Visual reinforcement: Operant acquisition in the presence of a free mirror*

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In Experiment I Siamese fighting fish performed operant responses that produced a mirror image to which the fish could display; consistent detectable display was not necessary for maintenance of operant performance. In Experiment II fish acquired and continued to perform an operant response that produced a mirror, although a "free" mirror was continually present; display rate to the contingent mirror increased while display rate to the "free" mirror was decreasing. An interpretation of these and previous data in terms of sensory reinforcement is suggested.

Siamese fighting fish (*Betta splendens*) learn to swim through a ring when that operant is followed by presentation of a mirror. When a male *Betta* confronts a mirror image of himself, he is likely to perform an aggressive display to it, which includes extension of the gill covers.

EXPERIMENT I

In the first experiment reported here, the frequency of aggressive threat displays that were actually performed by male *Betta splendens* was compared to the frequency of operant responses performed by these fish that resulted in presentation of the mirror to which the fish could display. A motor theory of reinforcement, such as that of Glickman and Schiff (1967), predicts that the maximum frequency of operants should depend upon the frequency of displays.

Method

Subjects

Ten male Siamese fighting fish without prior experimental experience served as Ss. They were selected from an aquarium supplier on the basis of healthy appearance.

Apparatus

A Plexiglas ring 1½ in. in inner diam and 7/8 in. wide was suspended with its center axis parallel to the long side of a Plexiglas tank measuring 4-5/8 x 6-1/8 x 6 in. One short side of the tank, perpendicular to the center axis of the ring, was covered with one-way plastic. Normally, illumination was provided by a 25-W bulb, situated behind the one-way plastic and in line with the center axis of the ring; under these conditions, humans reported seeing the bulb but no reflections when observing from the vantage point of the fish inside the tank (with the aid of a periscope).

The center axis of the ring intersected the center axis of a vertically mounted black plastic tube that had a miniature bulb

at one end and a photocell at the other. When the fish swam through the ring, the photocell relay was activated, advancing a counter and, during reinforcement sessions, turning off the external bulb while turning on a 7½-W bulb mounted just above the water surface inside the tank. This caused the one-way mirror to reflect the S's image for 40 sec, after which the inner light turned off and the outer light turned on. Water was maintained at 78°F ± 2°F throughout the experiments.

Procedure

After 2 days of operant level determination, Ss received three consecutive sessions of visual reinforcement training in which a ring-swimming response was followed immediately by 40 sec of mirror presentation. Two days of continuous extinction were then given each S, in which the mirror failed to appear following operant performance. Frequency and duration of aggressive displays (gill covers extensions) were recorded by a trained observer during every 5-min period for 2 h at the beginning of each 24-h period. Frequency of operant responses and their direction were also recorded. Swimming through the ring while the mirror was on had no effect; such responses were rare and are not included in the data.

Results and Discussion

During the determination of operant levels, the Ss differed in the frequency with which they swam through the ring (19 to 194 in 24 h). When swimming was followed by mirror onset, the frequency of ring swimming increased in all Ss by a factor of at least four over the course of 3 days, indicating that acquisition occurred. In extinction all Ss decreased the rate of ring swimming back to their initial operant levels (a range of 3 to 96 responses in 24 h).

On Day 1, 8 of the 10 Ss swam through the ring more frequently than they displayed to their mirror image after their operant responses produced the mirror. One S performed few operants but displayed once after each, and one S displayed slightly more often than he performed the operant. The same pattern of responding occurred during the 2-h observations on Days 2 and 3: Significantly more operants than displays were performed ($p < .05$, sign test).

Figure 1 shows the cumulative total responses for all 10 Ss during the last 2 h of Day 1. Eight of the 10 individual curves look very similar to this total curve.

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Fig. 1. Cumulative operant and display responses of all Ss during first 2 h of second day of acquisition, after 24 h with response-mirror contingency.

Operant responses for the mirror were performed approximately two and one-half times more frequently than were the displays to the mirror that was presented when the operant was performed. Even if Ss extended their gill covers as soon as the mirror appeared and kept them extended for 40 sec, there would have been at least one display per operant response. To find about 0.4 displays per operant strongly suggests that continuous visual reinforcement by performance of a display response at least once each time the mirror appears is not necessary to acquire or maintain operant responding in this context.

Correlation coefficients between operant and display frequencies were calculated during acquisition. Variance in propensity to display accounts for a moderate amount of the variance in operant behavior (Day 1, $r = 0.61$; Day 2, $r = 0.64$; Day 3, $r = 0.44$). There is, thus, some tendency for Ss that display more to perform more operants. This result indirectly confirms the finding (Baenninger, 1970) that dominant fish (which display) perform more operants for mirrors than subordinates (which rarely display).

Duration of displays showed virtually no relationship to operant performance. The correlation coefficients (r) between operant frequency and mean display duration were 0.06, 0.17, and 0.04 for the observation periods on Days 1, 2, and 3, respectively.

The direction in which fish swim through the ring when they perform the operant response has not been systematically observed in previous studies. If a fish is swimming through the ring in order to perform an operant, it might be expected that he would swim from the side farthest from the mirror toward the side of the ring where the mirror appears so that he is facing it when it appears. This would be a simple response chain, in

which an operant and an instinctive response become linked. Swimming in the "wrong" direction does not preclude the possibility of displaying after, since the fish can turn around to face the mirror. During the 2-h observations on Days 1, 2, and 3, the mean proportions of operant responses made by swimming toward the mirrors were .48, .44, and .41, respectively, suggesting no strong preference for either direction. Data on individual fish also did not indicate any directional predilection. A Friedman one-way analysis of variance indicated no trend in the mean proportions ($p > .05$). The direction of swimming seems to bear no relation to position of the mirror presented following an operant. Thompson (1966) required his Ss to chain responses, which they learned to do, but there seems to be no evidence in the present data that chaining or stereotypy occur when not required.

During the 2 days of extinction, displaying was never observed, and the level of operant responding fell to baseline (a mean of 86 responses in 24 h) within the 2-day period. The contingent appearance of a mirror seems to be necessary to maintain the ring-swimming operant, but consistent performance of the threat display that may be elicited by the mirror does not appear to be necessary to maintain operant performance. These Ss were in a sense putting themselves on a partial reinforcement schedule (an FR 2.5 on the average), if the assumption is made that display to a mirror constitutes a reinforcement. If mere appearance of a mirror is the reinforcement, then its complete absence clearly results in extinction; data are lacking on partial reinforcement using the visual reinforcement paradigm.

EXPERIMENT II

In previous experiments it has been shown that several factors may decrease the frequency of threat displays of male *Bettas*. Socially subordinate fish display infrequently or not at all in encounters with conspecifics (Baenninger, 1968); subordinate fish perform an operant response (ring swimming) less frequently than dominant conspecifics for visual reinforcement (mirror presentation) (Baenninger, 1970). Habituation of displaying occurs when a mirror is present for long periods (Clayton & Hinde, 1968). In addition, habituated fish spend a decreasing percentage of time in the presence of mirrors when given a choice (Baenninger, 1966). That habituation may be an aversive process has been implied by a recent series of experiments (Baenninger, 1970), in which it was shown that, if a mirror was present continuously, naive *Bettas* acquired an operant response which turned off the mirror for a short time; extinction of the operant occurred rapidly when its performance was no longer followed by mirror disappearance. Male *Bettas* that had completely stopped displaying during lengthy periods of cohabitation performed the operant more frequently to turn off a mirror than to turn it on.

If habituation of threat displays is aversive to a male *Betta*, then it should follow that he will not acquire an operant that turns on a mirror if there is a mirror continuously present to which he has become habituated. If Ss do acquire the operant under these circumstances, it would suggest that these fish have a rather strong motive to manipulate their environment, i.e., to perform acts that cause a change, since they will be acquiring an operant for a reinforcement to which they have become habituated.

A somewhat analogous experiment has been reported by Neuringer (1969), in which he showed that pigeons and rats will perform previously acquired operants or acquire arbitrary new ones for food reward when free food is continuously available to them in the operant chambers. Neuringer's conclusion was that "the act of producing food can serve as its own motivation and, therefore, as its own reward."

In the following experiment, male *Bettas* were in a situation where a mirror was always present to which they could display but where, in addition, they could perform an operant that turned on an additional mirror for a short time period. If they failed to acquire the operant, one could conclude that mirrors had become sufficiently aversive, presumably because of habituation, so that their normal operant acquisition was interfered with. If, on the other hand, acquisition of the operant occurred, it would appear more likely that fish in the visual reinforcement situation are working primarily for change in their visual environment. In addition, this data would complement Neuringer's (1969) finding in a very different operant situation using nonnutritive reinforcement and a different species.

Method

Subjects

Six naive male *Betta splendens*, all red or blue or a mixture of these hues, served as Ss. All were selected on the basis of healthy appearance from a local dealer.

Apparatus

The same apparatus was used as in Experiment I, except that a mirror was attached to one short side so that it was opposite the one-way mirror.

Procedure

Ss were isolated in 500-cc glass bowls containing aged water for 1 week prior to experimentation. Throughout their stay in the laboratory, they were fed freeze-dried brine shrimp pellets. Water temperature remained at 78°F, and tanks were cleaned every third day by siphon.

One day was allowed for operant level determination, during which the number of ring swims performed without visual reinforcement was determined for each S. The number of displays to the free mirror was recorded during the first hour in the apparatus, as well as any displays to the one-way glass (which did not appear as a mirror but may have had some reflective properties). Nine days followed, during which swimming through the rings turned on the contingent mirror for 40 sec. This was followed by 10 days of extinction, during which no mirror was

Fig. 2. Mean number of displays and number of operants during 1-h daily observations in acquisition and extinction phases.

presented following operant performance. Throughout acquisition and extinction, the total number of operants in 24 h was recorded. Each day fish were observed at about the same time for 1 h, during which the number of displays (gill cover extensions) to both the free and contingent mirrors were recorded, as well as the number of operants and the direction in which the fish swam as he performed them.

Results

During operant level determinations in the presence of the free mirror, only one S swam through the ring during 24 h, suggesting that the presence of the free mirror may have decreased operant level, since fish in Experiment I had a higher operant level. The results when the contingency between operant performance and mirror presentation was first put into effect are shown in Fig. 2. During the very first hour, the mean number of operants was greater than the number of displays to the contingent mirror. This relationship occurred during all but two of the subsequent 1-h daily observations during acquisition and extinction, thus replicating the results of Experiment I. There were never any displays to the contingent mirror during extinction, which confirms the ineffectiveness of one-way glass in eliciting displays when it was not illuminated as a mirror. During acquisition, there were always more displays to the free mirror than to the mirror for which fish had to perform the operant. However, as shown in Fig. 3, there was a progressive decline in the number of displays to the free mirror. This decline (Friedman analysis of variance: $\chi^2_R = 225.8$, $df = 9$, $p < .001$) probably represents habituation that was occurring to the free mirror at the same time that frequency of operant responses to obtain the contingent mirror, and displays to that mirror, were increasing. During extinction trials, no displays were made to the free mirror that was, of course, still present; presumably habituation was complete by this time.

Fig. 3. Mean number of displays to free mirror during 1-h daily observations. The first point was taken during operant level determination when no contingency was in effect.

Operant responses performed during successive 24-h periods increased greatly when they resulted in appearance of the contingent mirror, even though the free mirror was always available (Fig. 4). During extinction trials, there was a decrease in operant response frequency. Both the increase in acquisition and the decrease in extinction were more gradual than has been found in previous experiments in which no free mirror was present (Thompson, 1963; Hogan, 1967; Baenninger, 1970): The more usual finding has been that response frequency reaches its maximum during the first 24 h and extinguishes to baseline almost as quickly.

Unlike the finding in Experiment I, Ss in Experiment II showed a consistent preferred direction in performing the ring-swimming operant. Overall, they swam approximately twice as often toward the one-way mirror as away from it. Individual Ss all showed this trend on almost every day during acquisition and extinction. It is possible that this finding implies an aversion to the free mirror because of habituation; it is also possible that response chaining occurred in Experiment II because the free mirror functioned in some way to make it more likely.

Since the number of displays to the contingent mirror is a function of the time that mirror is present, which in turn depends on the number of operants performed, a rate of display measure (displays per minute) was calculated for both the contingent mirror and the free mirror using data from the 1-h observations during acquisition. These measures are shown in Fig. 5. The rate of displaying to the free mirror started high and decreased relative to the rate of displaying to the contingent mirror, which started low (on Day 1) and rose eventually, falling to the same rate as the free mirror after 9 days.

Discussion

Even in the presence of a free mirror, male *Bettas* acquired an operant response that turned on an additional mirror. Presentation of the mirror contingent upon responding was necessary to maintain responding; when the contingency was broken during extinction, the operant response rate dropped to baseline levels. Thompson (1963) found that switching of the lights without the one-way mirror in position was insufficient to maintain operant performance, indicating that this

Fig. 4. Mean number of operant responses during successive 24-h periods. Only one S responded during operant level determination.

Fig. 5. Mean calculated display rates to contingent and to free mirrors during acquisition phase.

form of visual change was an inadequate reinforcement for ring swimming. Goldstein (1967) found that increased activity due to mirrors was insufficient to explain the increase in ring-swimming responding when a mirror was contingent upon doing so.

Fish could discriminate between the two mirrors and, in fact, preferred the free one in the sense that the initial rate of displaying to it was considerably higher than to the contingent mirror when it was available. This preference disappeared as waning of displays to the free mirror occurred, and the rate of displaying to the contingent mirror increased; by the end of the acquisition period, there was no preference for either mirror. It is somewhat paradoxical that habituation could occur to one mirror while the same response was increasing in frequency to another mirror. One explanation may be that exposure to the free mirror was continuous and of long duration, while exposure to the contingent mirror was episodic and of relatively short duration. Although habituation is generally thought of as a highly stimulus-specific process, the degree of specificity shown by these results appears exceptional. If habituation is an aversive process, there seems to be virtually no generalization of any aversion developed to the free mirror stimulus; the contingent mirror (up to a point) appears to become increasingly attractive in two ways: Operants are more frequently performed to view it, and display rates to the mirror increase when it is viewed.

As in Experiment I, there were more operant responses performed than displays to the mirror that operant responses produced. Two Ss were seldom observed to display but reliably performed operants during the 1-h and 24-h periods. Again, there was a moderate correlation between number of operants and number of displays to the contingent mirror ($r = .71$), indicating that about half of the variance in operant responding could be accounted for by differences between Ss in their propensity to display.

The present data support Neuringer's finding that operant responses for food may be performed in the presence of free food. Those data left some ambiguity about whether acquisition could occur in the presence of free food. The present experiment extends Neuringer's findings by showing that a different species will acquire an operant for a nonnutritive reinforcer in the presence

of a highly similar free reinforcer. Performance of a display that the reinforcer elicits does not seem to be necessary to maintain the performance of the operant.

An interpretation of previous data (Baenninger, 1970) in terms of aversiveness of the habituation process is made unlikely by the present data. If the free mirrors were becoming aversive to Ss, it is improbable that they would work in the same situation to produce an additional mirror. Habituation clearly occurred to the free mirror, but the fact that Ss learned an operant for an additional mirror makes the aversive interpretation untenable.

Male *Bettas* appear motivated to manipulate their visual environment, either by moving themselves if that is possible (Baenninger, 1966) or by performing acts that result in a change of visual stimulation. The present results show that *Bettas* will work for additional visual stimulation even though they have become habituated to nearly identical mirror images.

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