CONDITIONING OF A FREE OPERANT IN *OCTOPUS CYANEUS* GRAY¹

PAMELA CRANCHER, M. G. KING,
ADRIENNE BENNETT, AND R. B. MONTGOMERY

MACQUARIE UNIVERSITY, SYDNEY, AUSTRALIA

Operant conditioning was studied in six specimens of *Octopus cyaneus* Gray. An "arm-out-of-water" operant, in which the octopus inserted an arm up a feeding-tube breaking the water surface, proved susceptible to reinforcement schedules. An apparatus was developed that provided automated reinforcement and recording. Performance was studied under continuous reinforcement, fixed-ratio and variable-ratio schedules, and extinction conditions.

Dews (1959) attempted to operantly condition a response of lever movement in three octopii (*Octopus vulgaris*). While the study provided a valuable demonstration that operant conditioning of the behavior was possible, it appeared to be limited to a continuous reinforcement schedule because of the difficulty of getting a discrete response, since the animals tended to retain a grip on the lever.

The present study sought to compare the behavior of *Octopus cyaneus* in a lever-pulling situation with the results of Dews, to condition a free operant in this species, and to determine whether different response patterns could be obtained with different reinforcement schedules.

METHOD

Subjects and Housing

Six *Octopus cyaneus* Gray were each held throughout the experiment in a glass tank 24 by 11.5 by 15 in. (60 by 29 by 39 cm) high and numbered 01 to 06 for identification. Each tank had a tightly fitting, screw-down lid through which a 1 in. (2.5 cm) outside diameter hose provided continuously circulating seawater and a 5 mm outside diameter air hose provided continuous aeration.

The octopii were of medium weight (220 to 400 g) and had been collected by scuba divers in Sydney Harbor and nearby coastal waters. During the experiment, the only food available to the octopus was small pieces of green prawn or raw fish (*Gracilius declivis*) used as the reinforcer. Prawn was cut into five or six pieces, each about 7 mm long and 400 mg in weight. The pieces of fish were cut to approximate the weight of the pieces of prawn.

Apparatus and Procedure

In a pilot study, attempts to condition a vertical or horizontal movement of a lever with *Octopus cyaneus* were unsuccessful and an alternative operant was chosen. The animals had readily learned to take pieces of prawn or fish from an open-ended transparent plastic feeding tube, mounted on the tank lid. The tube entered the water vertically to 6.5 in. (16 cm) above the tank bottom (Figure 1). During lever-training sessions, 01 had been observed to extend the tip of one arm up through the feeding tube to the upper surface of the lid. The base rate for the arm-out-of-water response was about twice per 30-min session. It was therefore decided to reinforce this movement as an operant response. The criterion response was lifting an arm sufficiently far above the upper rim of the feeding tube so as to break the light beam from photoelectric cells directed across the tube above the water level, as shown in Figure 1.

During 4 hr of lever-training sessions, 02 had not made the arm-out-of-water response. Consequently, shaping was undertaken by first touching the tip of the arm with food just be-

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Fig. 1. Apparatus for operant conditioning of *Octopus cyaneus* Gray.

low the surface of the water, then touching the arm, and withdrawing the food a little so that the arm broke the surface of the water. Successively greater movements of the arm above water were reinforced until the criterion was reached. Shaping for 02 required three 1-hr sessions, while animals 03 to 06 learned the response within the first 30-min training session. With the latter animals, some benefit may have accrued from the experimenter's experience with 01 and 02.

CONTINUOUS REINFORCEMENT

FIXED RATIO 2

VARIABLE RATIO 2

Fig. 2. Cumulative records of performance on continuous and intermittent schedules.

Since initial training sessions demonstrated the feasibility of the arm-out-of-water response, the apparatus was automated. When an arm broke the beam of photoelectric cells surrounding the top of the feeding-tube, a DSI Universal Feeder was activated to deliver the reinforcer on a pre-arranged schedule. Responses were automatically recorded on a cumulative recorder. The apparatus is shown in Figure 1 and includes provision for presentation of visual stimuli for discrimination training.

After shaping, sessions lasted 30 min, and were given three times a week, on alternate weekdays.

All animals were first trained with continuous reinforcement. The data shown were collected within one week of beginning training.

All fixed-ratio (FR) data (except for FR 2) were collected from 01. This animal was introduced to ratio schedules after three sessions of continuous reinforcement. Two sessions of each fixed-ratio schedule, from FR 2 to FR 6,

were given in random order. Animals 02 and 03 were introduced to FR 2 after three sessions of continuous reinforcement. One animal, 04, was introduced to a variable-ratio schedule (VR 2) after three sessions of continuous reinforcement.

RESULTS

Cumulative recordings for 30-min sessions of continuous reinforcement are given for all six animals in Figure 2.

It can be seen that continuous reinforcement typically produced a step-like pattern of responding; the pauses in responding usually indicate that the animal had left the feeding-tube. While rate of responding on continuous reinforcement varied among animals (Figure 2), the response rate of each animal was relatively consistent over sessions.

Fixed-ratio responding was investigated in one animal on schedules from FR 2 to FR 5, and appeared to be characterized by lower response rates with increased reinforcement ratios. The rate on a repeated schedule tended to be consistent.

The performances of three animals on FR 2 appear in Figure 2. Performances among animals showed variability, while the performance of 02 on repeated sessions was relatively consistent.

A consistently high rate of responding was produced by VR 2 (Figure 2). The contrast between response rate on FR 2 and VR 2 was marked and, if a reliable finding, is of theoretical interest. However, in view of the variability of performances among octopii these results need to be repeated with many animals.

Extinction following continuous reinforcement was marked by persistent responding. A spontaneous recovery of the response at the beginning of each session did not appear to be a reliable event (Figure 3).

General Observations

In general, the number of hours of deprivation did not appear an important variable; for example, 01 emitted 16 responses per hour on FR 4 after 48 hr and after 96 hr of deprivation. Water temperature appeared to affect the activity level, the animals working best with water temperatures above 20°C. The effect of these variables is currently being investigated in our laboratory, together with

Fig. 3. Three successive extinction sessions with one octopus following continuous reinforcement.

methods of assessment of normal growth rate and of food intake for this species.

DISCUSSION

The arm-out-of-water response conditioned in this study appeared similar to a common operant in the repertoire of the animal. *Octopus cyaneus* locates food by tactile exploration of crevices under rocks (Yarnall, 1969) which may explain the success of the present conditioning method. Lack of skeletal support may have caused the arm to drop back into the tube after about 5 sec, thus overcoming the problem encountered by Dews (1959) of ensuring discrete responses. This response may therefore be conditioned as a free operant.

Dependence of the response on reinforcement was shown by the extinction data. Responding was maintained both by continuous reinforcement and by the intermittent schedules used. Variability in response rate among animals appeared marked.

A "staircase" pattern of responding appeared typical with continuous reinforcement. More data are needed before a statement can

be made on responding with intermittent schedules. It is tentatively suggested that, with small ratio schedules, variable-ratio reinforcement may produce a steeper and more uniform response gradient than fixed-ratio reinforcement.

The need for investigations of variables such as deprivation state and ambient water temperature was noted.

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