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Operant Discrimination in the Schooling Fish, *Brachydanio rerio*

By BILL B. JACKSON

Although many species of fishes normally congregate in schools, the majority of these fishes will successfully survive in an individual existence. However, the question has been raised as to what extent the operant behavior of schooling fishes remains unchanged when they are isolated from the group.

Experiments by Welty (1934) have indicated that goldfish learn mazes more rapidly when grouped than when isolated. Further, he found that motor responses are retained by a group better than by an individual.

Breder and Halpern (1946) point out that fishes will sometimes not feed until they see a companion feeding.

In order to further explore this question an experiment was designed to study operant discrimination of a group of fishes behaving both as a school and as individuals.

METHOD

Subjects.

The subjects chosen for this experiment were three young *Brachydanio rerio*, each measuring about one inch in length.¹ *Brachydanio rerio* is a species of schooling fish belonging to the Cyprinidae, or carp family, and native to India.

These fishes seem to survive equally well in schools or as isolated individuals. For this reason it was thought that they would prove to be satisfactory subjects for this experiment. Further, this species exhibits a high general activity level, a factor which facilitates operant conditioning.

Apparatus.

The experimental environment consisted of a three gallon aquarium measuring 11 x 7.5 x 6.0 inches, filled with water having a mean temperature of 74° Fahrenheit and a pH of 7.6. In this aquarium was submerged a transparent lucite box 4.0 x 4.0 x 2.0 inches with a circular opening 0.5 inch in diameter in one face.

¹Adults average 1.75 inches according to Innes.

Apparatus

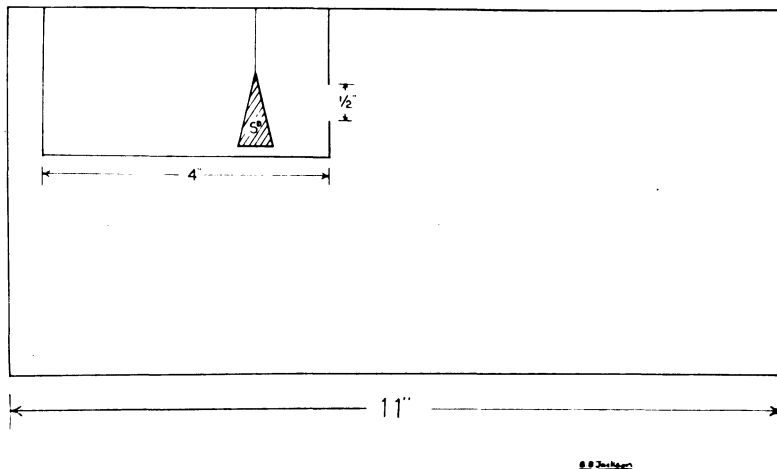


Figure 1

This small opening provided the only means by which the fishes could pass from the three gallon aquarium into the lucite enclosure.

Throughout the experiment the conditioned response was defined as the entrance of a subject into the transparent box. This arrangement was considered superior to the more usual forms of manipulandum for the following reasons. (1) Due to the small volume of this box it restricted the subject's movements and so tended to be somewhat negatively reinforcing.² This factor precluded any subject from remaining in the box for extended periods. (2) A static manipulandum (circular portal) also proved an effective solution to the problem arising from the fact that small fishes have a limited ability to manipulate their environment and are capable of exerting only a small amount of force.

As *Brachydanio rerio* exhibits great sensitivity to visual stimuli it was decided to use as the discriminative stimulus (S^D) a metal cone 0.5 inch in diameter at the base and 1.0 inch high, suspended in the aquarium by means of a thread attached to its apex.

The three subjects constituting the school were introduced into the experimental environment one day prior to the experiment's initiation in order to allow acclimatization to the water pH and temperature range.

²This was confirmed by the experimental results.

Experimental Procedure.

At the beginning of the experiment the observed operant rate, that is, number of box entrances per time period, was 0.0 and the actual operant rate was therefore assumed to be very low.

The first twenty-five days of the experiment were spent in strengthening the operant response through administration of aperiodic reinforcement. Finely powdered dry food was placed in the box for thirty minute periods twice each day at randomly chosen times between 0700 and 2200. On the twenty-fifth day of this schedule the response rate had increased to nine responses in fifteen minutes³ for the school.

After the twenty-fifth day the aperiodic reinforcement schedule was discontinued and discrimination training begun. This consisted of one fifteen-minute trial each day composed of the following steps:

1. Introduction of the S^D followed in one second by introduction of the reinforcement. Both were placed inside the small transparent box.
2. Fifteen minutes of elapsed time during which the S^D and reinforcement were continuously present in the transparent box. Records were kept during this period of (a) total responses (b) latency between introduction of the S^D and the first response.
3. Removal of S^D and five seconds later removal of the transparent box. Any subjects in the box at this time were poured out through the entrance with the water.
4. Thorough washing of the box to remove all reinforcing food and its reintroduction into the experimental environment approximately two minutes after removal.

Two concurrent sets of trials were carried out. Sixteen trials were given to the school, the three subjects together. Here, in addition to total responses and first latency, a record was kept of the identity of the first subject to commit the conditioned response. This was done in order to determine possible "leader" and "follower" relationships.

In the second set of trials each individual was isolated and observed separately. The procedure followed was identical with that for the school with a total of nine individual trials being carried out.

During the fifteen minutes immediately preceding each of the individual and school trials described above a record was kept of

³Mean of two observation periods.

responses and latencies in the absence of the discriminative stimulus (S^Δ). Later comparison of the S^D and S^Δ behavior records allowed measurement of the degree of discriminative behavior developed.

RESULTS

The results of this experiment are summarized in the table below. As specific interest was in differences between individual and school behavior primary concern was with comparisons between the relatively stable behavior obtained from the school and from isolated individuals during the later trials.

Table 1
Mean Values from Final Three Trials of School and of Individuals

	S^Δ	S^D
Responses in fifteen minutes by school divided by number of members in school (3).	0.22	5.77
Responses in fifteen minutes by individuals when isolated from other school members.	0.11	0.77
Latency of first response after presentation of S^D by any member in school (in seconds).	540.00	23.30
Latency of first response after presentation of S^D by individuals when isolated from other school members (in seconds).	—	270.00

Using the same subjects for both sets of trials precluded any comparison of the progressive development of the discriminative behavior.

All response rates of the school are divided by the number of school members to allow comparison with individual trial data. This is not to imply that each individual had the same response rate during each trial. But it was assumed that the three fishes' mean operant rates over several trials were equatable since the data concerning isolated behavior were highly similar for all subjects.

The conclusion that the school exhibited more effective discriminative behavior than any isolated member of the school is well supported. The school not only responded a greater mean number of times per individual in the presence of the S^D but also exhibited a much shorter mean latency of response after presentation of the S^D .

Further, individual subject data revealed that no individual fish discriminated as well when isolated as when a member of the school during any of the final three school and three individual trials. Every subject showed both longer latencies and a lower response rate when isolated.

The shortest latency of an isolated individual was forty-five sec-

onds and the highest response rate was two responses in fifteen minutes. The school's shortest latency was five seconds and largest number of responses during one fifteen-minute trial was eight per school member.

As the reinforcement (food) was present simultaneously with the defined S^D , it very probably provided an additional S^D due to its visibility and slight diffusion through the water. A control test revealed, however, that the introduction of the food without the defined S^D did not induce short latency responses.

It is interesting that there were no "leaders" in the school. All of the subjects were first to respond during some of the school trials and in individual trials all subjects responded in the presence of the S^D .

During the majority of trials the school tended to behave as a unit, with all members swimming in the same direction and parallel to one another. Which subject swam at the head of this group, however, seemed to be determined by the random movements of the school. Therefore, although the leading fish in the school tended to make the first response in the presence of the S^D , this was not always the same fish.

CONCLUSION

The results of this experiment indicate that the operant behavior of *Brachydanio rerio* was brought under the control of a discriminative stimulus. Furthermore, important differences in the discriminative behavior of this species when in a school and when isolated became apparent. Although the nature of the stimulus control remained constant, the fishes exhibited a much higher rate of response and shorter response latencies when in a school than when behaving individually. Finally, the behavior of the fishes in the school was seen to be largely independent of any specific "leader-follower" relationships. Similar behavioral comparisons with other species of schooling fishes would seem to hold promise as a subject for further research.

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