SUCCESSIVE REVERSAL DISCRIMINATION IN EASTERN FOX SQUIRRELS (*SCIURUS NIGER*)

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STATEMENT BY AUTHOR

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ABSTRACT

Six Eastern fox squirrels were tested in a Wisconsin General Test Apparatus on three series of criterial successive reversal discrimination problems. The data were analyzed in terms of errors on problems within each series, and errors within and across series, and were also compared with data obtained on roundtailed ground squirrels. The fox squirrels showed little improvement in performance either within a series, or across the series, and there was a general lack of significance between the two species of squirrel performances. Reversal indices were also calculated for the two species, and were also found to be insignificant in their differences. The inability of fox squirrels to perform well on this task was discussed.

INTRODUCTION

Discrimination learning set (DLS), as described by Harlow (1949, 1959), was devised in part, so that learning of one task could be studied in its effects on another, subsequent task. The basic DLS design was to train subjects (Ss) on discrimination problems wherein the Ss were presented a pair of stimulus objects, with only one of the objects, upon its being selected, leading to some sort of reward. Thus, the S had to learn that one of the pair of objects was always rewarded, and that the other object was always nonrewarded. Each pair of objects would be presented for a fixed number of trials, or each pair could be learned to a predetermined criterion of performance. Either way, the S may establish a "learning set" (Harlow, 1949), as shown by better performance on later problems than on earlier ones.

Discrimination reversal learning (DRL) is a modification of DLS. A typical DRL problem involves the presentation of a pair of stimulus objects as in DLS, with only one object rewarded. However, after a predetermined number of trials, or after S reaches a predetermined criterional performance, the reward contingencies on the object pair are reversed. That is, the same pair is again presented to the S, for a fixed number of trials, or until criterional performance is achieved, but the previously rewarded object is now nonrewarded, and the initial nonrewarded object is now rewarded. The process is then repeated with a new set of objects. To study DRL proficiency, one would plot the number of errors following the first reversal trial. Again, one could study the reduction of errors within the one problem, or between problems.

Successive reversal discrimination (SRD), as described by Schusterman (1966) and Gossette, Gossette, and Riddell (1966), is similar to RDL in that there is once again an initial establishment of a discrimination, and this is followed by a reversal of the reward contingencies. However, with SRD, the reversal of the reinforcement contingencies is repeatedly effected with the same pair of objects. Thus, on the third successive reversal, the rewarded object is now the same object which was rewarded on the initial discrimination.

DRL has been proposed by some experimenters, among them Bitterman (1960, 1965), Rumbaugh and Ensminger (1964), and Gossette et al. (1966), as yielding fair differences among different species of animals. Several aspects of an animal's performance on this sort of task have been studied. Among these aspects are the number of errors on the acquisition trials, the number of errors on the reversals, and the percentage of errors. There have also been attempts at studying the various relationships of errors, or trials, involved in acquisition in relation to these same elements on reversals. Possibly one of the reasons that RDL has instigated such experimentation and speculation may be that Harlow (1959) has related DLS tasks as being a prerequisite for all concept formation tasks. Here, in these studies, the concept involved is the learning set, or the learning to learn, which would seem to be one of the most basic concepts in the study of animal behavior. Since RDL is considered to be a modification of DLS, it might be conceived as being based on the same concepts, with emphasis on the concept of the win-stay, lose-shift strategy associated with DLS type learning (Schusterman, 1966).

The win-stay, lose-shift strategy relates to the efficient performance on DLS type tasks. That is, in order for the S to perform efficiently on these tasks, it must learn that upon being rewarded for choosing a certain object, it should continue to choose that object on subsequent trials, or, upon choosing an unrewarded object, S should shift its attention to the other object on subsequent trials. Gossette et al. (1966) state that the differences which evolve among species in learning this concept give the psychologist a powerful tool for the comparative analysis and study of learning processes.

There has been an assortment of indices developed for comparisons among various species, with the indices usually based on some ratio of errors or trials on reversals to the number of errors or trials on the initial acquisition (Rajalakshmi and Jeeves, 1965; Rumbaugh and Jeeves, 1966). As with many techniques developed in psychology, these indices have aroused much criticism (Warren, 1967; Bitterman, 1965). Most of this criticism is based on the facts that the indices were derived from a limited variety of species, and that the procedures and methodologies used have not been consistent or equivalent from study to study. Thus, the critics state that to use the indices for interspecies comparison really offers nothing useful to the study of learning behavior. However, further work continues in an attempt to establish some tool for comparisons, among this work being attempts at devising some sort of transfer index (Rumbaugh, 1968), and there remains the possibility that an index which is satisfactory and reliable may be developed in the near future.

The present experiment was undertaken with this goal in mind, and was intended to provide SRD data on a species which had not been tested previously. The Eastern fox squirrel (Sciurus niger) was chosen as the experimental animal. It is believed that the data obtained from this experiment would be basically comparable to studies performed with other species using the same apparatus and procedures, and would also fill an empty niche in SRD data. Multiple SRD problems and series were used in this experiment, as it is believed that this will be a stricter test of the win-stay, lose-shift strategy. The rationale here is that the *S*s would not only have to learn to transfer the strategy from one problem to another, with the same pair of objects, but must also learn to transfer this ability to another series of problems using a different pair of objects. Thus, it was believed that there would be a progressive decrease in errors to criterion on each successive reversal, or problem, and that this progression would continue into the next series.

METHOD

Subjects

The subjects (Ss) were one female and five male Eastern fox squirrels (Sciurus niger), which were obtained as young adults from a commercial supplier. One male and one female had had prior experience in a delayed response task (King, Flaningam, and Rees, 1968), while the remaining four Ss were experimentally naive. All animals had been in the laboratory at least three months prior to testing.

The Eastern fox squirrel is widely distributed over the eastern half of the United States, living primarily where there are nut trees within its home range. Its habitat in the northern half of the eastern U.S. is in open hardwood lots, and in pine forests in the southern half. The fox squirrel spends most of its time on the ground foraging for food, sometimes in clearings which are several yards from any trees. Its home range usually consists of 10 to 40 acres, with a population density ranging from about one squirrel per two acres to about three squirrels per acre. Fox squirrels nest in tree cavities or build twig and leaf nests in a crotch, or branches of a large tree, usually 30 feet or more from the ground. Their diet includes a great variety of nuts, acorns, seeds, fungi, birds, and cambair beneath the bark of small branches of trees. The animal buries nuts singly, many of which are never retrieved (Martin, Zim, and Nelson, 1951).

The fox squirrel adapts fairly well to captivity, but there is a great amount of individual variation in the degree of adaptation. For example, some animals after a short stay in the laboratory allowed themselves to be petted while in their home cages, while other animals would remain immobile at the rear of their home cages just as long as a human was present within the room where these cages were kept. As best as could be observed, the Ss did not hoard food in their home cages with the amount of food they received being contingent on it being consumed within an hour after being placed within the cage.

In a testing apparatus, fox squirrels initially displayed some signs of emotional behavior (fear or avoidance), but this behavior usually disappeared within a few sessions in the test situation. However, some animals were highly emotional and difficult to train; when in the test situation, if there was any activity slightly out of the usual routine, these animals would "freeze," remaining immobile for 10-15 minutes at a time.

Apparatus

The testing was done in a modification of the Wisconsin General Test Apparatus, which has been previously described in detail by Harlow and Bromer (1938). The test compartment (14 in. wide by 30 in. long) displaying the stimulus objects and the object presentation tray was separated from S's transport cage (14 in. wide, 14 in. long, and 10 in. high) by manually operated opaque and plexiglass screens. The opaque screen prevented S from observing the tray during the intertrial interval while the plexiglass screen prevented S's escape from the transport-test cage, yet allowed space for S to respond to the objects. The experimenter (E) observed S's responses through a stationary one-way screen (9-1/2 in. long by 3-1/2 in. high). The object tray was 14 in. wide by 5-3/4 in. deep, and contained two 1-1/4 in. diameter foodwells separated by 5 in. center to center. A 3/8 in. diameter hole ran horizontally from the back of the tray up to the foodwell and retained the reinforcers equidistant from the foodwells. E was able to move the reinforcer up to the foodwell with a 3/8 in. diameter dowel. The tray's speed and movement were controlled by two weights attached to a pulley/cord arrangement, and were thus independent of E's movement, except for the presentation and the retrieval of the tray from the test compartment. The tray advanced at approximately 1/3 ft. per sec., a speed which had been previously found to be optimal by other experimenters in the laboratory (Rees and King, unpublished data). Attached to the bottom of one side of the tracks for the opaque screen was a microswitch which activated a Hunter timer in order to time the duration of the intertrial interval.

The stimulus objects were constructed from junk and hardware items (small toys, bottlecaps, pencil parts, costume jewelry, etc.), and were mounted on 1-3/4 in. squares of 1/4 in. multicolored wood. Each pair varied in multiple dimensions. During testing, the objects were placed on special object holders which had a plexiglass barrier on the front 1/2 in. high, thus preventing the Ss from touching the objects, or from imparting an olfactory cue to the objects themselves as a result of contact. The object holders remained in a constant position on the test tray, and were in tracks to prevent the Ss from pulling them into the test cage. A response was recorded whenever the object was pushed back to a line 1/4 in. behind the objects.

Procedure

Ss were placed on 24-hour food deprivation schedules and were trained to enter a transport-test cage. Then they were trained to displace a single neutral object covering one of the foodwells to procure a preferred reinforcer. All Ss were offered sunflower seeds, currants, and Noyes food pellets to determine individual preferences, with the result that sunflower seeds were the choice of all. After 40 single adaptation trials, with an equal number of trials given at each of the foodwells, Ss were presented with a two-object discrimination problem in which the reward values of the objects had been randomly determined. The position of all objects during pretraining and testing was determined by a Gellermann (1933) sequence.

Three pairs of stimulus objects were used in the experiment. Each pair of objects was presented for seven problems which were the initial acquisition of the discrimination followed by six reversals. These seven problems composed one series. However, the third pair of objects was presented for a shortened series composed of only two problems, an acquisition followed by one reversal. The procedure employed in the presentation of the problems and series was as follows: At the start of each trial, the E raised the opaque screen and allowed the stimulus tray to slide up to S. After S had displaced an object, the screen was lowered, the tray retracted, and the objects either actually, or simulatively switched in order to control the intertrial interval noise. During the intertrial interval of 12 sec., the objects were manipulated, food tubes refilled, and response outcomes recorded. Each S was presented 40 trials per day with the noncorrection procedure. After S had made 9 out of 10 correct responses on a problem, the reward values of the stimulus objects were reversed, and Ss were retested to the same criterion. All Ss were presented with the same three pairs of stimulus objects, and all Ss had the same object reinforced on each trial. Stimulus objects were thoroughly cleaned after each S, and again before testing the next S.

RESULTS

Calculations of the results are based on only four of the six animals. Two of the animals, both naive, after 3900 trials were unable to get beyond the second problem of the first series, so their data were not included in any of the results reported here.

There was no significant difference between the total number of errors on Series 1 (4723) and Series 2 (3479) ($t = 1.113$, $df = 3$, $p > .10$). Series 3 was not included in this calculation as it contained only two problems. Table 1 presents the summary of the one-way analyses of the problem and series errors. The analysis of the problem 1 errors, for all three series, showed that the series and the series by subject values were insignificant ($F = 1.84$, $df = 3/8$, $p > .75$; $F = 0.82$, $df = 6/8$, $p > .75$). The problem 2 errors, which are based only on the errors of the second problem of each series, obtained values which were insignificant for the series and the series by subject interaction ($F = 0.27$, $df = 2/6$, $p > .75$; $F = 1.22$, $df = 6/8$, $p > .75$). The average problem errors, as reported in Table 1, were derived from the average values of the errors on problems 2 through 7, and again the series and series by subject values were insignificant ($F = 0.78$, $df = 1/3$, $p > .75$; $F = 1.07$, $df = 3/4$, $p > .75$). Since these average

Table 1

A Summary of the One-Way Analyses of Variance for the Problem Errors

Source of variance	SS	df	MS	F	Sig.[a]
Problem One Errors[b]					
Total	39101	11			
Within subjects	24875	8	3109		
Series	9487	2	4724	1.84	NS[c]
Series x subjects	15388	6	2564	0.82	NS
Problem Two Errors[b]					
Total	33905	11			
Within subjects	20229	8	2528		
Series	1699	2	849	0.27	NS
Series x subjects	18530	6	3088	1.22	NS
Average Problem Errors[d]					
Total	20226	7			
Within subjects	17773	4	4443		
Series	3486	1	3486	0.78	NS
Series x subjects	14287	3	4762	1.07	NS

[a]Level of significance.

[b]This includes problem errors for all three Series.

[c]Nonsignificant.

[d]This includes the problem errors for only Series 1 and 2.

problem errors were based on problems 2 through 7, these data were based only on Series 1 and 2.

Figure 1 shows the mean trials to criterion for Series 1 and 2 as a function of the seven problems. It should be noted here that on both Figure 1 and Figure 2, problem 1 is labelled A for acquisition, and problems 2 through 7 labelled R_1 through R_6, for reversals. Figure 1 shows an increase of trials on problems 2 and 3, then there begins a gradual decrease in trials to criterion through problems 4, 5, and 6, and then again an increase on problem 7. A trend analysis was calculated for this curve, but none of the values proved to be significant.

The number of errors to criterion on all problems of Series 1 and 2 was analyzed in conjunction with data obtained from a similar experiment (Rees and Flaningam, unpublished data) using roundtailed ground squirrels (*Citellus tereticaudus*). Table 2 presents the summation of the two-way analyses of the data. For Series 1, the species, problems, and the problem by species interaction values were insignificant ($F = 2.15$, $df = 1/6$, $p > .75$; $F = 0.78$, $df = 6/36$, $p > .75$; $F = 1.24$, $df = 6/36$, $p > .75$). On Series 2, the species and the problem values were also insignificant ($F = 1.14$, $df = 1/6$, $p > .75$; $F = 1.79$, $df = 6/36$, $p > .75$), but the problem by species interaction was found to be significant ($F = 2.52$, $df = 6/36$, $p < .05$). The mean errors to criterion on both Series 1 and 2 for

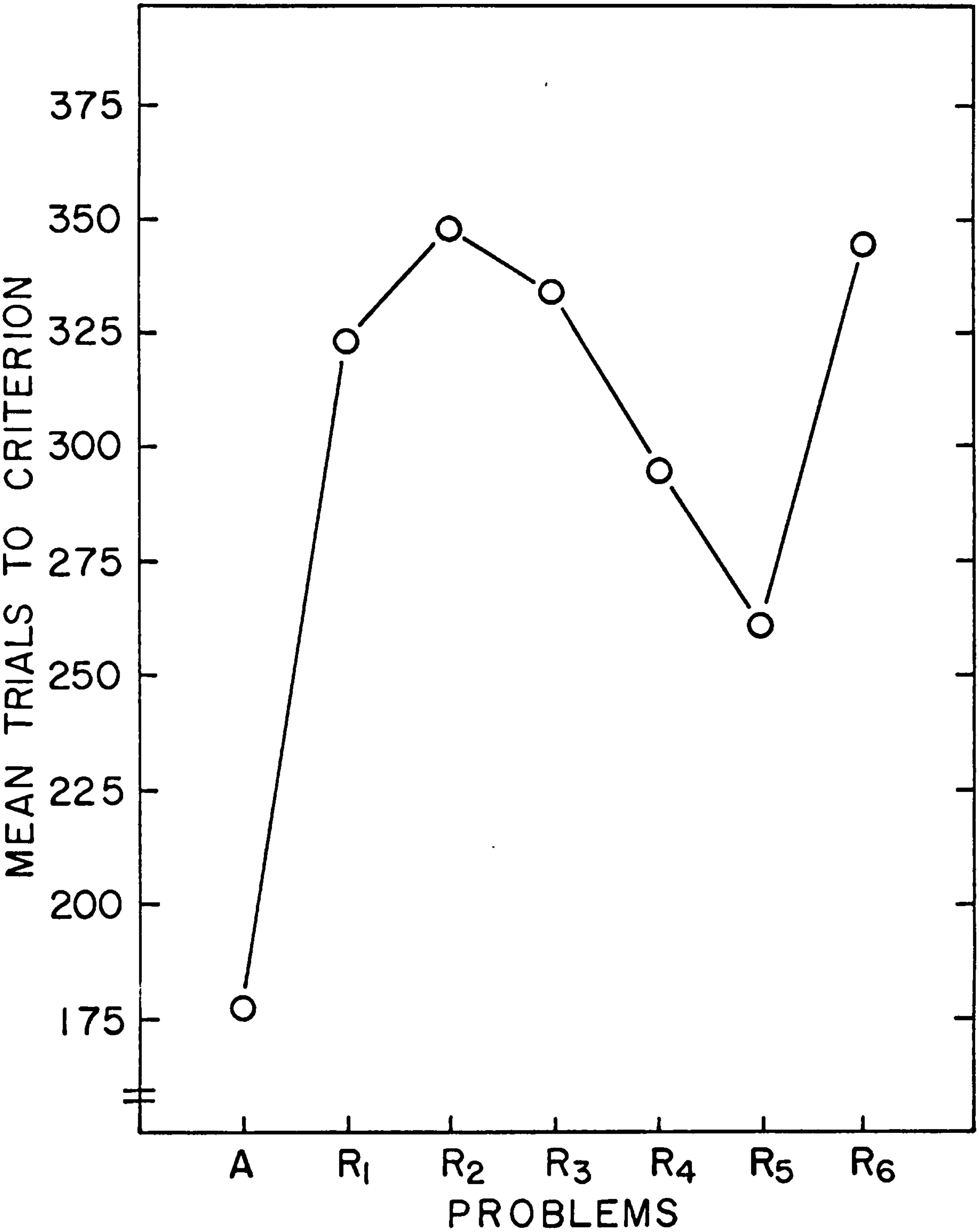

Fig. 1. The mean number of trials to criterion on Series 1 and Series 2 combined as a function of the problems.

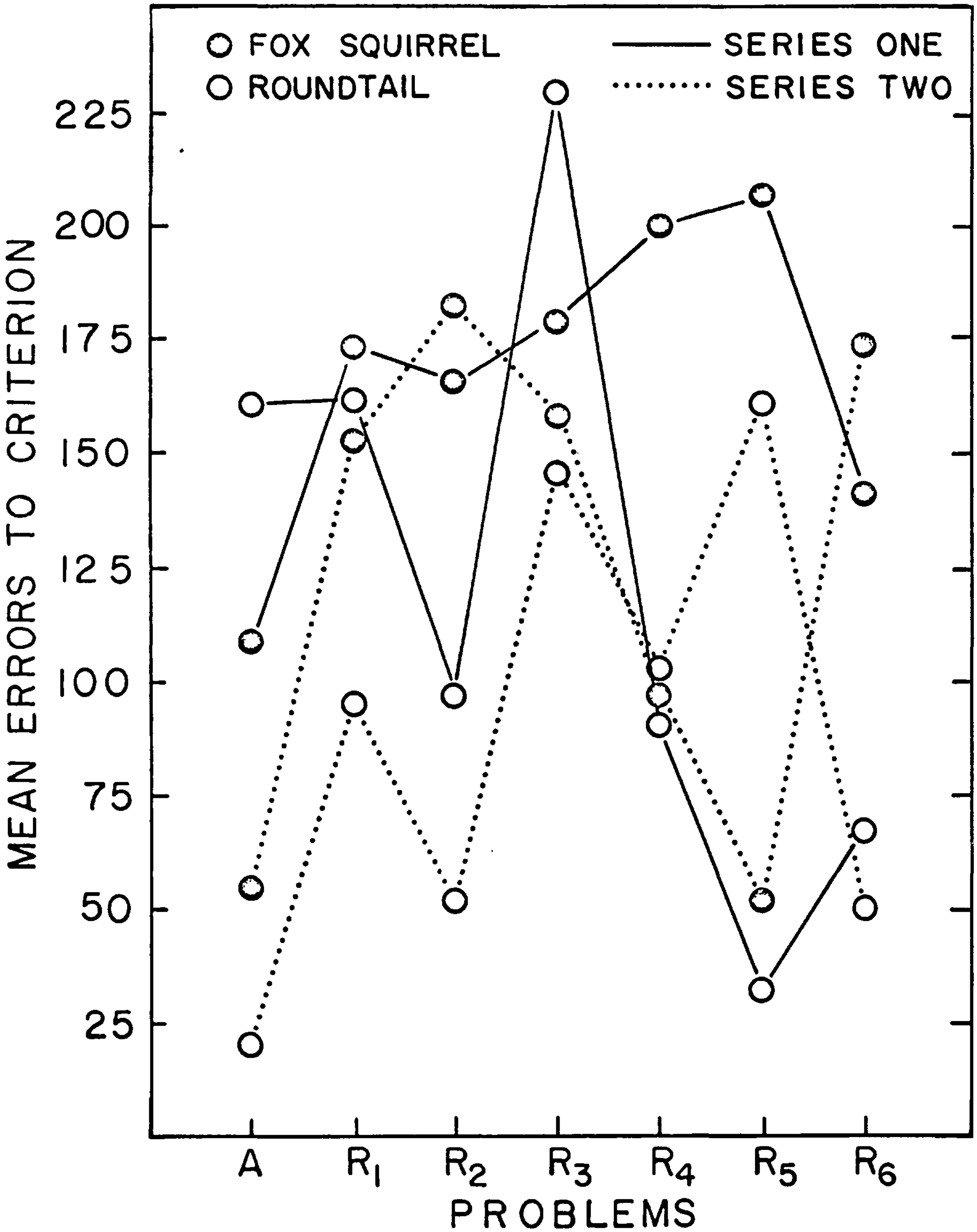

Fig. 2. The mean number of errors to criterion on Series 1 and Series 2 for the fox and roundtailed squirrels as a function of the acquisition and reversal problems.

Table 2

A Summary of the Two-Way Analyses of Variance for the Number of Errors to Criterion on Series 1 and 2

Source of variance	SS	df	MS	F	Sig.[a]
Series 1					
Between subjects	126692	7			
Species	33467	1	33467	2.15	NS[b]
Ss within groups	93225	6	15537		
Within subjects	533325	48			
Problems	52224	6	8704	0.78	NS
Problems x species	82649	6	13774	1.24	NS
Error	398452	36	11068		
Series 2					
Between subjects	102368	7			
Species	16388	1	16388	1.14	NS
Ss within groups	85980	6	14330		
Within subjects	344382	48			
Problems	59839	6	9973	1.79	NS
Problems x species	84351	6	14058	2.52	0.05
Error	200192	36	5561		

[a]Level of significance.

[b]Nonsignificant.

these species are presented in Figure 2 as a function of the seven problems. To explore more fully any possible differences tetween the two species, t tests were calculated on the errors to criterion on Series 1 and Series 2, with the results again insignificant ($t = 1.40$, $df = 3$, $p > .75$; $t = 1.06$, $df = 3$, $p > .75$).

In order to provide additional information, reversal indices were calculated for the fox and roundtailed squirrels, using two different techniques. The first technique involved using mean errors on problem 1 divided by the mean errors of only problem 2 on all three series, and this resulted in values of 1.52 and 1.10 for the fox and roundtailed squirrels, respectively. These values were not significantly different ($t = .39$, $df = 3$, $p > .75$). The second technique involved dividing the mean number of errors for problem 1 for Series 1 and 2 only, by the mean number of errors on problems 2 through 7 for both series, and this resulted in values of 1.06 for the fox squirrel and 1.02 for the roundtailed squirrel. Again, these values were not found to be significantly different ($t = .07$, $df = 3$, $p > .75$).

DISCUSSION

The data from this experiment would seem to illustrate several things of interest. One of these might be that the olfactory cue may have been more of a confounding error in previous experiments than what was believed, or reported. Elaborate care was taken in the present experiment through use of the revised stimulus tray, and procedures of the E, to control for this cue. Thus the confusing performance by the Ss in this experiment may have been due to the lack of, or diminished, olfactory cues.

Another possibility may be that the Ss attention, or orientation was inconsistent from trial to trial. Attention has been discussed (Mackingtosh, 1965) as being one of the most important factors in discrimination learning. In this experiment, the E attempted to have the animals oriented in the same position before releasing the tray, but this was almost an impossible task with the animals moving around during the intertrial interval and trying to maintain the 12 sec. interval between tray presentation. Thus, the result was that on some of the trials, the Ss would attend to both objects before making their selections, but on other trials, they would attend to only one object, usually the object which was nearer to them upon the tray's approach to the Ss. The animals would seem therefore, not to have performed the task as had been hoped. That is, it was possible that the Ss were not attending to both objects on every trial, which would probably be a necessary prerequisite for efficient and consistent improvement in object discrimination. There was a slight improvement as reversals, or problems, continued, but, there seemed to be little sign that the Ss had developed any sort of a reversal learning set. This result may correspond to a statement by Munn (1964) that the improvement in performance over repeated discriminations could have evolved from the general adaptation of Ss to the experimental situation.

Still another possible explanation for the results of this experiment may have been that the experiment was not continued longer. This was suggested by the only significant result in the difference between the fox and roundtailed squirrels on the problem by species interaction on Series 2. The lack of significance elsewhere, however, questions the meaning of this result. And, since each S had at least 3900 trials, this would seem to have been enough to fully demonstrate any learning which might have taken place, and compares favorably to the number of trials used on related species (Gonzales and Shepp, 1961; North, 1950; Sutherland, 1966), for which consistent improvement in performance was shown.

The possibility that the animals were inhibited in their performance due to the lack of object-touching was also considered; however, Peterson and Rumbaugh (1965) using squirrel monkeys, showed that object contact was an insignificant variable. In the present experiment, though the fox squirrel is not closely related to the squirrel monkey, object touching was also not considered significant. The reason being that in the present experiment, though the Ss could not actually touch the stimulus objects, the objects visually presented to them, the Ss, a contrast in pattern or silhouette within each pair. North (1950), using albino rats, a more closely related species to the fox squirrel, found significant interreversal improvement using stimuli which were less contrasting than in the present experiment. And, in addition, the Ss in North's experiment did not touch the stimuli.

The present experiment basically seems to indicate that replication is needed, not only of this experiment, but with other, previous experiments using similar species. Similar techniques and procedures should be used in the other experiments, especially the controls for olfactory cues, in the hope that the results of the present experiment may not be viewed as completely unique. There might also be the possibility that the fox squirrel, selected for this experiment, may not be adaptable to this sort of experimentation, and another type of task may demonstrate more clearly this animal's ability on visual discrimination. Until then, from the results of the present study, it would have to be concluded that the fox squirrel's ability on successive reversal discrimination problems would seem to be rather poor comparatively, and is needful of further exploration.

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