PHYSIOLOGY

Shuttle-Box Learning Depends on Behavioral Entropy in Auto Track System

K. G. Gurevich and A. V. Toropov

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny,* Vol. 128, No. 11, pp. 491-493, November, 1999
Original article submitted April 27, 1999

The entropy of rat behavior in the auto track system and shuttle box gradually decreased by the end of the experiment. A significant correlation was revealed between the entropy of free behavior in the auto track system and animal's ability to perform a shuttle box task: rats with minimum entropy exhibited low learning abilities. When comparing the behavior of outbred, Wistar, and August rats, the minimum entropy of auto track system behavior was found in August rats.

Key Words: *auto track system; shuttle box; entropy*

Animal behavior in different tests can be described as a sequence of elementary acts [1,4]. This approach provides discrete character of information and test results are presented as a multidimensional distribution. In particular, Auto Track System (ATS), a widely used behavioral tests, allows to determined about 10 parameters simultaneously [1,2]; however, the results of such experiments are difficult to interpret.

We have previously considered the possibility of consecutive application of different statistical methods to obtain more complete information about animal behavior. This procedure facilitates interpretation of experimental data [1], but hampers their visualization because of using of multidimensional scales. These shortcomings can be circumvented by using the integral characteristics of behavior, such as entropy [2, 3,7], which can help to compare data obtained in different behavioral tests.

The aim of this study was to investigate the dependence of learning in a shuttle box (SB) on the entropy of rat's behavior in ATS.

Research Center of Mental Health, Russian Academy of Medical Science, Moscow

MATERIALS AND METHODS

The study was carried out on 84 outbred, 71 Wistar, and 36 August male rats weighing 180±20 g from the Stolbovaya Breeding Center, Russian Academy of Medical Sciences. The animals were maintained under standard vivarium conditions for 3 week before the experiments.

All behavioral tests started 2 h after switching on vivarium illumination. Free behavior was tested for 5 min in a ATS (420×420×200 mm) as described elsewhere [1]. Goal-directed ambulations, rearings, freezings and stereotyped movements (sniffing, grooming, scratching) were considered as elementary acts.

On the next day Wistar rats were trained in a shuttle-box. The training lasted for 10 days with 20 daily session timed as follows: rest (30 sec), light stimulus (10 sec), interstimulus interval (10 sec), tone (10 sec), electrical shock (10 sec). The session was stopped after the animal ran to another compartment. The following elementary acts were considered: transitions during conditioned (active avoidance) and unconditioned (passive avoidance) stimuli, intersignal transitions, and no transitions. Fisher's test [5] was used to confirm non-random dominance of transitions. On day 10 of training, 35 rats performed active avoid-

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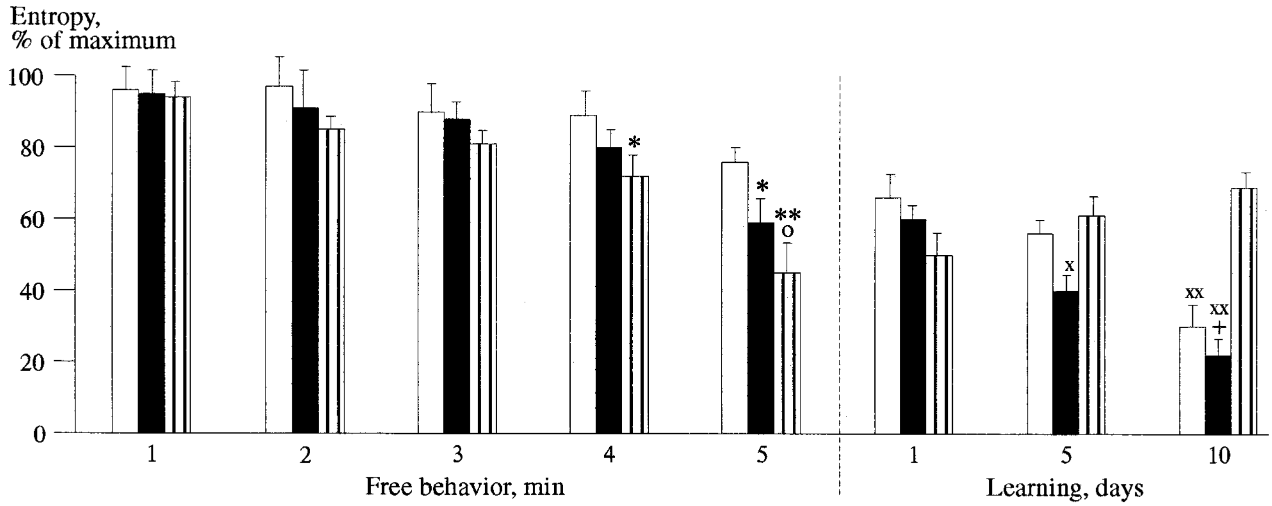

Fig. 1. Behavioral entropy in Wistar rats in the auto track system and shuttle box. $^*p<0.05$, $^{**}p<0.01$ in comparison with the 1st min; $^{\circ}p<0.01$ in comparison with the 2nd min; $^{x}p<0.05$ in comparison with day 1; $^{+}p<0.05$ in comparison with day 5 of learning. Open bars: rats with active avoidance strategy; filled bars: passive avoidance strategy; shaded bars: no strategy.

ance, 27 passive avoidance, and 9 animals exhibited no behavioral strategy.

The probability of elementary acts within a given time interval was calculated by the formula:

$$p_i=n_i/\sum_j n_j,$$

where n_i is the number of outcomes for a given elementary act, Σn_i is the sum of all elementary outcomes. Entropy was calculated by conventional methods [2,3]:

$$H=-\sum_i^N p_i \log_2 p_i$$

and expressed in percent from the maximum entropy which was determined as:

$$H_{max}=\sum^N 1/N \log_2 N,$$

where N is the number of elementary outcomes.

RESULTS

At the first stage we analyzed the dynamics of behavioral entropy in Wistar rats tested in ATS and SB (Fig. 1). Entropy of free behavior (ATS test) decreased with time and reached its maximum after 5 min, i. e. by the end of the test. This level can be considered as background entropy determined by individual genotype or phenotype.

Shuttle-box avoidance conditioning correlated with background entropy (Fig. 1): the choice of active avoidance strategy was typical of animals with maximum entropy, while those with the minimum entropy followed no behavioral strategy.

Entropy is an integral characteristic of animal behavior [2]. The less organized or the more chaotic is behavior, the higher is the entropy [2,3]. It can be suggested that animals with high behavioral entropy retain behavioral plasticity even under stable conditions of ATS, which allows them to adapt to variable conditions of SB. Actually, the highest entropy (chaotic behavior) on day 1 of learning was demonstrated by animals with maximum background entropy. We assumed that the large repertoire of behavioral reactions allows them to choose the optimal strategy of behavior and minimize or avoid stress associated with painful stimulation.

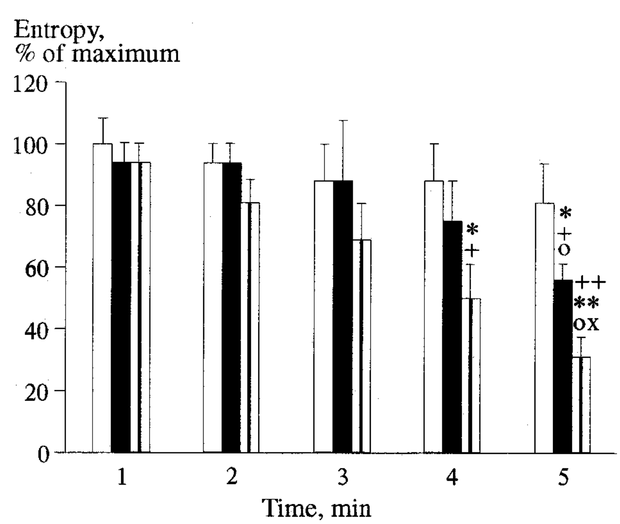

Fig. 2. Entropy of free behavior in the auto track system. Open bars: outbred rats, filled bars: Wistar, shaded bars: August. $^*p<0.05$, $^{**}p<0.05$ in comparison with the 1st min 1; $^{\circ}p<0.01$ in comparison with the 2nd min, $^{+}p<0.05$, $^{++}p<0.01$ in comparison with outbred rats; $^{x}p<0.05$ in comparison with Wistar rats.

On the other hand, the choice of behavioral strategy organizes behavior. After 10-day training in SB, the entropy in animals following either active or passive avoidance strategy was significantly lower than in animals without strategy. The latter were characterized by minimum background entropy in ATS. Thus, the entropy of free behavior can predict the results of SB conditioning. It should be noted, that applying the whole arsenal of statistical methods (Student's *t* test, correlation, cluster and discriminant analyses) we found no correlations between SB learning and individual parameters of free behavior in ATS. Similar data were reported by other researchers [6,8].

At the next stage we studied the dependence of free behavior entropy on genetic characteristics (Fig. 2). Similarly to Wistar rats, both outbred and August rats showed a gradual decrease in entropy to its baseline value, which was the lowest in August rats and the highest in outbred animals. From the correlation established between the SB learning and entropy of free behavior (Fig. 1) it can be suggested that August rats are bad learners, Wistar rats can show different results, while outbred animals are the best learners. This suggestion is confirmed by published data [4].

Thus, the results of learning in SB can be predicted by calculating the entropy of free behavior in ATS: minimum entropy is typical of animals choosing no behavioral strategy, while maximum entropy is characteristic of those following a definite strategy.

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