

RAPID ACQUISITION OF AN AUDITORY LOCALIZATION DISCRIMINATION BY RATS¹

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Acquisition of a sound localization discrimination by rats was investigated. Two loudspeakers were located outside an experimental enclosure containing two levers and a dipper feeder. In the same-side condition, responses on the lever nearest the sound-producing speaker were reinforced. Animals in this condition acquired the discrimination rapidly, generally within the first session. In the opposite-side condition, responses on the lever furthest from the sound-producing speaker were reinforced. Acquisition for animals in this condition began below the chance level (50% correct responses) and took on the order of 10 sessions to approach the final, high level. The course of acquisition in both cases appeared to depend upon an initial tendency of rats to respond on the lever nearest the source of sound in this situation. The rise-decay time of the 4-kHz tone burst signal clearly affected the performance level reached. It did not, however, affect the rate at which the discrimination was acquired.

An earlier paper (Harrison and Beecher, 1969) described a sound localization discrimination that rats learned with unusual rapidity. In this discrimination, sound was presented to the rat from one of two loudspeakers outside its wire enclosure. If the animal responded on the lever nearest the speaker producing the sound (correct response), the response was reinforced by food; if the animal responded on the lever furthest from the speaker (error) the response produced a blackout. The rats learned this discrimination rapidly, making better than 90% correct responses by the end of the first session, and their final performance was at or near the 100% correct response ceiling. Treating acquisition rate and performance level as indicators of stimulus control, we concluded that location is a dominant aspect of an auditory stimulus.

In that discrimination it was arbitrarily decided to reinforce responses on the lever nearest the sound-producing speaker, and the pos-

sibility exists that this particular arrangement was responsible for the rapid acquisition. The present experiment examined this possibility by comparing acquisition under two reinforcement conditions: (1) responses on the lever further from the sound-producing speaker were reinforced, or (2) as in the earlier experiment, responses on the nearer lever were reinforced.

A second possible factor in the rapid acquisition was the use of highly locatable auditory stimuli. All animals were trained with a 4-kHz tone burst signal having rapid onset and termination (rise-decay time approximately 0.2 msec). When, following acquisition, the rise-decay time of the signal was increased to 50 msec, performance dropped 10 to 20%. This effect coincides with the general finding that slow rise-decay tone bursts (*i.e.*, pure tones) are difficult to localize. Cats, squirrel monkeys, and bats, in a similar experimental situation, also show performance losses at slow rise-decay times (Beecher, 1970). It has been reported numerous times that humans have difficulty locating this sort of sound (Deatherage, 1966; Mills, 1958; Perrott, 1969; von Békésy, 1967). Of interest also is that many vertebrate species use slow rise-fall, pure-frequency signals as alarm calls when predators are present (Marler, 1955, 1967; Tembrock, 1964). A hard-to-localize signal is an obvious advantage in that situation (Mar-

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ler, 1967). Rapid acquisition, then, may be a simple result of using highly discriminable (locatable) stimuli, and the present experiment examined this possibility by using various stimuli during acquisition.

METHOD

Subjects

Ten male albino rats (Sprague-Dawley strain), none of which had been used in auditory experiments before, and four of which had never been used in any type of experiment (R 41, R 42, R 43, R 44), served as subjects. During the experiment, an animal's weight was reduced to approximately 75% of its free-feeding weight. The reinforcer used in experimental sessions was a 50% mixture of sweetened condensed milk and water (0.05 ml per presentation).

Apparatus

The experimental chamber was a wire cage, 8 in. high by 8 in. long by 11 in. wide (20 by 20 by 28 cm). On top of the cage was a 10-w houselight, which provided the only illumination in the room. Two levers (levers L and R, Fig. 1) were mounted in the front wall, 4 in. (10 cm) apart and 3.75 in. (8 cm) above the floor. A liquid food dispenser was located between the two levers. Two loudspeakers (speaker L and R) were located outside the cage at approximately the animal's head level. The speakers were separated by a distance of 4 ft (122 cm) and an angle of 180° (Fig. 1). The experimental chamber was suspended on a stand of supporting rods in the middle of a room 2.1 m by 2.4 m by 2.7 m high, the walls and ceiling of which were covered with acoustic tile.

Acoustic Signal

Pure tones were generated by an oscillator (General Radio 1210C), shaped into tone bursts by an electronic switch (Grason-Stadler

829D), passed through a bandpass filter (Krohn-Hite 310-AB), amplified (Krohn-Hite DCA-10 amplifier) and delivered via a matching transformer (Krohn-Hite MT-56) and scheduling equipment to one of the two loudspeakers (University Sphericon T-202) located in the experimental room. The acoustic signal produced was monitored with a Brüel and Kjaer 0.5-in. condenser microphone and observed on an oscilloscope.

The signal was a tone burst of 100 msec duration, repeated at the rate of two per second. The frequency of the signal was either 4 kHz or 10 kHz. Four rise-decay times were used: 0.2 msec ("Fast" setting of the Grason-Stadler switch) 0.5, 2.5, and 25 msec. The intensity of the 4-kHz tone, as measured with a General Radio sound level meter (weighting A, reading corrected for the loss in the cable) was 75 db (re 20 $\mu\text{N}/\text{m}^2$). This sound pressure level was an average of readings at several standard positions in the cage. The 10 kHz signal was set so that its peak-to-peak amplitude was equal to that of the 4 kHz signal.

Procedure

Discrimination schedule. The animal was first trained to press levers L and R to produce food. Data are presented beginning with Session 0 (all conditions final but no sound stimuli). The sounds were introduced in Session 1.

Stimulus presentations (trials) occurred every 30 sec. A trial consisted of tone bursts occurring twice per second until the animal made a response. The first response during the trial produced, if correct, food for 5 sec or if incorrect, a 5-sec blackout, and ended the trial. On a given trial, tone bursts occurred from either speaker L or speaker R (Fig. 1). For an animal in the same-side condition, a response was correct (was reinforced) if it occurred on the lever on the same side as the speaker producing the tone bursts; it was incorrect (produced a blackout) if it occurred on the lever on the side opposite the speaker producing the tone bursts. Hence, lever L responses were correct (only) during sound from speaker L and lever R responses were correct (only) during sound from speaker R. For an animal in the opposite-side condition, a response on the lever on the side opposite the sound-producing speaker was correct, whereas a response on the lever on the same

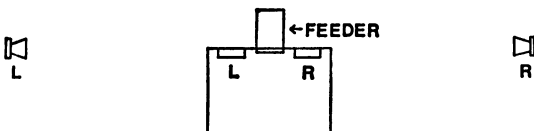


Fig. 1. Schematic diagram of apparatus from above (to scale).

side as the sound-producing speaker was incorrect. Hence, lever L responses were correct (only) during sound from speaker R, and lever R responses were correct (only) during sound from speaker L. After a reinforcement or blackout, the next trial occurred 30 sec later, unless the animal made a response within 5 sec of the scheduled trial; such a response prolonged the intertrial interval 5 sec from the response.

The speaker chosen (L or R) on a particular trial was determined by the order RLLRL-LRRLR. If the animal persisted in responding on one lever, the order was modified according to the following correction procedure. If on two consecutive trials the animal made errors on the same lever, *i.e.*, to the same speaker, then that speaker would be selected on succeeding trials until a correct response occurred, or until 10 such errors had occurred in succession. After either of these events, the speakers were again switched in the order indicated above. The measure of discrimination performance was the percentage of correct responses in all trials of a session (both stimuli combined).

Sessions were 45 min long.

Control procedures. Occasional tests were made to assure that the behavior was actually under the control of the location of the sound source producing the tone burst signal. Some of these tests are described here. (1) On a given trial, the oscillator gain control was turned all the way down. A response on such a trial would indicate that the animal was responding on the basis of a mechanical or electronic artifact. (2) The particular order of selection of speakers (given above) was altered, to determine if the animal was responding on the basis of this order. (3) The two loudspeakers were interchanged, to determine if the animal was responding on the basis of differences that might exist between the speakers, rather than on the basis of the difference in their location. All such tests indicated that these other factors were not supporting the animals' behavior.

Conditions

Eight of the rats learned the same-side version of the discrimination, and the other two rats, the opposite-side version. The signal values used for each animal are shown in Table 1.

Table 1
Conditions

Rat	Same (S) or Opposite (O) Side	Tone Frequency (kHz)	Rise-Decay Time (msec)
R42	O	10	0.2
R43	O	10	0.2
R25	S	10	0.2
R41	S	10	0.5
R44	S	10	2.5
R50	S	10	25
R51	S	10	0.2
R52	S	4	25
R53	S	4	25
R55	S	4	25

RESULTS

Acquisition of the Discrimination

Figure 2 gives the percentage of correct responses per session for each of the 10 rats. Session 0 was the baseline session in which there were no auditory stimuli (the loudspeakers were disconnected while all other features of the schedule were unchanged), hence the data point represents per cent correct on "mock trials". Performance in the no-sound session was at or near 50%, which is the expected or chance level.

The 4-kHz, same-side rats (top row, Fig. 2) quickly reached a stable level of per cent correct responses. This level was lower for the 25-msec animals (R 52, R 53, R 55) than it was for the 0.2-msec animal (R 51) by 10 to 15%, which is consistent with our earlier data (Harrison and Beecher 1969). The rate of learning, *i.e.*, the rate at which this level was reached, was, however, essentially the same for all four animals. In particular, the 25-msec animals did not take long to reach their stable level; only R 55 showed any kind of learning curve, with poorest performance in Session 1.

The 10-kHz, same-side rats (second row, Fig. 2) did not show as wide a range of final performance levels as the 4-kHz, same-side rats; median per cent correct responses of Sessions 2 through 8 were 96, 98, 94, and 94% for R 25, R 41, R44, and R 50 respectively. The rate of learning for these animals was fast, though less so for R 41 and R 44 than any of the other same-side animals. As indicated above, these two rats were the only two experimentally naive animals in the same-side group. Thus, the lack of prior experience may have been a

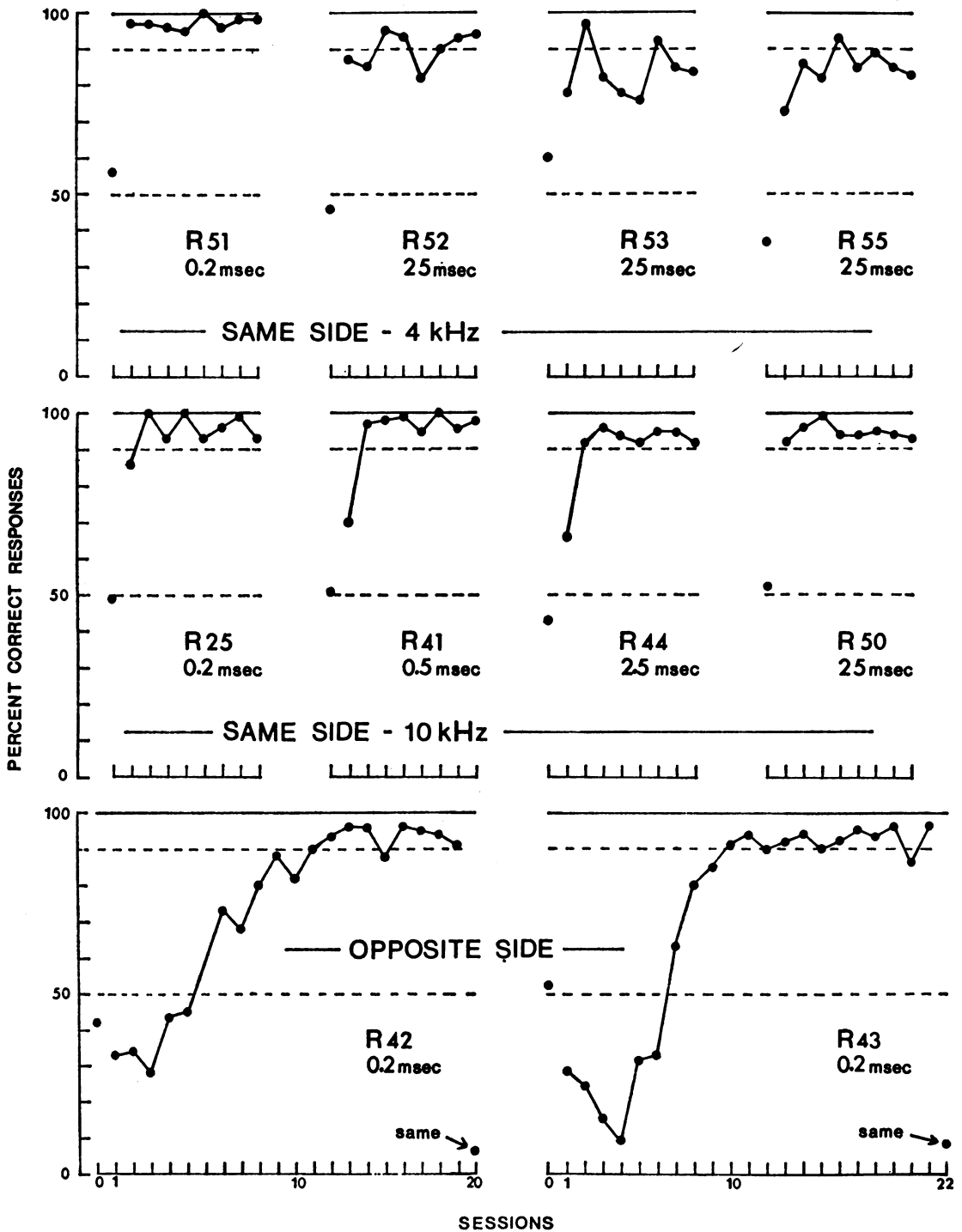


Fig. 2. Acquisition of the discrimination. Session 0 (data point not connected) was no-sound session. Final session for Rats R 42 and R 43 (data point not connected) was same-side condition. Dotted lines at 50% (chance level) and 90%.

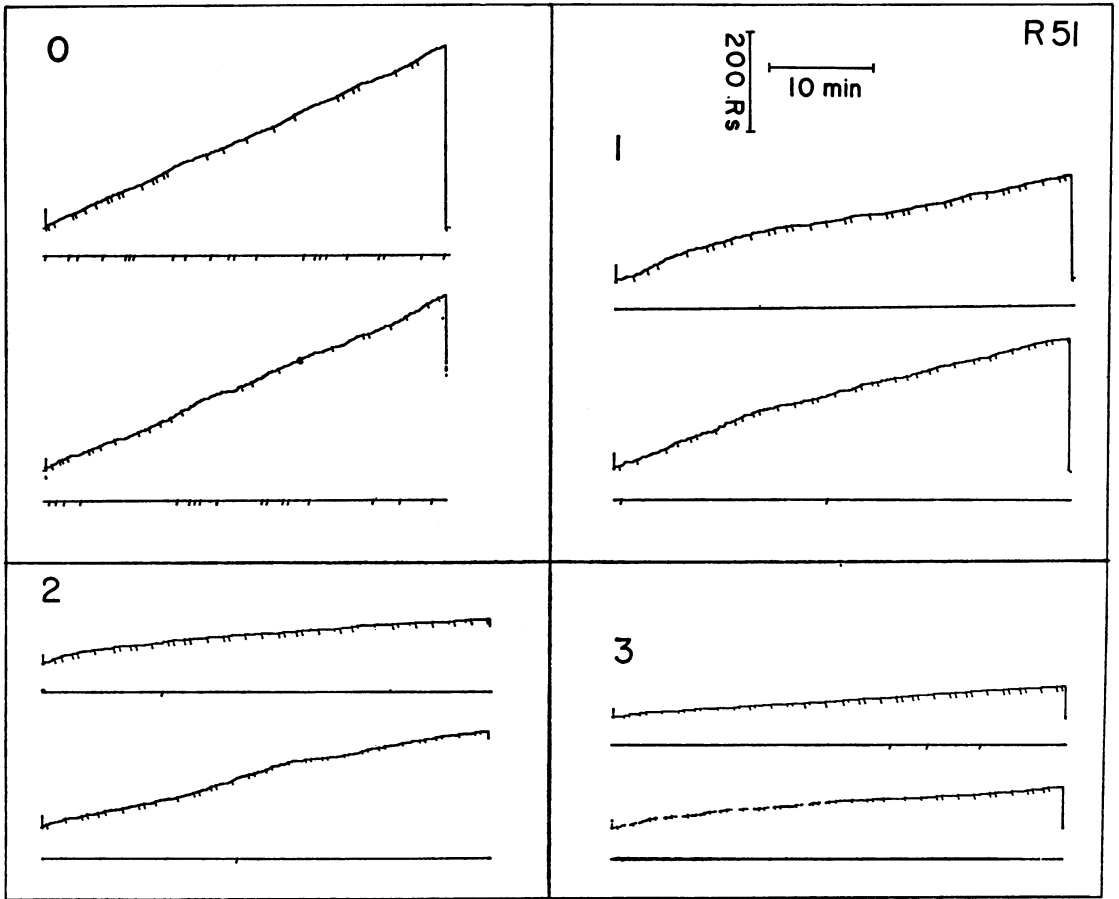


Fig. 3. Cumulative record of responses on left lever (upper record of pair) and on right lever (lower record of pair), rat R 51. Deflections of response pen indicate reinforcements (or correct responses), deflections of the event pen indicate blackouts (or errors). Session 0, no acoustic signal.

factor in the relatively poor first session performance shown by these animals.

The data from opposite-side animals (bottom row, Fig. 2) were quite different from those of same side animals: the discrimination was acquired much more slowly. Whereas the performance of any same-side animal in Session 1 was considerably better than chance, the performance of the opposite-side animals in Session 1 was poorer than chance, and remained so for 4 to 5 more sessions. Better than 90% performance was eventually reached by both animals. In the final session for these two animals, the conditions were switched to same-side and each of the animals continued to make mostly opposite-side responses (now errors).

Figure 3, cumulative records from animal R 51's first four sessions, provides one detailed

example of the rapid acquisition shown by the same-side animals. It is apparent that one could interchange Sessions 1, 2, and 3 and still describe acquisition of the location discrimination in the same way. The one feature that distinguishes Sessions 1 through 3 is the number of intertrial responses, which diminished from one session to the next, reaching the typical stable low level in Session 3. Records of succeeding sessions are virtually identical to those of Session 3. Thus, acquisition of the location discrimination was essentially immediate, and actually preceded acquisition of the sound *versus* no sound discrimination. In this respect, Fig. 3 is representative of all same-side animals. R 41 and R 44 are partial exceptions to this generalization in that both animals showed brief position preferences at the beginning of Session 1.

Performance in Early Trials

The preceding data suggest that, regardless of signal conditions or reinforcements contingencies, there was a strong tendency for rats in this situation to respond on the lever on the same side as the sound-producing speaker. For the opposite-side animals many sessions were required for the reinforcement contingencies to overcome this tendency.

The same-side response tendency appeared to be present very early. Only the animal's very first trial, of course, can be considered to be free of the effects of the reinforcement contingencies. Table 2 shows what each animal did on that trial and also in the first 10 trials. Eight of the 10 rats responded on the same-side lever in Trial 1. All 10 rats made 50% or more same-side responses in Trials 1-10 (and eight of 10, 60% or more). There is no obvious difference on Trials 1 to 10 between R 42 and R 43 (same-side responses not reinforced) and the other animals (same-side responses reinforced).

Table 2

Response on first trial (S = same side response, O = opposite side response) and percent same-side responses in first 10 trials.

Rat	Trial 1	Trials 1-10
R25	O	60
R41	O	50
R44	S	60
R50	S	60
R51	S	90
R52	S	70
R53	S	90
R55	S	70
R42*	S	80
R43*	S	50

*Opposite-side responses reinforced (all other animals, same-side responses reinforced).

DISCUSSION

The data suggest that the rats brought into this experiment a tendency to respond on the lever on the same side as the sound-producing speaker; in most animals this tendency was apparent immediately upon introduction of the tone burst stimuli. When this tendency was appropriate to the behavioral situation and reinforcement contingencies, as it was in the same-side condition, the rat acquired the discrimination rapidly. When this tendency was inappropriate, as it was in the opposite-

side condition, it interfered and the rat acquired the discrimination slowly. The same-side response tendency appears, then, to be the basis for the unusually rapid acquisition noted in our earlier experiment (Harrison and Beecher, 1969).

Characteristics of the acoustic signal, while fixing the performance level reached in this localization discrimination, did not affect the rate at which this level was reached: all animals reached their final performance level at the same rapid rate. Since no animal gave stable performance of less than 85%, this conclusion must be restricted to the 85 to 100% range of performance. The present experiment indicates, therefore, that the fast rise-decay time of the 4-kHz signal was not a variable in the fast acquisition shown by rats in the earlier experiment.

Table 3 compares the 4 kHz data of the present experiment with similar data from Harrison and Beecher (1969). It can be seen that the differences between performance levels at fast and slow rise-decay times found in the two experiments are similar. The present experiment did not show a clear effect of rise-decay time at 10 kHz, though there is a slight decrement at the two longer (2.5 and 25 msec) rise-decay times (Fig. 2).

Table 3
Median per Cent Correct Responses

	Rise-Decay Time	
	Fast*	Slow*
RB13†	99	92
RB14†	99	85
RB4†	99	81
R51	97	—
R52	—	93
R53	—	85
R55	—	84

*Fast = 0.2 msec, slow = 50 msec (RB 13, RB 14, RB 4) or 25 msec (R51, R52, R54, R55).

†Data for RB 13, RB 14, RB 4 from Harrison and Beecher (1969).

Though in the present experiment the rats tended to respond on the lever nearest the sound source, this tendency cannot be described simply as one of "going toward the sound", for as Fig. 1 shows, this would lead the animal wide of the lever. Harrison, Downey, Segal, and Howe (1971) found that rats also acquire the same-side discrimination

rapidly under two other arrangements: with the speakers directly behind the levers, or with the speakers at the sides of the cage, back from the levers. The similar results under these different arrangements suggest that in rats the same-side tendency will occur despite some discrepancy between the location of the sound source and the location of its associated response lever.

In this regard, there is an interesting difference between monkeys and rats (Beecher, 1970; Harrison *et al.*, 1971). With speakers behind the response levers (same-side responses reinforced) monkeys acquire the discrimination rapidly, like rats. With the speakers remote as in Fig. 1 (same-side responses reinforced) monkeys require 10 to 20 sessions to reach the 90% correct response level. While possible explanations of this species difference are considered in more detail in Harrison, *et al.*, (1971), one comment can be made here. Monkeys in this situation can be observed to visually orient to the sound source. In the speaker-adjacent condition this orienting response results in the monkey facing the correct response lever. In the speaker-remote condition, on the other hand, this orienting response directs the monkey's head and eyes away from both response levers. Observation of rats in these situations fails to reveal any obvious orientation towards the sound sources. Thus, it appears that a detailed examination of orienting behavior in these situations may illuminate some of the effects observed.

What we are calling the same-side response tendency may reflect, then, at least in part, unconditioned behaviors (such as orientation reflexes), and these may be different for different species. The tendency very likely also reflects the past history of the animal, in which responses most often have been reinforced when in the direction of the auditory discriminative stimulus (and in avoidance situations,

when in a direction away from the auditory discriminative stimulus). A typical instance of this class of experience occurs in this experiment before the tone burst stimuli are even introduced: during magazine training reinforcement follows an approach in the direction of the sound of the feeder, rather than some other direction.

We conclude that the rapid acquisition observed can be attributed to unconditioned tendencies or the past history of the animals in localization situations or to some combination of these two factors.

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