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Spatial reversal learning in rats, pigeons, and goldfish*

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Four rats, four pigeons, and four goldfish were trained under comparable conditions for 40 trials per day on a spatial discrimination and a series of 30 daily reversals. All three groups of animals showed a significant reduction in errors per reversal over the course of the experiment, but the rats improved much more rapidly than the pigeons, who in turn improved more rapidly than the goldfish.

Although a number of investigators have recently observed substantial differences in the performance of different animal groups trained on serial reversal tasks (e.g., Bitterman, 1965; Gossette, 1966; Mackintosh, 1969), several questions of interpretation remain. One problem is to know if any particular difference observed between, say, the performance of goldfish and rats reflects anything more than differences in the experimental condition under which the two groups were studied. A second question is whether or not differences in performance should be described as qualitative or quantitative. Bitterman (1965), for example, has argued that since fish typically show no improvement in performance over a series of reversals, there must be qualitative differences in mechanisms of learning (or retention) between them and rats. The complete absence of improvement in fish, however, may be due to less than optimal experimental conditions; one obvious respect in which the apparatus used for fish has usually differed from that

used for rats or pigeons has been in the contiguity between stimulus, response, and reinforcement. Fish have usually been reinforced by food dropped onto the surface of the water—often near the back of their tank. Rats and pigeons usually receive reinforcement from a magazine located close to the response keys. When we trained some rats on a series of spatial reversals under conditions similar to those reported in the present study—with the exception that the food magazine was located on the back wall of the box, we found that, although still showing highly significant improvement, they averaged nearly twice as many errors per reversal as the rats in the present study. It therefore seemed desirable to study the reversal performance of fish under more favorable conditions. In this experiment, we used a reinforcement device described by Ames (1967), which delivered paste food to a magazine located midway between the two response keys.

METHOD

The Ss were four male hooded rats, approximately 4 months old, four White Carneaux pigeons, approximately 6 months old, and four 5-in. goldfish. Motivation was maintained by feeding sufficient food

after each day's trials to maintain the rats at 85% and the pigeons at 80% of their ad lib weights; the goldfish were fed a pinch of Tetramin staple food each day.

The apparatus used for the rats was a 9 x 9 x 9 in. box housed in a sound-insulated shell. One wall of the box contained two 1-in.-diam response keys mounted 2½ in. from the floor and 4 in. apart, with a magazine opening midway between them. Correct responses were reinforced with one 45-mg Noyes pellet and the illumination of a light in the magazine opening for 3 sec. The pigeons were trained in a standard two-key box, also with a central magazine opening. Reinforcement consisted of 3 sec access to grain during which the magazine was illuminated. The fish were trained in their living tanks. A black Plexiglas box was fitted tightly over the tank and contained a black Plexiglas screen which covered one end wall of the tank. The screen contained two 1-in.-diam holes 3 in. from the bottom and 2 in. apart. Behind the holes were mounted paddles which, when touched, activated two phonograph cartridges whose outputs were amplified to operate relays. Midway between the two paddles was the opening of the magazine. Reinforcement was delivered by raising the shutter that covered the opening of the magazine and turning on a light for 5 sec. Food (Tetramin tube food) was delivered to the magazine opening via a 14-ga polyethylene tube attached to a hypodermic syringe mounted on the top of the box. For each reinforcement, a motor was operated for 2 sec to drive the syringe.

The training procedure was identical for all Ss. After being pretrained to eat from the magazine and being reinforced for responding to whichever response key was illuminated from behind with a white light, all Ss received 40 noncorrection trials daily for 31 days. A trial started with the illumination of the two response keys with white light. A response on either key turned both lights off, and, if correct, led to reinforcement. After reinforcement (or immediately after an incorrect response) there was a 25-sec intertrial interval spent in darkness. All Ss were initially trained with the left key correct, and were thereafter reversed every day for a total of 30 reversals. All experimental events were programmed and recorded automatically.

RESULTS

Figure 1 shows the mean number of errors per problem for original learning and each of 30 reversals. It is clear that the rats were very much more efficient than either the pigeons or the goldfish,

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Fig. 1. Mean number of errors per problem in original learning and each reversal.

reaching an asymptote of less than five errors per problem after about 10-15 reversals. The difference between the performance of pigeons and goldfish was quite small, although it appeared that the pigeons made more errors in earlier reversals (reflecting better within-problem learning, hence more errors at the beginning of each day), and, on average, fewer errors in later reversals.

For purposes of statistical analysis, the performance of each S was averaged over blocks of 10 reversals; the resulting data, transformed into the percentage of correct responses per 10 reversals, are shown in Table 1. An analysis of variance performed on these error scores revealed significant effects due to species, blocks of reversals, and to the interaction ($F = 72.28$ and $df = 2/9$, $F = 67.83$ and $df = 2/18$, $F = 7.99$ and $df = 4/18$, respectively; in all cases, $p < .001$). Separate analyses compared rats with pigeons and pigeons with goldfish. In the former case, all three effects (species, blocks, and interaction) were

significant ($F = 68.47$, $df = 1/6$, $p < .001$; $F = 80.22$, $df = 2/12$, $p < .001$; and $F = 3.91$, $df = 2/12$, $p < .05$). In the comparison between pigeons and goldfish, the main effect of species was not significant ($F < 1$), but that of blocks was significant ($F = 25.21$, $df = 2/12$, $p < .001$), while the interaction was also significant ($F = 4.60$, $df = 2/12$, $p < .05$). We can conclude that rats made fewer errors overall and improved more rapidly than pigeons, while pigeons improved more rapidly than the goldfish. There is, however, evidence that the goldfish showed some improvement; all four Ss performed more accurately over the final block of reversals than over the first block, and an analysis of variance performed on their scores showed a significant effect of blocks ($F = 6.49$, $df = 2/9$, $p < .05$).

Table 1 also presents data relevant to one interpretation of differences in reversal performance. Gonzalez, Behrend, & Bitterman (1967) have suggested that a decline in errors over reversals may be due to a decline in

interference between successive problems; if Ss come to forget from one day to the next which alternative was last correct, they will make fewer errors at the outset of each new problem. Gonzalez et al suggested that goldfish might be inefficient reversal learners because they do not forget. In order to examine this possibility, we calculated the probability of an error on Trial 1 of each reversal over the last 10 reversals; the higher the probability of such an error, the more S must remember the reinforcement contingencies of the preceding problem. The data are shown in Table 1. It can be seen that there is an orderly increase in the probability of error from rats to pigeons to goldfish, but the differences were small and did not approach significance ($F < 1$). It should be pointed out, however, that these data do not necessarily provide an accurate estimate of the amount of forgetting that occurred, since, as Table 1 also shows, the proportion of correct responses over the final 10 trials of each reversal, and therefore the amount of room for forgetting, was markedly greater in rats than in pigeons or goldfish. These data, therefore, do not really help to resolve this particular question.

In conclusion, the present study suggests that goldfish, like some other fish (Setterington & Bishop, 1967) and most other vertebrates, are capable of some improvement when trained on a series of reversals. The case for a qualitative difference between fish and other vertebrates is therefore weakened. Indeed, under the present conditions, it is clear that there was at most a small quantitative difference between goldfish and pigeons. The major difference observed here (and not for the first time, see Mackintosh, 1969, Fig. 1) was that rats are very much better at reversal learning than either pigeons or goldfish.

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Table 1

	Percent Correct Responses Per Reversal			Reversals 21-30	
	1-10	11-20	21-30	Proportion of Errors Trial 1	Proportion of Correct Responses Trials 31-40
Rats	66.7	86.2	89.2	.55	.93
Birds	50.2	60.5	68.1	.58	.80
Fish	54.7	56.7	62.3	.65	.73