An apparatus for operant conditioning of *Octopus cyaneus* Gray

R. S. HALES, PAMELA CRANCHER, and M. G. KING
Macquarie University, Sydney, Australia

An arm-out-of-water response was conditioned as an operant in *Octopus cyaneus* Gray. The response was limited to a vertical tube, 2.54 cm i.d. Photoresistive sensors, illuminated with modulated light arranged around the tube above the waterline, detect the presence of an opaque object in the tube. The signal from this response detector is amplified and used to initiate a commercial motor-driven universal feeder according to the reinforcement schedule maintained by the logic control circuit. A sample cumulative record for performance on a CRF schedule is given.

Previously, all data on sensory discrimination in the octupus have been gethered by variations of instrumental techniques (Wells, 1962; Sutherland, Mackintosh, & Mackintosh, 1963). Recently, Walker, Longo, and Bitterman (1970) observed that, while an operant technique had not been perfected, the methods of Nixon (1969) showed promise. The development of an operant response using positive reinforcement is considered valuable, since by this method (1) higher rates of response may be obtained than by instrumental techniques, (2) there are considerable experimental advantages in the automation of data gathering, (3) the equivocal effects of punishment are avoided, and (4) a smaller experimental space is needed for each animal. An attempt by Dews (1959) to operantly condition a response of pulling a lever horizontally had only limited success; Dews attributed this to the difficulty of getting discrete responses: the animal tended to retain its grip on the lever. Attempts by Crancher, King, Bennett, & Montgomery (in press) to condition horizontal or vertical lever pulls were unsuccessful for the same reason. However, a low base rate (about twice an hour) of putting an arm out of water was noticed in one of the three experimental animals, and it was decided to reinforce this as an operant response. Each animal was housed in a glass tank, 28 cm wide x 61 cm long x 39.5 cm high, which was filled with running sea water to within 4.5 cm of the top. The response was localized to simplify reinforcement and recording by constraining the arm movement to an open-ended transparent Perspex tube, 20.5 cm long with 2.54 cm i.d., which was suspended from the tank lid. In training, a response was recorded when the animal inserted an arm into the tube and raised it about 2 cm above the water level, at which time it was reinforced by having a piece of prawn dropped onto the arm. A response was defined operationally as the interruption of a light beam in the detector. The arm had to be removed from the detector and then reinserted to register the next response. The time that the arm could be maintained above the level of the water appeared to be limited, perhaps by lack of skeletal support, to a maximum of about 5 sec; this ensured a discrete response. Having found that the arm-out-of-water response was a conditionable response, apparatus was designed to automate the technique.

THE APPARATUS

The automatic conditioning apparatus can conveniently be considered as having three distinct functions: (1) the response detector, (2) the amplification of the signal to a suitable logic level, and (3) the logic control circuit which will not be described here.

The Response Detector

The response detector comprised photoresistive sensors, illuminated with modulated light, which detect the presence of any opaque object through the hole in its center.

The mechanical layout is shown in Fig. 1. Three small screws clamp the detector to the outside of the transparent Perspex tube through which the octopus inserts an arm. The detector is clamped to the tube so that the lower edge is just above water level, as shown in Fig. 2. Three holes, spaced 120 deg apart, hold small 24-V indicator lamps, while three other holes house 1.43-cm-diam cadmium sulphide light-dependent resistors mounted directly opposite the indicator lamps. Because of the number and size of the light-dependent resistors, any movement of an octopus arm through

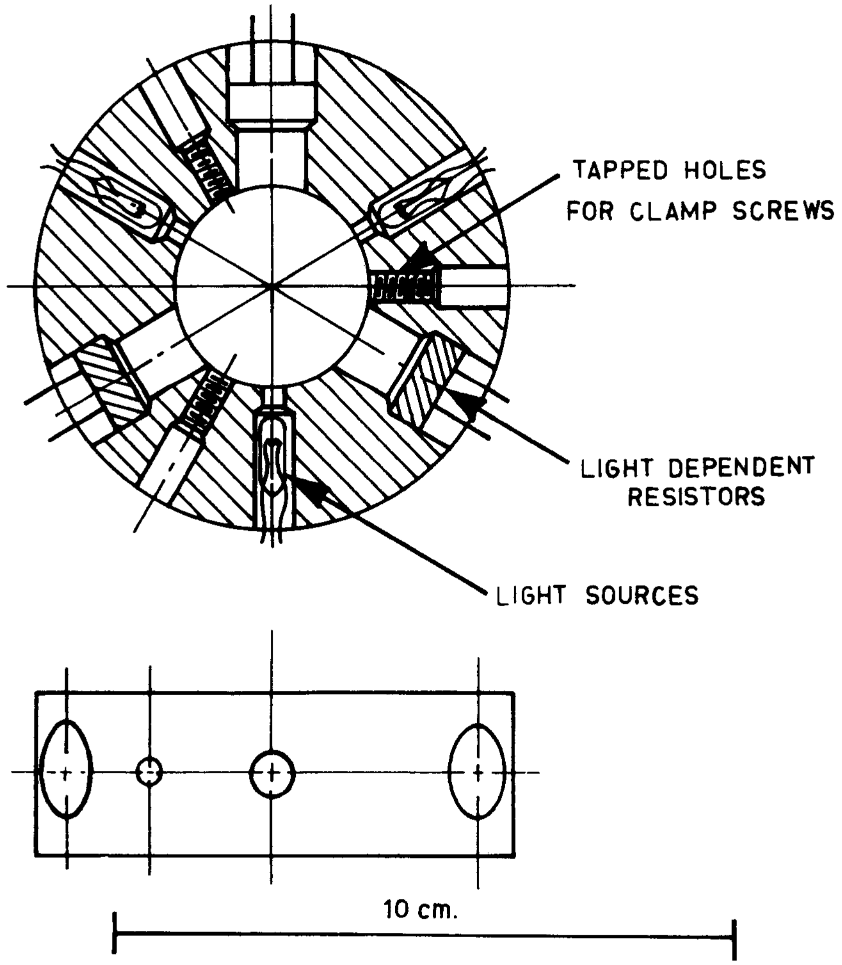

Fig. 1. Plan and elevation of octopus operandum.

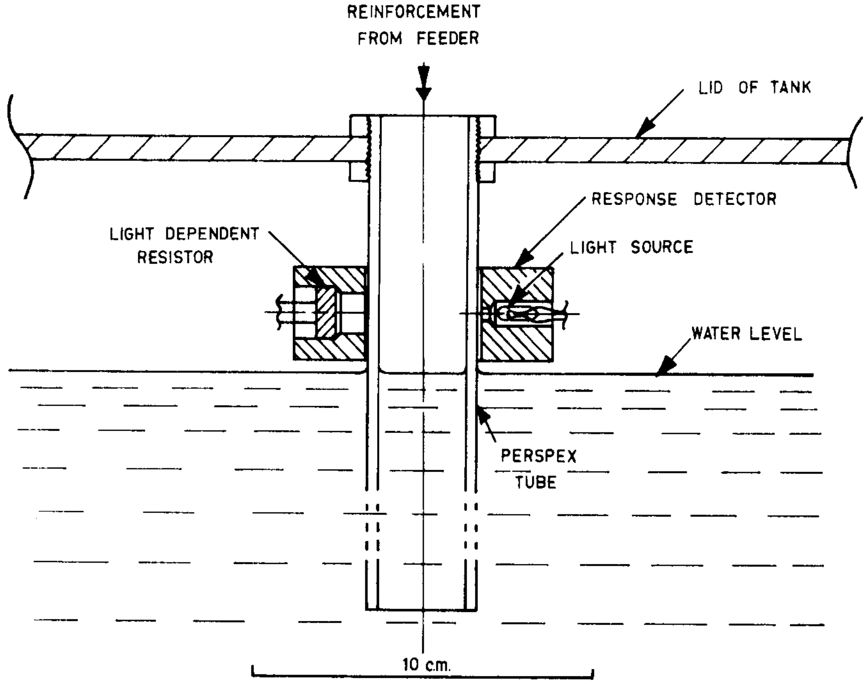

Fig. 2. Side view of experimental situation.

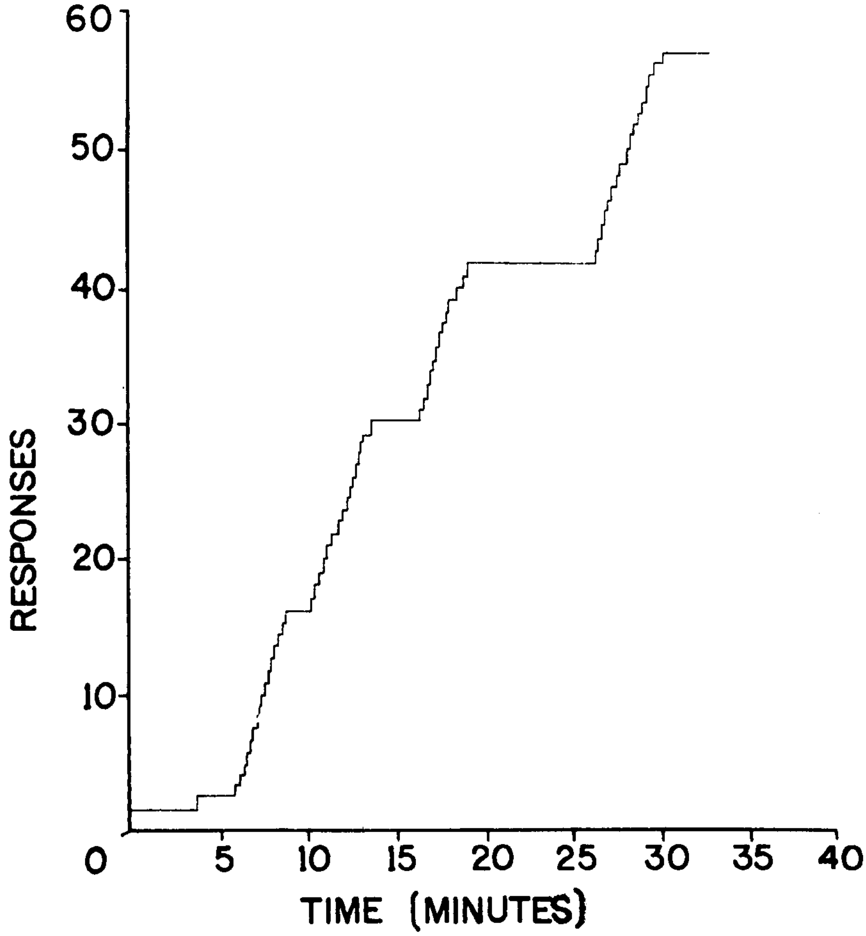

Fig. 3. Cumulative record of performance by an octopus on a CRF schedule.

the detector results in an increase in resistance of at least one light-dependent resistor. These resistors are connected in series so that any shadow falling on the face of one causes an increase in the total resistance, which results in a decreased signal fed to the amplifier circuit.

Amplification of the Signal

The apparatus must be sensitive to small changes in light intensity due to an object in the detector and yet be relatively insensitive to changes in ambient light intensity such as might occur if visual stimuli were presented.

A convenient method of achieving this is to modulate the light source. A 30-Hz multivibrator drives the lamps through a transistor switch which acts also as a constant current limit should the lamps become short circuited. Thus, the lamps are flickering at 30 times/sec. The varying light intensity causes the light-dependent resistors to produce a 30-Hz signal, which is ac coupled to a differential amplifier. The ac coupling eliminates changes due to slow changes in ambient light intensity. Higher frequency changes in intensity, such as those produced by fluorescent lamps, do not affect the circuit since their frequency is faster than the response time of the cadmium sulphide light-dependent resistors.

The output of the differential amplifier is full-wave rectified and averaged and then fed to a level detector which provides a logic output indicating the presence of the octopus arm in the operandum.

A sample cumulative record is shown in Fig. 3. The octopus performed on a CRF schedule reinforced with fresh prawn pieces approximately 7 mm long. Of interest are the plateaux of nonresponse which increase in time over the test period. These occur when the octopus begins to consume prawn pieces which it hoards under its mantle. Free operant performance by *Octopus cyaneus* Gray on a variety of schedules is reported by Crancher et al (in press).

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