*A SIMPLE TECHNIQUE FOR DELIVERING LIQUIDS
DIRECTLY TO THE MOUTH OF AN
UNRESTRAINED RAT¹*

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A simple surgical procedure is described that makes it possible to deliver liquids directly into the mouth of a freely mobile rat. Data presented show that an 8% sucrose solution delivered by this technique is an effective reinforcer in a variety of simple and discriminative schedules of reinforcement.

In studies of positive reinforcement, the usual procedure is to deliver the reinforcer to some more or less arbitrary spot in the experimental environment and require the organism to execute a "magazine response", *i.e.*, go to that spot to get the reinforcement. This procedure is usually quite satisfactory, but there are circumstances in which it would be an advantage to deliver the reinforcement directly to the organism, thus eliminating the need for any magazine response.

Such a capability would, for example, permit experiments designed specifically to evaluate the importance of the magazine response to known phenomena of positively reinforced behavior. For example, Bower and Kaufman (1963) suggested that the magazine response is the element responsible for mediating transfer of training from the classical conditioning paradigm, where stimuli are simply paired with reinforcement or nonreinforcement, to the instrumental paradigm where these stimuli exert strong control over some independently acquired instrumental response (*e.g.*, Bower and Kaufman, 1963; Bower and Grusec, 1964; Trapold and Fairlie, 1965; Trapold, 1966; and Trapold and Winokur, 1967). It has also been suggested (Pliskoff, Wright, and Hawkins, 1965; Gibson, Reid, Sakai, and Porter, 1965) that some of the apparent differences between brain stimulation-reinforced behavior and behavior maintained with conventional appetitive reinforcers may lie in some aspect of the magazine response required by the latter but

absent in the former. If conventional reinforcers could be delivered directly to an organism, such suggestions could be evaluated by directly comparing behavior maintained with a magazine response and that maintained without such responses.

Techniques for delivering liquid reinforcers directly to rats have been described previously, but they have been found to have distinct drawbacks. For example, DeBold, Miller, and Jensen (1965) describe a seemingly simple procedure for putting a chronic fistula into the mouth of the rat. One part of this procedure, however, involves drilling a hole, through which the fistula will pass, down through the nasal bones and the roof of the mouth. It is very difficult, in drilling, to avoid rupturing one or more of the bone sutures; this results in severe hemorrhaging into the nasal passages and the lungs, and consequently in a high incidence of fatal pulmonary congestion.

Deaux and Patten (1966) describe a non-surgical technique for achieving the same end. In this technique, the organism is outfitted, before each experimental session, with a harness-like arrangement that supports a portable drinking tube consisting of a length of metal tubing that curves from above the head outward in front of the face and then back, terminating directly in front of the mouth. The other end of this metal tube is connected to flexible tubing from a liquid dispenser. Thus, the animal is free to move about, with the reinforcer always delivered to a point just in front of its mouth. This technique is deficient in that organisms will not readily accept being fitted with the harness without struggling. In addition, individual differences in head size and shape make it necessary to support the

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metal tube well above the head and to curve it well out in front of the face before it bends back toward the mouth to get the tube in the proper attitude for licking. This loop of metal tube catches on protrusions in the experimental environment and generally interferes severely with freedom of subject movement.

Because of these shortcomings in existing techniques, a better method was sought for delivering liquid reinforcing agents directly into the mouth of the rat. The technique finally developed is essentially a compromise between that of DeBold *et al.* (1965) and of Deaux and Patten (1966). In some respects, it also resembles the technique described by Teitelbaum (1966) for providing rats with a chronic gastric fistula.

Figure 1 shows a drawing of a completed preparation. Essentially, it consists of a long hypodermic needle. The hub is attached to the skull by the screw-and-dental-acrylic technique commonly used to attach brain electrodes to the skull. The needle portion is bent so as to run outside the skin, down the midline of the face, around the side of the nasal opening, and into the mouth between the top incisors.

Fig. 1. Drawing of completed preparation.

The details of the operative procedure are as follows. The animal is first anesthetized according to the procedure described by Rye and Elder (1966). Then the cranial area from the eyes back to the base of the skull and from ear to ear is shaved. A small hole is made with a No. 57 drill between the upper incisors at the gum line. At this point, there is a space between the incisors filled with calcium de-

posits, and care should be taken not to drill into the teeth themselves; the hole should be restricted as much as possible to this space.

A piece of 19-gauge stainless steel hypodermic tubing, about 3-in. long, is then tempered by heating and bent to conform to the individual rat as shown in Fig. 1. A good first approximation to this bend can be achieved as follows: beginning about 5 mm from one end of the straight piece of tubing, a half-circle bend is made by wrapping the tube around half the circumference of a $\frac{1}{16}$ -in. diameter rod. Then, at the ends of this half-circle bend, both the short 5 mm length and the long straight length of tubing that remains beyond the bend are bent in the same direction, perpendicular to the plane of the half-circle bend. The 5-mm length will then go into the hole between the teeth, the half-circle bend will carry the tube around the side of the nose and back to the midline, and the long straight section of tubing will run up the midline and over the top of the head. After this procedure, only minor additional bending is necessary to achieve a snug individualized fit. After the tube has been properly bent, it is removed and saved until later in the operation.

The rat is then placed in a device that will hold the head firmly. A homemade device, similar to the animal holder of a commercial stereotaxic instrument, is used in which the head is held with ear bars and a bite bar. An incision is made along the midline beginning slightly in front of the eyes and extending back to about 1 cm past the occipital bone. The periosteum layer from the occipital bone, to a point 1 cm anterior to the bregma, is scraped back to the lateral ridge and clamped. Four holes are then drilled through the skull, one in each of the four quadrants demarcated by the intersection of the midline and the bregma. These are drilled with a No. 57 drill held in a pin vice so that only about $\frac{1}{8}$ in. of the drill tip is exposed. The exact location of the holes is not crucial. A 0-80 flat-head stainless steel machine screw $\frac{3}{16}$ -in. long is then carefully screwed (self-tapping) into each of the holes until there is a sharp decrease in the force needed to turn the screw, indicating that it is completely through the thickness of the skull.

The bite bar is removed, but the earbars left in, and the previously bent hypodermic

tubing is inserted into the hole between the incisors and repositioned on the face. Approximately at the intersection of the midline and the bregma, in the middle of the four screws, the hypodermic tubing is bent upward perpendicular to the skull and cut off so that the length of the perpendicular section is 6 to 7 mm. The tube is again removed from the rat. A 22-gauge stainless steel hypodermic needle with a standard Luer-Lok hub is then cut to about 2 mm in length, fitted into the end of the 19-gauge tubing, and soldered to provide an air-tight joint.

After the metal tube has been fabricated, any remaining traces of blood and bone dust are removed from the skull and the skull is thoroughly dried. The metal tube assembly is then adjusted to its final position and fixed in place by tying it to the screws with fine de-tempered stainless steel wire. Dental acrylic (Yates Nuset) is then built up around the screws and the tube, going as high as possible on the needle without interfering with the Luer-Lok connection. The wound is then closed with wound clips and the rat given an intramuscular injection of Bicillin (0.30 cc) to prevent infection.

Rats thus fitted have been used in a standard operant conditioning chamber with the food magazine and water cup removed so that the chamber contains only a response lever, a jewel light centered above the lever, and a houselight. Polyethylene tubing is run from the output of a Davis Model LR-130 liquid pump placed outside the chamber level with the chamber floor, over a pulley system mounted above the chamber and down to the rat inside the chamber. Sufficient counterweighting is hung on the polyethylene tubing between the pump and the pulley so that the length that descends to the rat is kept taut above its head but does not impose any noticeable pull on the rat itself. Permanently affixed to the end of the polyethylene tubing is a waterproof swivel joint modeled after that described by Epstein and Teitelbaum (1965) but modified so that its output end is a female Luer-Lok fitting. This fitting is locked directly to the hypodermic needle hub protruding from the rat's head, thus completing a positive leak-proof and twist-proof connection between the liquid pump and the rat. As added assurance against the Luer-Lok connection becoming disengaged during a session, it is useful to

put a small piece of masking tape across the Luer-Lok joint. Using this precaution, a rat has never become disconnected from the liquid pump during a session.

At the time of writing we have worked with approximately 50 rats prepared in this manner. The rats were maintained at 80% of free-feeding body weight by controlled feeding after each daily session. Reinforcement was the delivery of 0.075 ml of 8% sucrose solution. Some rats reacted emotionally when initially exposed to sucrose delivered in this fashion, so they were routinely adapted to the reinforcer for two 100-min sessions during which sucrose was delivered independently of behavior at varying intervals averaging 60 sec (VI 60-sec). During these sessions, the response lever was removed from the chamber. Sucrose delivery was also routinely preceded by a brief (0.3 sec) signal (offset of jewel light), although this may not be necessary to the efficacy of the technique. After this preliminary training, the lever-pressing response was acquired very quickly and without shaping when every response was reinforced (CRF).

To illustrate the efficacy of this technique, Fig. 2 shows representative data from rats rewarded in this manner. Frame I shows cumulative records from two 30-min sessions for Rat #55-SO. Record A is the fourth session on a VI 60-sec reinforcement schedule. After this session the schedule was shifted to VI 30-sec, and record B shows the second session on this schedule. In both cases performance was stable, and as is characteristic with more conventional reinforcers, response rate was higher on the denser schedule of reinforcement (27.5 *vs* 36.0 responses per min).

Frame II shows cumulative records for Rat #113-SO in the first and fifth 50-min sessions on a multiple variable-interval extinction (*mult* VI EXT) schedule in which 2-min presentations of a 2000 cps tone alternated with 3-min presentations of a 20 pps click. In the presence of the tone (S^D) responding was reinforced on VI 30-sec; in the presence of the clicks (S^A) responding was never reinforced. This schedule was instituted after the preliminary training procedure described above and two, 1-hr sessions on simple VI 30-sec. In the first session (record A) performance was generally stable, but negative acceleration during S^A periods developed as the session progressed. By the fifth session (record B) a good discrimi-

Fig. 2. I. Cumulative records from one rat on VI 60-sec (A) and VI 30-sec (B). II. Cumulative records from one rat on *mult* VI 30-sec EXT with 2 min S^D alternating with 3 min S^A. Record A is from the first session and record B is from the fifth session. Changes from one component to the other are not designated. III. Performance of one rat in the fourth session on FI 3-min after an extended history of FI 2-min training. IV. Mean performance of nine rats on *mult* CRF (EXT + DRO) averaged across all rats in blocks of 30 trials. Graph A shows mean latency of response from the beginning of the first component (CRF). Graph B shows mean number of responses in the second component (EXT + DRO).

nation had developed; there was very little responding during S^A (2.6 responses per min), but at the appearance of S^D, responding changed to a moderate and stable rate of about 30 responses per min.

Frame III of Fig. 2 shows performance during the fourth 2-hr session for Rat #62-SO on a 3-min fixed-interval (FI 3-min) schedule following extended FI 2-min training. Performance was similar to that obtained with other reinforcers: response rate was positively accelerated during most intervals, the typical FI "scallop".

Frame IV shows group average latency data from nine rats with an extensive history on *mult* VI EXT that were shifted to a schedule that amounts to *mult* CRF (EXT + DRO). Each "trial" consisted of the onset of the houselight. The first response after light onset was reinforced and terminated the houselight. The intertrial interval was variable with

a nominal average of 60 sec. To this interval was added the condition that light onset would not occur until 20 sec had elapsed without an intertrial response. The response measure was response latency from light onset. Each daily session consisted of 60 trials, and graph A plots the mean across rats of latency for each half-session. Latencies decreased to an asymptote of about 6 sec in a fashion very similar to that of rats performing on exactly the same schedule of food reinforcement (Trapold and Winokur, 1967). Graph B shows mean number of intertrial responses per block of 30 trials. As response latency decreased, response probability in the "intertrial interval" also decreased sharply. The rate at which intertrial responding extinguished was similar to that obtained when conventional food reinforcement is used on this same schedule; the marked decrease in intertrial responding from the first to the second half of each session is

also characteristic of this schedule with other reinforcers.

This preparation has proven to be extremely durable provided certain simple precautions are followed. The first is to make sure the skull is completely clean and dry before applying the dental acrylic. If it is not, infections are likely to develop between the skull and the acrylic that will eventually cause the entire assembly to disengage from the skull. The other precaution is to line the home cages with a mesh fine enough (less than $\frac{1}{4}$ -in.) that the Luer-Lok hub can not get caught in it. Most of the early losses were due to the hub catching on the $\frac{1}{2}$ -in. mesh of our commercial cages, and the assembly pulling off as the rat struggled to free itself. By following these two precautions we have achieved an overall loss rate of about 10% over a 90-day period during which rats perform daily for about 1 hr. Some preparations have remained intact and functioning for over 150 days at the time of writing. It should be noted also, that if a preparation comes off, it is a simple matter to reoperate and install a new one. This has been done in two cases and the reoperated rats were back in service within 48 to 72 hr with at most only transient performance decrements. Some damage is done to the skull when the screws pull out, making it difficult to install new ones. Thus, when reoperating we have used the technique described by Goldstein (1967), rather than the one described above, for securing the assembly to the skull.

A possible source of trouble with this technique is the hole between the top incisors. If this hole were to extend too far into the teeth proper, the end of the metal tube would probably be forced downward and eventually out of the mouth as the incisors continue to grow. This has not happened in any of our preparations, perhaps because an animal has not been used if the separation between the incisors was small enough to raise any questions.

We have never seen any indication that this preparation interferes in any way with normal

eating or drinking. Occasionally, food particles become lodged in the end of the tube in the mouth, but in all cases these have been cleared out easily by forcing a little water through the tube.

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