arrow indicates the entrance and the solid arrow the resource goal.

Animals were maintained at 75 and 80 percent of initial body weight for three days prior to the trials to increase their motivation to explore and learn the complex maze. Individuals were introduced into the labyrinth at the entrance, which was subsequently closed. Sweet potato and lettuce were put into the goal cage, the entrance to which was closed with a removable paper lid.

The time spent and the numbers of errors made by individuals to reach the goal cage were recorded for each individual during learning trials (days 1 to 6) and memory trials (15, 30, and 60 days after the learning experiment). In the memory trials each animal was tested only once at only one of the three time intervals. At the end of each trial, the labyrinth was thoroughly washed to ensure that no odors from the previous trial remained. At the end of the experiments animals were fed *ad libitum*, recovered initial body weight after a few days, and remained in good physical condition. They were then returned to their site of capture.

Since both time and error values did not fit a normal distribution, we applied logarithmic transformation to the data. Since error values were zero in some trials we decided to add a constant to this variable before transformation. A repeated measures ANOVA design was used to test the null hypothesis of no differences in time spent to reach the food resource cage and number of errors made before reaching the resource cages during the first to sixth day of

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the learning experiments. A paired t-test was used to test the null hypothesis of no difference in time spent to reach the food resource cage and number of errors made before reaching the resource cages on day 6 of the learning experiment and on days 15, 30 and 60 of the memory experiment.

Concerning spatial learning, individuals of *C. talarum* markedly improved their performance (measured as the number of errors and time spent to reach the resource cage) within the complex maze after the first trial and maintained a similar performance during consecutive trials (Fig. 2). Similar results have been reported for the solitary subterranean rodent, *Spalax ehrenberghi*, which exhibited a clear improvement in performance after the initial trial, and learned a complex maze significantly faster than did surface dwelling rats and voles (11).

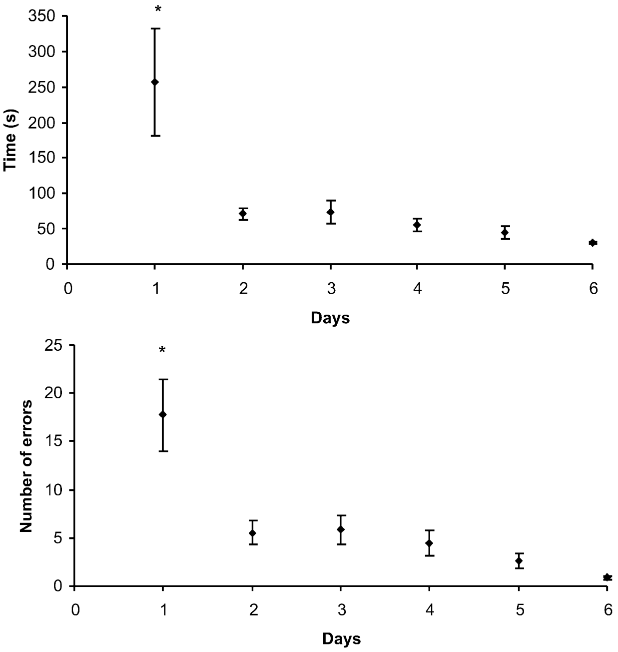

Fig. 2. – Time ± SEM (standard error of the median) spent (A), nd number of errors ± SEM made (B) by *Ctenomys talarum* to reach the resource cage in the complex labyrinth during learning experiment (n = 9). * indicates statistical differences between the first and the other trials ($p < 0.05$).

Sex differences in spatial learning abilities have been documented for several species of rodents (2, 7, 14), while no sex differences were found in the learning performance in other species (8, 11). *C. talarum* exhibited no sex difference in learning ability ($F_{time} = 0.12$, $F_{errors} = 0.15$, d.f. = 7, n = 9, P_{time} and $P_{errors} > 0.5$). This lack of difference in learning performance between males and females of *C. talarum* may be due to the similar size of their burrows (1), since sex differences in learning abilities between male and female rodents have been associated with differences in their home range sizes (8).

The orientation abilities exhibited by many species that are able to avoid or return to particular places in their home ranges involve some kind of spatial memorization (3). *Ctenomys talarum* was able to memorize the complex maze for a period of between 30 and 60 days after the last trial of the learning process, showing a highly developed spatial memory Comparable results were recorded for *S. ehrenbergi* (11) (Table I).

TABLE 1

Time that animals spent traveling trough the labyrinth to reach the resource cage (Time) and number of errors made to reach the resource cage (errors) for the sixth day of the learning trial and for all the days of the memory trial. Values are showed as mean ± SD. (RM ANOVA $t_{time\ 6\text{-}15} = -0.36$, $t_{time\ 6\text{-}30} = -2.92$, $t_{time\ 6\text{-}60} = -6.58$, $t_{error\ 6\text{-}15} = -0.5$, $t_{error\ 6\text{-}30} = -2.52$, $t_{error\ 6\text{-}60} = -4.45$; d.f = 2, n = 3 ; $P_{time\text{-}error\ 6\text{-}15}$, $P_{time\text{-}error\ 6\text{-}30} > 0.05$ and $P_{time\text{-}error\ 6\text{-}60} < 0.05$).

day	Time (seconds)	errors
6	30.78 ± 6.8	0.89 ± 0.6
15	28.67 ± 3.05	1.33 ± 0.58
30	91.33 ± 40.45	4.67 ± 2.31
60	195.67 ± 39.55	13.67 ± 4.16

The restricted sensory input existent in the subterranean ecotope (4) together with the inability of *C. talarum* to use the earth's magnetic field to obtain spatial information (unpubl. data), suggest that *C. talarum* may also rely on internal cues for accurate spatial orientation in their subterranean environment. Internal cues or path integration is a navigational process by which signals generated during locomotion allow the individual to establish its location in relation to its point of departure. Path integration may occur without the help of external references (6). Future studies should focus on determining if *C. talarum* is really able to measure self-generated information without external references to orientate in their subterranean environment.

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