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Comparison of Pavlovian serial conditional discrimination in rats and hamsters in the same experimental situation

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Abstract

The present study compares behavioral changes between two distinct rodent groups, hamsters (*Mesocricetus auratus*) and Wistar rats, when submitted in the same homogeneous experimental situations to a serial conditional discrimination procedure which involves water deprivation and the processing of temporal variables. Both hamsters and rats acquired serial positive conditional discrimination as indicated by higher frequencies of magazine-oriented behavior during the tone followed by reinforcement (T+) and preceded by the feature stimulus light (L) and during the empty interval, than during the tone alone not followed by reinforcement (T-). Rats' frequencies of magazine-oriented behavior were high during T+ and T-, initially during training, and decreased during T- as the training progressed. However, the hamsters' frequencies of magazine-oriented behavior started very low and increased only during T+ as the training progressed. Comparison of the frequencies of magazine-oriented behavior during the empty interval in relation to the frequencies during the preceding L period showed that rats' frequencies remained very high and hamsters' frequencies increased during training. These results suggest that rats and hamsters have different behavioral strategies for the acquisition of a conditional discrimination. The results of the comparisons made in these experiments support the view of the importance of an ecological psychology approach to the understanding of complex learning in animals.

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Key words
- Conditional discrimination
- Hamsters
- Wistar rats
- Behavior repertoire

Introduction

Several studies have shown that the control exerted by stimulus contingencies is dependent on motivational, contextual and species-specific variables. For instance, the changes of behavioral repertoire in rodents and pigeons induced by fixed periodic delivery of reinforcement and recorded by temporal allocation of terminal and interim responses during the inter-reinforcement interval (1) are organized differently. The induced behaviors and their temporal allocation depend on the reinforcement stimulus used: food and water for rats (2), food or intracranial stimulation for hamsters (3,4), or the contextual stimuli present in the experimental box such as water, nesting material

and the chance to see other animals, for food-deprived pigeons (5).

These effects of motivational and contextual variables on the behavioral organization can be better interpreted if we consider the adaptive and phylogenetic aspects present in the behavioral control and the role of the species-specific responses. Different groups of animals (species, genders, families, etc.) have been studied in comparative psychology but usually comparing data obtained in nonhomogeneous experimental situations. Richelle and Lejeune (6) and Lejeune (7) have emphasized the importance of experiments submitting distinct groups of animals to the same experimental situation for a more rigorous comparative approach. Data collected from different groups of animals, but in the same experimental situation with a similar procedure and recording of behavior system, have made significant contributions to the analysis of the adaptive and phylogenetic aspects of the behavioral processes. For instance, Furumoto (8) compared the performance of "White Carneaux" and "wild" pigeons, very close phylogenetically. Bueno et al. (9), studying three groups of rodents, detected differences amongst hamsters and Wistar and McCollum rats, in the temporal allocation of behaviors for long-lasting but not for short-lasting fixed time schedules of water reinforcement. These data suggest that different rodents can have different behavioral strategies in similar situations which depend on their different resources for adaptation to the environment.

Studies of complex learning in animals using procedures of Pavlovian conditional discrimination employ behavioral repertoire changes as an index of learning. Holland (10) observed that auditory stimuli paired with reinforcement deliveries elicited startle, head jerks and some magazine behavior, but visual stimuli paired with an unconditioned stimulus evoked rearing at stimulus onset. Several reports have shown the relationship between stimulus modalities and topography and allocation of rat responses in conditional discrimination experiments (11-15).

In a conditional discrimination procedure, a compound stimulus with simultaneous presentation of its elements (XA) is followed by reinforcement (A+), but one of its elements (A-), when presented alone, is not. The feature stimulus X is assumed to act as an elicitor of the response to the unconditioned stimulus, and the A stimulus has less or no control on the behavior. So, in a simultaneous feature-positive discrimination the X element activates the neural pathway for the unconditioned stimulus. In another situation the same compound stimuli are presented serially to the animal with an empty interval, which is an interval without a presentation of a stimulus, between the stimuli (X→A and A-). In this case, feature stimulus X is assumed to have a modulator function on the elicitor stimulus which is A. In a serial feature-positive discrimination, the X stimulus activates the A-unconditioned stimulus association, and A is the pathway for the unconditioned stimulus. Ross and Holland (15) submitted Wistar rats to trials with simultaneous compound light-tone stimuli followed by reinforcement and to trials with tone not followed by reinforcement (LT+; T-); in the same experiment the rats were submitted to a procedure with serial compound stimuli (L→T+; T-). The results showed that the auditory stimulus or common element T evoked conditioned behaviors specific to auditory stimuli only when it was preceded by a serially composed visual feature stimulus. The authors suggest that there are three sources of response in the serial feature-positive discrimination: 1) the acquisition of a conditional, occasion-setting function in response to the light feature permitted the generation of head jerk behavior by tone-food associations; 2) associations between the light and food resulted in the display of rear and magazine behaviors during the light and subsequent trace intervals, and 3) associations between light and

tone may have produced head jerk behaviors during the trace intervals and caused suppression of startle responding to the tone. The form of the conditioned behaviors depends on the nature of the conditioned stimulus (15). So, the topography of the response is related to the stimuli used.

Studies have shown that hamsters have specific behavioral strategies to compensate for water deprivation (16) and for timing allocation during foraging activity (17) in comparison with rats. There is insufficient evidence in the literature about the learning mechanisms of hamsters in laboratory complex learning. The present study aims to compare behavioral changes between two distinct rodent groups, hamsters and Wistar rats, when submitted in the same laboratory to a serial conditional discrimination procedure which involves water deprivation and the processing of temporal variables.

Material and Methods

Subjects

The subjects were 6 male Wistar rats and 5 male golden hamsters (*Mesocricetus auratus*), experimentally naive, bred in the Central Colony Room of the University of São Paulo. The rats were about 90 days old at the beginning of the experiment and were housed singly in steel cages in the laboratory colony room, on a 12-h light-dark cycle (lights on from 8:00 to 20:00 h). They were maintained at 85% of their *ad libitum* body weight throughout the experiment by limiting their access to water. Food was available at all times in their individual cages.

Apparatus

The apparatus consisted of six identical experimental chambers (FUNBEC model), each 20 x 20 x 23 cm, with a transparent acrylic front, back and top and aluminum sidewalls and floor. Each chamber contained a 1-cm diameter water magazine located in the center of the chamber floor on the right side. The chambers were installed on a wooden rack, located inside a soundproof experimental room with transparent acrylic windows. A constantly lit 5-W lamp was mounted above each chamber. A normally unlit 5-W bulb ('house light') was mounted on the shell, 2 cm above the top of the chamber on the right side. This lamp served as the feature stimulus.

Two speakers (20 W) for delivering auditory stimuli were placed outside the wooden rack, on the left side, and served as conditioned stimulus (a tone of 1000 Hz, 30 dB). An RFM model audio generator (Departamento de Fisiologia, Faculdade de Medicina de Ribeirão Preto) was the source of the auditory stimulus. An interface and software program developed in our laboratory (18) and a PC-XT microcomputer controlled all stimuli. Two TV cameras (Sharp) were mounted 2 m from the experimental chambers, each spanning four chambers in the field of view. Two-videocassette recorders model VR9837AT01 (Magnavox, Greenville, TN, USA) were programmed to record the behaviors occurring during each trial.

Procedure

The subjects were first trained to drink from the magazine and then submitted to a total of 20 serial positive conditional discrimination training sessions. Each session consisted of two types of trials: 6 reinforced serial compound (L→T+) trials, which consisted of a 5-s presentation of the positive feature (L), i.e., steady illumination by the house light, followed by a 5-s empty interval (→) and a 5-s 1000 Hz target tone, which terminated with the delivery of water (T+); 6 non-reinforced tone-alone trials (5-s 1000 Hz target tone), which consisted of the presentation of a 5-s target tone not followed by water delivery.

Each session lasted 38 min. The trials

were mixed randomly throughout each session: the intertrial intervals (mean of 3 min, minimum of 2 and maximum of 4 min) and trial orders were changed daily. All sessions occurred between 20:00 and 22:00 h. Both Wistar rats and hamsters were submitted to the sessions at the same time.

The acquisition criterion of conditional discrimination was a 30% difference of magazine licking responding between T+ and T- during three consecutive sessions.

Behavioral observations

Ten behavioral categories were recorded: magazine sniffing/licking - movements of whiskers and nose twitching within the magazine or licking it (movements of mouth and tongue inside the water magazine) with the four paws on the floor; head jerk - short, rapid, horizontal and/or vertical head movements, usually oriented toward the water magazine; sniffing - movements of whiskers and nose twitching, standing in the middle of the chamber in front of the magazine with the four paws on the floor; near magazine sniffing - movements of whiskers and nose twitching in the middle of the chamber near the magazine with the four paws on the floor; rearing - standing on the hind legs with both forepaws off the floor, whether touching the walls or not, but not grooming; grooming - scratching, fur licking or face-washing; near magazine sitting - standing motionless with four paws on the floor in the middle of the chamber near the magazine, but with nose or head clear (≈3 cm from the magazine); sitting - standing motionless with four paws on the floor in the middle of the chamber in front of the magazine; locomotion - moving from one side to another of the chamber, standing with the four paws on the floor; others - behavioral categories not included in one of those described above.

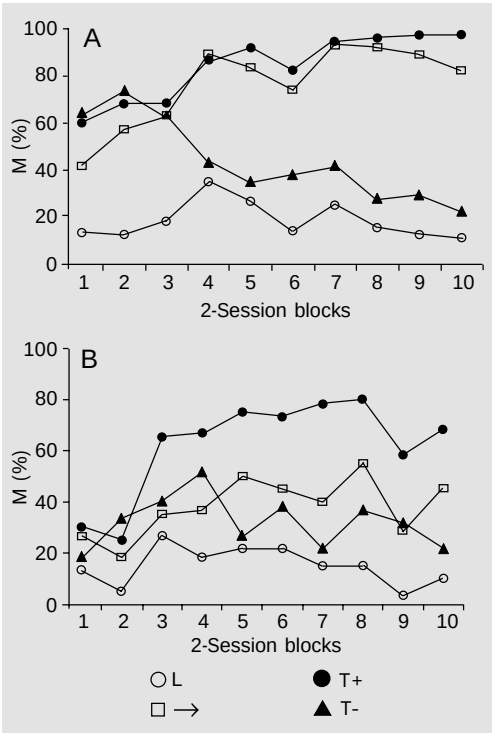

Figure 1. Magazine sniffing/licking behavior (M) during periods of serial compound trials [feature (L); empty interval (→); target followed by reinforcement (T+)], and during tone-alone trials (T-), for Wistar rat (A) and hamster (B) groups in 2-session blocks of discrimination training. Data are reported as means in percent.

Data analysis

The behavioral categories were recorded for all trial sessions. The frequency of magazine sniffing/licking during the auditory stimulus (T+ and T-) was the primary index of learning of the conditional discrimination: the animals should respond with the magazine sniffing/licking response during the tone preceded by the feature stimulus (L) but should not respond during the tone-alone trials. Response frequencies were subjected to three-way repeated measures analysis of variance (ANOVA). The factors used were group (Wistar rats and hamster), 2-session blocks (10 blocks), and trial periods (L, →, T+, T-). A significant level of $P<0.05$ was adopted for all statistical analyses.

Results

Figure 1 shows the acquisition of discrimination by the Wistar (A) and hamster (B) groups for the magazine sniffing/licking category of behavior. Both groups acquired the discrimination, responding more during the T+ trials than during the T- trials. How-

ever, the acquisition of discrimination showed significant differences between groups, as shown by the results of ANOVA for the magazine sniffing/licking category. A three-way ANOVA (groups by session blocks by trial periods) revealed a significant main effect of group ($F_{1,9}$ = 10.89). Interactions of groups with periods ($F_{3,27}$ = 6.17) and groups with session blocks and trial periods ($F_{27,243}$ = 2.76) were also significant. In addition, the main effects of session blocks ($F_{9,81}$ = 2.95) and trial period ($F_{3,27}$ = 64.68) were significant, as were the interactions of session blocks with trial period ($F_{27,243}$ = 7.64).

The differences between group acquisition were examined further by Newman-Keuls tests for individual comparisons. Furthermore, Newman-Keuls tests showed that the magazine sniffing/licking response of Wistar rats was greater than that of hamsters in T- trials over the first 2-session blocks, in T+ over the first and last 2-session blocks and in the empty interval in the 2-, 4-, 5-, 7-, 8-, 9-, and 10-session blocks. In addition, rats response during the first 3-session blocks showed only significant differences between L feature and empty interval and the two target periods (T+ and T-). Also, the rats' response showed 1) significant differences between the T+ and T- periods from the 4th session block, 2) increased response during T+ and → periods over the training sessions, and 3) decreased response during T- periods over the course of session blocks. However, the hamsters' response showed differences between periods only from the 3rd session block, i.e., a greater response during T+ periods when compared with L feature and empty interval. Also, the hamsters' response showed 1) differences between T+ and T- periods from the 5th session block, 2) constant levels during T- periods over the session, and 3) increased response during T+ periods over the course of training.

Table 1 shows behavior during the L feature, empty interval and target followed by reinforcement (T+) and followed by non-reinforcement (T-) over the last 8 sessions of discrimination training for the Wistar and hamster groups. During the L feature, the behavior of most animals comprised categories of rearing and near magazine sniffing. Offset of the L feature produced a substantial decrease of rearing and near magazine sniffing and an increase in the levels of magazine sniffing/licking behavior for Wistar rats during the empty interval. In contrast,

Table 1. Behavioral categories of Wistar rats (RT group) and hamsters (HM group) during periods of serial compound trials [feature (L); empty interval (→); target followed by reinforcement (T+)], and during tone-alone trials (T-), in the last 8 sessions.

Events	Groups	Behavior categories									
		M	H	NMS	S	MSI	SI	L	R	G	O
L	RT	15.97	1.74	17.01	10.07	4.51	1.04	2.78	43.75	3.13	0.00
	HM	10.83	0.00	22.92	12.08	14.17	1.25	6.25	27.92	2.92	1.67
→	RT	88.89	1.74	1.74	2.43	0.35	0.00	2.08	1.74	1.04	0.00
	HM	42.08	0.00	18.33	10.00	7.50	1.25	2.08	15.83	2.50	0.42
T+	RT	95.83	1.74	0.35	0.69	0.00	0.00	0.35	0.69	0.35	0.00
	HM	71.25	0.00	8.33	13.75	3.33	0.42	0.83	1.67	0.42	0.00
T-	RT	31.25	0.35	16.67	11.46	5.90	8.33	3.13	2.78	20.14	0.00
	HM	27.92	0.00	20.83	22.08	12.92	0.83	2.08	9.58	1.67	2.08

Data are reported as means in percent. M, magazine sniffing/licking; H, head jerk; NMS, near magazine sniffing; S, sniffing; MSI, near magazine sitting; SI, sitting; L, locomotion; R, rearing; G, grooming; O, others.

hamsters showed a moderate decrease in levels of rearing and near magazine sniffing and an increase in levels of magazine sniffing/licking behavior during empty intervals. During target trials followed by no reinforcement (T-), the Wistar group showed greater grooming and sitting levels, and the hamster group showed greater near magazine sitting, near magazine sniffing, sniffing, and rearing levels. These results suggest that, under the experimental conditions used here, the hamster group had greater levels of exploratory behavior (e.g., rearing and some sniffing behaviors) than the Wistar group.

Discussion

The results show that hamsters - as the literature had already shown for rats - are able to learn complex tasks such as conditional discrimination. Hamsters and rats acquired the serial positive conditional discrimination, indicated by higher frequencies of magazine-oriented behavior during the tone (T+) preceded by the light feature stimulus than during the tone alone (T-).

There were differences between hamsters and Wistar rats in the behavioral repertoire organization during acquisition. During the early period of training sessions the rats showed high frequencies of magazine sniffing/licking during the empty interval, T+ and T-, indicating no discrimination. After about 6 sessions, the rats started to show a differentiation, increasing the frequencies of magazine sniffing/licking during T+ and decreasing them during T-. The frequencies of magazine sniffing/licking remained low during the light feature stimulus, but as the training session progressed, frequencies increased significantly during the empty interval between the feature and the target stimuli. In contrast, during the early period of the training session, the hamsters did not show high frequencies of magazine sniffing/licking, at any time during the trial, showing no discrimination. With the progress of training, the frequencies of magazine sniffing/licking started to increase during T+, with a difference from the light feature stimulus and the empty interval periods after 4 sessions and from T- after 8 sessions. So, the rats started to respond to the training with high frequencies of magazine sniffing/licking in an undifferentiated manner during all periods of the trials and as the training progressed showed only an inhibition of magazine sniffing/licking during T-. However, the hamsters started with very low frequencies of magazine sniffing/licking and showed an excitatory process acting on the control of magazine sniffing/licking only during T+ as the training progressed. The magazine sniffing/licking response in empty interval during training remained with very high frequencies for rats and increased a little for the hamsters in relation to that recorded during the preceding L period. These results suggest that rats and hamsters have different behavioral strategies for the acquisition of a conditional discrimination.

This assumption is also supported by the fact that, although both groups showed a stable conditional discrimination at the end of training, the total frequencies of magazine sniffing/licking were higher for the rats and the differences in magazine sniffing/licking frequencies between T+ and T- were of about 70% for rats and only 35% for hamsters.

There are some differences between the behavior category system employed by Ross and Holland (15) and the system used in the present study. Ross and Holland (15) had food as unconditioned stimulus and recorded head jerk as conditioned response. The unconditioned stimulus of the present research was water and the conditioned response recorded was magazine licking/sniffing. However, the relationships between topography and sources of responding examined by Ross and Holland (15) can be found in the present study and others (11) using the same behavioral category system. The acquisition of conditional, occasion-setting function in re-

sponse to the L feature permitted the generation of magazine licking/sniffing behavior by T-food associations, indexed by T+ and T- differences. Associations between the L and water resulted in display of rear, near magazine sitting and sniffing behaviors during the L and subsequent trace intervals. Associations between the L and T+ may have produced magazine licking/sniffing behaviors during the trace intervals. This effect of L-T association was well pronounced for Wistar rats (88.89% of magazine licking/sniffing responses) causing suppression of rear, near magazine sitting and sniffing responses; for the hamsters the magazine licking/sniffing percentage of responses was lower than that of the rats during the trace interval (42.08%) and did not cause suppressions of rear, near magazine sitting and sniffing. During the T the hamsters showed a significant percentage of near magazine sniffing and sitting responses (11.66%), in contrast to Wistar rats. These results suggest that the feature-positive serial conditional discrimination procedures affect differently the sources of responding in Wistar rats and hamsters.

The organization of the behavioral repertoire of the hamsters in this complex learning condition involves high frequencies of general activity or behaviors classified frequently in the literature as exploratory, such as near magazine sniffing, sniffing, rearing, and the rats concentrate their activity on more magazine-oriented behaviors. This higher frequency of general activity and exploratory type behavior of hamsters in comparison to rats appears during the empty interval, the T+ and T- periods of the trials. This higher induction of general activity in hamsters than in rats can be interpreted as a consequence of water deprivation. Some authors have described the induction of sitting behavior in hamsters when submitted to water deprivation, but with a long-lasting reinforcement in 60- and 120-s fixed time schedules (9). In this experiment the interval between the presentation of the feature cue and the delivery of reinforcement was 15 s, close to the short-lasting 30-s fixed time interval which maintained the variability and temporal allocation of behaviors in the study by Bueno et al. (9).

The presence of several short duration external cues in the conditional discrimination procedure is another factor that contributes to the maintenance of the hamster activities in this situation. So, deprivation alone cannot be considered to act on the hamster behavior without the combination with other factors such as timing and context, specific of its foraging strategies.

The higher frequency of magazine sniffing/licking early in the training independently of trial conditions, and the maintenance of this very high frequency of magazine sniffing/licking during the empty interval and T+ period after the acquisition of the discrimination suggest that the rats had a more consummatory or goal-oriented behavioral strategy to solve the complex conditional discrimination task in this experiment. The low frequency of magazine sniffing/licking early in the training, the selective increase only of magazine sniffing/licking frequency during the training in the T+ trial condition, and the presence of a high level of general activity and exploratory type behaviors during the different periods of the trials suggest that the hamsters used a more exploratory or foraging strategy of behavior to solve the complex conditional discrimination task. In this case, the comparisons made in this experiment support the importance of an ecological psychology approach to the understanding of complex learning in animals.

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