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T-Maze Shock Avoidance in the Hermit Crab *Dardanus arrosor*

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Specimens of the hermit crab *Dardanus arrosor* go indistinctively towards any of the arms of a T-maze if lighting is uniform. The difference between the probabilities of going towards one arm rather than the other tends to zero as the number of trials is increased. If only one of the arms is lightened, hermits go preferably towards the dark one: The difference between the two probabilities tends to 0.500. If the animals attracted by the dark zone are electroshocked (60 V, 2.5 seconds) near their oral zone, the probability of going towards the light zone increases (statistically significant). Differences between the learning abilities of both sexes are not significant.

There are few studies about learning in marine invertebrates (10). *Dardanus arrosor* shows complex behavioral patterns (1, 2, 3) which may be partially modified by learning processes: working with *Pagurus longicarpus*, FINK (6) observed habituation to mechanical rhythmic stimulus; ROSS (9) and BALASCH and MENGUAL (4) show that the behavior of *Dardanus* towards associated sea anemone is modified if predator is present; shell selection behavior depends on learning processes during the larval phase (7, 8).

The aim of this work is to observe how *Dardanus* react to conditioning experiences. The crab is trained through electric shocks (instrumental conditioning) to avoid the dark zone of a T-maze, the usually prefered one.

Materials and Methods

Specimens of *D. arrosor* were collected in off the coast of Barcelona and then left for 48 hours in tanks of 60 × 40 cm without any manipulation, and then carefully observed in order to reject all the injured animals. A T-maze (fig. 1) was placed into the experimental tank.

In order to verify whether animals have any preference for one of the two arms of the maze (Experiment 1) the subject is placed in A. After a while it goes from A to C and then to one or the other arm.

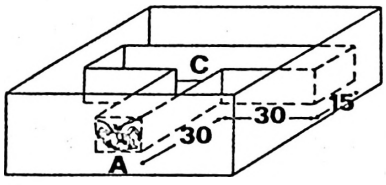

Fig. 1. *T-maze: Animals were left in A. C: central point where the crab choose to go to the light or to the dark zone (Size in cm).*

17 animals were tested, with 10 trials per animal.

To confirm the described attraction (5) towards the dark zones, one arm of the maze was lightened and a gradient of increasing darkness was established from one to the other edge of the maze. When the crab reaches the central point C, it can choose either to walk through the lightened arm or to the dark one. Ten animals were used and 15 trials were done with each of them (Experiment 2).

To produce a reversal behavior to the normally dark attracted animals, subjects walking to the dark zone were electroshocked (60 Volts, 2.5 seconds) at a distance of 2 cm of their oral zone (Exper. 3). The animals walking to the lightened zone were left for 2 minutes before beeing removed. A too quick handling could be associated with punishment (negative reinforcement). 26 crabs, with 70 trials per animal were used. The times that the lightened ending was chosen out of a total of T assays were noted. The obtained index $\alpha = L/T$ permits the comparison between the different subjects, as well as the detection of an increase in the probability of walking to the lightened zone after several shocks. A previous experiment with five subjects with an identical handling (70 trials) and without electroshock was done.

As standardized conditions were necessary, the flow of current marine water was stopped during experiments.

Results

Experiment 1. No preference in the choice of one or the other arm of the maze was observed (86/84) along the 170 trials (10 × 17).

Experiment 2. The dark arm (D) was chosen 112 times out of 150 trials, and the lightened one (L) 38; so, D/T and L/T were 0.747 and 0.253 respectively. The difference between the probabilities to choose one arm or the other $|P(D)-P(L)| = |(D/T)-(L/T)|$ tends to 0.49 as the number of trials increases (fig. 2).

Experiment 3. The mean of the indexes α from the non shocked animals was $\alpha_m = 0.234$, with a s = ± 0.063. On receiving the electroshock, usually the 80 % of the animals retract themselves into the shell, and the 20 % flee to any part of the maze. 20 % of the animals presented 50 % of retractions and 50 % of flights, but the retraction was the most generalized response. The results from the shocked animals (Table I) show that the mean of the α indexes is $\alpha_{ms} = 0.497$, with a standard deviation $s_s = \pm 0.210$.

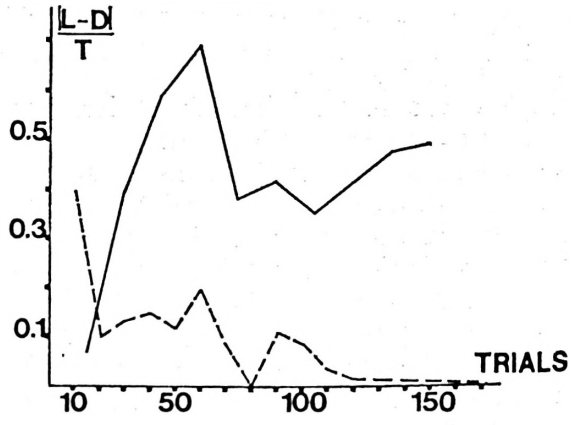

Fig. 2. *Dashed line: The difference between the probabilities to go to one arm or to the other $|P(L)-P(D)|$ tends to zero when there is no differential illumination.*
Continuous line: When one arm is lightened (L) as the other is in the dark (D) the difference between P (L) and P (D) tends to 0.5.

Table I. *α indexes of the 26 animals after 14 days of training.*

Animal and Sex	α Morning	Animal and Sex	α Evening
1 F	0.404	15 M	0.366
2 F	0.271	16 M	0.653
3 M	0.529	17 F	0.528
4 F	0.172	18 F	0.822
5 F	0.685	19 F	0.557
6 F	0.428	20 F	0.657
7 M	0.444	21 F	0.333
8 M	0.585	22 F	0.142
9 F	0.271	23 M	0.589
10 F	0.500	24 F	0.914
11 F	0.657	25 F	0.287
12 M	0.842	26 M	0.171
13 F	0.661		
14 M	0.441		

The difference between this value and the one of the control subjects is statistically significant [t-Student test: $t = 2.733 > 2.045$ ($p = 0.05$)], that is to say that normal behavior is modified by conditioning. Figure 3 shows graphically the ratio L/T along time (trained animals, first 14 days). The lineal regression coefficient is $r = 0.549$, a value not included into the interval (—0.532, +0.532) ($p = 0.05$). Then, it may be concluded that the probability that animals go towards light (L) grows.

Differences between the 16 females and the 10 males used are not significant (Student t test): $\alpha_{mm} = 0.497$, $\alpha_{mf} = 0.507$.

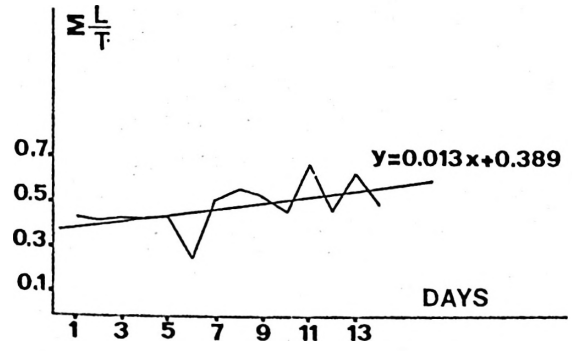

Fig. 3. *Along the 14 first days of training, the probability to go to the light arm (L) of the T-maze grows.*

Thus, *Dardanus* is able to modify its natural behavior by learning.

Some animals were trained in the morning and others in the evening. Although there are no significant differences between them for the α index, the mean times spent in carrying out the trials were significantly different in both groups: $t_{am} = 45.8$ sec/trial and $t_{pm} = 106.9$ sec/trial ($p = 0.05$).

Discussion

In habituation behavioral studies with *Pagurus longicarpus* FINK (6) found a wide range of individual variations, without a clear explanation, and some differences if the animals were used in the morning or in the evening.

The present results agree with Fink's observations. Six trained animals have shown α indexes equal or less than the control animals, but the trained animals as a whole are significantly different in regard to the controls. Time spent to perform the run is shorter in morning trained animals.

Dardanus arrosor seems to be able to discriminate between the two arms of a T-maze with differential illuminations (usually walks to the dark zone). It can be conditioned to avoid an electroshock and to walk to the lightened zone, modifying its normal behavior.

This learning ability is unrelated to sex.

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Resumen

Ejemplares de *Dardanus arrosor* (Crustacea anomura) se dirigen aleatoriamente hacia una u otra rama de un laberinto en T con igual iluminación: la diferencia en la probabilidad de ir a una u otra rama tiende a 0 al aumentar el número de ensayos. Si se oscurece una

de las dos ramas mientras que la otra permanece iluminada, se dirigen preferentemente hacia la zona oscura: la diferencia en la probabilidad de ir a una u otra rama tiende a un valor próximo a 0,500. Mediante la administración de descargas eléctricas (60 V durante 2,5 segundos) a 2 cm de la región oral cada vez que el animal se dirige a la zona oscura, se consigue un incremento significativo en la probabilidad de que los animales se dirijan espontáneamente hacia la zona iluminada.

No existen diferencias significativas entre las capacidades de condicionamiento de los machos y de las hembras.

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