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The method of training dogs in auditory recognition memory tasks with trial-unique stimuli

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Technical communication

Abstract. Three adults dogs were trained in a auditory recognition delayed-matching-to-sample (DMS) task. The experimental setting consisted of one central speaker located in front of the dogs head, two side speakers with nearby response pedals and one rotary food delivery system. Three hundred twenty natural sounds were used as trial-unique stimuli. Sample stimuli were always given through the central speaker. After the delay of 1.5 s, both sample and testing stimuli were activated alternately through the two side speakers. Bar-press response toward the sample stimulus was rewarded by food. The DMS training was continued until attaining a criterion 90% correct responses in 90 consecutive trials. After a control pause, the dogs were retrained to the criterion, and then they were given performance tasks with delays extended to 10-, 30-, 60- and finally to 90-s, in blocks of 90 trials. Dogs required about 1,000 trials of auditory recognition memory training in order to reach the criterion. Their behavior was also stable after the control pause. The dogs performance declined gradually with extended delays reaching an average of 63.4% for the delay of 90 s. Results indicate that the DMS task with auditory stimuli alternating during the testing stage of trial, is a promising method for testing auditory recognition memory.

Key words: auditory delay-matching-to-sample, trial-unique stimuli, dogs

INTRODUCTION

Clinical reports about severe and global anterograde amnesia - i.e., a profound and permanent loss of the ability to form new memories, caused by bilateral removal of the medial temporal lobe (Scoville 1954, Scoville and Milner 1957, Penfield and Milner 1958) - led to a series experiments which might reproduce the syndrome in animals (Mishkin et al. 1982). Like the clinical syndrome, memory loss among animals with experimentally induced amnesia may be global in nature affecting the storage of sensory information in all modalities. Up to now, however, only visual and tactile recognition tasks have been examined, and determination, whether medial temporal lesions produce an impairment in auditory memory as well, it has become increasingly important for many reasons, to see whether the same effects can be found in audition.

There is a considerable number of investigations showing that despite a rich vocal communication system (Snowdon et al. 1982), monkeys encounter great difficulty learning simple or complex task when acoustic, rather than visual, stimuli are used for discrimination (e.g., Wegener 1964, D'Amato and Salmon 1982). Researchers continue having difficulty in training monkeys in auditory memory tasks (Stępień and Cordeau 1960, Stępień et al. 1960, Dewson and Cowey 1969, Dewson and Burlingame 1975, Cowey and Weiskrantz 1976, D'Amato and Colombo 1985, Kojima 1985, Colombo and D'Amato 1986, Wright et al. 1990, Kowalska, Mishkin and Saunders, unpublished data). Thus, for monkeys, untill now there is no test developed for auditory recognition memory, which might be comparable to that of visual or tactual recognition task with trial-unique stimuli (Gaffan 1974, Mishkin and Delacour 1975, Murray and Mishkin 1984, respectively).

Although monkeys learn such auditory tasks only with great difficulty, dogs learn them relatively easily (e.g., Kowalska and Zieliński 1980), which is just the reverse of the situation in vision, where dogs show a distinct disadvantage including an inability to transfer a learned rule from auditory to visual stimuli (Pietrzykowska and Sołtysik 1975a, 1975b). In fact, a large amount of evidence have been accumulated, which indicates that dogs are extremely receptive to auditory stimuli. This evidence, based on studies of differentiation, generalization, and reversal learning (e.g., Dąbrowska 1971, 1975, Brennan et al. 1976, Kowalska 1980, Kowalska et al. 1975a, 1975b, 1981, Kowalska and Zieliński 1976, 1980, 1986, Zieliński et al. 1979), and delayed response (Ławicka 1969, Kowalska 1995), rise the question of whether dogs might perform better than monkeys not only in differentiation learning but also on memory tasks.

The aim of this study is to train dogs to perform auditory recognition with trial-unique stimuli, a test of one-trial memory.

METHODS

Subject

Three adult, experimentally naive male mongrel dogs weighing 13-20 kg, were used in the study. The animals were housed individually in cages (2.7 x 1.2 x 3.0 m) in which they had free access to water. Food was given once a day, 15-20 h before testing. Experimental sessions were conducted 5 or 6 days per week.

Apparatus

The experiment was carried in sound-proof testing chamber. Background noise in the testing chamber was 22 dB (A) (re. 20 μPa) measured with Bruel and Kjaer precision sound level meter Type 2209, time constant S, slow). The dogs stood in a harness on a platform measuring 74 x 185 cm (see Fig. 1). An enclosed 16-cup rotary food delivery system, the top area of which measured 66 x 66 cm, was raised 20 cm above the platform and located in front of the dog. At the center edge of the food tray, which was closest to the dog, a circular opening, measuring 9 cm in diam., contained a cup dispensing the food reinforcement. A two-way magnet speaker, 12 cm in diam., was mounted in front of the dog, 50 cm above the food tray. Two additional identical speakers were located on the sides at approximately the same height as the dog's head. The response pedals were placed on the right and the left side of dog's paws, just below the side speakers. The surface area of the pedal measured 22 cm long and 11.5 cm wide, and the pedal was fixed at an angular orientation toward the dog from a maximal height of 17 cm from the platform base. Overhead illumination was provided by two 40 W light sources. A one-way window and two-way speaker system provided visual and acoustical access to the dogs from outside the chamber during experimental sessions.

All programming equipment was located in an outer room. The experiment was controlled by a PC computer

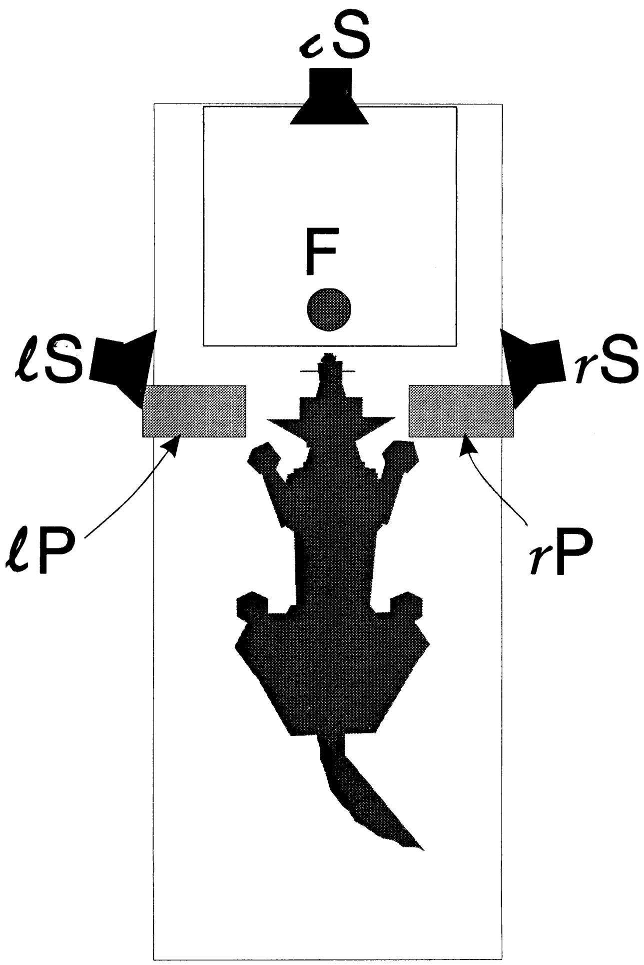

Fig. 1. The experimental situation. cS, lS, rS: central speaker, left speaker, right speaker; lP, rP: left pedal, right pedal; F, feeder.

(486SX, 25MHz) via printer port and Sound Blaster Pro audio card. During the experiment, the number of correct and incorrect responses (in "no go" trials), the number of correction trials and trial response latencies were collected as dependent measures.

Stimuli

The stimuli consisted of 320 natural sounds: animals' voices, (e.g., birds, sea lions, pigs, elephants, seagulls, crickets, cats, monkeys), sound-effect records (e.g., swimming sequence, sleigh with bells, pencil sharpener, tapping, crunching paper, coffee percolator, toothbrush, string of firecrackers, electric shower, vacuum cleaner, blizzard, rain, Big Ben, calliope, drive bomber, ping pong), pulses (40 CPS - 4 KC, delays 5-50 ms, width 0.5-5.0 ms) tones (100-3,000 Hz) as well as few notes melodies, played by the different musical instruments (recorder, piano, violin, electronic organs, merlin, timpani, music box). The sounds were derived from commercial recordings or were recorded by us. All sounds were digitized (sampling frequency 22.05 kHz, 8 bit resolution, mono) using Marantz TDM 220 tape recorder as a source and Sound Blaster Pro as an A/D converter. The stimuli were processed using a sound editing program Creative Voice Editor v.2.15 in order to obtain similar sound intensities averaging of 60 dB(A) (measured in the same way as described above) and equal lengths of 1.5 s. Additionally, the beginning (20 ms) and the end (50 ms) of each stimulus were faded in and out, respectively, in order to avoid clicks when stimuli are switched on or off. Each of the sounds emitted from the speaker was presented in three (or more) identical bursts of 1.5 s interrupted by silence of 1.5 s.

Procedure

The dogs were trained in several stages.

STAGE A - PRELIMINARY TRAINING

Prior to the introduction of sounds presentations, the dogs were habituated to the training situation that involved 2-4 days during which subjects were accustomed to the chamber, the harness and rotation of the food delivery cups by free reinforcement with the meat (about 10 g). During the initial sessions, the dogs were actually encouraged to press the right pedal during presentation of the sound emitted through the right side speaker. At this stage there were used only three auditory stimuli: a 1,000 Hz tone, a 60 dB noise, and a short melody). Each of the sounds was emitted until the animal pressed the pedal. Instrumental response interrupted the emission of the auditory stimulus and caused immediate food delivery. Fifteen trials were given per one experimental session. Intertrial intervals were 40 s. When the dog performed an instrumental response to the right pedal at the level of 80% in one session, the training on the left side speaker and response to the left pedal started to the same criterion. After elaboration of instrumental responses on both sides, the random order (according to a "Gellerman's series", Gellerman 1933) for the emission of the stimuli, and sides of their presentation was introduced. Daily experimental sessions consisted of 15 trials. Training was continued until the dog reached criterion 80% correct responses for both sides, on two consecutive experimental session (30 trials).

STAGE B - INSTRUMENTAL TRAINING WITH TRIAL-UNIQUE AUDITORY STIMULI

At this stage the bank of different auditory stimuli was introduced. They were grouped in 16 sets of 20 different stimuli. Each trial started by emission of sound through the central speaker, located in front of the dog. Presentations consisted of three identical bursts of sound, each of 1.5 s, interrupted by 1.5 s silence (total 7.5 s). An instrumental response to the sound from the central speaker was never reinforced by food at this stage, and at the subsequent consecutive stages of experiment. After the delay of 1.5 s the same sound was presented through one of the side speakers in the same way. An instrumental response performed on the same side was automatically reinforced by food (10 g of meat). Training of 15 trials per session (ITI - 40 s), was continued until the dog reached criterion of 90% correct responses in 6 consecutive experimental sessions (90 trials).

STAGE C - GO, NO-GO, RECOGNITION TASK WITH TRIAL-UNIQUE STIMULI

This stage was a modification of the Konorski's Test (Konorski 1959) by introducing responses in the right and left sides as well as trials with unique stimuli. Eight sets of 20 pairs of different auditory stimuli were used at this stage (a total of 320 different sounds). Within each pair, the auditory stimuli were selected to be easily distinguished by the human observer (e.g., tropical birds vs. two notes on recorder, horse walks vs. tone 2,200 Hz, dripping faucet vs. blizzard, mean cat vs. Niagara Falls). Each trial consisted of two phases: (1) sample sound presentation through the central speaker, and after the delay, (2) the test stimulus, same or different from the sample stimulus, presented through a lateral speaker. In both phases, sample and testing sounds were given in the three bursts, each of 1.5 s, interrupted by 1.5 s period of silence. The manner of presenting acoustic stimuli in the modified version of Konorskis Task is shown on Fig. 2. On the testing phase, during the "same" (or go) trials, the identical sound to the sample was activated through one of the side speaker. Pressing the pedal on the side of sample sound emission within 9.0 s automatically terminated the sound and cause food delivery. In the event of no response, the sound automatically terminated after 9.0 s with no reinforcement. During the "different" (or no-go) trials, the different than sample sound was activated through one of the side speaker, at the same way as during the "same" trials. Pressing the pedal in "different" trials did not interrupted the sound and was never reinforced by food. After the 40 s ITI, the next trial started with a completely new pair of sounds. At this stage, the experimental session consists of 20 trials (10 "same", and 10 "different" trials). Every session started with a new set of acoustic stimuli. The positions of pairs of sounds within the session were chosen randomly by computer, the side of stimuli presentation as well as relations between "same" and "different" trials changed according to "Gellermans series." At the beginning of this stage, the correction trials were introduced, which consisted of complete repetitions of the trials, 20 s after an erroneous response. No corrections were given during criterion trials. The dogs were trained until they started to respond differently on the same and different sounds (latency response comparison) with a significant difference (Mann-Whitney U-test, one tailed) on 6 sessions within 10 consecutive sessions, and then they were switched to the next stage.

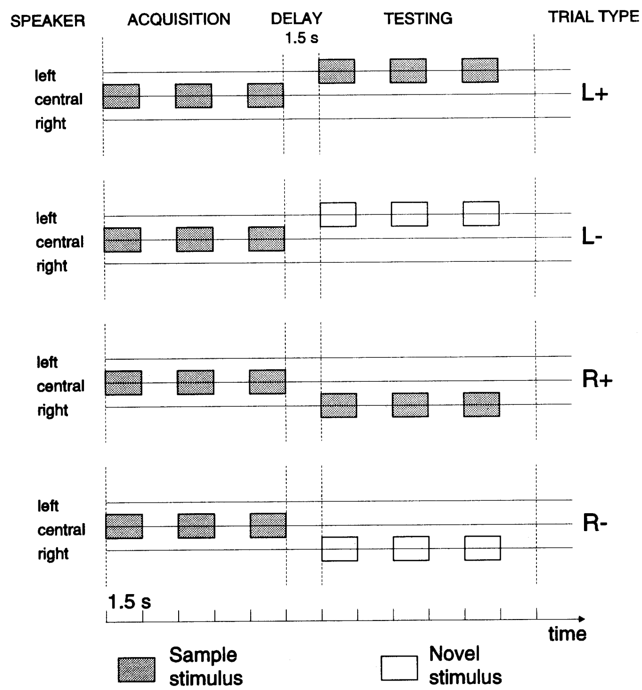

Fig. 2. The manner of presenting acoustic stimuli in a modified version of the Konorski's Task (Stage C). L+, R+: positive ("same" or go) trials; L-, R-: negative ("different" or no-go) trials.

STAGE D - DELAY MATCHING-TO-SAMPLE WITH TRIAL-UNIQUE STIMULI

In this stage the same sets of auditory stimuli were used as in Stage C. Again the trial consisted of two parts:

(1) sample presentation and (2) test with the sample sound presentation and the new one. Again pedal pressing on the activation of sample sound through the central speaker was never reinforced. After the delay of 1.5 s (during the testing phase) both the familiar sample sound and a new sound were given, in bursts of 1.5 s, alternatively through the side speakers. Three alternations of both sounds were given (total 9.0 s). The correct choice, pressing the pedal close to the speaker with sample sound presentation, caused the termination of the trial and a food delivery. Response to the side different than sample (new) stimulus presentation, also caused termination of the trial but, was never associated with reinforcement. The next trial started with a new pair of sounds. At this stage there were 15 trials per session with a 40 s ITI. In each of the sessions a different set of acoustic stimuli was used. Within a session, pairs of sounds were chosen randomly by computer from the sets of 20 pairs. The side of presentation of the sounds, as well as which sound (familiar or new one) was presented as first in the testing trial, in a random order, according to "Gellerman series", were balanced in 2 consecutive sessions (30 trials). Additionally, sounds presented as a sample and the testing within the pairs were also contrabalanced, thus, on this way, the number of sets' sounds used in the experiment were duplicated. The way of presenting alternating auditory stimuli in the DMS task is shown on Fig. 3.

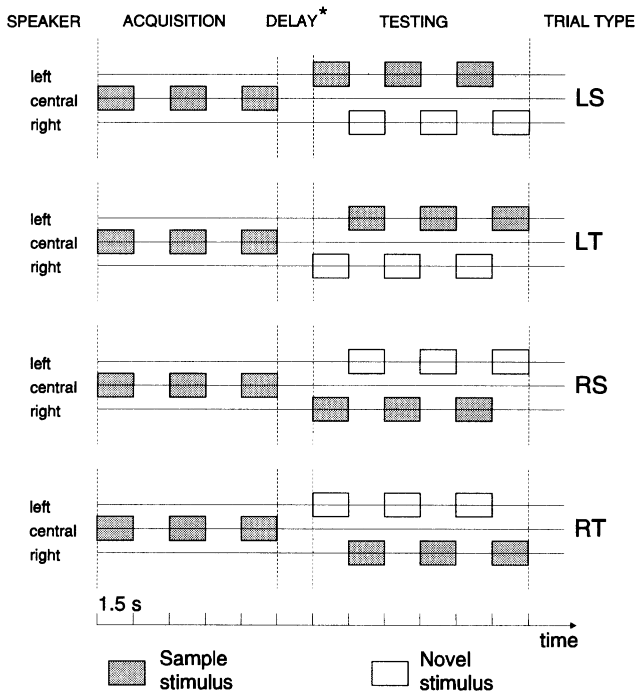

Fig. 3. The manner of presenting acoustic stimuli in DMS task with alternating sounds (Stage D). LS, testing trial started with sample sound on the left side; LT, testing trial started with the testing sound on the left side; RS, testing trial started with the sample sound on the right side; RT, testing trial started with the testing sound on the right side. * The delay was 1.5 s in stage D and E, and 10 - 90 s in stage F.

At the beginning of this stage some facilitations were introduced to make this task easier for animal. During testing the new, different than sample, sounds were presented only one or two times and then turned off, whereas the sample sound continued. Correction trials (repetition of whole trial) were introduced 20 s after erroneous response, when performance dropped below the 75% of correct choices. Training was continued until the dog reached criterion of 90% correct choices (in the task, with 3 full presentations of both sounds during the testing stage) in 90 consecutive trials (6 experimental sessions).

STAGE E - RETRAINING AFTER A REST PERIOD

Dogs that had reached the criterion in DMS auditory recognition tasks had a 2 week control break in experiments after which they were retrained to the same criterion as before.

STAGE F - PERFORMANCE TASK WITH EXTENDED DELAYS

The next day after reaching criterion the dogs continued training in the same behavioral tasks, but the interval delay between acquisition and testing phases was extended in stages from 1.5 s to 10 s, 30 s, 60 s and finally to 90 s. Each delay was tested in separate blocks of 6 sessions (90 consecutive trials). During block sessions, no correction trials were introduced.

RESULTS

The results obtained at different stages of training of the auditory recognition memory tasks are shown at the Table I. At the two early stages of training, dogs were shaped to perform instrumental responses in an average of 210 trials (Stage A), and respond to the direction of auditory stimulus in an additional 30 trials (Stage B) as an average. At the next stages of training the acual auditory recognition memory tasks were introduced. The results indicated individual differences in dogs'

TABLE I

The number of trials (*T*), errors (*E*) for the different stages of training (A,B,C, and D), and percent of performance within criterion sessions (%)

	A		B		A+B	C		D			C+D
	T	%	T	%	T	T	E	T	E	%	T
D-1	240	97.7	60	97.7	300	900	384	180	57	90.0	1080
D-2	270	90.0	15	93.3	285	680	275	675	140	90.0	1355
D-3	120	93.3	15	91.1	135	360	167	150	48	94.4	510

performance at these stages. At Stage C, where the go, no-go principle was used in training, the dogs required a mean of 613 trials and 275 errors. After experience with recognition task supported on go, no-go paradigm, a training of Delay Matching-to-Sample auditory recognition task (stage D) was relatively shorter, especially for two dogs, D-1 and D-3. At this stage the animals reached criterion in an average of 335 trials with 82 errors.

After the control pause, two dogs needed additional training in order to reattain a criterion with original delay of 1.5 s. (D-1: 120 *T* and 17 *E*, and D-3: 15 *T* and 2 *E*). The levels of dogs performance in criterion sessions and during following blocks of 90 sessions with extended delays are shown in Table II.

During Stage F, the performance scores for each dog decreased gradually across the delays. Although some individual differences were observed at this stage, especially for delays of 10 s (6.6%) and 90 s (11.1%), the average individual scores across the five delay conditions (AVE) did not differ substantially.

TABLE II

Percent of correct responses during criterion sessions of the auditory recognition DMS task with the delay of 1.5 s. (Stage E), and in performance training with extended delays (Stage F). AVE indicates the average scores across the five delay conditions (1.5 - 90 s)

		E	F				
		1.5 s	10 s	30 s	60 s	90 s	AVE
D-1		90.0	82.2	71.1	66.7	56.7	73.3
D-2		91.1	75.6	74.4	66.7	65.6	74.7
D-3		90.0	80.0	74.4	70.0	67.8	76.4
	X	90.3	79.3	73.3	67.8	63.4	

DISCUSSION

The results demonstrate that dogs are able to learn the auditory recognition DMS task with trial-unique stimuli. After preliminary training with shaping instrumental bar-press responses, the criterion of the auditory recognition memory tasks (counted both for Konorski's Task and DMS task) was acquired in about 1,000 trials as an average, and the dogs reached a high level of performance (90%), stabilized in 90 consecutive trials. The subjects' behavior was also stable after the control pause. One dog reattained the DMS criterion immediately, whereas two other dogs needed short additional training to the criterion, during which they perform of the auditory DMS task at the level of 86%. During the performance task, the dogs performance declined gradually with extended delays reaching an average of 63.4% for the delay of 90 s.

The earlier data on dogs obtained by Brown and Sołtysik (1971), have shown that learning of the same-different Konorski's Task with four pairs of auditory stimuli was very difficult. The dogs were trained in go, no-go differentiation in which the different pairs of tones (high tone followed by low tone, or vice versa) were positive stimuli whereas the same pairs of tones (two successive low tones or high tones) were negative stimuli. Learning the task with a 1-s intertone interval required an average well over 1,000 trials for each kind of trial. This finding means that training was twice longer than the recognition memory training with trial-unique stimuli used in current experiment. Brown and Sołtysik (1971) reported that transfer to longer delays was poor. However, they trained dogs with extended delays to a criterion, and the maximum interstimulus interval obtained under these circumstances was 20 s.

Data on monkeys have shown that learning of the Konorski's Task supported a matching-to-sample principle (same trials reinforced), with four compound pairs of sounds and with interstimulus delay of 0.5 - 1 s, required thousands of trials (DAmato and Colombo 1985, Kojima 1985, Colombo and DAmato 1986, Colombo et al. 1996). The performance task with extended delays was also fragile. In one study it took additional 3,200 trials to extend the delay interval to 7- and 9-s for two different monkeys (Kojima 1985). In the Colombo and DAmato (1986) study, monkeys were tested in blocks with extended delays and they dropped below 80% with the delay of 32 s. These results are similar to that obtained for the 30 s delay on dogs in current experiment.

Up to now there are no clear data showing trial-unique training in auditory recognition task. An attempt of trial-unique procedure was recently described by Wright et al. (1990) who trained two monkeys in the "same-different" task. The 38 training sounds comprised 25 trials (13 "different" trials and 12 "same" trials) of the particular sequence to be learned by monkeys until they achieved the 80% performance criterion. Then, the sounds were scrambled and selected pseudorandomly to make up a new 25-trial session (13 "same" and 12 "different" trials) in which monkeys were trained to the same criterion. This procedure was repeated for the five acquisition trainings with five different sequences. It appears that even in this paradigm, monkeys needed over 2,000 trials to learn "same-different" concept. Thus, a comparison of the data obtained in this experiment with results obtained on monkeys trained in auditory recognition tasks might led to the conclusion that dogs learn the auditory DMS task with trial-unique stimuli relatively easy.

Although dogs have learned the auditory DMS task relatively easy, their learning scores were still worse that those for monkeys trained in a visual recognition task to the similar criterion. Mishkin and Delacour (1975) had been shown that monkeys learned DMS task with trial-unique objects in 360 trials with 159 errors, as an average. The visual recognition task was learned faster (less than 100 trials with 25 errors) when delayed non-matching to sample (DNMS) procedure was used. So far, such data were not collected for auditory recognition tasks. The forgetting scores in the performance task on each of extended delays for dogs trained in auditory task were also lower than those for monkeys trained in visual task (Mishkin 1978). Recently Milgram et al. (1994) described successful learning of a DNMS visual task in dogs. Animals were trained to displace an object in order to receive food reward hidden under it. A group of young and middle age dogs learned the task in about of 300 trials and made about 150 errors during acquisition of the task. However, since in the visual recognition task a criterion of 80% correct choices in 20 consecutive trials was used, it is difficult to compare these data with data obtained in the auditory recognition task in current experiment.

Thus, comparison of learning and performance both for dogs and monkeys on recognition memory tasks indicate that the delayed-matching-to-sample task with trial-unique auditory stimuli alternating during the testing stage of trial is a valuable and promising method for testing auditory recognition memory.

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