Fig. 3. Optical arrangement and stimulus field for experiments on displacement thresholds. L_1 & L_2 , objective lenses; L_3 , field lens; L_4 & L_5 , condensers; L_6 , eye lens; D , diaphragm; S , object (scope face); I , image plane; G , beamsplitter; f , background field stop; A , background pupil stop (conjugate with iris); C , colored glass (color temperature correcting); O , opal glass; B , light bulb; F , neutral filter; E , eye.

The stimulus light can be either a round dot or a line with axis parallel to the direction of motion. The line is obtained by feeding the output of a linear sweep generator into the appropriate deflection plates of the CRT, and using a high repetition rate (1323 sweeps per sec). The line length is varied by altering the peak voltage of the sweep generator.

The (nominal) luminance of the fused stimulus was measured by an SIE photometer, which has the advantage of making matches in a very small illuminated area. The final calibration of the excursion rate during displacement was made directly on the scope display. The external deflection signal to be calibrated was left attached to the vertical input. A sine wave from a calibrated oscillator was fed into the horizontal plates. The frequencies of such signals were properly chosen and the wave amplitude increased to facilitate wave-number counting. A mm scale was

taped on the scope face vertically beside the signal. Photographs were then taken of single operations of the ramp function generator. By counting the number of waves extending over a given distance in mm, the rate of excursion could be computed. Rates so obtained were used to state the rates of excursions of the stimulus.

In order to calibrate the chosen sweep frequency which formed the visual signal appearing as a fused line, an external sinusoidal signal from an oscillator was introduced through the Z-input to modulate the line intensity.

When the frequency of this external signal was set at an integral multiple of the chosen sweep frequency, a standing wave pattern of bright lines and dark interspaces was present.

By measuring the synchronized signal with an electronic counter, the chosen sweep frequency was computed to be 1323 ± 2 cycles per sec. At this frequency the sweep was, for all stimulus lengths, seen as "fused."

The S views the stimulus S through the optical system of Fig. 3 [with its various lenses (L_1 to L_6)] designed to minimize the possibility of extraneous perceived motion. The image of the target I is in the same optical plane as the field stop F , thereby eliminating parallax. This arrangement has the result that a 15 deg circular background of white light (color temperature 5500 deg K) is seen after reflection by the mirror G in the same plane as the CRT trace. Baffles are used to reduce stray light, so that the lens mounts and barrels cannot be seen. The exit pupil of the surround is 12 mm; that of the target is slightly larger. The large exit pupils are used so that small movements of the S 's head do not result in apparent changes in the visible field. A mouthbite locates and supports the head. Positioning adjustments are carried out with a small diameter diaphragm, D , at the objective lens, which decreases the exit pupil and thereby assures centering of the eye.

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NOTES

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Operant behavior in the great horned owl¹

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An apparatus and method successful in producing free operant behavior in a Great Horned Owl are described. Key pecking responses were reinforced with balls of ground beef. Some sample data are shown.

The owl is a potentially interesting S for operant studies of vision and audition, since both of these senses appear to be involved in food-getting behavior under nocturnal conditions. Hecht & Pirenne (1940), Walls (1942), and Dice (1945) have

called attention to the specialized visual system of owls, which seems to be highly developed for sight at low levels of illumination. Quantitative behavioral studies of visual capacities in these birds are practically non-existent, although the literature abounds in anecdotal report and speculation based upon anatomical evidence (Walls, 1942; Polyak, 1957). The auditory system of owls represents another uniquely adapted sensory system. The external ears and aural axes are asymmetrical in most species of owl and thus appear to be particularly well-suited to enhancement of directional cues for auditory localization (Payne, 1961). Payne & Drury (1959) have provided evidence that owls do depend heavily upon auditory cues for prey localization in a totally darkened environment.

Operant techniques provide a promising approach for quantitative behavioral measurements of sensory capacities in lower animals. Among birds, the pigeon has been a popular S for studies of such sensory processes as dark adaptation (Blough, 1958), flicker thresholds (Hendricks, 1966), and auditory thresholds (Heise, 1953). Operant procedures have also been used successfully in several other avian species. To date, however, only a few such studies have involved carnivorous birds. Witoslawski et al (1963) reported a variety of schedules of reinforcement using the black vulture (*Coragyps atratus*), and Whitt & Crawford (1967) observed two species of hawk (*Buteo jamaicensis borealis*, and *Accipiter cooperii*) on a continuous schedule of reinforcement. The present study, concerned with operant behavior in the Great Horned Owl (*Bubo virginianus*), provides a background for studies of stimulus control in this species.

METHOD

Subjects

The principal S was an adult Great Horned Owl (*Bubo virginianus*). This bird, "Igor," acquired at 2 to 3 months of age from a dealer in wild animals, was handled regularly by one of the Es, and was relatively tame. A second adult owl was used in preliminary sessions. He later died of what appeared to be a vitamin deficiency, probably intensified by food deprivation.

The birds were housed in 34 x 29 x 31 in. cages in a laboratory animal room. They were maintained on Ken-L Ration dog food until experimental sessions began. During the experiment, their diet consisted of the ground-beef balls coated in bone meal that served as reinforcements. These meatballs were approximately 3/8 in. in diameter. They also received small, supplementary feedings of dog food. Igor's diet was later supplemented with multiple vitamins, since the meatballs did not contain an adequate vitamin content.²

Before magazine training began, the normal feeding weight of each bird was established. During the course of the initial session, their regular food ration was reduced until they reached a weight level approximately 80% of the free-feeding value. During the remainder of the experiment, they were maintained at an 80-85% value.

Apparatus

A modified refrigerator chassis housed the experimental chamber. Its door contained a 6 x 7 in. one-way mirror and a black curtain to cover it. Inside the chamber, a white, masonite panel, extending from ceiling to screen-wire floor, was mounted vertically on a supporting framework of flex-angle. This panel divided the box into a subject chamber 14 in. wide, 16 in. deep, and 23 in. high, and a second, slightly smaller compartment. The latter held the response key, a white noise source, a buzzer, and a

small light mounted so that it illuminated the key and the food cup. A 6-W house light was mounted on the ceiling of the subject chamber, and a fan provided ventilation.

The manipulandum was a Gerbrands pigeon key with a section of its frame removed. It was placed behind a window 3 in. wide and 2-1/4 in. high in the central panel so that the end of the key (a 1-1/8 in. square section) protruded above the lower edge of the window. The purpose of this arrangement was to allow the owl to view a stimulus field while pecking the response key. In the present study, a portion of the refrigerator's white interior was visible beyond the black key. A relay just below the key operated with each key peck, providing an audible click.

Reinforcements were delivered through a 1-1/4 in. pipe to a small, aluminum food dish fixed to the floor of the subject chamber in the corner to the left of the key. The bottom edge of the pipe was 9-1/2 in. above the food cup, and it extended upward through a hole in the top of the refrigerator. A rotary, reinforcement delivery mechanism was attached to the roof of the refrigerator. This device consisted of a 3/4 in. Plexiglas disc mounted on a circular steel plate and attached to a stepping relay and gear assembly. The disc was 10 in. in diameter and contained 40 equally-spaced holes, each 5/8 in. in diameter along the outside edge of the disc. A slot in the steel plate was lined up with the opening in the top of the refrigerator, allowing the contents of a single hole to fall into the food cup as a pulse to the stepper rotated the disc.

A Gerbrands Cumulative Recorder graphed key-pecking responses. Standard relay circuitry programmed response contingencies. Sounds produced by the relays were not audible within the box.

Procedure

The key-training procedure involved several phases. The first was a period of adaptation to the experimental chamber. During these sessions, food was dropped into the dish, while, at the same

Fig. 1. Cumulative records showing Igor's performance on FR-20 VI-30 sec, and FI-1 min. In each case the record shown is the one obtained on the last day that particular schedule was run. The FI curve shows only a 25 min portion of the session, starting with the first response.

time, the pipe was tapped and moved slightly. Once the bird was eating regularly from the food dish, "magazine training" began. When food was presented, the buzzer sounded, the magazine light came on, and the house light went off. These cues were present from the moment of food delivery until the meatball was consumed by the owl.

When Igor readily approached the food cup at reinforcement, key-pecking was hand-shaped. Then followed six days of continuous reinforcement (CRF). During this period, the circuitry was changed so that first the house light, and then the magazine light remained on continuously. The buzzer thus remained as the only cue to food delivery. (This procedure avoided the complications that changes in the lighting pattern would introduce to future visual experiments.) Also during the CRF phase, the duration of buzzer presentation was reduced to 3 sec.

Each daily session lasted until Igor had received 39 reinforcements. The sessions following the six days of CRF included a series of fixed ratios (FR), a variable interval (VI), and a series of fixed intervals (FI).

Magazine training was successfully achieved in both Ss. The second owl died during the period of key-training. For Igor, the shaping procedure required about 20 reinforcements.

RESULTS

Figure 1 shows cumulative records of Igor's responses on some of the schedules described above. (These records include eating time, approximately 4 sec, since the pen moved continuously during the session.) The records demonstrate clear differential effects of the various reinforcement schedules. Further study, using a larger number of Ss and varying such parameters as deprivation level and amount of reinforcement, would reveal more exactly the nature of schedule-controlled behavior in this species.

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NOTES

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2. Since ordinary ground beef is apt to be deficient in protein it is important to purchase meat containing a relatively low fat content. Forty of these meatballs were not quite enough to maintain the birds at the desired weight level; however, the ground beef and bone meal did constitute the major portion of their diet during the experiment.

A combination stereotaxic drill press and electrode carrier¹

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A method of transforming a vertical rack and pinion-type electrode slide into a miniature drill press is described. Advantages of the instrument are noted and several applications suggested. Specifications are included for the aluminum electrode mold for cat cortical electrode casts.

Drilling through the calvarium with a hand-held dental drill is a variable and time-consuming procedure. Because the handpiece cannot be well supported, a rose burr is usually used. Moreover, holes are drilled undesirably large, with irregular margins and non-vertical walls. Smaller, circular holes, with vertical side-walls offer several advantages.

Commercial units are available (David Kopf; Trent Wells) which circumvent the above-mentioned difficulties. However, these units are not free of disadvantages: they are expensive (approximately \$200), large, and most importantly, they are separate units. Thus, drilling and implanting electrodes requires changing from the drill press to the electrode carrier and a new determination of stereotaxic coordinates. We describe here a drill press-electrode carrier (Fig. 1) with which perfect holes may be drilled and electrodes implanted. Use of the instrument reduces the number of operations necessary to implant any kind of electrode or cannula and simultaneously improves the calibre of these implantations. One application of the instrument utilizing an efficient cast cortical electrode is also given.

Fig. 1. Stereotaxic Drill Press-Electrode Carrier.