OPERANT RESPONDING IN SIAMESE FIGHTING FISH
(*BETTA SPLENDENS*) AS A FUNCTION OF
SCHEDULE OF REINFORCEMENT AND
VISUAL REINFORCERS¹

P. DIANE TURNBOUGH AND KENNETH E. LLOYD

WASHINGTON STATE UNIVERSITY

Siamese fighting fish were trained to emit an operant response that was reinforced by the opportunity to view a motion picture film image of another fish. Performance under various schedules of reinforcement was examined. When reinforcement followed every response and when reinforcement was delivered after every second response, the number of responses per session was higher than during operant level or during extinction. Reinforcement delivered following intervals of no responding (differential reinforcement of other behavior) markedly decreased responding. Light from a projector without film was found to be as effective a reinforcer as film reinforcement. Responding when projector light reinforcement followed every response was maintained at approximately the same level as that obtained under film reinforcement. Responses per session decreased when only the light was delivered on a differential-reinforcement-of-other-behavior schedule. The behavior of the fish during presentation of the film was markedly different from their behavior while the projector light was being presented.

An unconditioned aggressive display response in male Siamese Fighting fish (*Betta splendens*) can be elicited by the presence of another male *Betta splendens*, a model of a male *Betta splendens*, or its own mirror image (Forselius, 1957; Hess, 1953; Lissmann, 1932; Simpson, 1968). Recent research has indicated that these eliciting stimuli can function as reinforcing stimuli for operant responding (Anson, 1969; Baenninger, 1970; Goldstein, 1967; Grabowski and Thompson, 1968; Grabowski and Thompson, 1969; Hogan, 1967; Hogan, Kleist, and Hutchings, 1970; Melvin and Anson, 1969; Thompson, 1963; Thompson and Sturm, 1965).

¹Part of this paper was a dissertation submitted to Washington State University in partial fulfillment of the requirements for the Ph.D. degree. The research was partially supported by the Washington State University Research Fund. Portions of these data were presented at the 1972 meeting of the American Psychological Association, Honolulu. The authors are particularly indebted to Grant L. Morris for his invaluable assistance in the design and construction of the apparatus and for his many helpful suggestions throughout the experiment. Thanks are also due to Drs. F. Dudley Klopfer and Robert F. Chapman for their constructive criticisms and encouragement and to Rod Peters for his assistance with data collection. Reprints may be obtained from P. Diane Turnbough, The Bert Nash Community Mental Health Center, Inc., Fourth and Missouri Streets, Lawrence, Kansas 66044.

Hogan *et al.* (1970) and Thompson (1969) reported a failure of schedule control using fixed-ratio (FR) schedules of visual reinforcement. Instead of exhibiting the usual increase in rate following increases in the ratio requirement, responding remained at a relatively constant rate throughout a range of values from FR 1 to FR 6 (Hogan *et al.*, 1970). Thompson (1969) was unable to maintain stable responding beyond FR 4. These authors did not report the shaping procedures they used in attempting to establish ratio performance. The failure to demonstrate typical fixed-ratio responding may be due to the weak strength of the visual reinforcer, to the shaping procedure employed, or to the relative ease with which the subject could emit the response at a high rate (Morse, 1966). A more precise demonstration that the response is under the control of the consequent stimulus is afforded by use of a differential-reinforcement-of-other-behavior (DRO) schedule of reinforcement (Reynolds, 1961). In a DRO schedule, a reinforcer is presented after a fixed period of time has elapsed since the last response. This schedule eliminates the possibility of a response being paired with reinforcement and at the same time permits the frequency of reinforcement per session to remain constant with prior experimental conditions.

The present experiments investigated further the degree of schedule control exerted by visual reinforcement. In Experiment I, successive performance under various reinforcement conditions was compared. The reinforcer was a motion picture of a male *Betta splendens* emitting a display response. Although the film proved to be an effective visual reinforcer, preliminary procedures in Experiment I indicated that the projected light from the projector alone could serve as a reinforcer. Experiment II investigated the reinforcing effectiveness of only the projected light without the film under different reinforcement schedules, followed by a film reinforcement condition for comparison of performance with the two reinforcing stimuli.

EXPERIMENT I

METHOD

Subjects

Four adult, blue-green male fish (*Betta splendens*) were fed frozen brine shrimp daily after the last fish had been tested.

Apparatus

Figure 1 is a schematic drawing of the apparatus. A 15-gallon tank was divided into four separate 18 by 29 cm (7 by 11.5 in.) compartments by three vertical partitions painted flat gray to prevent a reflected image from their surface. The partitions were mounted on a Plexiglas platform measuring 29 by 72 cm

Fig. 1. Schematic drawing of the apparatus showing four fish compartments; the film projector and projection screen; the light source, the photoelectric cell and the reflecting mirrors; and the E-shaped response chamber. The insert at upper left shows the response chamber in detail. All numbers refer to centimeters. Fish 2 is being tested. A response occurred whenever the fish interrupted the light beam in either the upper or lower half of the response chamber.

(11.5 by 28.5 in.). The tank was covered by a Masonite sheet in which were recessed four 7-W incandescent lamps. The lamps were centered above each chamber and provided 0.05 millilambert (0.16 cd sr/m^2) illuminance normal to the water surface. The overhead houselights were illuminated only during the testing session. Translucent paper covered the sides, back, and upper portion of the front of the tank. Dim illumination in the experimental room was provided from a fluorescent light in an adjoining room during the testing session. The ambient luminance at the tank level between sessions varied between 11.4 and 14.8 millilamberts ($36.28\text{--}47.10 \text{ cd/m}^2$) on a 14-10 hr light-dark schedule. The tank water temperature was maintained at $27^\circ \pm 2^\circ \text{ C}$.

An E-shaped Plexiglas response chamber 2.5 by 7.5 by 7.3 cm (1 by 3 by 2.75 in.) was mounted in floor guides adjacent to the front of the tank being used. The sides adjacent to the front of the tank glass and to the tank itself were open. A light source located outside the front wall of the tank transmitted a horizontal light beam onto a mirror located in the upper half of the response chamber. This mirror faced downward 45° from the vertical and reflected the light downward and vertically within the response chamber to a second mirror located in the lower half of the response chamber. This second mirror faced upward 45° from the vertical and reflected the light beam horizontally to a photoelectric cell located outside the tank directly beneath the light source. A vertical opaque partition between the light source and the mirrors prevented the subject from viewing its reflected image. The opaque partition contained two 1-cm (0.5 in.) holes drilled in the path followed by the incident and reflected light beams (see Figure 1, upper left detail). The response chamber and photocell were removed between sessions. The same response chamber was used for all four fish.

The response of swimming into the upper or lower portion of the E-shaped response chamber interrupted the photocell light beam and closed a relay. Closure of the relay operated an event recorder and the reinforcing mechanism. The horizontal partition of the E-shaped response chamber divided the incident and reflected light beams to prevent the fish from tripping the two beams in rapid succession by swimming up and down within

the response chamber. Only entries into the upper or lower parts of the chamber were counted as responses. To emit a second effective response, the fish was required to leave the box and then reenter. Responses emitted during the 10-sec reinforcement period were neither counted nor reinforced. The overhead houselight was extinguished during reinforcement.

A 16-mm film was made of a red male *Betta splendens* (Grabowski and Thompson, 1968, and Thompson and Sturm, 1965, found coloration and movement to be important variables in determining reinforcement strength). A 10-sec closed-loop segment of the film was used as the reinforcing stimulus. The film was back projected onto a 15 cm by 24 cm (6 by 10.25 in.) ground-glass screen (the projected field size was 11 cm high by 13.6 cm wide (4.5 by 5.5 in.) from a 750-W projector mounted on a stand outside the tank. The illuminance normal to the tank wall during film presentation was 13.2 millilamberts (42.01 cd sr/m^2). During conditions where only the projector light without the film was used as the reinforcer, the illuminance normal to the tank wall was 210.0 millilamberts (668.37 cd sr/m^2). The screen was connected by a stationary arm to the projector so that both projector and screen could be moved as a unit to each of the four experimental chambers. The screen was situated against the front of the tank glass such that the fish had to leave the response box to view the image of the fish in the film. The projector lens was 83 cm (33 in.) from the screen. This distance adjusted the size of the projected image to be in approximate scale with the subjects.

Procedure

The number of sessions in each experimental condition for the four fish is listed in Table 1. After operant level, the criterion for changing from one experimental condition to another was five consecutive sessions of stable response frequencies, all of which were higher or lower than the response frequencies of the prior experimental condition. If, for example, the conditions changed from reinforcement to extinction, then the extinction condition was continued until response frequencies for five sessions decreased and stabilized at a value lower than the lowest frequency of the last five sessions of the prior reinforce-

ment condition. Five days of adaptation to the experimental chambers preceded the operant level measures. The operant level measure was the number of responses emitted in 30 min with responses having no environmental changes. Throughout the experiment, the fish were tested daily for 30 min at approximately the same time². The order of testing the fish was varied over days.

During initial testing of the reinforcement apparatus, the fish showed a marked increase in activity following the onset of the projector lamp when no film was being projected onto the screen. Consequently, the fish were ob-

the reflection of a mirror image of the subject from the water-air interface during the 10-sec presentation of light only.

After responding had stabilized on the FR 1 (Light) condition, every response was reinforced with the film (FR 1 [film]). After responding stabilized on FR 1 (Film), the fish were placed on Extinction (a return to operant level conditions). Reconditioning on FR 1 (Film) followed Extinction.

During the next condition, the fish were on a DRO 100-sec schedule of film reinforcement. During this condition, a reinforcer was delivered whenever 100 sec had elapsed without a response. The time value of the DRO was based upon the mean number of reinforcements per session received by each of the subjects during the last five days of the previous FR 1 (Film) condition. Since all four fish were responding at approximately the same rate at the end of the last FR 1 (Film) condition, the same DRO value was used for all subjects.

Following a subsequent return to FR 1 (Film), an attempt was made to establish fixed-ratio performance with Fish 3 and 4 using a shaping procedure. During shaping, reinforcement was delivered following bursts of two or three responses. Some responses were reinforced on FR 1 to maintain responding following long periods of no responding. Shaping was discontinued after 12 days for Fish 3 and after 23 days for Fish 4 when it proved ineffective in producing rate increases. A simple FR 2 (Film) was employed for the remainder of the ratio condition. Reconditioning on FR 1 (Film) ended Experiment I.

RESULTS

The median number of responses per session for the last five sessions under each condition for each of the four subjects is shown in the left panel of Figure 2. The vertical bars at each data point in Figure 2 indicate the range of response frequencies during the last five days of an experimental condition. The median number of reinforcements per session received during DRO (Film) and FR 2 (Film) is also shown. It can be seen that response frequencies for all four subjects increased over operant level during the FR 1 conditions. Film reinforcement maintained responding at a slightly higher level than light-only reinforcement. Switching to either Extinction or DRO reduced responding for all subjects. During

Table 1

Number of sessions of each condition in Experiments I and II.

Experiment	Experimental Condition	Fish			
		1	2	3	4
I	Operant Level	9	5	7	5
	FR 1 (Light)	10	13	10	12
	FR 1 (Film)	24	21	25	25
	EXT	12	16	12	17
	FR 1 (Film)	5	14	11	6
	DRO (Film)	8	9	9	8
	FR 1 (Film)	42	26	20	9
	FR 2 (Film)	-	-	19	34
	FR 1 (Film)	-	-	5	8
II	FR 1 (Light)	5	5	-	-
	DRO (Light)	6	6	-	-
	FR 1 (Light)	11	11	-	-
	FR 1 (Film)	6	5	-	-

served with light only as reinforcement for every response (a fixed ratio of one response to one reinforcement or FR 1) before any conditioning with the film. The entire reinforcing mechanism was operative during the light-only condition with the exception of no film being in the projector. An air bubbler was used to produce surface waves to prevent

²Session lengths in eight previously published experiments had varied from 2 to 24 hr (the median was 7 hr). Due to this large difference in session length, responding in the present 30-min sessions was compared to responding in 12-hr sessions with Fish 3 following Experiment I. The number of its responses was recorded for each of the twenty-four 30-min periods within the 12-hr session. In FR 1 (10 sessions) and DRO 600-sec (five sessions) the number of responses in 12 hr and in the first three or four 30-min periods were in close relative agreement. After 6 hr, response frequencies decreased to very low levels and differences in responding between FR 1 and DRO disappeared. These data in no way warranted the use of longer sessions.

Fig. 2. Median number of responses per session for the last five 30-min sessions under each condition for each fish. The vertical bars at each point represent the range of scores. The triangles indicate the median number of reinforcements per session for the last five sessions under DRO and FR conditions. The left panel contains data from four fish in Experiment I. The right panel contains data from two fish in Experiment II.

DRO (Film), the response frequencies for some sessions for Fish 2, 3, and 4 dropped below their Operant and Extinction levels. Putting the fish on FR 1 (Film) following DRO increased responding for Fish 2, 3, and 4. In order to reestablish responding for Fish 1 following DRO (Film), it was necessary first to shape its responses by presenting reinforcements when it approached the response chamber. During FR 2 (Film) with Fish 3 and 4, responding remained at approximately the same level as was obtained during the preceding FR 1 (Film) condition, even though the number of reinforcements per session decreased to half the number received in FR 1 (Film). A slight increase in rate was observed for both fish during reconditioning on FR 1 (Film). The absence of any overlap between FR 1 conditions and Extinction or DRO conditions attests to the degree of control exerted by the experimental manipulations.

Figure 3 contains the number of responses from Fish 1 for all sessions in all conditions. The number of reinforcements delivered during DRO (Film) and shaping under FR 1 (Film) are also shown. With the exception of the shaping procedure in FR 1 (Film), the data from Fish 1 were typical of the other fish with respect to response frequency, day-to-day variability, and number of sessions per condition.

EXPERIMENT II

The purpose of Experiment II was to investigate the reinforcing effectiveness of the projector light only in maintaining performance successively under FR 1 (Light), DRO (Light), and FR 1 (Light) conditions. Reconditioning on FR 1 (Film) following the last FR 1 (Light) condition provided a comparison of performance under the two reinforcing stimuli.

METHOD

Subjects and Apparatus

Fish 1 and 2 from Experiment I served as subjects. The apparatus was the same as that used in Experiment I. The air bubbler was used in all sessions.

Procedure

Following their last session on FR 1 (Film) in Experiment I, Fish 1 and 2 were placed on FR 1 (Light) with light-only reinforcement until responding met criterion. The schedule

was then changed to DRO 150-sec (Light) for Fish 1 and DRO 100-sec (Light) for Fish 2. The DRO values were again derived from the mean number of reinforcements delivered per session to each fish for the last five days of FR 1 (Light). Following DRO, a shaping procedure was used to reestablish responding on FR 1 (Light). After responding had stabilized on FR 1 (Light), the fish were again placed on FR 1 (Film) reinforcement.

RESULTS

The medians of the last five days under each condition for Fish 1 and 2 are in the right panel of Figure 2. Response frequencies maintained under FR 1 (Light) and FR 1 (Film) were approximately the same and were also similar to the response frequencies obtained under the preceding FR 1 (Film) condition of Experiment I. Responding during DRO (Light) decreased to the level of responding during DRO (Film) in Experiment I. The session-by-session data for Fish 1 in Experiment II are in the lower right portion of Figure 3.

DISCUSSION

The results of Experiment I demonstrated the effectiveness of the film image of another male as a reinforcer for maintaining operant behavior in *Betta splendens* with 30-min sessions. Performance obtained under FR 1 and FR 2 conditions confirmed the findings of previous studies that used mirror images and models as reinforcers to condition similar operant behavior in *Betta splendens* (e.g., Hogan *et al.*, 1970; Thompson, 1963). As in the earlier research, response frequency during FR 1 increased substantially over operant level, decreased to a low level during Extinction, and showed no increase above FR 1 under FR 2. The present procedure of employing DRO and recovery periods after each experimental condition more adequately demonstrated that the behavior in question was under the control of the various response contingencies. It was possible to demonstrate a schedule effect of reinforcement with DRO that has not been possible to demonstrate with FR.

The advantage of using DRO was that the frequency of reinforcement per session was held constant with the prior FR 1 condition.

Fig. 3. Number of responses per session for all 30-min sessions under all conditions in both experiments for Fish 1. The triangles indicate the number of reinforcements per session delivered during DRO conditions and during shaping under FR conditions.

The response frequencies obtained under FR 1, together with the decrease in responding that occurred under DRO, strongly argued against attributing the increases under FR 1 to any general activity increases elicited by the reinforcing stimulus.

In Experiment II, light only was as effective as film reinforcement in maintaining respond-

ing, *i.e.*, response frequencies during FR 1 (Light) and FR 1 (Film) were the same. Anson (1969) and Thompson (1963) reported that shutting off a light following a response had no significant effect on response frequency. The change in illumination was the same as that which occurred during mirror reinforcement but with the mirror absent. It would ap-

pear then that light onset when made response contingent can be reinforcing, whereas light offset is not. It is also possible that the apparent differences in the effects of changes in illumination may be due to the intensities used. The previous two investigators produced changes in illumination by extinguishing 75-W lamps, whereas a 750-W projector lamp was used in the present experiments.

The response frequencies under FR 1 (Light) and FR 1 (Film) were approximately the same. Even though both film and light only were similar in their reinforcing effectiveness, the fish responded differently to the two reinforcers. During many film reinforcement periods, the fish displayed aggressively to the film image, following the movement of the image as it changed position on the screen. Initially, there was rather consistent displaying to the film, but this decreased for all subjects during the experiment. Following light only, the fish engaged in a variety of different behaviors. Responding varied from no observable response to feeding-like behavior (picking up particles from the bottom of the tank), swimming slowly away from the response area, swimming rapidly back and forth in the front portion of the tank, and remaining motionless in front of the screen. The intensity of the illumination inside the tank was much greater during light only than during film reinforcement. The observed differences in the behavior of the fish in the presence of the two reinforcers could have been a function of differences in light intensity as well as a function of differences in film image.

REFERENCES

Anson, J. E. *Operant behavior of Siamese Fighting Fish as a function of mirror duration and consequential image-induced aggressive display*. Unpublished doctoral dissertation, University of Alabama, 1969.

Baenninger, R. Visual reinforcement, habituation, and

prior social experience of Siamese Fighting Fish. *Journal of Comparative and Physiological Psychology*, 1970, 71, 1-5.

Forselius, S. Studies of anabantid fishes. *Zoologiska Bidrag fran Uppsala*, 1957, 32, 93-302.

Goldstein, S. R. Mirror image as a reinforcer in Siamese Fighting Fish: A repetition with additional controls. *Psychonomic Science*, 1967, 7, 331-332.

Grabowski, J. G. and Thompson, T. Effects of visual reinforcer brightness and color on operant behavior of Siamese Fighting Fish. *Psychonomic Science*, 1968, 11, 111-112.

Grabowski, J. G. and Thompson, T. Effects of shock on mirror reinforced behavior of *Betta splendens*. *Psychonomic Science*, 1969, 15(3), 173-174.

Hess, H. H. Temperature as a regular of the attack-response of *Betta splendens*. *Zeitschrift fur Tierpsychologie*, 1953, 9, 379-383.

Hogan, J. A. Fighting and reinforcement in the Siamese Fighting Fish (*Betta splendens*). *Journal of Comparative and Physiological Psychology*, 1967, 64, 356-359.

Hogan, J., Kleist, S., and Hutchings, C. Display and food as reinforcers in the Siamese Fighting Fish (*Betta splendens*). *Journal of Comparative and Physiological Psychology*, 1970, 70, 351-357.

Lissmann, H. W. Die Umwelt des Kamffisches (*Betta splendens* Regan). *Zeitschrift Vergleichende Physiologie*, 1932, 18, 65-111.

Melvin, K. B. and Anson, J. E. Facilitative effects of punishment on aggressive behavior in the Siamese Fighting Fish. *Psychonomic Science*, 1969, 14, 89-90.

Morse, W. H. Intermittent reinforcement. In W. K. Honig (Ed.) *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 52-108.

Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 57-71.

Simpson, M. J. A. The display of the Siamese Fighting Fish, *Betta splendens*. *Animal Behaviour Monographs*, 1968, 1, 1-73.

Thompson, T. Visual reinforcement in Siamese Fighting Fish. *Science*, 1963, 141, 55-57.

Thompson, T. Aggressive behaviour of Siamese Fighting Fish. In S. Garattini and E. B. Sigg (Eds.) *Aggressive behaviour*. Amsterdam: Excerpta Medica Foundation, 1969. Pp. 15-31.

Thompson, T. and Sturm, T. Visual-reinforcer color, and operant behavior in Siamese Fighting Fish. *Journal of the Experimental Analysis of Behavior*, 1965, 8, 341-344.

Received 18 October 1972.
(Final Acceptance 18 June 1973.)