Probability-matching in the goldfish¹

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Two groups of goldfish were trained in an instrumental situation with food reward for correct choice and guidance after incorrect choice. One group was trained in 70:30, 20:80, and 50:50 visual problems, the other in a 70:30 spatial problem. The results obtained resemble those for the African mouthbreeder.

Previous experiments with the African mouthbreeder have shown random probability-matching both in visual and in spatial problems (Bitterman, Wodinsky, & Candland, 1958; Behrend & Bitterman, 1961), although different results have been obtained in experiments with representatives of certain other vertebrate classes (Bitterman, 1965). The present experiments with another species of fish were prompted by an interest in the generality over that class of the results for the mouthbreeder.

Method

The Ss were 12 goldfish, about 4 in. long, obtained from a local dealer. They lived in individual 2-gal. tanks set on open racks in a temperature-regulated laboratory room. Each tank was equipped with an aerating bottom filter. The Ss were maintained on a 24-hr. feeding schedule; the 40 *Tubifex* worms earned in experimental sessions were supplemented in post-session feedings with .03 gm of dry food.

Each S was trained in its individual living tank, which was carried to an enclosure of black Plexiglas. Fixed to the roof of the enclosure on thin rods of stainless steel were two circular targets (1.25 in. in diameter) made of clear Plexiglas, their centers 2.75 in. apart and 1.75 in. below the level of the water. Two In-Line projectors were mounted on the enclosure behind the targets in such a way that colored lights and patterns could be projected on them. The targets were manipulanda as well as discriminanda, the response of S being to strike at one of them. The rods on which the targets were mounted were set into the needle-holders of crystal phonograph cartridges, and any contact of S with one of the targets generated a voltage which, suitably amplified and integrated, was used to operate relays that recorded the response and determined its consequences. Reinforcements were live *Tubifex* worms delivered by an automatic feeder at the end of the tank opposite the targets. With each delivery of a worm, that end of the tank was diffusely illuminated for 6 sec. The light signaled the delivery of the worm and permitted S to find it. All the events of each experimental session were programmed automatically. A six-pen Gerbrands event-recorder was used to register the stimuli presented, the responses made to them, and the consequences of response.

After target-training, each animal was given 40 trials per day by the guidance method. Each trial began (after

a 6-sec. interval of darkness) with the illumination of both targets. If S chose the positive target, the target-lights were turned off, and a reinforcement cycle was initiated, after which there was a 6-sec. intertrial interval in darkness. If S chose the negative stimulus, there was a 6-sec. time-out in darkness, after which the correct target alone was illuminated and S was rewarded for response to it. The next trial began 6 sec. later. In this procedure, then, each trial ended with a reinforced response; it was possible, therefore, to control exactly the distribution of reinforced responses to the two stimuli.

Six of the animals were trained on visual problems. One target was red and the other was green on each trial, the lateral arrangement of the two colors varying from trial to trial in accordance with Gellerman orders. For the first 21 days, the reinforcement ratio was 70:30, with green the more frequently reinforced (majority) color. The schedule of reinforcement was the same as that used in earlier experiments with the mouthbreeder. It was constructed with the restriction that there be at least one minority reinforcement in each block of five trials and no more than two such reinforcements in succession. Each of the colors was equally often reinforced in each lateral position. On Days 22-65, the reinforcement-ratio was 20:80, with red more frequently reinforced and one minority reinforcement in each block of five trials. On Days 66-91, the reinforcement-ratio was 50:50, and the schedule was constructed on the basis of Gellerman's rules.

The remaining six Ss were trained 61 days on a 70:30 spatial problem with two red targets. The schedule was the same as that used in previous work with the mouthbreeder. There was at least one minority reinforcement

Fig. 1. Percent choice by individual Ss of the original majority stimulus on each day of training in 70:30, 20:80, and 50:50 visual problems.

in each block of five trials, with no more than two such reinforcements in succession.

Results

The visual results for individual Ss are plotted in Fig. 1. After a few days on the 70:30 problem, the curves began to cluster closely about the 70% level. In the last 10 days on the problem, the mean majority choice was 66%, with a range of 60 to 74%. There was no evidence of visual reward-following or its opposite (negative recency): the mean majority choice was 66% on trials following majority reinforcement and exactly the same on trials following minority reinforcement. For individual Ss, the differences ranged from -9% (the strongest indication of negative recency) to 10% (the strongest indication of following). None of the animals showed a substantial spatial preference: the mean left choice was 55%, with a range of 49 to 59%.

When the reinforcement-ratio was shifted to 20:80, the choice-ratio changed accordingly in all animals. (Curves are plotted only for five Ss, because one was lost soon after the shift.) In the last 10 days, the mean choice of the former majority stimulus was 20%, with a range of 16 to 25%. There was no indication of reward-following: the mean majority choice was 19% after majority reinforcement and 21% after minority, with a range of -2 to 7% in individual differences. There was a somewhat stronger left preference here than in the 70:30 problem (the mean was 62% and the range was 53 to 66%).

When the reinforcement-ratio was shifted to 50:50, the choice-ratio again shifted accordingly, although close matching was not achieved by the time that it became necessary to terminate the training. The mean preference for the original majority stimulus in the last 10 days was only 41%, with a range of 35 to 51%. There still was no strong tendency to respond in terms of position (the left-preferences ranged from 40 to 65%,

with a mean of 51%), and no suggestion of visual reward-following (the mean majority choice was 43% after majority reinforcement and 39% after minority, with a range of -9 to 4% in individual differences).

Of the six Ss trained on the 70:30 spatial problem, five tended to match, while the choice-ratio of the sixth continued to hover about 50%. In the last 10 days of training (which were quite representative of the performance of the animals almost from the beginning), the mean majority choice was 71%, with a range of 53 to 79%. If the deviant animal is excluded, the mean is 75%, with a range of 68 to 79%. There was no indication of spatial reward-following: whether or not the deviant animal is excluded, the mean majority choice was 76% after majority reinforcement and 72% after minority, with individual differences ranging from -2 to 9%.

Discussion

In probability-learning experiments of this general design, the goldfish behaves very much like the African mouthbreeder. A rather close correspondence of choice-ratio to reinforcement-ratio is evident in the behavior of individual animals, and the correspondence does not seem to be an artifact of such systematic tendencies as position-habits and reward-following (or its opposite). It is in this sense of the term that random visual and spatial probability-matching may be said to have been demonstrated in both species.

References

- Bitterman, M. E. Phyletic differences in learning. *Amer. Psychologist*, 1965, 20, 396-410.
- Bitterman, M. E., Wodinsky, J., & Candland, D. K. Some comparative psychology. *Amer. J. Psychol.*, 1958, 71, 94-110.
- Behrend, E. R., & Bitterman, M. E. Probability-matching in the fish. *Amer. J. Psychol.*, 1961, 74, 542-551.

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