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One-trial visual recognition in cats

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Technical communication

Abstract. The ability of normal cats to perform delayed matching- and nonmatching-to-sample with trial-unique stimuli was investigated both in a modified Wisconsin General Testing Apparatus requiring manipulatory responses and in a Nencki-type testing room requiring locomotor responses. Cats trained in the WGTA learned the two tasks at about the same rate, on average, as that reported for monkeys. However, unlike monkeys, whose strong preference for novelty facilitates their learning of the nonmatching rule and retards their learning of the matching rule, the cats learned the two different rules at about the same rate, suggesting that cats do not share the monkey's strong preference for novelty. In contrast to their relatively rapid learning of the manipulatory versions of the two tasks, cats learned the locomotor versions only slowly or even failed to learn. Experimental analysis indicated that a major source of the cats' difficulty on these locomotor versions was interference from a strong tendency in the large testing room to use visuospatial strategies. Nevertheless, once the matching or nonmatching rule was learned at short delays, whether in the WGTA or the testing room, the cats performed at criterion levels without further training even at delays of 10 minutes, indicating that this species, like monkeys, has a highly developed long-term recognition memory ability.

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Delayed matching- and nonmatching-to-sample (DMS and DNMS) tasks have been widely used to study one-trial object recognition in monkeys (Gaffan 1974, Mishkin and Delacour 1975, Mishkin et al. 1962) and to elucidate the cerebral mechanisms that mediate this type of cognitive visual memory (Mishkin and Murray 1994, Squire 1992). Similar studies have been carried out in rodents (for review see Steckler et al. 1998) and other mammals, such as dogs (Callahan et al. 2000). But to our knowledge there are no such reports on cats, although some researchers have shown that cats have good memory for spatial locations as measured by their performance on the classical spatial delayed response task (Beritashvili 1971, Fletcher 1965, Konorski 1967, Warren et al. 1972). The purpose of the present study was to compare the performance of cats on different versions of nonspatial delayed matching- and nonmatching-to-sample in order to determine which method yields the best performance, the long-term goal being to investigate the neural basis of nonspatial visual memory in this species.

Fifteen experimentally naive adult normal cats of both sexes (eight male, seven female) weighing 3–4.7 kg were used in this study. The animals were housed in individual cages (1.5 m × 1.0 m × 1.0 m) in which they had free access to water. Food was given once daily, 20 h before testing. Experimental sessions were conducted 5 days per week. The care and use of the animals complied with Georgian regulations, with Guidelines prepared by the Ethics Committee of the Institutional Animal Care and Use Committee of the Research Center for Experimental Neurology, and with the National Institutes of Health Guide for the Care and Use of Laboratory Animals.

Five different tasks were used, two requiring manipulatory responses, and three – locomotor responses.

TASK I: M-DMS (MANIPULATORY VARIANT OF DMS). Four cats, two of them males, were trained on this task. The Wisconsin General Testing Apparatus (WGTA) was adapted for use with cats so that they could use their forelimbs to displace objects and retrieve food (Fig. 1). The apparatus consisted of two main parts: A cat cage (55 cm × 65 cm × 60 cm) placed on a table inside a darkened, sound-shielded room; and a test tray containing three identical food wells, each a round glass jar (25 mm deep and 73 mm in diameter). The stimuli consisted of an array of 600 junk objects, which differed from each other in size, form, texture, and color (the latter providing mainly brightness cues for cats).

Fig. 1. Photo of the WGTA-type apparatus used for Tasks I and II. The side of the cat cage facing the test tray consists of metal bars. The tray, located 15 cm in front of the bars, contains three food wells 15 cm apart (center to center). The opaque screen between the cage and the tray is shown in the raised position.

During preliminary training, cats were shaped behaviorally to displace cardboard covers placed over the three food wells to obtain rewards (each a small piece of boiled meat, 0.5 cm^3) hidden in the wells. They were then trained in the same way to displace one of three pretraining objects, which were presented singly in random order over one of the three food wells. Finally, the cats were given 20 pseudotrials to familiarize them with the structure of the task: One of the three pretraining objects was presented as the "sample" object over the baited central well; 10 s later the two other objects were presented over the lateral wells, both or neither of which were baited, in random order. The cat was allowed to displace only one of the two "test" objects. The pseudotrials were separated by 30 s intervals. During the 10 s delay intervals and the 30 s intertrial intervals, an opaque screen separated the cat from the test tray. This preliminary training was completed in 7–12 days.

Formal testing was then begun, using trial-unique objects. Each trial consisted of two parts, a sample presentation followed by a choice test. After the animal displaced the sample object from the central well and retrieved the reward (no other object was on the test tray), the opaque screen was lowered for delay intervals of 5 s and 10 s in pseudorandom order. The screen was then raised revealing the sample object again together with a novel object, each covering one of the two lateral wells, and the cat was allowed to choose. A new pair of objects was used on every trial, and the left-right positions of the sample and novel objects on the choice test varied pseudorandomly. In the choice tests of this task, the sample object was always baited, requiring the animal to learn the rule of delayed matching-to-sample. Twenty such trials, separated by 30 s intertrial intervals, were presented daily until the animal achieved the criterion score of 80 correct trials in 100 across five consecutive sessions. There was no correction for errors. The time limit for the behavioral response was set initially to 10 s, and to 5 s at final stages of training; withholding the response beyond that limit was scored as error. The response of the animal toward the central food well was scored as an error in both manipulatory and locomotor situations. There was no correction for errors (e.g., an animal after making an incorrect response to the central well was not allowed to correct it by the response to a side well in the same trial, nor in the following one).

TASK II: M-DNMS (MANIPULATORY VARIANT OF DNMS). Four cats, two of them males, were trained on this task. The procedures were the same as those used for Task I, except that now the novel object was always baited on the choice test, requiring the animal to learn the rule of delayed nonmatching-to-sample.

TASK III: L-DMS (LOCOMOTOR VARIANT OF DMS). Four cats, one of them a male, were trained on this task. A schematic representation of the Nencki-type testing room (Konorski 1967) is shown in Figure 2. The cat cage (labeled as “St.c” in Fig. 2), measuring 45 cm × 45 cm × 50 cm was equipped with an opaque screen. To facilitate perception of the stimuli from the cat cage, only the stimulus array's larger objects (15–20 cm high and 3–5 cm in diameter) were used in this and the following tasks.

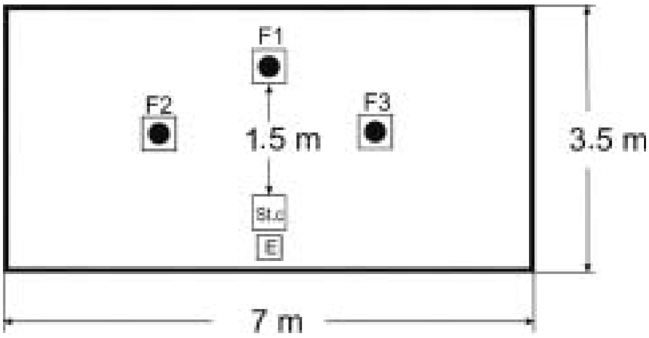

Fig. 2. Schematic representation of the Nencki-type testing room used for Tasks III–V. Abbreviations: (St.c) start-cage; (F1, F2, F3) three identical food wells; (E) location of the experimenter. Arrow inside the figure (calibration bar) indicates the approximate distance between the start-cage and the food wells.

The three stages of preliminary training were similar to those given in the WGTA, except that the animals were shaped behaviorally to run to the food wells to retrieve rewards, and then to return to the cage and reenter it. The preliminary training was completed on average in 2 days.

Both for the pseudotrials of preliminary training and during formal testing, objects were placed in front of the baited central food well (F1 in Fig. 2) for the sample presentation, and in the front of the lateral wells (F2 and F3 in Fig. 2) for the choice test. When the animal returned to the cage from the central food well after the sample presentation, the opaque screen was lowered for the delay period (5 s and 10 s in random order, as before), after which it was raised so that the animal could choose between the lateral food wells marked by sample and novel objects. On this task, as in Task I, the food well marked by the sample object was always baited on the choice tests, requiring the animal to learn the rule of matching-to-sample. In all other respects also, the procedures for this task were the same as those used for Task I.

TASK IV: L-DNMS (LOCOMOTOR VARIANT OF DNMS). Three cats, all males, were trained on Task IV. All procedures were the same as those used in Task III, except that on the choice tests the novel object was always baited, requiring the animal to learn the rule of nonmatching-to-sample.

TASK V: L-DR (LOCOMOTOR VERSION OF SPATIAL DELAYED RESPONSE). The four cats that had been trained on Task III were transferred to Task V. This task was adapted from the “place trials” of the object-location task described by Parkinson and coauthors (1988), in which only spatial location was relevant for successful performance, object quality being irrelevant. For the sample presentation, a trial-unique object was placed in front of one of the three food wells, which were baited, and which the cat approached in order to retrieve the reward. For the choice test, the sample object appeared again in front of the same food well as before, and this food well was also baited as before, while an object identical to the sample appeared in front of one of the other two, unbaited, food wells. The spatial locations of the baited well and of the covered but unbaited well were selected pseudorandomly. In all other respects, this task was the same as Task III (L-DMS).

TESTS WITH EXTENDED DELAYS: TASKS I–IV. Immediately after completing training at the 10 s delay, each cat was retrained to criterion on the same task it had received before, but at a 30 s delay. Two weeks later each cat was tested for retention at the 10 s and 30 s delays, retrained to criterion if necessary, and then trained to criterion at both 5 min and 10 min delays. These tests with extended delays were presented in 20 trial daily sessions in pseudorandom order. Statistical assessments of the behavioral data were performed on the number of trials and errors preceding criterion at each training or retraining stage by Mann-Whitney *U* test (Hollander and Wolfe 1973).

In present study following results have been obtained:

TASKS I AND II: M-DMS AND M-DNMS. The data gathered on the manipulatory versions of delayed matching and nonmatching are presented in Table I. The eight cats trained on one or the other of these two tasks learned in an average of 224 trials and 81 errors.

Although the group trained on DNMS learned slightly more quickly than the group trained on DMS, the difference was not significant. These results differ from those reported in monkeys (Mishkin and Delacour 1975), which showed a distinct advantage in learning DNMS as compared with DMS. It was concluded from the latter set of findings that monkeys have a preference for novelty, a preference that hastened their learning of the nonmatching rule and retarded their learning of the matching rule. On the basis of the findings in the present study, it appears that cats either do not have this preference for novelty or do not exhibit it to the same degree as monkeys do.

These conclusions regarding a species difference in preference for novelty and the effects of this difference on learning in cats and monkeys are supported by a direct comparison between the scores of the two species. Comparing our cats with monkeys from Mishkin and Delacour (1975) study it must be noted that in these two cases different learning criteria were used (80% in 100 consecutive trials for cats vs. 90% in 40 consecutive trials for monkeys). From the statistical point of view such comparison at first may seem not to be meaningful. But let us consider the data from Mishkin and Delacour paper: it is evident that their monkeys in M-DMS task ("E-M" in their notation), before reaching 90% criterion, reached criterion of 80% correct responses within 40 trials (median for trials to reach this criterion – 320), after which their learning curve raised monotonously to higher levels of performance (90% correct responses in 40 trials); thus it may be assumed that their monkeys in criterial trials in M-DMS task performed at least as efficiently as our cats in their 100 criterial trials. As to the M-DNMS task ("E-NM" in Mishkin and Delacour's notation) monkeys reached criterion of 80% correct responses in at least 60 trials to criterion in spite of non-monotonous character of their learning curve (Mishkin and Delacour 1975, Fig. 1). It is worthwhile to mention that according to our results cats after having achieved 80% correct criterion in 100 trials performed subsequent lengthened delay tasks at least at the same (80%) proficiency level in both tasks (Table IV). From these statements

Table I

Individual scores preceding criterion on manipulatory Tasks I and II (criterion sessions were not included into the trials and errors to criterion indices)

Task I: M-DMS			Task II: M-DNMS		
Cats	Trials	Errors	Cats	Trials	Errors
Alpha	190	66	Anna	180	91
Beta	260	92	George	200	75
Gamma	350	116	Strong	170	50
Delta	220	75	Nancy	220	84
MEDIAN	240	84	MEDIAN	190	80

Table II

Individual scores preceding criterion on locomotor Tasks III and IV (criterion sessions were not included into the trials and errors to criterion indices)

Task III: L-DMS			Task IV: L-DNMS		
Cats	Trials	Errors	Cats	Trials	Errors
Tetra	1060 (F)	520	#1	510	245
Shava	640	255	#2	725	350
Natsara	900	390	#3	1000 (F)	470
Tsotskhala	1040 (F)	435			

F denotes failure to achieve criterion within 1 000 trials, although two cats (Tetra and Tsotskhala) achieved criterion in additional 60 and 40 trials, respectively, while on the third cat (Natsara) training was disconnected after 1 000 trials

one may conclude that it is meaningful to compare our cats with monkeys from Mishkin and Delacour work mentioned above. The eight monkeys in the study by Mishkin and Delacour (1975) learned one or the other version of the two tasks in an average of 225 trials and 85 errors, an overall mean score remarkably similar to that of the eight cats in the present study. However, the monkeys' scores were distributed very differently between the two tasks: DMS, 360 trials and 150 errors; DNMS, 90 trials and 21 errors. As a result, although the cats learned the nonmatching rule significantly more slowly than the monkeys did (two-tailed Mann-Whitney $U_{4,4}$=0, P=0.03, for both trials and errors), they tended to learn the matching rule slightly more quickly than the monkeys, though the difference in this case is not significant.

TASKS III AND IV: L-DMS AND L-DNMS. The results obtained in the Nencki-type testing room are presented in Table II. Compared with the cats trained in the WGTA, those trained on the locomotor versions learned relatively slowly, with some animals even failing to reach criterion within the limit of 1 000 trials.

The cats in this situation exhibited a strong tendency to return to the central food well on the choice test, suggesting that visuospatial strategies, which are well developed in cats (Warren 1965, Warren et al. 1972), had interfered with their learning of the object matching and nonmatching rules. To examine how readily cats might learn a locomotor task in which memory for spatial cues was relevant and memory for object cues was irrelevant, we transferred the animals that had been trained on Task III to Task V.

TASK V: L-DR. As shown in Table III, all four cats, including the two that had previously failed to learn the locomotor version of delayed object matching, learned the locomotor version of spatial delayed response within just four sessions (i.e., 80 trials).

The results support the suggestion that the cats' strong tendency to use visuospatial strategies in the large testing room interfered with their learning of the object matching and nonmatching rules in that situation.

PERFORMANCE AT EXTENDED DELAYS: TASKS I–IV. As shown in Table IV, those cats that had mastered object matching and nonmatching up to delays of 10 s committed about the same number of errors as before to master the same task at a delay of 30 s.

Once they had attained the criterion score at 30 s, however, the cats re-attained this criterion almost

Table III

Individual scores preceding criterion on the locomotor spatial memory task, Task V: L-DR (criterion sessions were not included into the trials and errors to criterion indices)

Cats	Trials	Errors
Tetra	60	25
Shava	40	15
Natsara	80	45
Tsotskhala	80	38

Table IV

Median errors to criterion for initial learning of Tasks I–IV at 10 s and 30 s, and for relearning after a two-week rest at both 10 s and 30 s and at extended delays of 5 min and 10 min (criterion sessions were not included into the trials and errors to criterion indices)

MEDIAN ERRORS						
Tasks	Learning		Relearning		New learning	
DELAYS	10 s	30 s	10 s	30 s	5 min	10 min
M-DMS	84	90	0	2	6	2
M-DNMS	80	86	0	0	4	0
L-DMS	413	310	0	4	6	0
L-DNMS	350	325	0	0	4	0

immediately both when tested for retention after the two-week rest period and when delays were subsequently increased to 5 min and 10 min.

Previous comparisons of the visual learning and memory abilities of cats and monkeys were based mainly on the use of the learning-set paradigm (Passingham 1981, Warren 1965), and these comparisons indicated inferior performance of cats on trial 2, a measure of one-trial memory. Based on the evidence gathered on the tasks used in the present experiment, however, the one-trial memory of cats seems to be quite comparable to that of monkeys, in terms of both overall speed of rule learning, at least in the WGTA, as well as level of retention over long intervals (Mishkin 1982). The results suggest that delayed matching- and nonmatching-to-sample are useful measures for investigating the neural basis of long-term visual memory in cats. During comparison of cats' performance on the visual recognition task with the performance of monkeys the following distinction is evident: cats perform the locomotor version of the recognition tasks poorly, due to their reliance on visuospatial strategies directed to find food in a particular place visited a bit earlier. Perhaps this distinguishes them, as a group, from monkeys, although this speculative point needs special comparative study. It might be supposed that this difference is caused to a substantial degree by cats' inherent tendencies to exhibit the predatory behavioral patterns directed mostly by visual checks of the spatial locations of relevant objects (Warren 1965). These tendencies, of course, should be present in primates too, but to a much lesser extent, because monkeys' manipulatory activity is more developed.

Altogether, it appears that cats, like monkeys, have a highly developed long-term recognition memory ability.

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