Physiological Psychology
1973, Vol. 1, No. 1, 83-84

Solution of a spatial constancy problem by goldfish*

DAVID INGLE and DIANNE SAHAGIAN
Neuropsychology Laboratory, McLean Hospital, Belmont, Massachusetts 02178

Goldfish readily learned to escape from a compartment by turning toward a door in the same real direction, although they approached the choice point from opposite directions on alternate trials. This ability reflects some capacity for discrimination of spatial relationships in the environment independent of a body-centered reference system.

While the ability of fish to solve visual discrimination tasks and to learn simple mazes is well known, fish have not been trained to perform more "abstract" discriminations. The present study explores the ability of the common goldfish, *Carassius auratus*, to learn a spatial constancy problem. Figure 1 illustrates a diamond-shaped box which goldfish enter from either end and from which they can escape via one of two side doors. If the inner structure of the box provided a cue as to the fish's direction—i.e., going north or south—could the fish then learn to swim consistently to the same door—i.e., eastwards—regardless of the direction of entry into the compartment? Such learning would reveal a sense of "spatial constancy" for the fish: the ability to remember spatial directions regardless of the S's own body orientation.

METHOD

Eight large goldfish, about 6 in. in length, were selected on the basis of good performances in prior, unrelated discrimination tests. These Ss were first accustomed to the diamond box (10½ in.² and 7½ in. deep), which was placed in the middle of a 3-ft² aquarium with water filled to a 6-in. depth. Since the walls of the aquarium were internally lined with white plastic sheeting, and the tank was centered beneath an elongated fluorescent light oriented along the axis connecting the two entry compartments, it appeared that the fish would have only the stripe patterns within the box to use as directional cues. Prior to training, fish were habituated to the apparatus by swimming five times from each entry box and making spontaneous exits through the open doors. During habituation and training procedures, fish were quickly but gently cradled in the E's hand and smoothly placed into one entry box. During initial training, some fish had to be lightly prodded with a glass rod to exit from the entry box into the diamond compartment, but eventually fish swam promptly out and sought an exit from the diamond box without prodding.

On the second day, one side door was covered from behind with an unscratched piece of Lucite, so that the edges of the plastic could not be seen from within the box. Since fish were trained four at a time, plastic barriers restrained three fish to regions near one end of the tank or the other, so that the fish within the box could not see the others until having passed through the open door. Fish were trained in daily sessions, consisting of at least 20 trials. If the S was engaged in a "criterion run" of 18/20 correct choices, he was allowed up to 30 trials to complete such a sequence. Fish were placed in opposite entry boxes in random sequence, such that a correct choice of the open door required alternation of turns on many trials. When the fish bumped the Lucite door, an error was scored, and when the fish's nose passed the open door, a correct choice was scored. If a fish hesitated within the box and did not make a choice within some 30 sec, he was manually lifted back to the start box and prodded therein in order to motivate a more prompt exit.

RESULTS

As Table 1 indicates, seven of the eight fish reached the 18/20 criterion score within only two training sessions, and the remaining fish took three sessions.

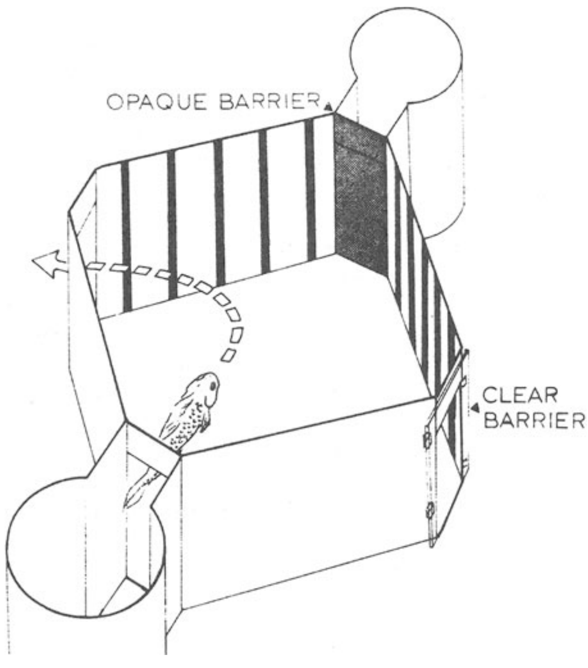

Fig. 1. The diamond-shaped box used in the present study has two identical entry compartments (top and bottom), an open door (left), and a door backed by a clear Lucite barrier (right). The entry opposite to the fish's approach is blocked by a black sliding door. Five red stripes cover two walls of the box, while the remaining walls are all white. Fish are manually placed within one entry compartment at the start of each trial.

*This research was carried out while the first author was supported by an NIMH Career Scientist Development Award (K0213175). The second author worked as part of the McLean Hospital Volunteer Program.

Table 1
Training and Test Scores of Goldfish Trained to Avoid Barrier in Diamond Box

Fish Number	Trials to Criterion	Number Correct Trials After Box Turned Around	Number Correct Trials with Barrier Alteration
1	8	6/10	10/20
2	49	9/10	10/20
3	8	9/10	14/20
4	26	9/10	10/20
5	7	9/10	9/20
6	24	7/10	13/20
7	5	Died	–
8	25	8/10	8/20
Mean	19.0	57/70 81%*	74/140 53%

**This score is significantly different from chance as well as from that of the control test (53%) at p < .01 (one-tailed) according to the binomial probability test.*

Unfortunately, the fastest learner, Fish No. 7, died before further tests could be made. The other seven fish were given a retraining test on the day following the third test session, in which they were given 10 additional trials on the task they had mastered. Within this retraining session, the seven fish made a total of only five errors, and all performed correctly in the second five trials. At this point, the diamond box was turned around by 180 deg, so that fish could not rely upon cues extraneous to the box itself for choosing the "constant direction." Although the fish seemed mildly disturbed by the reorienting of the box, they nevertheless scored 81% correct within the final 10 trials. Finally, on the next day, the same seven fish were given another 20-trial session, in which the box was placed in its original position and the Lucite door barrier was alternated from side to side on successive trials. Since the group averaged only 53% correct choices, it was evident that these fish did not directly sense the position of the barrier.

DISCUSSION

The present data show that goldfish can learn to swim in a constant direction relative to visual cues within a small enclosure, even if they must approach the choice point from opposite directions and alternate the direction of turns on different trials. This ability might have been classified as a conditional discrimination task, i.e., stripes ahead, go left; stripes behind, go right. We choose the term "spatial constancy" since it describes the fish's overt behavior and does not infer an implicit rule governing the response selection. Following the conclusion of these experiments, we learned that the same paradigm had been successfully carried out by Tolman et al (1946) with rats, under the designation "place learning." In light of the very rapid acquisition of the rats' "place-directed" habit, it is perhaps surprising that brain lesion and memory experiments have relied so heavily on "response learning" procedures.

We suspect that this type of "conditional discrimination" normally serves the purpose of learning routes within an organism's home territory. For example, it is presumed that fish, as well as rats, move quickly through a complex terrain to seek protection of their "home" when frightened by a predator. To test this hypothesis, it would be useful to perform laboratory experiments on these vertebrate species whose ecology places the *greatest* and the *least* demands for using a "spatial map" of the environment. Furthermore, the present study should reemphasize how little we know of the *limits* of learning capacities among fish. A better knowledge of these limits could provide a needed foundation for thinking about "comparative intelligence" within the vertebrate phylogeny.

REFERENCE

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(Received for publication July 31, 1972; revision received September 6, 1972.)