VISUAL-REINFORCER COLOR, AND OPERANT BEHAVIOR IN SIAMESE FIGHTING FISH¹

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Male Siamese Fighting Fish (*Betta splendens*) were conditioned to emit an operant response sequence reinforced by presentation of a model of a male Siamese Fighting Fish in aggressive display. Operant response rate varied as a function of the color of the model with respect to the color of the subject.

Previous research has shown that stimuli evoking unlearned aggressive behavior can be used to reinforce operant responses (Thompson, 1963). Such stimuli can also function as unconditioned stimuli in the classical conditioning of aggressive display (Adler and Hogan, 1962; Thompson and Sturm, in press). It has also been demonstrated that *Bettas* can discriminate color (Lissmann, 1932). The present experiment was designed to assess the relative reinforcing properties of models of male *Bettas* of different color.

METHOD

The subjects were three male *Bettas* purchased from a local aquarium supply store. Fish A was red and 6 cm long, Fish B was blue and 6 cm, long, and Fish C was blue with a green dorsal fin and was 6.5 cm long. The fish were fed frozen brine shrimp once daily and maintained in conditioned tap water at constant tank temperature of 27° C. They were individually maintained and tested in rectangular 2-gal aquarium tanks visually isolated from each other.

Each fish was tested for 1 hr at approximately the same time each day. Fish A was tested from 1:30 to 2:30 p.m., Fish B from 2:30 to 3:30 p.m., and Fish C from 3:30 to 4:30 p.m. The 1-hr session began with the first reinforced response.

A sequence of responses positioned the fish where it would be immediately presented with the visual stimulus. The fish was required to swim through three gates in an underwater maze in a prescribed order. The gate positions are shown in Fig. 1. At each gate, a beam of light was focused into the tank on a small mirror ($\frac{3}{4}$ by $\frac{3}{4}$ cm) and reflected back out against a photoelectric cell. The mirrors were small enough not to elicit display from the fish to its image. By passing through a gate, the fish interrupted the beam and closed a relay. When all three relays were closed in order, the visual reinforcer was presented. One of six colored models of male *Betta* was mounted on an electric train so that only the model could be seen by the fish. The model appeared in lateral display on the left side of the tank, stopped in front of the third gate for 4 sec (which allowed the fish enough time to display aggressively), and then moved slowly across the front of the tank from left to right (see Fig. 1). The model traveled across the front of the tank in 4 sec, allowing the fish to follow and continue presenting to the stimulus. After moving beyond the end of the tank, the train changed speed, circled back, and stopped at the left side of the tank, out of sight. In order to see the model again, the fish was required to renegotiate the maze.

The reinforcing stimuli were six models made of painted balsa wood (body) and colored cellophane (fins). All scales, fin spikes, and fin rays were drawn on the model with black ink, based on Lissmann's description of the lateral view of male *Bettas* (Lissmann, 1932). A 6-v lamp (GE-1129) was illuminated behind the model as it passed in front of the tank to increase the luminescence of the fins.

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Fig. 1. Side and top views of experimental apparatus for operant conditioning of Siamese Fighting Fish. The model electric train (9 and 10) used to present the reinforcing model (7) can be seen in the stopped position. The subject (14) is about to pass through gate 5c which will cause the model to move quickly to position A, where it will stop for 4 sec, then continue slowly to position B, where it will increase speed as it circles around the tank on the track (11) stopping again until the next response sequence (5a→5b→5c) has been completed. All dimensions are in cm.

The ceiling light over the tank illuminated the body of the model. The colors of the models were as follows: models 1 and 2—red 5R⁴/₉; models 3 and 4—blue 10PB³/₉; models 5 and 6—green 5G⁴/₇, as matched with colors in the Munsell Color System Atlas. All models showed the full aggressive display. The models were run for two blocks of five sessions to determine their reinforcing properties. The following order was employed to control for a possible order effect: blue, red, green, green, red, blue. Two models of the same color were used to control for slight differences in body shape due to hand carving between the differently colored models. The five sessions with the second model also replicated the first five sessions with the same-colored model.

RESULTS

Figure 2 shows the cumulative number of responses leading to presentation of each model by the three fish. The separation between session five and session six on the graph indicates that the last five sessions were not

run continuously with the first five. As the graph indicates, the red fish (A) responded at the highest rate with the green model, at an intermediate rate with the blue model, and at the lowest rate with the red model. The blue fish (B) responded most leading to presentation of the red model, second most to the green model, and least to the blue model. The blue-green fish (C) responded approximately the same as Fish B, except that the differential rate between the red and green models was greater than between the green and blue models. For fish B the differential rates were approximately equal among the three model colors.

A more detailed presentation of response distribution during the 60-min sessions for each fish, leading to the three colored models is shown in Fig. 3. The most responses occurred during the first 10 min of each session, tapering off to rates from 4 to 10 times the operant level throughout the remainder of each session. The overall rate differences leading to the three different colored models can be more clearly seen in the individual curves.

PERCENTAGE OF OPERANT RESPONSES FOLLOWED BY AGGRESSIVE DISPLAY

Model Sessions	Red		Blue		Green	
	1-5	6-10	1-5	6-10	1-5	6-10
Betta A (Red)	96	100	97	97	100	97
Betta B (Blue)	100	98	100	100	100	100
Betta C (Blue-Green)	99	100	95	95	92	85

Fig. 2. Cumulative records of complete response sequences leading to presentation of the red, green, and blue models for each fish. The table indicates the percentage of reinforced operant responses which were followed by aggressive display for each fish.

Fig. 3. Total responses during successive 10-min periods for each model and all three subjects. Operant levels are indicated on each set of graphs for each subject (O.L.).

The greatest consistent differences were between the reinforcer maintaining the highest rate and the two weaker reinforcers. This was less evident with Fish B's performance; Fig. 3 shows the three curves are much closer together than those produced by the other two subjects.

It would seem that all three fish emitted the lowest number of responses to the color most like their own, and in the case of Fish B and C the highest rate of response was to the color least like their own. The response rates to the two models of the same color are in close agreement, as can be seen in Fig. 2 and 3. This would suggest that the slight body-shape differences due to hand carving had little effect on the response rate.

The table in Fig. 2 indicates the percentage of time the fish displayed aggressively when the model was presented after the appropriate response. All displayed on more than 95 per cent of the reinforcements, except for green-blue fish (C) with both green models.

DISCUSSION

It was previously reported that the stimuli which elicit unlearned aggressive display in male *Bettas* can function as reinforcers for operant behavior (Thompson, 1963). The highest response rates were maintained by the mirror image of a male *Betta*, intermediate rates by a moving model of a male *Betta* in

aggressive display, and low rates by the same model in a stationary position. These data suggest that the subject's coloration with respect to the model's coloration may be an important variable determining operant reinforcing strength. It appears that the fish will respond least when the reinforcer coloration is like its own and most when the coloration is unlike its own. This might seem on the surface to contradict the results obtained in the earlier study, since the color of the mirror image is the same as that of the subject and should, therefore, be associated with the lowest rate. In fact, the mirror image is a highly complex stimulus, composed of all of the movements and color changes which occur during the aggressive display sequence. Because of the complex nature of the mirror image, the present study dealt solely with one aspect of the visual reinforcing stimulus—coloration.

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