Table 1. Mean number of saccades per second (Rate) of subjects R.S. and A.S. viewing small (5.4 minutes of arc) and large (31.2 minutes of arc) targets under "fixate" and "hold" instructions. The standard deviations (S.D.) and number (N) of recording trials are given for each condition.

Instruction	Target	Rate	S.D.	N
	Subject: R.S.			
Fixate	Small	2.01	0.49	22
Fixate	Large	1.47	.70	25
Hold	Small	0.45	.50	20
Hold	Large	.50	.48	23
	Subject: A.S.			
Fixate	Small	1.40	0.34	48
Fixate	Large	0.86	.39	47
Hold	Small	.57	.26	49
Hold	Large	.33	.19	46

This mean saccade-vector magnitude is equivalent to a saccade whose extent on a single average meridian is 5.78 minutes of arc. The typical value for fixation microsaccades reported by other investigators is 5.6 minutes of arc, a value sufficiently similar to that observed in the present experiment to suggest that "normal" fixation patterns were produced by the instruction to "fixate."

A second experiment was performed to find out whether "fixate" and "hold" instructions could be maintained in the absence of a visible fixation target. Four kinds of trials were employed. Subjects were asked either to "fixate" or to "hold" for 21.3 seconds. On half of the trials under each instruction (F2 and H2), the fixation target (5.4 minutes of arc at 1.0 mlam) visible during intertrial intervals was obscured by a shutter when the subject began recording. After 10 seconds the shutter opened and the target was visible for the remainder of the trial. On the other half of the trials (F1 and H1) the target remained visible only for the first 10 seconds; the shutter then closed for the remainder of the trial. Both subjects served in this experiment; each recorded 36 trials, 9 under each condition.

Figure 1 shows representative recordings for R.S. Note in F1 and H1 typical "fixation" and "hold" performance in the first portion of the trial until the shutter removed the target from view. The second halves of the F1 and H1 trials show performance in the absence of any visible target object. Note that the variability of the eye about its mean position was considerably increased when the target was not visible (6). Also, even in the absence of a visible target, "hold" and "fixate" performances were different: there were more saccades when R.S. "fixated" an

imaginary target than when he tried to "hold" his eye still in darkness. When the target disappeared at the onset of the trial and reappeared after 10 seconds (F2 and H2), the results were virtually the same: a single large saccade corrected the position error noticed when the target reappeared and typical "fixation" and "holding" ensued.

These experiments suggest that microsaccades initiated during "fixation" may be under voluntary control. Subjects can inhibit them for prolonged periods when they are instructed to "hold" their eyes still. Furthermore, this inhibition of microsaccades does not, in itself, lead to increased variability of the eye about its mean position, which shows that there is an effective low-velocity corrective system for holding the eye in position on all meridians. Nachmias had previously shown that when a subject attempts to maintain fixation both saccades and drifts can contribute to position control of his eye. In his work, however, saccadic correction was most prominent; corrective drifts were observed on only a few meridians where saccadic correction was not effective (7). In the present experiments drift correction frequently takes over completely under "hold" instructions.

It is not known, at present, whether each microsaccade that is executed under "fixation" instructions is a voluntary act. We prefer at this time to assume that there is a microsaccadic system that is called into play when "fixation" is attempted. This assumption, however, is based exclusively on the very small size of these saccadic movements, and further experiments will be necessary to determine whether it is a system, rather than individual saccades, that is being called forth by an effort of the will.

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theory underlying the recording of two-dimensional motions of the eye with an apparatus similar to that employed in the present experiments, and L. Matin [*ibid.* **54**, 1008 (1964)] for an analysis of various systems for measuring eye position.
4. Three judges counted saccades. Agreement among judges was almost perfect. In those very rare instances where there was a disagreement, the count that went contrary to our hypothesis was accepted, that is, the lower value on "fixate" trials and the higher value on "hold" trials.
5. The differences in saccade rates were so large relative to the standard deviations that we felt formal statistical treatment was not necessary. The fact that saccade rates are lower with larger targets under fixation instructions has been reported previously (see Steinman *3*).
6. The increased variability in eye position found when a target is removed from view has been reported previously (see *2, 3,* and *7*).
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8. We thank A. Skavenski for serving as a subject, Ellen Mindlin for carefully measuring the film, and Elizabeth Kocher for insisting that we collect data on what seemed an unlikely problem. Supported by NIH grant NB-06361-01 to R.M.S. and a NIH predoctoral fellowship to R.J.C.

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Learning-Set Formation by Mink, Ferrets, Skunks, and Cats

Abstract. The ability of mink, ferrets, skunks, and cats to learn to discriminate between objects was compared. Performance of mink and ferrets was similar to that reported for primates. This observation suggests that there is considerable overlap among mammals in ability to form learning sets.

Interproblem learning, or the progressive improvement in learning consecutive, nonspatial, visual discrimination problems, is used to compare complex learning ability of mammals under laboratory conditions (1, 2). While formation of learning sets has been observed in a variety of species, including rats, cats, and racoons (3), studies with primates (2, 4, 5) suggest that the latter are quantitatively superior to most carnivores in this type of learning. We investigated formation of learning sets in carnivores representing the mammalian mustelidae (weasel) family, a group whose complex learning abilities have not been systematically studied in the laboratory.

The subjects were seven mink and eight ferrets, skunks, and cats. Mink (*Mustela vision*), pearl variety, and ferrets (*Mustela furo*) were commercially developed strains. Skunk were *Mephitis* or striped variety. Animals ranged in age from 9 to 12 months. About half were males. Subjects were raised from infancy in laboratories and were fed canned cat
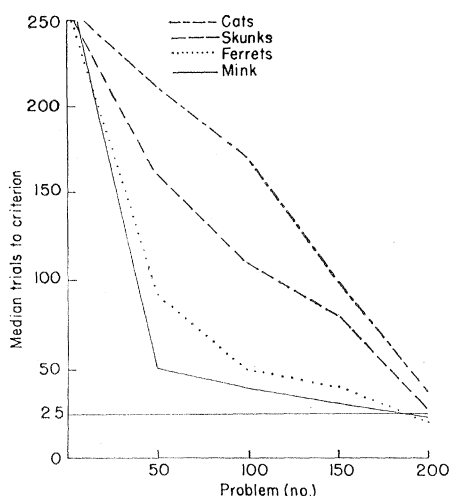
Fig. 1. Interproblem learning in mink, ferrets, skunks, and cats.

food supplemented with vitamins, brewers yeast, and fish flour. Median body weights of subjects were 3.18 kg, 3.9 kg, 4.1 kg, and 5.9 kg for mink, ferrets, cats, and skunks, respectively.

Animals were tested in a modified Wisconsin General test apparatus (1) with a 50.8-cm-square starting area from which subjects had access to a retractable tray. The tray supported two swinging doors to which the stimulus objects were attached. A one-way vision screen between the experimenter and the tray prevented the subject from seeing the experimenter. A wooden panel was lowered between the tray and the starting area when the tray was baited so that the subject could not see the location of the food reward. The stimulus objects were pairs of wooden figures which varied in visual dimensions of form, brightness, surface area, and thickness. Test objects were similar to
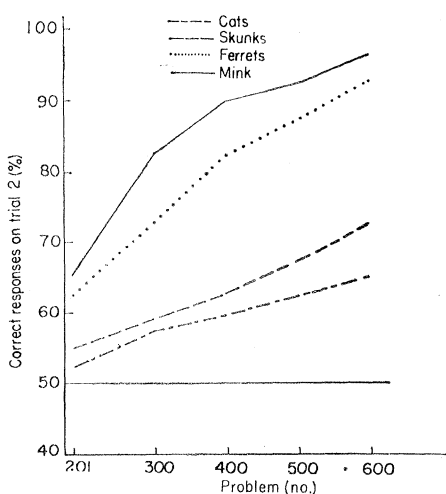
those used in learning-set studies with monkeys (1, 2). Objects were randomly paired and ordered. The correct object on any given trial was determined from a table of random numbers.

Subjects were tested on a series of 600 object-discrimination problems. On each trial, the subject was required to push open one of the two doors to which the pair of objects were attached. Choice of the correct object was rewarded with a piece of meat placed behind the door; there was no punishment for errors. After the subject made a choice, the wooden panel was lowered, and objects on the door were reset for the next trial. The spatial position of the rewarded object was varied in a balanced, irregular sequence, and the errors were not corrected.

Testing on the first 200 problems was continued to a criterion of 20 correct out of 25 responses. The remaining 400 problems were presented for six trials each. Each subject was presented 50 trials a day, 7 days a week. Subjects were fed daily rations immediately after trials. Subjects were maintained at 80 percent of normal body weight.

Interproblem learning by all subjects on problems learned to criterion is shown in Fig. 1. Median trials to criterion ranged from 250 on the first block of trials to 20 for some subjects on later problem blocks. Groups differed considerably in overall performance, with mink demonstrating the most rapid improvement across problem blocks. All species tested performed similarly on initial visual discriminations.

Improvement in learning from one problem to another can be expressed in terms of an increase in percentage of correct responses on trial 2 of sequential groups of problems (2). Figure 2 indicates the percentage of correct responses performed by all subjects on trial 2 of successive groups of six-trial problems. Performance of each species on trial two of adjacent pairs of 100-problem blocks was analyzed by Wilcoxon matched-pairs signed ranks tests (6). All groups showed highly significant ($P < .001$) intraspecies differences. Correct choices in trial 2 by all species increased substantially over successive problem blocks. Curves for mink and ferrets indicate a particularly high degree of interproblem learning.

These findings suggest that under the present experimental conditions cats are inferior to certain species of the weasel family in performance on con-

secutive visual discriminations. However, substantial differences appear among the latter subjects, with mink demonstrating the greatest improvement in interproblem performance, while skunks are intermediate in performance between ferrets and cats. Performance of mink and ferrets on trial 2 of sequential problem blocks is superior to that of some primates, namely marmosets and platyrrhine monkeys (4). The curve for mink resembles that for rhesus monkeys and chimpanzees (7), although the rate of improvement is somewhat slower in the former species. Mink and ferrets also showed one-trial learning of problems after considerable prior training on similar problems, a phenomena usually observed only among primates.

These data suggest that quantitative rather than qualitative differences characterize mammalian interproblem learning (8). They also suggest that ferrets and mink are excellent subjects for studies of complex learning ability. The reliability of observed interspecies differences may suffer severely as the same comparisons are made under varying problem-solving conditions which may shift the advantage from one species to the other (9). The extent to which species differences in motivation, visual capacities, and the like may have affected final performance can only be determined by further experimentation.

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Fig. 2. Discrimination learning-set formation by mink, ferrets, skunks, and cats.

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