pairs, and only two subjects forgot more control than experimental pairs. No subject substituted an experimental *B* word incorrectly. Perhaps because of the rapid pacing of the paired-associates list, subjects either anticipated correctly in the recall test or failed to answer.

Pairing of shock with associates of memory items clearly interfered with their subsequent retrieval. Two interpretations of this finding may be considered. First, the shock may have resulted in differential retroactive interference mediated by the superior retention of the experimental *D* words. If learning a list of such *D* words between initial learning and recall produces retroactive interference, then the particular form of motivation employed may be irrelevant. The same effect may be obtainable with positive reinforcement, and, indeed, with any operation that produces superior retention of experimental words. This possibility, however, seems unlikely in view of the retroactive facilitation effects reported by Horton and Wiley (*3*). Using a three-stage chaining paradigm, they found that, after learning an *A-B* and a *B-C* list, learning an *A-C* list facilitated *A-B* retention.

Nevertheless, the experiment was repeated with an independent sample of 40 subjects drawn from a different college population: paid volunteers attending summer session at Dickenson College, Carlyle, Pennsylvania. Half of these subjects received shock associated with the experimental *D* words; the other half received money reward associated with the experimental *D* words. As in the original experiment, trials to learn List 1 and number of correct anticipations during List 1 learning did not vary as a function of any experimental conditions. Again, as in the earlier experiment, recall of the experimental *D* words was significantly superior to recall of control *D* words (100 percent versus 49 percent correct recall for the shock group; 95 percent versus 55 percent of the money group; $P < .01$ in both cases). In terms of these variables, this second experiment replicated the first.

Differential forgetting as a function of shock was similar to the data obtained earlier. Fifteen percent of the experimental *A-B* pairs were forgotten, compared to 5 percent of the control pairs, and this difference is significant at the .05 level. In contrast, no significant difference in forgetting was obtained between experimental and control pairs in the money-reward condition (10 and 11 percent, respectively). In this money condition, 22 pairs were forgotten, 6 experimental and 16 control. This is very close to the distribution that would be expected by chance, namely 6.6 and 15.4.

These additional data are unambiguous. The differential forgetting shown is specific to an unpleasant event, shock, and is not attributable to the differential recall of shock-associated words.

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Reversal Learning and Forgetting in Bird and Fish

Abstract. *Pigeons and goldfish were trained in red-green discrimination in daily sessions, with the rewarded color changed every 2 days. Improvement in the performance of the pigeons could be traced to decrements in retention from each day to the next. The goldfish showed no improvement and no decrements in retention. The results suggest that progressive improvement in habit reversal is a product of proactive interference, and that the absence of improvement in the fish is due, not to the lack of some higher-order process which operates to produce improvement in higher vertebrates, but to a difference in learning-retention mechanisms.*

Suppose that on each of a series of trials we offer a rat or a pigeon a choice between two stimuli, *A* and *B*, rewarding it today for choosing *A*, tomorrow for choosing *B*, the day after for choosing *A*, and so forth. With each change in the training conditions, the animal changes its preference—today it develops a preference for *A*, tomorrow for *B*, the day after for *A*, and so forth. The first reversals are accomplished with some difficulty, the animal persisting during the early trials of each day in the choice of the rewarded alternative of the preceding day, but, as training continues, the number of errors made each day declines progressively. This is the phenomenon of "progressive improvement in habit reversal," known for many years (*1*), but until now little understood.

One explanation of progressive improvement has been that the animal comes to adopt a "win-stay, lose-shift" strategy, with response on each trial based on the sensory aftereffects or short-term memory of the events of the immediately preceding trial; but the aftereffects interpretation is contradicted by the fact that reversal performance is not impaired by substantial increases in the intertrial interval (*2*). Another explanation has been that the animal comes to attend more and more readily to the relevant (reward-correlated) dimension of stimulation, but the attentional interpretation is contradicted by the fact that improvement takes place concurrently in two different dimensions of stimulation which are equally often relevant and irrelevant (one relevant when the alternative is irrelevant) in a long series of problems (*3*). That the improvement is due to some higher-order process has been suggested by the fact that it does not occur in the fish—although the fish is capable of repeated reversal, it shows no decline in errors per reversal as training continues—but the nature of the process has not been specified (*4*).

We shall contend here that the process is after all a simple one—that improvement in reversal results from decrements in retention which are produced by proactive interference. From experiments on human memory, it is well known that learning of *X* may impair the retention of subsequently learned *Y* (proactive interference), just as the retention of *X* may be impaired by the subsequent learning of *Y* (retroactive interference), both effects being due apparently to the competition of antagonistic response tendencies; the greater the amount of potentially competing material learned before *Y* is learned, the poorer the retention of *Y* (*5*).

Data from some recent experiments on habit reversal in rat and pigeon indicate that the preferences which are established in each experimental ses-

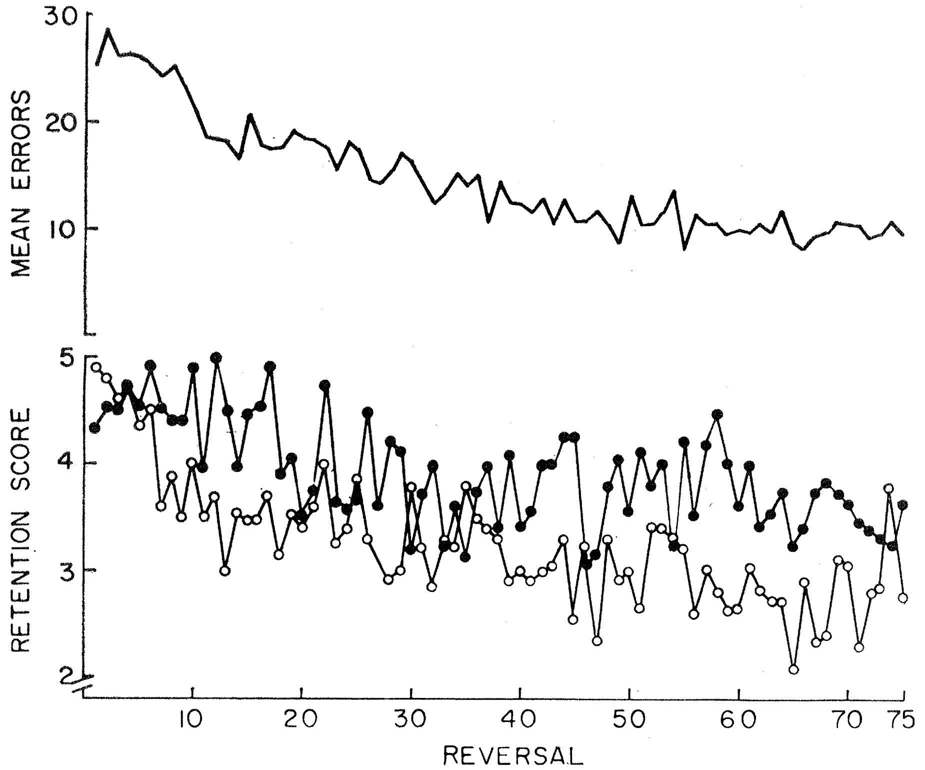

Fig. 1. The relation between improvement in habit reversal and forgetting in the pigeon. The upper curve shows mean errors per reversal. Mean retention scores are plotted in the two lower curves. One (solid circles) shows retention measured on the early trials of nonreversal days. The second (open circles) shows retention measured on the early trials of reversal days.

sion become increasingly unstable over time—that reversal becomes progressively less difficult because the animal begins each day with a progressively weaker preference for the rewarded stimulus of the preceding day (*6*). If, instead of rewarding A and B on alternate days, we use a quasi-random order involving two or three A-positive or B-positive days in succession, we find that performance on nonreversal days (A-positive after A-positive or B-positive after B-positive) *deteriorates* progressively as performance on reversal days (A-positive after B-positive or B-positive after A-positive) improves (*7*). The deterioration in nonreversal performance follows (as does improvement in reversal performance) from the assumption of decreasing retention. To the extent that a preference established on day N persists until day $N + 1$, nonreversal is easy and reversal is difficult; to the extent that the preference is lost, nonreversal becomes more difficult and reversal becomes easier.

The relation of improvement in habit reversal to forgetting may be seen in the data from a *2-day* reversal experiment with a group of 12 pigeons. After gradual reduction to 85 percent of their satiated weights, the animals were trained to discriminate between red and green in a series of 40-trial daily sessions, with red positive on odd pairs of days (1–2, 5–6, and so forth) and with green positive on even pairs of days (3–4, 7–8, and so forth). Each trial began, after a 6-second intertrial interval in darkness, with the illumination of two plastic keys (one red and the other green, the positions of the two colors varying randomly from trial to trial). A peck at the correct key turned off both key lights and activated a grain feeder for 3 seconds. A peck at the incorrect key produced a 6-second time-out in darkness, after which there was opportunity for correction. No more than four repetitive errors were permitted; after the fourth, the correct key alone was illuminated and the animals were rewarded for pecking it (guidance procedure). The training was conducted in sound-reduced, ventilated enclosures, with all events programmed automatically, responses being recorded on tape (*8*).

In the upper portion of Fig. 1, the course of improvement in reversal is plotted in terms of the mean number of errors made during the 2 days (80 trials) of each of 75 reversals. Separate plots (not here presented) for the first and second days of each reversal indicated considerably more improvement on the first day than on the second. The curve for the first day falls ($F = 17.28$, $\mathrm{df} = 74/814$, $P < .01$) almost as sharply as that for both days combined. The curve for the second day is relatively flat, although its decline nevertheless is statistically reliable ($F = 4.28$, $\mathrm{df} = 74/814$, $P < .01$).

Two measures of retention are plotted in Fig. 1. One of them (solid circles) is based on the difference between performance on trials 36 to 40 of each reversal and performance on trials 41 to 45 of that reversal; it measures the extent to which the preference existing at the end of the first day carries over to the second day of each reversal. The other measure (open circles) is based on the difference between performance on trials 76 to 80 of each reversal and performance on trials 1 to 5 of the next reversal; it measures the extent to which the preference existing at the end of the second day of a reversal carries over to the first day of the next reversal. Since good retention tends in the first (nonreversal) case to produce a low error score, but in the second (reversal) case to produce a high error score, the two difference scores were adjusted in such a way that, for both measures, a high score means good retention and a low score means poor retention (*9*). Both the retention measures are substantially more variable than is the measure of overall performance (as would be expected from the fact that they are based on much smaller numbers of trials), but their decline over reversals is highly reliable ($F = 3.93$, $\mathrm{df} = 74/814$, $P < .01$), and the pattern of their decline parallels the decline in total errors per reversal closely enough to suggest that the improvement may be accounted for in terms of changes in retention.

The only fact which may seem to contradict the forgetting interpretation is that performance on the second day of each reversal improved as retention of the preference established on the first day declined. Both changes were relatively small (there was greater improvement in first-day performance and more forgetting of the preference established on the second day), but their direction nevertheless was unanticipated: decline in retention should tend to impair nonreversal performance. An explanation of the discrepancy is found in the fact that the strength of the preference established on the first day (as measured by performance on trials 36 to 40) increased markedly with continued training; this effect was strong enough, apparently, to override the increased forgetting. (It should be noted that the retention scores are relatively insensitive to absolute levels.) The increasing strength of preference established by the end of the first day reflects a decreasing preference at the start of that day for the rewarded color of the preceding day, and the decreasing initial preference is itself a relatively pure effect of decreasing retention. The strength of preference established by the end of the second day (as measured by performance on trials 76 to 80) was high at all stages of training.

In a subsequent series of two-day reversals, 12 preference tests (six reversals and six nonreversals) were made with retention intervals of either 20 minutes, 24 hours, or 48 hours, in counterbalanced order, each animal serving as its own control. Pooling the results of repeated tests made it possible to use only the data for initial test trials, and thus to avoid entirely the effects of differential reinforcement. The retention function (plotted in terms of the probability of choosing the previously reinforced alternative on trial 1—72 percent after 20 minutes, 48 percent after 24 hours, and 51 percent after 48 hours—is, then, a pure recall function. It shows that the preference established on a given day could be detected after 20 minutes but not after 24 hours or more ($F=5.78$, df=2/22, $P<.01$). Early in training, the recall of the animals was about the same after 24 hours as it was in these final tests after 20 minutes. These data provide further evidence that, in the course of continued reversal training, the preferences established become increasingly unstable over time.

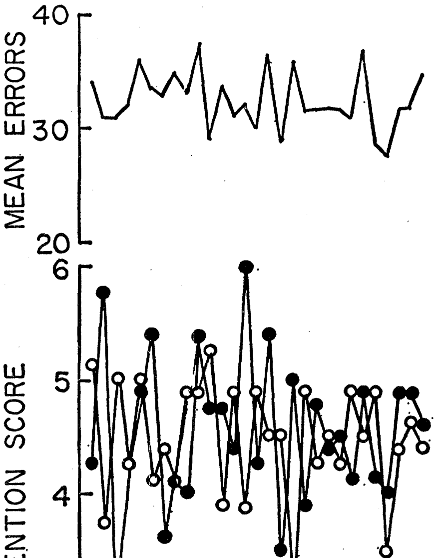

Fig. 2. The relation between improvement in habit reversal and forgetting in the goldfish. These curves are presented for comparison with those of Fig. 1 and are based on the same measures.

What, then, of the fish, which does not show progressive improvement in habit reversal? If changes in reversal performance are produced by changes in retention, the fish should show no changes in retention with continued training. To obtain some retention data, we trained a group of 11 goldfish (10 cm long) in a series of 30 2-day reversals under conditions analogous to those used for the pigeons (*8*). There were plastic targets, illuminated with red and green lights, at which the animals were trained to strike, and a worm feeder to reward correct choice; again, all the events of training were programed automatically and responses were recorded on tape.

The results are summarized in Fig. 2. As expected from previous experiments on reversal learning in the fish, the upper curve, which is plotted in terms of mean errors per reversal, shows no improvement over reversals. These results stand in marked contrast to those for the pigeons, whose error curve had fallen about 75 percent of the distance between initial and terminal levels in the same number of reversals (Fig. 1). As expected from the forgetting interpretation of progressive improvement in the pigeon, the retention curves for the fish, which are plotted in the lower portion of Fig. 2, also show no decrements over reversals. Retention in the fish was high at the outset (as in the pigeon), and it remained high. Although not as much as the pigeons, the fish did, of course, show a substantial amount of learning *within* reversals (the error level on the 1st day was about twice that on the 2nd day), which means that there was a substantial amount of acquisition on which to base the retention scores. Seven of the 11 goldfish, which subsequently were trained in a series of 14 2-day reversals with 80 instead of 40 trials per day, showed still more within-reversals improvement. Their error scores rose substantially (because the greater number of training trials produced stronger preferences to be reversed), but their retention scores were unchanged.

Previous experiments on habit reversal in the fish led us to ask why the fish does not show progressive improvement. Now we may ask instead why the fish seems not to forget. It is conceivable, of course, that we may be able to demonstrate progressive improvement in the fish by finding a set of conditions more conducive to the development of proactive interference. In view, however, of other evidence which is accumulating (*10*), it is not unlikely that the basic mechanisms of learning are different in the fish than they are in higher animals and that there are corresponding differences in the mechanisms of retention.

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