TECHNICAL NOTE

MEASUREMENT OF CONSUMMATORY BEHAVIOR
IN THE FISH¹

Ames (1967) has devised a liquid-food dispenser for fish which has several advantages over the pellet and worm dispensers used previously (Longo and Bitterman, 1959, 1963). Not the least of its advantages is that it permits the measurement of consummatory behavior in the fish much as consummatory behavior in the rat is measured with a drinkometer. A technique is reported here for recording each contact of the fish with a small foodcup from which it sucks liquid food. The foodcup response can be used, not only to monitor the intake of food, but also as an operant, providing an analogue in the fish of instrumental licking in the rat (Hulse, 1960). Another rat analogue is the combined lever and food cup described by Bremner and Trowill (1962). As an operant, the foodcup response of the fish is much like the target-striking response long used in this laboratory (Haralson and Bitterman, 1952). The main difference is in the greater spatial-temporal contiguity of response and reinforcement afforded by the new technique, which may account for the fact that the foodcup response is established more quickly and emitted at higher rates.

The apparatus is diagrammed in Fig. 1. A Davis Liquid Pump (model LR-131) dispenses discrete amounts of Tubiflex (the commercially available liquid fish food used by Ames) through a length of No. 20 thin-wall Teflon tubing into a small cup of clear Plexiglas protruding through a $\frac{3}{4}$ -in. circular opening in a shield of $\frac{1}{8}$ -in. black Plexiglas. The foodcup is fixed to one end of a thin metal rod, the other end of which is set into the needle holder of a crystal phonograph cartridge (Astatic 16). Both the cartridge and the shield are mounted on the hinged lid of a black Plexiglas enclosure to which the animal is carried in its individual 2-gal living tank. The Teflon tube enters behind the shield through a small opening in the lid of the enclosure; one end of the tube is slipped over the 20-ga needle of a syringe driven by the pump, and the other end fits into a small hole at the back of the foodcup. The cup may be illuminated with lights of different color by standard Christmas-tree lamps mounted in a box on one end-wall of the enclosure; the light passes through a $\frac{3}{4}$ -in. disk of diffusing Plexiglas set into the end-wall.

As the fish takes the food with which the foodcup is primed, a voltage is generated across the phonograph cartridge. The voltage is amplified and used to drive a

Fig. 1. A scale drawing of the apparatus showing the animal's living tank (A) in the Plexiglas enclosure (E). The shield (S) through which the foodcup (F) protrudes, and the cartridge (C) containing the rod (R) which supports the foodcup, are attached to the hinged lid of the enclosure. The upper-left inset shows a side-view of the cartridge and the Plexiglas wedge (W) on which it is mounted. (The angle of the wedge compensates for the angle of the needle holder.) Any slight movement of the foodcup generates a voltage across the cartridge, and the voltage is converted into a discrete relay closure by the circuit shown in an accompanying figure. (The cartridge is sturdy, and the only necessary limitation on the movement of the rod is provided by the lid.) Discrete quantities of liquid food are pumped into the foodcup through the flexible tubing (T) which runs to it behind the shield from a Davis feeder (not shown). The scale of the drawing may be appreciated from the fact that the height of the box, which contains the lamps (L), is 2.5 in. The enclosure and tank walls are contracted (at B) to save vertical space. The full outside height of the enclosure is 9 in.

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Fig. 2. The amplifying circuit. The (crystal) cartridge is an Astatic 16; the gain control is a 10-meg pot; the bias is a 10 K pot; the fixed resistances are 0.5 w; the capacitors are 50 v dc; the two-pole response relay is Potter & Bromfield KRP 11DG, 24 v dc (its free switch is used to program the consequences of response); the single-pole cutoff relay is Sigma 11F 6000.

relay which records the response and operates the pump to replace the food which has been taken. To convert the output of the cartridge into a discrete relay-closure, the vacuum-tube circuit of Longo and Bitterman (1959) may be used, or the simpler, solid-

state circuit shown in Fig. 2. It should be noted that the new circuit is appropriate to any of the various uses of the crystal cartridge as a response or activity detector (Bitterman, 1966). When the circuit is balanced, each contact with the cup pulses the (P & B) response relay, the duration of the pulse being determined by the size of the capacitor across the coil of the relay. The size of the capacitor across the sensitive (Sigma) cutoff relay, which forms the pulse, determines the maximal rate of response which the circuit will follow. The optimal values of these capacitors will vary with the application. To balance the circuit: (1) turn the gain control down until the transistor base is positive; (2) reduce the bias resistance until the response relay runs free, and then increase the resistance slowly until the response relay stops; (3) turn up the gain control to the required level. A well-regulated power supply is essential.

Very little pretraining is required. The fish first learns to take Tubiflex from a hand-held hypodermic syringe with a length of Teflon tubing slipped over the needle. Then it is carried in its living tank to the Plexiglas

Fig. 3. Satiation curves of a 5-in. goldfish tested in weekly sessions. The tracing at the left is for a session in which each contact with the foodcup yielded 0.006 cc of food. The tracing at the right is for a session in which each response yielded 0.013 cc of food. In each case, the session was terminated when the animal had failed to respond in 5 min. The calibration marks show 16 contacts and 112.5 sec.

Fig. 4. VI-reinforcement of the foodcup response. The tracing at the left is for a 4-in. goldfish after several sessions of training on VI 1-min. The tracing at the right is for the same fish after its performance had stabilized on VI 2-min. Calibration: 18 contacts, 112.5 sec.

Fig. 5. Extinction of the foodcup response after training with continuous reinforcement. Calibration: 16 contacts, 112.5 sec.

enclosure and, with the lid open, fed there in the same manner. Finally, the lid of the enclosure is brought down, the foodcup is primed and illuminated, and the animal is left to find the food. In a relatively short time after initial contact with the foodcup, most animals begin to take food at a steady rate and continue to feed until satiated. Reproduced in Fig. 3 are the satiation curves of a 5-in. goldfish recorded in two sessions separated by an interval of one week. In the first session, each response yielded about 0.006 cc of food, and the animal made 527 responses before reaching the criterion of satiation (no response in 5 min). In the second session, with each response yielding about 0.013 cc of food, the animal made 192 responses to criterion. As is evident in the tracings, the rate of response was greater for the smaller reward.

Although the initial response of the fish to the foodcup is elicited by the food which it contains (untrained animals do not respond to an empty foodcup), the cup alone soon comes to elicit the response, and response to the cup can be sustained by reinforcement with food, either continuous or intermittent. The first portion of Fig. 4 shows the performance of a 4-in. goldfish, trained on a VI 1-min schedule with 0.006 cc of food per reinforcement. The animal subsequently was shifted to a VI 2-min schedule, and after its performance had stabilized again the record shown in the second portion of Fig. 4 was made. If reinforcement is withheld entirely, response to the foodcup gradually disappears, as shown in Fig. 5, which is the record of

another 4-in. goldfish extinguished for the first time after extensive training with continuous reinforcement.

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