

*SIDMAN AVOIDANCE IN THE FISH*¹

ERIKA R. BEHREND AND M. E. BITTERMAN

BRYN MAWR COLLEGE

Goldfish trained in a shuttle box under conditions in which changing compartments postponed shock for 20 sec showed a substantial, negatively accelerated increase in rate of crossing. That the avoidance-contingency was responsible for the change in behavior is suggested by the fact that no significant increase in rate of crossing appeared in control animals which were paired with the experimentals and shocked whenever the experimental animals were shocked; there is some evidence, indeed, that the control animals were handicapped in their subsequent adjustment to the avoidance condition. The introduction of a warning stimulus (light) in the last 5 sec of the response-shock interval decreased the rate of crossing in the first 15 sec and increased the rate of crossing in the last 5 sec. Reducing the shock-shock interval from 20 sec to 2.5 sec had no marked effect. The results are compared with those obtained in analogous experiments with higher animals.

The present experiments on avoidance learning are part of a larger series of experiments designed to examine the behavior of fish under a variety of conditions analogous to those used for the study of learning in higher animals (Bitterman, 1960). There is little reason, perhaps, to expect that avoidance learning in the fish will differ in any important respect from avoidance learning in higher animals, but an assumption of functional similarity and a demonstration of it are quite different things. In any event, no survey of learning in the fish would be complete without an examination of its behavior in some representative avoidance situations.

In our first work on avoidance in the fish, we used the traditional discrete-trials procedure and an apparatus patterned after the mammalian shuttle box (Behrend and Bitterman, 1962; Wodinsky, Behrend and Bitterman, 1962). We turn now to a study of Sidman avoidance (Sidman, 1953a) in the same apparatus. Although most of the mammalian work on Sidman avoidance has been done with lever-pressing, other responses also are suitable. Running in a revolving cage has been used for the rat (Mowrer and Keehn, 1958), and a still more generalized class of behavior (defined only in terms of the activation

of an electronic stabilimeter) now is in use in this laboratory for animals as diverse as pigeon and cockroach. Changing compartments in a shuttle box, the response selected for the present work, has been used for the dog (Black and Morse, 1961) and for the rat (May, 1948).

EXPERIMENT I

The purpose was simply to establish the phenomenon of Sidman avoidance in the fish, with appropriate control for sensitization. Two groups of fish were trained, an experimental group and a yoked control group. Each control animal was trained at the same time as a paired experimental animal and shocked whenever the experimental animal was shocked, but its own responses did not postpone shock. After performance had stabilized, half the control animals were shifted to the experimental condition, and half the experimentals were shifted to the control condition.

Subjects

Thirty-two goldfish, 2 to 3 in. long, were obtained from a local dealer. They were divided at random into two groups of 16, one of which was designated at random as the experimental group and the other as the control. The animals lived in individual 2-gal. tanks on open shelves in the (temperature-controlled) laboratory. They were carried to and from the apparatus in small nets.

¹This research was supported by Grant M-2857 from the National Institute of Mental Health. The assistance of Barbara Bauman and Gertrude Jefferson is acknowledged with thanks.

Apparatus

A set of four shuttle boxes was used in which four animals could be trained simultaneously. It has been described in detail elsewhere (Horner, Longo, and Bitterman, 1961). Each shuttle box was a narrow Plexiglas chamber divided into two compartments by a "hurdle". The water level in each compartment was several inches high, but in the region of the hurdle its level was somewhat less than an inch; high enough to permit crossing, but low enough to discourage loitering above the hurdle. The arrangement gave the crossing response an all-or-none character; except when in process of crossing, the fish was either in one compartment or the other. Crossing was detected by means of photocells, and the location of each animal was monitored by a ratchet-relay. Experimental contingencies were programmed automatically.

Procedure

Each fish was given 20 daily training sessions, each lasting 20 min. Two of the four animals in each set of four (four animals were run simultaneously in the four shuttle boxes) were experimentals (E), and the remaining two were controls (C). The experimental animals were trained from the outset (no shaping being necessary) with an R-S interval of 20 sec; *i.e.*, each time the animal changed compartments, shock was postponed for 20 sec. The S-S interval also was 20 sec; an animal remaining in one compartment would be shocked every 20 sec. The duration of shock was 0.25 sec, and its intensity was the same as that used in the earlier, discrete-trials work with goldfish—just enough to produce consistent, low-latency escape reactions in pilot animals. Current was controlled by variation in voltage, the actual value used being 6 v. A.C. Counters read at the end of each session gave three scores for each experimental animal: total number of responses (crossings); number of responses in the last 5 sec before a scheduled shock (*i.e.*, number of responses made 15-20 sec after a previous response or shock); and number of shocks. A shuttle box containing a control fish was yoked to the box of each experimental fish in such a way that the control animal was shocked when and only when the experimental animal was shocked. The total number of responses made by each control

animal in each session also was read from a counter.

After 14 sessions, each of the main groups (experimental and control) was divided into two matched subgroups on the basis of previous performance. In the next six sessions, the training of one of the experimental subgroups (E-E) and its control subgroup (C-C) continued as before. The remaining experimental subgroup (E-C) was shifted to the control condition (the boxes of both the C-C and E-C animals in each set of four being yoked with that of the E-E animal), while the remaining control subgroup (C-E) was shifted to the experimental condition.

Results

The principal results of the first experiment are summarized in Fig. 1, which shows mean number of responses per session for the four subgroups. (Data on the temporal distribution of responses and on the frequency of shock are considered in conjunction with the results of Experiment II.) The mean curves for the experimental subgroups rise in negatively accelerated fashion over the first 14 sessions, while those for the control subgroups show little change. The mean curves are quite representative of the changes which took place in the behavior of the individual animals in the different groups. An analysis of variance of Lindquist's Type I shows the Treatments (experimental *vs.* control) and Days effects to be significant at about the 5% level and the interaction significant well beyond the 1% level.

The results of the change in conditions for two of the subgroups which was introduced in session 15 also may be seen in Fig. 1. Mean

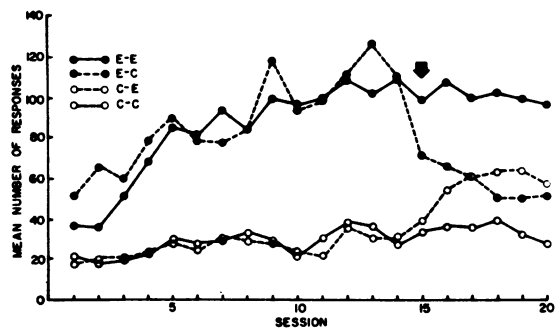


Fig. 1. The performance of experimental groups (E) compared with that of yoked sensitization controls (C). The arrow shows the point at which the conditions of training were changed for two of the groups.

number of responses in subgroup E-C falls sharply, while mean number of responses in subgroup C-E rises moderately. Analysis of variance for the last six sessions shows the subgroups effect to be significant beyond the 0.1% level, with orthogonal comparisons yielding a significant difference between subgroups E-E and E-C, but not between C-C and C-E. These statistical results reflect the fact that every animal in E-C showed a sharp change in rate of response when the conditions of the experiment were changed, while the changes in rate shown by the animals in C-E were much less marked and immediate. Two of the C-E animals showed no change at all before the termination of the experiment.

Discussion

The results for the first 14 sessions may be taken to mean that the Sidman procedure affects the behavior of the fish in much the same way as it does the behavior of mammals; an increase in rate of response is produced when, and only when, response postpones shock. The effectiveness of the avoidance contingency is shown further by the decline in the response-rate of subgroup E-C after the elimination of the contingency in the fifteenth session. The insignificance of the increase in the response-rate of subgroup C-E after the introduction of the contingency in session 15, when considered in relation to the quite marked and consistent change produced by the contingency in the first six sessions of the experiment, implies negative transfer of training from the control to the experimental condition. A related phenomenon has been reported by Mowrer (1940) for the rat. Animals subjected to inescapable shock learn to escape shock less readily (when a means of escape subsequently is provided) than do unshocked controls. Mowrer's interpretation of his finding (in terms of response-competition) applies as well in the present case. There is little reason to doubt that continued training under the experimental condition would have brought the response-rate of subgroup C-E to the E-E level. The experiment was terminated after the twentieth session because it did not seem important to establish that fact.

EXPERIMENT II

In this second experiment, the role of a warning stimulus was studied. The introduc-

tion of such a stimulus under Sidman conditions generates an interesting situation in which the discriminative properties of the stimulus are pitted against whatever aversive properties it may acquire in consequence of its pairing with shock. Work with mammals (Sidman, 1955; Sidman and Boren, 1957) has shown a marked tendency for response-rates to increase in the presence of a warning stimulus and to decrease in its absence (relative to baselines established in prior training without the stimulus). The purpose of the present experiment was to inquire into the generality of this phenomenon.

Subjects

Sixteen goldfish, drawn from the same population as those used in the first experiment, were assigned at random to two groups of eight.

Apparatus

The same as that of the first experiment was used, with one feature used which was not involved in that experiment. At the end of each compartment in each of the shuttle boxes was a lamp which, when energized, illuminated the compartment. The illumination served as the warning stimulus.

Procedure

Again there were 20 daily training sessions for each animal, each session lasting 20 min. The eight animals of one group (N-W) were trained for 14 sessions without a warning stimulus (N) under conditions exactly the same as those for the experimental animals of Experiment I. Beginning with the fifteenth session, a warning stimulus (W) was introduced: light came on in the compartment occupied by the animal during the last 5' sec of the R-S interval. (The light terminated with response or, if there was no response in the 5 sec after the light came on, with shock.) For the animals of a second group (W-W), the warning stimulus was used in all 20 sessions. Again in this experiment, the animals were trained in sets of four, with counters keeping track of response-frequencies and of shock-frequencies.

Results

Mean number of responses in the two groups are shown in Fig. 2. Responses in the last 5 sec before shock was scheduled (when

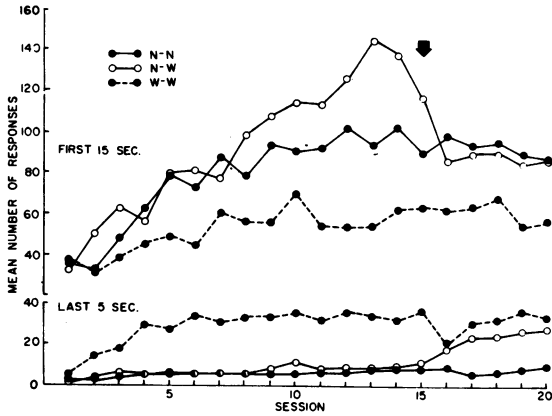


Fig. 2. Performance with (W) and without (N) a warning stimulus in the last 5 sec before the scheduled shock. The arrow shows the point at which the conditions of training were changed for group N-W.

the light was on in the W-condition) and responses in the first 15 sec after a previous response or shock (when the light was off in the W-condition) are plotted separately. Shown also in Fig. 2 are the corresponding values for the subgroup E-E of Experiment I (here designated as group N-N) which was trained for 20 sessions with no warning stimulus. Mean number of shocks received by each group in each session is plotted in Fig. 3. The curves seem quite representative of the distributions of individual data which they are intended to reflect, and the dependability of the main trends reflected in the curves is attested by the outcomes of appropriate analyses of variance.

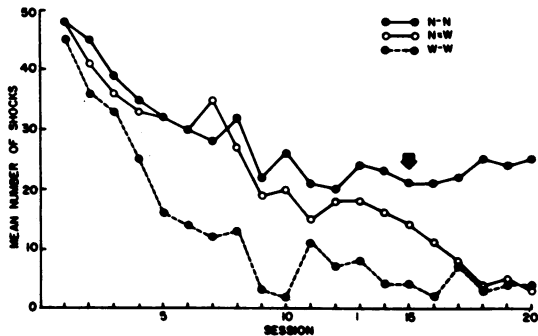


Fig. 3. Frequency of shock in Sidman training with (W) and without (N) a warning stimulus. The arrow shows the point at which the conditions of training were changed for group N-W.

Compared with animals trained with no warning stimulus, animals trained with the stimulus made fewer responses in the first 15 sec of the 20-sec interval; made more responses

in the last 5 sec of the interval, *i.e.*, when the signal was present; and received fewer shocks. (The first and third differences are significant at about the 5% level, and the second well beyond the 1% level.) Total number of opportunities to respond in the last 5 sec is given by the sum of the number of responses in the last 5 sec and the number of shocks received. Probability of response in the last 5 sec was about 0.8 when the warning stimulus was present and only about 0.2 when it was absent.

The change in the conditions of training introduced in session 15 for group N-W produced marked changes in behavior. Mean number of responses in the last 5 sec began gradually to approach the level of group W-W, and mean number of shocks received fell progressively to the W-W level. In both these respects, the differences between groups N-W and N-N during the last six sessions proved to be significant at a level of confidence well beyond 1%. The only ambiguity in the data for the last six sessions is presented by responses in the first 15 sec. The number of these responses made by group N-W falls sharply, but not to a level significantly below that of group N-N. This discrepancy seems due to a sampling error; as the data for the first 14 sessions indicate, the N-W animals were more reactive at the outset. Measured in relation to pre-shift performance, the post-shift response-rate of group N-W is clearly below that of group N-N.

Discussion

The results suggest that a warning stimulus in Sidman training affects the fish in much the same way as it does the rat. Although the stimulus is paired repeatedly with shock, the animals do not avoid it, but utilize it, tending to postpone response until the stimulus appears. Certainly there is no hint in these data that the mechanisms of avoidance learning in fish and rat are different in any respect.

EXPERIMENT III

The significance of this third experiment is twofold. First of all, it provides some further data on the effect of introducing a warning stimulus which can be evaluated in relation to the performance of a properly matched control group. (The results of Experiment II are to a certain extent ambiguous because of a

sampling error.) Secondly, the experiment provides some information about the effect on the behavior of the fish of a short S-S interval. As Sidman (1953b) has noted, shortening the S-S interval introduces an escape-contingency into the situation.

Subjects

Twenty-five goldfish drawn from the same population as those used in the preceding experiments.

Apparatus

The same as that used in the preceding experiments.

Procedure

All animals were trained without the warning stimulus for five, 20-min sessions. The R-S interval was 20 sec, and contingent on failure of response in the R-S interval was a series of shocks, 0.25 sec in duration and about 2.5 sec apart, which terminated instantly with response. The procedure was not quite a Sidman with an S-S interval of 2.5 sec because the series of shocks lasted no longer than 15 sec; if the animals failed (as they did occasionally in the early sessions) to change compartments within the 15-sec period after the onset of shock, shock was terminated and the R-S timer reset.

After the fifth session, the animals were divided into two groups approximately equated on the basis of each of three measures of performance in those sessions: number of responses in the first 15 sec before a scheduled shock, number of responses in the last 5 sec, and number of shocks (defined as number of shock-series which were initiated or the number of failures to respond in 20 sec after resetting of the R-S timer). The training of group N-N, containing 12 animals, continued as before in nine subsequent sessions, while for group N-W, which contained 13 animals, a warning stimulus (the light used in Experiment II) was introduced during the last 5 sec of the R-S interval. Where there was failure of avoidance, the light remained on during the shock-series and terminated with the series.

Results

The performance of the two groups is plotted in Fig. 4 in terms of mean number of re-

sponses in the first 15 sec, and in the last 5 sec before the scheduled shock-series. For group N-N, number of responses in the first 15 sec rises in negatively accelerated fashion to an asymptote which is achieved by about the fifth session; number of responses in the last 5 sec remains low. Group N-W behaved in much the same way during the first five sessions, but then, with the introduction of the warning stimulus in the last 5 sec, rate of response in the first 15 sec declined precipitously, while rate of response in the last 5 sec rose. Analysis of variance shows both effects to be significant at a level of confidence beyond 1%. The two groups do not, however, differ in number of shocks; curves for the two groups plotted in terms of mean number of shocks per session decline in similar fashion to an asymptotic value of about 18.

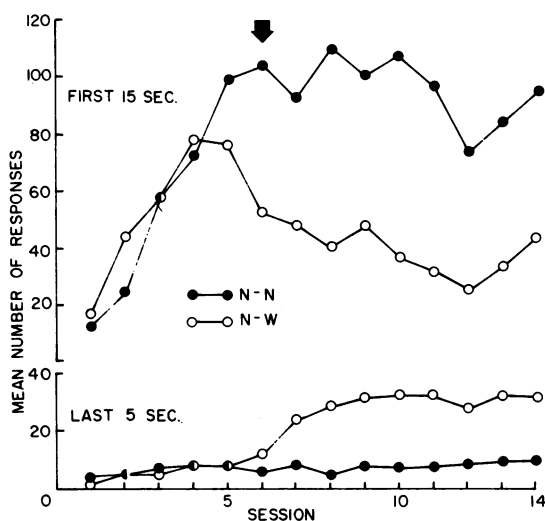


Fig. 4. Performance with (W) and without (N) a warning stimulus in the last 5 sec before the scheduled shock. The arrow shows the point at which the conditions of training were changed for group N-W.

Discussion

The results of this experiment are in general accord with those of the second experiment insofar as the effect of introducing a warning stimulus is concerned, and go beyond them in one important respect—the introduction of a warning stimulus is shown clearly to produce a decline in rate of response during the first 15 sec relative to the rate of matched control animals for which the stimulus is not introduced.

A comparison of the performance of group N-N in this experiment with the performance of groups N-N and N-W in the first 14 sessions of the previous experiment (during which both were trained without the warning signal) shows one substantial difference: the curve plotted for number of responses in the first 15 sec reaches asymptote somewhat earlier in the present case (by the fifth session as compared with the tenth or a still later session). Another difference between the results of the two experiments is to be found in the fact that the W-condition did not produce better shock-avoidance than the N-condition in the present experiment. At asymptote, the frequency of shock under both conditions was much the same as under the N-condition of the previous experiment (Fig. 3). Whether these differences in the results of the two experiments are due to the difference in S-S interval or to sampling error, is impossible to say without a more systematic study. In work with the rat (Sidman, 1953b), a decrease in the S-S interval from 20 sec to 2.5 sec seems to be of little consequence when the R-S interval is 20 sec.

CONCLUSIONS

Avoidance training of the Sidman type has much the same effect on the fish as it does on higher animals. A comparison of experimental animals with yoked sensitization controls demonstrates that rate of response is increased by the avoidance-contingency. Animals trained with a warning stimulus make fewer responses in the absence of the stimulus, and more responses in its presence, compared with their own performance in prior training without the stimulus, or with the performance of con-

trol animals trained without the stimulus. The introduction of an escape-contingency by a marked reduction in the S-S interval does not seem to produce any qualitative change in the over-all pattern of results. In general, there is now no reason to suspect that the mechanisms underlying avoidance learning in fish and rat are different in any important respect.

REFERENCES

- Behrend, E. R., and Bitterman, M. E. Avoidance conditioning in the goldfish: Exploratory studies of the CS-US interval. *Amer. J. Psychol.*, 1962, **75**, 18-34.
- Bitterman, M. E. Toward a comparative psychology of learning. *Amer. Psychologist*, 1960, **15**, 704-712.
- Black, A. H., and P. Morse. Avoidance learning in dogs without a warning stimulus. *J. exp. Anal. Behav.*, 1961, **4**, 17-23.
- Horner, J. L., Longo, N., and Bitterman, M. E. A shuttle box for fish and a control circuit of general applicability. *Amer. J. Psychol.*, 1961, **74**, 114-120.
- May, M. A. Experimentally acquired drives. *J. exp. Psychol.*, 1948, **38**, 66-77.
- Mowrer, O. H. An experimental analogue of "regression" with incidental observations on "reaction-formation". *J. abnorm. soc. Psychol.*, 1940, **35**, 56-87.
- Mowrer, O. H., and Keehn, J. D. How are intertrial "avoidance" responses reinforced? *Psychol. Rev.*, 1958, **65**, 209-221.
- Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 1953a, **118**, 157-158.
- Sidman, M. Two temporal parameters of the maintenance of avoidance behavior by the white rat. *J. comp. physiol. Psychol.*, 1953b, **46**, 253-261.
- Sidman, M. Some properties of the warning stimulus in avoidance behavior. *J. comp. physiol. Psychol.*, 1955, **48**, 444-450.
- Sidman, M. and Boren, J. J. A comparison of two types of warning stimulus in an avoidance situation. *J. comp. physiol. Psychol.*, 1957, **50**, 282-287.
- Wodinsky, J., Behrend, E. R., and Bitterman, M. E. Avoidance conditioning in two species of fish. *J. anim. Behav.*, 1962, **10**, 76-78.

Received December 29, 1961