INSTRUMENTATION & TECHNIQUES

A system for behavioral evaluation of the visual capacities of cats

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An automated testing apparatus for evaluating the visual capacities of cats is described. It features ease of training, reliability, and flexibility in the type of stimuli that can be presented. For presentation of complex visual stimuli, a closed circuit television display system has been devised that is compatible with the behavioral testing apparatus.

Much of the burgeoning knowledge about the central nervous system is derived from the cat, and, although it is not an ideal model of the primate visual system, it has other very important advantages as an experimental subject. These include availability, moderate cost, reasonable size, tractability, a well-developed brain, and a varied behavioral repertoire.

Several methods for testing the vision of cats have recently been employed with some success (Berkley, 1970; Berkley, Warmath, & Tunkl, 1978; Burns, Spratt, & Webb, 1972; Fox & Blake, 1971; Loop & Berkley, 1972; Mitchell, Giffin, Wilkinson, Anderson, & Smith, 1976). The present paper describes an efficient method for training cats that is more versatile and applicable to testing the visual capacities of cats than previous methods have been (Berkley, 1970).

The training and testing apparatus for use with cats (or other animals of comparable size) described here has several very important advantages over other methods: (1) It is fast; (2) it produces consistent and reliable behavior; and (3) it is completely automated. Automation, while of itself not really important, is important from the point of view of eliminating possible experimenter bias. Thus, the tractability that makes the cat so attractive as a pet and a research subject often can be a dangerous source of error. For example, the manner in which the animals are treated in a situation requiring trial-by-trial handling can influence the outcome of the tests regardless of the honest intentions of the experimenter. Automation eliminates this very important problem.

OVERALL DESCRIPTION

Basically, the apparatus consists of an animal cham-

ber, a response and reward compartment, and a stimulus presentation bench (see Figure 1). The animal chamber has an aperture at one end through which the animal is trained to thrust its head into the response compartment. This compartment, covering the aperture from the outside, is a small Plexiglas chamber that contains the manipulanda, stimulus viewing windows, and a reward terminal.

Both the chamber and the head compartment are enclosed in an outer chamber that contains lights for ambient illumination, a fan for air circulation, and speakers for masking noise or auditory cue delivery. The outer chamber has a window in front of the Plexiglas head compartment that permits the animal to look at display devices located on the display bench. The

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Figure 1. Two views of the overall testing apparatus for use with cats. Details of the response keys, feeder mechanism, and so on, have been omitted for clarity. Lighting for illuminating the background screen is shown; similar lighting may be arrayed inside the outer chamber to maintain a constant level of light adaptation. The display device bench has a distance scale to facilitate the accurate location of the targets. Drawing is approximately to scale. See text for further details.

bench extends from the bottom of the window away from the test chamber for some distance to support the stimulus display devices used. The general arrangement of the apparatus is shown in Figure 1.

A variety of stimulus displays can be set up on the bench, such as a back-projection screen for use with a slide projector, a cathode-ray tube for display of gratings or other targets, an optical bench for the generation of luminance or spectral varying targets (flicker lights, annuli, split fields, spectral targets, etc.), or a TV monitor for the display of figures, complex scenes, or moving targets.

The test program employed with the two-key apparatus programs the position of the correct stimulus, records the correct and incorrect responses, determines when rewards will be delivered, and contains a number of program subroutines that prevent the development and use of undesirable response strategies.

Thus, the program contains subroutines to prevent: (1) position habits (repeated responding to one side regardless of display position of correct stimulus), (2) simultaneous activation of both response keys, (3) responding during the intertrial interval, and (4) responding too soon after the onset of a trial. These response variables are crucial in producing behavior sufficiently stable and reliable for psychophysical tests.

A variety of response parameters may be recorded, including correct-incorrect choices, response latencies, position habits, session time, sequential runs of correct choices, and so on. The program is run on a special-purpose computer, but it is sufficiently simple to be programmed using traditional relay or transistor logic.

Details of the program have been described elsewhere (Berkley, 1970; Berkley & Sprague, in press; Berkley et al., 1978; Bloom & Berkley, 1977; Tunkl & Berkley, 1977).

DETAILS OF COMPONENTS

Some of the details of the system setup are shown in Figure 1. Individual components are drawn approximately to scale. The dimensions of the test chamber are not critical except for the height of the head aperture. The center of this hole should be 8 in. from the floor of the test chamber and should not exceed 4 in. in diameter. A slot may be made at the top (similar to an inverted keyhole) to permit recording or stimulating wires attached to the cat's head to pass through. Convenient dimensions for the test chamber are: 20 in. long x 15 in. high x 10 in. deep. It may be made of plywood or Plexiglas and should have scattered small perforations for ventilation.

As shown in Figure 1, there is a small compartment fastened on the outside of the test chamber over the aperture through which the cat thrusts its head. Details of this head chamber are shown in Figure 2. It is constructed from 3/16-in. Plexiglas and has several important features: (1) It does not exceed 3.75 in. in depth; (2) it contains the reward terminal; (3) both response

Figure 2. Detail plan of the head chamber for use with cats. The configuration shown is for use with a two-choice simultaneous discrimination paradigm, but it may be easily modified for one key for single-response paradigms. Important features are the response key stop, easily removable keys (see Insert A), and interchangeable collars to reduce the caliber of the chamber wall aperture, through which the animal thrusts its head. The dimensions shown are for use with normal size adult cats, 3-6 kg, but the dimensions should be scaled down if cats under 3 kg are to be used. Center of chamber aperture over which head chamber is mounted is 8 in. above the floor for adult cats.

keys are easily removable for cleaning by extraction of the single hinge pin; and (4) there is a sturdy stop limiting the outward excursion of the keys. Without this stop, the cats quickly learn to jam the keys outward and break either the keys or the switches they operate. Other details are less important.

The reward delivery system, for example, determines the precise configuration of the food terminal. A simple tube terminating at the forward bottom edge of the chamber can be used to deliver liquid rewards or food pellets, or a special block can be placed there for delivery of food paste (see Berkley, Crawford, & Oliff, 1971).

One additional component required is a series of Plexiglas annuli (collars) that can be fastened over the test chamber aperture to reduce its caliber (see Figure 2). This is necessary to prevent the animals from placing both head and forepaws in the head compartment and attempting to operate both response keys. Three annuli with apertures of 3.00, 3.50, and 3.75 in. are sufficient with cats from 3 to 6 kg. The annulus plate may be attached to the wall of the test chamber with wing nuts for easy removal.

The test chamber described above is contained in a larger chamber, as shown in Figure 1. This outer chamber provides some sound shielding, but, more impor-

tantly, it isolates the animal from extraneous visual stimuli. When the chamber is properly arranged, the cat sees only the stimulus display when it looks out the front window. The chamber is also a convenient place to locate small audio speakers for masking noise or auditory cues, lights for monitoring levels of light adaptation, ventilation fans, and so on.

STIMULUS DISPLAY SYSTEMS

By making the display system separate from the test apparatus, a high degree of flexibility may be achieved in the types of visual capacities tested. The visual display devices are simply placed on the bench as shown in Figure 1 and are easily moved or changed between animals or experiments. CRT and optical bench visual display system descriptions are available in the literature (e.g., Berkley, 1970; Bloom & Berkley, 1977) and will not be described here. A versatile closed circuit TV (CCTV) display system is described below.

The TV display system consists of two CCTV monitors, one located on the display bench in front of the animal and the other in a separate programming area used for monitoring stimulus conditions. The input to these display monitors is generated via either video cameras or videotape deck and passed through a TV control device (special effects generator, SEG). The SEG is controlled by the programming system in use. The configuration of the entire CCTV system is shown in Figure 3. Both a one-camera and a two-camera system are depicted. When using the two-alternative forced-choice paradigm and the two-camera system, a stimulus pair is drawn (photographed) on a card (e.g., 5 x 7 in. plain office file card) and placed in the stimulus stage, where it is illuminated and viewed by one camera

Table 1
Specifications and Sources for Various Parts of the System

Test Chamber	
Microswitches	No. 11SM23-T, SPDT (available from most electronic supply houses).
Feeder Mechanisms	
Food Paste Dispenser	See Berkley, Crawford, and Oliff (1971) for parts and construction.
Pellet Dispenser	Model D-1 pellet dispenser (190- or 300-mg pellet size), No. G5100, from Ralph Gerbrands Company, 8 Beck Road, Arlington, MA 02174.
Pellets	Cat Food (Formula I), 190- or 300-mg pellets, from P. J. Noyes Company, Inc., Whitfield Road, Box 381, Lancaster, NH 03584.
Liquid Reward Valve	Skinner two-way electric valve, all stainless steel, No. BZDA9052 (125 V ac or 24 V dc), from Skinner Electric Valve Division, Skinner Precision Industries, Inc., 95 Edgewood Avenue, New Britain, CT 06050.
Stimulus Display	
Back-Projection Screen	From either Polacoat, Inc., 9750 Conklin Road, Blue Ash, OH 45242 (Polacoat Lenscreen LS60) or Harkness Screens, Ltd., The Gate Studios, Station Road, Boreham Wood, Herts WD6 1DQ, England (Translite Rear Projection Screen, Natural).
CCTV Display	Cameras: SONY AVC 3260W/view finder, GBC wide-angle lens, fl 5-8.5 mm Videotape: SONY AV3650 TV control: Special Effects Generator, SONY SEG 1A, or Panasonic WJ4600, or SONY VCS-31 Display monitor: Panasonic 5-in. diagonal CCTV monitor WV760 or Shibaden 5-in. diagonal CCTV monitor.

Note—Only those parts critical or unusual are listed. Further details may be obtained by writing to the author.

Figure 3. Block diagram of the closed circuit TV stimulus presentation apparatus for use in a two-alternative forced-choice paradigm. All components are labeled. SEG is the commercial special-effects generator permitting the manipulations listed. Left-right stimulus position change is achieved by either (1) selection of either camera with the two-camera setup, or (2) reversal of the horizontal scan of the display monitors when the single-camera or tape-deck system is used. See text for further details and Table 1 for components list.

through the half-silvered mirror. A second camera also views the card on the stimulus stage but via the reflection from the mirror. The reflected view of the stimulus received by the second camera left-right reverses the stimulus pair drawn on the display card. Both cameras make an input to the SEG, and the program control sends the signal from either the first or second camera to the monitors. Thus, when the first camera is sending its signal to the monitors, the stimulus pair is displayed as drawn; when the input comes from the second camera, the stimulus pair is left-right reversed.

A second scheme permits using one video camera or the videotape deck. In this case, only one camera or the videotape is used. Left-right stimulus reversal is achieved by reversing the polarity of the horizontal scan voltage on the video tube of the display monitor using a two-relay switch. This electronic modification is quite simple and is shown in Figure 4. The two-relay switch is simply operated by applying a voltage to close the left or right relay. The effect of reversing the video scan in the monitors is to left-right reverse the video

Figure 4. Schematic circuit diagram for producing horizontal scan reverse (e.g., left-right position) in TV monitor. Dotted boxes indicate relays. Any convenient, small double-pole, single-throw (normally open) relays may be used and are best mounted on the monitor chassis.

picture. The same system is used when the videotape is used as the stimulus signal source except, of course, that a videotape of the stimulus must be prerecorded.

The advantages of the TV display system are many. Using the SEG, for example, contrast reversal may be achieved via a simple switch closure. Contrast and luminance may also be electronically controlled. The SEG unit also permits splitting the display screen in various ways and displaying targets being scanned by up to four cameras. An important feature of this system is the ability to display complex and/or moving scenes using the videotape deck.

The system has several disadvantages: (1) The frame-rate on a commercially available CCTV system is 60 frames/sec and may be below the fusion frequency for the animal being tested (Loop & Berkley, 1975). (2) Fine-acuity targets cannot be accurately displayed because of the limited resolution of the TV display. (3) Care must be exercised in avoiding electronic tran-

sients that may be used as cues by the animals. (4) When using the scan-reverse display method, the individual stimuli displayed must be left-right symmetrical to avoid a position-asymmetry cue.

The asymmetry problem is particularly apparent when moving targets are used. For example, two different targets shown as rotating clockwise when in the left-right configuration are shown rotating counter-clockwise when displayed in the right-left configuration. This provides the animal with a cue that is confounded with the targets displayed. There are several solutions to this problem, such as the use of vertical movement or the introduction of random changes in motion direction when making the display tape. In the latter solution, both directions of movement will be seen in left-right and right-left configurations and will no longer be available as a cue for the position of the correct stimulus.

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