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A bite manipulandum for the development of operant behavior in predacious fishes

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An inexpensive bite manipulandum is described for use in operant conditioning studies with predacious fishes such as the largemouth bass. Compression of a rubber nipple by a fish bite is transduced by a mounted phonograph speaker. The use of the fish's natural foods as reinforcers in conjunction with this device makes it possible to obtain schedule-of-reinforcement data not previously obtainable with this species. Sample interval and ratio data are provided.

In operant conditioning studies involving fish, the subject is often required to press either a flat paddle (Haralson & Bitterman, 1950) or a food cup manipulandum (Holmes & Bitterman, 1969). Displacement is detected by a microswitch, a phonograph cartridge, or a photoelectric system (Wolach & Roccaforte, 1976). None of the published manipulanda have proved to be particularly suitable for our experiments on visual discrimination learning in the largemouth bass, *Micropterus salmoides*. Our fish are captured from local ponds and streams, and they do not readily accept food pellets or the prepared liquid food that is usually used with the food cup manipulandum (Holmes & Bitterman, 1969). Wild bass are more responsive to natural reinforcers such as live worms, minnows, and crayfish.

In the past, we used nightcrawler worms and a paddlepress response. Reinforcers were ejected from a hole near the center of the paddle. With bass, the paddlepress response is adequate for some studies, but it does not allow a great deal of flexibility of experimental design. For example, it is difficult to train a bass to press a paddle consistently on any schedule other than continuous reinforcement (CRF). Part of the difficulty in training the bass to paddlepress on schedules other than CRF is probably due to the tendency of this aggressive species to collide with the paddle with much more force than is necessary to register a response. This may be related to the predacious nature of the consummatory behavior of the bass, which includes rapid pursuit of prey and forceful striking. During training, a lesion resembling a blister invariably develops on the lower lip, and this appears to affect responding.

We developed the bite manipulandum for bass in order to make it possible to use the natural prey of this species as reinforcers in conjunction with another response, biting, which appears to be more reliable and more amenable to schedule training. In contrast to the hard paddle, the bite manipulandum is a soft bulb that contracts only the biting surfaces of the subject's jaws. It is designed for use with medium-sized fish with biting jaws. The size of the nipple and feeding tube could be adjusted to accommodate the size of the fish.

The bite manipulandum is a reliable alternative to the other response-detection systems used with fish. It has solved many of the problems we encountered in trying to study wild, predacious species using manipulanda designed primarily for hatchery-reared fish. The bite device is similar in concept to an infant sucking-response detector used by developmental psychologists (see e.g., Sameroff, 1968).

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APPARATUS

The manipulandum is diagrammed in Figure 1. A rubber lamb nipple (Stock No. 71, Farnam Company, Omaha, Nebraska 68112) is mounted on clear .25-in. (.64-cm) Plexiglas with silicone cement. Two holes are drilled in the Plexiglas to allow rear access to the nipple chamber. One hole is for a flexible plastic feeding tube (outside diameter approximately .44 in., or 1.1 cm). The other hole accommodates an adaptor for the air tubing (Living World Invisible Minitubing, Stock No. 43338, Metaframe Corporation, Elmwood Park,

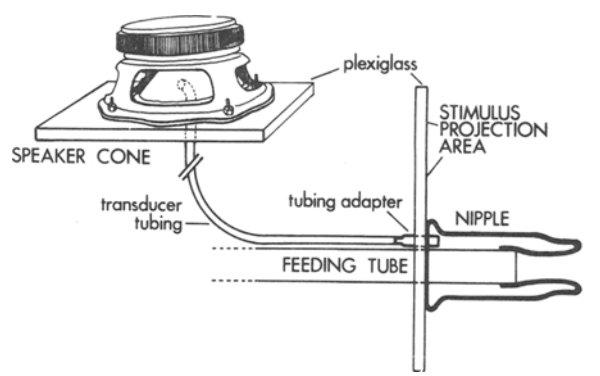

Figure 1. Schematic of the bite manipulandum and speaker transducer.

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New Jersey 07407). The feeding tube and adaptor are bonded to the Plexiglas with epoxy glue and silicone cement. The tip of the nipple is cut off, the cut end is inverted and stretched over the end of the feeding tube, and the area of contact between the nipple and the feeding tube is sealed with silicone cement. Inversion of the nipple tip allows the end of the feeding tube to be recessed within the nipple, so that the tip of the manipulandum is sensitive to compression. There are no "dead spots" on the manipulandum. Silicone cement keeps the nipple in place over the feeding tube and tubing adaptor.

One end of the air tubing fits over the adaptor and the other end is passed through a hole drilled in a .5-in. (1.27-cm) sheet of Plexiglas until the tip of the tubing extends out the other side about 1 cm. The tubing is then bonded in the hole with epoxy glue and silicone cement. An inexpensive 4-in. 8-ohm acoustic suspension speaker (Gemco 410-1) is bolted face down on another sheet of Plexiglas and sealed with Mortite Weatherstrip and Caulking Cord (Stock No. B-2, Mortell Company). (If another speaker is chosen, it should be an acoustic suspension type with a large magnet. The larger the magnet, the higher is the output from the speaker.) When mounted and sealed, the bite manipulandum and the speaker form separate airtight chambers connected by air tubing. Compression of the nipple by a fish bite displaces the speaker membrane so that the speaker acts as a pressure transducer. The speaker has a lower input impedance across its coil than a phonograph cartridge and is, therefore, less susceptible to noise pickup. Response-detection circuitry designed for phonograph cartridge input invariably includes filters for 60-Hz and other noise. The speaker transducer is no more susceptible than a cartridge transducer to any external mechanical vibration except that in the audio range. The audio range sensitivity can be corrected with filters. The speaker can be hung from the ceiling to protect against incidental vibration, although vibration is not a problem at the sensitivity settings used for operant experiments with bass.

The signal from the speaker is processed by a circuit that is basically a solid state version of that reported by Longo and Bitterman (1959). The circuit has several additional control options, including a wider range of inputs and a choice of analog or discrete output. (The circuit diagram and circuit board pattern are available without cost from the authors.) However, many of the features of this general-purpose circuit are not necessary to convert the speaker output into digital form. Experimenters equipped with response-detection circuitry designed for phonograph cartridge input can convert to the bite manipulandum and speaker transducer with minor equipment modifications. The response-detection circuits of Holmes and Bitterman (1969) and Woodard and Bitterman (1974) may be used with a speaker if the speaker output is first fed into the converter circuit shown in Figure 2. In order to properly interface with the converter circuit, the value of the capacitor that

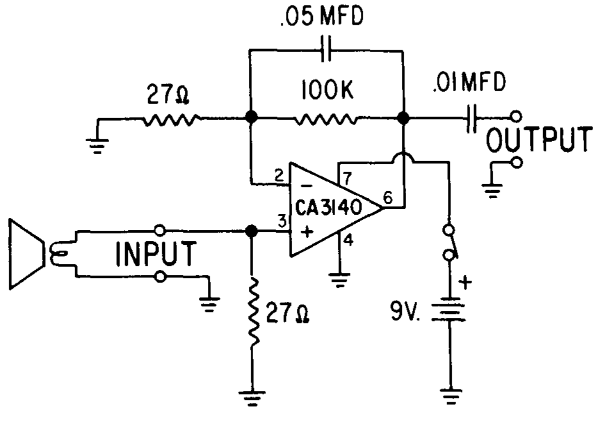

Figure 2. A circuit for converting the Holmes and Bitterman (1969) and the Woodard and Bitterman (1974) response detection circuit to speaker transducer input.

determines the inactive time in the Holmes and Bitterman circuit should be 140 MF. A low-pass filter is provided in the converter circuit design to correct for the sensitivity of the speaker transducer to external mechanical vibration in the audio range.

For discrete-trials procedures, it is convenient to mount the manipulandum on a rod extending from a Plexiglas frame inserted into the subject's home tank during training sessions. A sliding door (raised by pulleys) is also mounted on the frame. The door functions to separate the fish from the manipulandum during the intertrial interval. The reinforcement (a piece of nightcrawler) is delivered from a plastic 60-cc syringe mounted on the frame, through the feeding tube, and into the fish's mouth.

BEHAVIORAL DATA

Two bass were used to determine the usefulness of the bite manipulandum in assessing performance for bass experiencing discrete-trials partial reinforcement training in discrimination learning situations. For one fish, reinforcement was available for the first response that occurred after an elapsed interval of 16 sec. The interval began when the door was opened. Later, the interval was stepped up to 24 sec. The intertrial interval was 60 sec. Twelve trials were given during each session. Figure 3 shows the data for six consecutive daily sessions (three sessions of 16-sec training and three of the 24-sec training). The intervals were divided into quarters for response counting. The quarter-interval response data show a scalloping effect similar to that reported in free-operant FI studies (Rozin, 1965).

A second bass was given daily CRF training and then required to complete five bites (analogous to FR 5) to obtain reinforcement. This required seven sessions. Twelve trials were given during each session, with a maximum trial duration of 60 sec. At this point, the response was brought under stimulus control. The stimulus signaling the availability of rein-

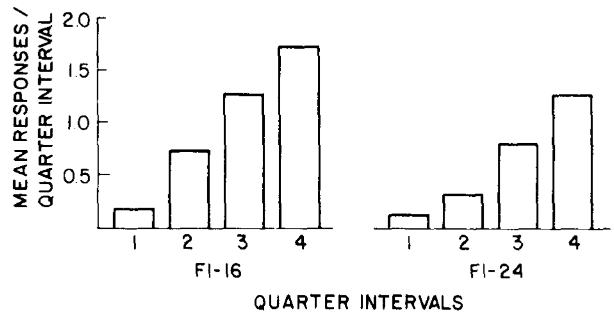

Figure 3. Biting responses of a bass trained on discrete-trials schedules in which reinforcement was available for the first response after intervals of either 16 sec or 24 sec. The data are represented as the mean number of responses per quarter interval per trial. The intervals are divided into quarters on the graph, revealing the scalloping effect characteristic of free-operant FI data. The subject was given three sessions of 12 trials on each schedule.

Table 1
Discrimination Ratios (dr) and Mean Trial Durations (in Seconds) of a Bass Trained to Four Discrete-Trials Schedules of Reinforcement

		Mean Trial Duration	
Schedule	dr	S+	S−
CRF		.89	
FR 5	.66	7.10	48.03
FR 7	.84	9.65	60.00
FR 10	.85	16.75	60.00

Note—Data for each schedule represent the mean of two consecutive sessions. All CRF (FR 1) trials were reinforced.

forcement (S+) was a disk of white light projected on a Plexiglas target just above the nipple. On nonreinforced trials (S−), the projector light was turned off. All trials were terminated after five responses or 60 sec, whichever came first. For discrimination training, the number of trials per session was increased to 24, with 12 being reinforced. Reinforced and nonreinforced trials were presented randomly. Performance efficiency was expressed as a discrimination ratio (dr), computed by dividing S+ responses by the sum of the S+ and S− responses (Table 1). The data were collected while the subject was still in the process of acquiring the discrimination, and it is doubtful that asymptotic drs were obtained. The data for ratios 5, 7, and 10 were taken during Sessions 12 and 13, 14 and 15, and 17 and 18, respectively. The dr of .85 for FR 10 represents a total of 42 responses during 24 S− trials in which 240 such responses were possible. Trial durations are included in Table 1 to give an idea of the time required for a subject to complete each ratio. Opening the sliding door activated the timer, which stopped when the subject made the final response of the ratio. By the end of training, the fish seldom made any responses during S− trials. However, the bass completed the ratio on every S+ trial. Therefore, after sufficient training, the mean S− trial duration became the maximum, 60 sec.

The first few responses on the initial day of training were usually hard, sustained bites with associated head shaking. These initial responses were often quite savage. With the instrument settings used, even these strong, prolonged responses were recorded as a single response. The subject had to release the manipulandum and allow some decompression of the nipple before another response could be registered. The subject quickly learned to make discrete responses without excessive force. The response topography became very stereotyped.

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