Formation of the "Bobber Upthrust Response" for Food-Obtaining in Bluegill Sunfish *Lepomis macrochirus**¹

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Four bluegill sunfish were trained by the operant conditioning technique to activate an automatic feeder by nudging the bobber upwards in order to be provided with a food pellet. This conditioning was completed in 40 to 45 days for three of the fish but required about 105 days for the last remaining fish. Due to the extremely low reaction displayed by the fish towards the bobber, the fish had to be trained to respond to the feeding tube namely, by nudging or poking at it and it was only after this that the fish were seen to respond easily to the bobber.

The frequency at which the bobber was found to be nudged upwards was much lower when compared to that for the feeding tube; the former frequency ranged from 0.5 to 0.7 times/min while the latter ranged from 3.7 to 5.9 times/min.

There have been many studies which deal with the conditioning of fishes. Conditioning has been utilized by many authors as an analytical technique for study on the sensory physiology of fishes. A few though, analysed the process of conditioning itself in fishes for the purpose to define the learning capacity of them from the comparative psychological standpoint.¹⁻⁹⁾

On the other hand, it was only since recent times in Japan that investigations into the conditioning of fishes attracted the attention of certain people who were engaged in the practical area of fisheries.^{8,9)} In other countries, however, especially in Russia, the applicability of conditioning techniques to the grounds has been already proved as reviewed by YAMAGISHI.⁹⁾

In order to develop this technique for more effective utilization, there is urgent need to understand much more about the capability of fishes to acquire and retain behavioral habits; that is conditioned behaviors. Also needed is a better understanding of the possible combined effects of conditioned stimulus and of other various sorts of stimuli in nature and the retention or deterioration of a formed conditioned behavior.

The present authors have been continuing a series of conditioning experiments by using bluegill sunfish *Lepomis macrochirus* with the intention of understanding the ability of this species to acquire and retain some new type of feeding behavior.

The bluegill was chosen for its easy handling and also for its higher status along the phylogenetic hierarchy among teleosts. A simple conditioned response was initially produced along this line of investigation. A response to the bobber placed in an aquarium was rewarded with food. The response will be designated as the "bobber-upthrust response" in the present series of investigations.

The present paper shall give a description on the production process of the response in individual fish.

Materials and Methods

Four bluegills, all male, were isolated for experimental use into separate experimental aquaria on September 11, 1975, at the age of 39 months. A stock from which they had been sampled was spawned in June of 1972 in an outdoor tank on the college campus and were fed on a population of water flea during the first 3 month period of their lives, after which they were switched to a fish meal diet.

All the aquaria, 30×60×36 cm, were installed in an isolated room in which illumination was provided by four 30 W fluorescent bulbs fixed to a ceiling 3 m high, in order to eliminate possible disturbances in the fish performance due to intervening external stimuli.

*¹ Studies on Conditioning of Bluegill Sunfish -I.

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The walls of the aquaria were covered with opaque plastic sheets, save for the front which is required for observation use, in order to prevent the fish from seeing one another. The tanks were filled with dechlorinated tap water up to a depth of 30 cm, and was circulated through a mounted filtering system and continuously aerated. Moreover, the water was refreshed regularly once every 2 weeks. During the period of experiments, the water temperature ranged from 20.2°C to 21.3°C and its pH was kept almost constant within a range between 6.8 and 7.5.

Procedure of Conditioning

"Shaping"¹⁰ was needed to induce the fish to hit the introduced bobber because too low a frequency of the response of the fish, either in a group or in isolation, was revealed during preliminary one-hour observations. The plastic feeding tube (Fig. 1A), instead of the bobber, was at first set up in the aquarium for feeding. The food pellet (Nihon Haigō Shiryō K.K. product 5P; 20 mg/piece on an average) was supplied to the fish piece by piece through this tube during the 15 min feeding period everyday. Repetition of feeding in this way conditioned the fish to hit or bite at the tip of the exit of the feeding tube even when no food was found there.

Subsequently, the celluloid bobber¹¹ was substituted for the feeding tube intermittently for 3 to 5 minutes during the daily feeding time which was extended to 30 minutes. After the fish began to thrust up the bobber, the bobber was fixed in the aquarium during the whole period of the feeding time. The bobber upthrust response was also consistently rewarded.

Observations and Recordings

Observations were started immediately after isolation by viewing the performance of the fish through the front wall of aquarium. The isolation seemed to exert a serious effect on the performance of the fish; they exhibited a strong tendency to retreat into a rear corner of the aquarium. Thus the early observations were concentrated on the habituation process of the fish to the new isolated situation.

Recorded were the dates at which the fish initiated (1) picking up and ingesting the food at the rear corner of the aquarium (first feeding response), (2) visiting a central area of the aquarium (first visit of central area), (3) swimming around over a whole area of the aquarium without being disturbed by any external stimuli (first free swimming),

and (4) catching the food just beneath the water surface such as they had done when in a group (first free feeding).

After the completion of the habituation process, the observations were directed to the performance of the fish in relation to a newly introduced strange object, the feeding tube. Recorded were the dates of (5) the first orientation to the feeding tube by the fish, in which it pointed the snout to the tube (first orientation), and (6) the first hitting response to the tube by the fish (first hitting response).

In addition, the frequency at which the fish hit the feeding tube were also recorded for each 15 min daily feeding time.

After initiation of the substitution of the bobber for the feeding tube, recorded were the dates at which the following performances of the fish appeared; (7) the first orientation of the fish to the bobber (first orientation) and (8) the first hitting or biting response (first upthrust response).

The frequency of the bobber upthrust response was recorded as in the case of the response to the feeding tube. The fish sometimes displayed at first a hitting response to the hood instead of the bobber. These responses were also reinforced and their frequency was recorded too.

Results

The formation process of the bobber upthrust response is summarized in Table 1. The Table shows some individual variation in the formation rate among the fish. One fish (Fish 4) out of the four could not be conditioned at least within a period of 55 days of the present experiments. However, this fish eventually was conditioned too 105 days after isolation.

The other 3 fish were successfully conditioned with a small variation in the formation rate, varying from 36 to 40 days of isolation.

A detailed description on each stage of the formation shall be given below.

Habituation

Records on the habituation process were obtained for all the fish, including Fish 4, as shown in Table 1. The number of days required until completion of the habituation varies from 5 to 15 days.

For a few days after isolation the fish stayed inactive at the rear corner of the aquarium. During this period they took in food pellets only in their immediate vicinity, as if those on the other parts of the bottom were out of sight. One to 6 days later (see Table 1), the fish began to swim

Table 1. Process of formation of the bobber-upthrust behavior in 4 bluegill sunfish *Lepomis macrochirus* (1975)

Behavioural patterns		Fish			
		1	2	3	4
Habituation to isolation	First feeding response (1)	Sept. 12 (1)*	Sept. 12 (1)	Sept. 13 (2)	Sept. 14 (3)
	First visit of central area (2)	Sept. 13 (2)	Sept. 18 (7)	Sept. 15 (4)	Sept. 14 (3)
	First free swimming (3)	Sept. 13 (2)	Sept. 18 (7)	Sept. 17 (6)	Sept. 17 (6)
	First free feeding (4)	Sept. 15 (4)	Sept. 18 (7)	Sept. 17 (6)	Sept. 19 (8)
First application of feeding tube		Sept. 16 (5)	Sept. 22 (11)	Sept. 26 (15)	Sept. 22 (11)
Response to tube	First orientation (5)	Sept. 18 (7)	Sept. 28 (17)	Sept. 27 (16)	Oct. 27 (46)
	First hitting response (6)	Sept. 19 (8)	Sept. 28 (17)	Sept. 30 (19)	Nov. 3 (53)
First introduction of bobber		Oct. 16 (36)	Oct. 20 (39)	Oct. 16 (35)	
Response to bobber	First orientation (7)	Oct. 16 (36)	Oct. 21 (40)	Oct. 19 (37)	
	First upthrust response (8)	Oct. 16 (36)	Oct. 21 (40)	Oct. 20 (39)	

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* Numbers in parenthese indicate the numbers of days after isolation (Sept. 11, 1975).

out from the rear corner and visit other parts of the aquarium to take the food there. But they still seemed to be highly sensitive to external stimuli, so that their visits were often interrupted by retreating reactions, resulting in a failure to obtain food. As they were getting less sensitive to the external stimuli, the fish expanded their visiting area over the whole of the aquarium bottom. Subsequently, the fish spent almost all the time cruising around spontaneously throughout the aquarium and also began to catch the food pellet on its way to the bottom. Moreover, the fish showed a high feeding activity with which they caught the food just beneath the water surface as they did when in a group.

The feeding tube was introduced for the first time after ten successful attempts of this type of feeding activity.

Progression of the mentioned habituation process was different from fish to fish as shown in Table 1.

Response to the Feeding Tube

The dates at which the feeding tube was initially introduced are given in Table 1.

The introduction of the feeding tube exerted some repulsive effect upon the performance of Fish 2 and Fish 4 for 2 and 3 days respectively. The fish were again forced into the rear corner of the aquarium and they came out from the rear corner only for picking up the pellet under the feeding tube. Such repulsive effects were not noticed in Fish 1 and 3.

After elimination of the retreating tendency, Fish 2 and 4 showed occasional approaches to the

feeding tube while cruising through the aquarium like Fish 1 and Fish 3. The orientation to the feeding tube was observed for the first time on the 3rd day for Fish 1, on the 7th day for Fish 2 and on the 2nd day for Fish 3, after initiation of introduction of the feeding tube, as shown in Table 1.

A duration of the orientation shown by Fish 4 was too short to be clearly noticeable, unlike those shown by the other fish. Hence a special feeding tube (Fig. 1B) was devised for particular application to Fish 4; the tube was equipped at its exit with an openable transparent plate in order to make it possible for the fish to get direct sight of

Fig. 1. Feeding tube.

(A) original feeding tube, (B) special feeding tube modified for Fish 3.

R: roof plate of aquarium, W: water surface, P: transparent plate, S: string for opening of the "P" for food supply.

Fig. 2. Frequency of the responses of the fish.

A: Fish 1, B: Fish 2, C: Fish 3, D: Fish 4.

Black circle: the hitting responses to the feeding tube, open circle: the bobber upthrust responses.

the food pellet prior to its supply. The fish showed an orientation to the exit of the tube on the next day to the first trial of feeding through the new type of feeding tube. However, this orientation could not be regarded as the same to those shown by the other fish to the original feeding tube, because it was apparently a direct response to a visible attractant, that is the food pellet. Moreover, the response was very unstable and disappeared shortly afterwards with reappearance of the retreating tendency. The stable orientation was finally formed in Fish 4 on the 36th day of the application of the feeding tube, after several repetitions of appearance and extinction of the mentioned unstable orientation, as shown in Table 1.

Once they had initiated the orientation to the feeding tube, including the stable one of Fish 4, all the fish began to hit the tube as soon as within one week (see Table 1). However, again the hitting response was unstable and disappeared in a few days in Fish 4, as shown in Fig. 2. In contrast

the frequency of the hitting responses of the other 3 fish, expressed as the number of response minute, increased rapidly and attained its maximum value under the constant reinforcement, as shown in Fig. 2. Maximal frequency values were found on the 4th to 9th day after initiation of the hitting response. Thereafter, the demand feeder¹¹⁾ was fixed on the roof of the aquarium and operated by a manual hand switch to provide the food supply. A slight decreasing trend in the frequency of responses in Fish 3, as shown in Fig. 2, might be caused by the introduction of the feeder.

Mean frequency of the responses for the three fish after reaching their maxima were as follows;

Fish 1 $4.6 \pm 1.53^*$ time/min

Fish 2 3.7 ± 1.25

Fish 3 5.9 ± 2.30

* standard deviation

The frequency of the responses fluctuate day by day with the coefficient of variation 30 to 39% around mean values for each fish.

Fig. 3. Proportion of the effective bobber upthrust responses to the over-all responses to the bobber. A: Fish 1, B: Fish 2, C: Fish 3.

Bobber Upthrust Response

The bobber was presented at first only to Fish 1 in 3 sessions from September 29 to October 1 as shown in Fig. 2, for the purpose of checking the tendency of the fish to transfer its response from the tube to the bobber. The fish did not show any reaction towards the bobber except for a single approach to it. Therefore, the substitution experiments of the bobber for the tube was delayed to the days dated in Table 1.

Probably thanks to continued reinforcement of the response to the feeding tube, Fish 1 oriented to and also thrust up the bobber with great ease (see Table 1 and Fig. 2). The other 2 fish also responded to the bobber in almost the same way as that of Fish 1, and the bobber upthrust response was initiated within a few days after the first presentation of the bobber as shown in Table 1.

During the presentation of the bobber, the fish could obtain the food pellet only by operating the feeder by itself, which worked automatically when activated by the bobber upthrust response of the fish. However, the response in all the fish was sometimes imperfectly performed at its earlier stage of the formation; the fish often hit the hood instead of the bobber.¹¹ In addition, the force of the upward thrust was too weak to work the feeder. These ineffective responses were also reinforced by the food supply which was provided by manual operation of the feeder.

In contrast with the very slow increase in the frequency of the over-all bobber upthrust responses as shown in Fig. 2, the proportion of the effective responses to the over-all responses increased very rapidly and attained its maximal values of 0.8 to 1.0 within 6 to 11 successive sessions as shown in Fig. 3. This implied the completion of the formation of bobber upthrust response on the following dates; October 28 for Fish 1, October 30 for Fish 2 and November 1 for Fish 3, in 1975, which were the 48th, the 49th and the 50th day of the conditioning respectively.

The mean frequency of the bobber upthrust

responses for each fish were as follows;

Fish 1	$0.7 \pm 0.33^*$	times/min
Fish 2	0.5 ± 0.27	
Fish 3	0.7 ± 0.34	

* standard deviation

The frequency of the responses fluctuated day to day with the coefficient of variation of about 50% around its mean values. The bobber upthrust response was less frequent than the response to the feeding tube; the mean frequency of the former response stayed at the level of only 0.11 to 0.15 of those of the latter one.

In conclusion, the bluegill sunfish have been conditioned to thrust up the bobber at the formation rates of 42 to 44 days. This is calculated by subtracting the number of days required until habituation from those required to be conditioned completely.

Discussion

It is evident that the above mentioned formation procedure of the bobber upthrust response in the bluegill sunfish is a type of "operant conditioning" based on the feeding behavior of the fish. The thrusting response seemed to be a difficult task for the species to display, which was reflected in the very low operant level and also in the low frequency of the formed bobber upthrust responses. This may be due, at least in part, to the character of the fish species which has been reported by some authors¹² as a sucking feeder but not as a voracious one. In turn, this low operant level was the reason for the necessity of the shaping procedure. It consisted in the transfer process of the response from the feeding tube to the bobber. As shown in Table 1, the fish which has learned sufficiently to hit or bite the tip of the feeding tube can transfer this response very easily from the tube to the bobber within few days after the initiation of its substitution for the tube. This suggests to us that the formation procedure of the response to the feeding tube would constitute the more essential

part of the conditioning technique in question.

In addition, the present experiment has revealed that there was a great difference in the frequency of occurrence between these different kinds of responses; the frequency of the response to the feeding tube was 7 to 9 times, on the average, greater than that of the bobber upthrust response. There was no reason to take into account the differences which were due to difference either in the feeding tendency among the individual fish or in the strength of the reinforcement between the responses, since the mentioned comparison was made between the responses of the same individual fish and both the responses were reinforced consistently in the same way. Therefore the present authors think that it might originate from differences in nature of the "operanda"¹⁰ to which the fish must respond for the food; the feeding tube and the bobber. However, further experimental analyses should be designed and also conducted for the purpose of clarifying the effect of different operandum upon fish behavior.

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