A TRACKING PROCEDURE FOR DETERMINING THE CAT'S FREQUENCY DISCRIMINATION¹

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A tracking procedure was used to investigate the time required to train cats to discriminate between a frequency-modulated tone and a steady tone. The animal was reinforced with food on a VR schedule only when the steady tone was present and the animal pressed the correct bar (one of two). After reinforcement, the steady tone usually changed to a frequency-modulated signal; by pressing the other bar, the tone could be changed to its steady state and the reinforcement then obtained as before. A major difficulty was the lack of control by the auditory stimulus on the cat's responses. This problem was solved by introducing interpress time outs which forced the animal to hesitate after every press. The use of light cues to signal the time outs and the correct bar to press accelerated the rate at which the training progressed.

With cats, this conditioning procedure apparently requires a much longer training period before the actual threshold determinations than the more commonly used avoidance conditioning procedures. However, when animals are to be tested repeatedly over a period of several months or longer, the procedure may prove the more desirable one because it reduces experimental neurosis.

The cat has often been used as a laboratory animal in auditory studies. In most of the studies in which behavioral thresholds were determined, avoidance conditioning procedures were used successfully. Generally, the animal can be conditioned to respond to the appropriate auditory signal within a few preliminary training sessions, and thresholds can then be determined (Culler, *et al.*, 1935; Elliott, *et al.*, 1960; Schuknecht, 1953). However, a major disadvantage of avoidance conditioning is that "neurotic" behavior develops in the testing situation. If the preliminary training is conducted with care, such behavior can be held to a minimum and will not interfere with the determination of thresholds. On the other hand, in studies in which the animal's threshold is repeatedly determined over a period of months or years, the incidence and severity of "neurotic" behavior increase to such an extent that reliable thresholds often cannot be found. In studies in which threshold determinations are to be repeated, a less traumatizing procedure would clearly be desirable. Obviously, one such procedure

is the use of reward rather than punishment as the reinforcer. Aside from the problem of the trauma, the major considerations here are the time required for preliminary training, and the size and reliability of the auditory thresholds obtainable with such a conditioning procedure.

This is a report of our experiences in the initial training of cats with a procedure described by Blough (1958). It involves the use of operant-conditioning procedures and a feedback loop, in which the animal's responses govern the stimulus and the stimulus, in turn, determines the animal's responses. During this training, the stimulus is controlled in an all-or-nothing fashion. For example, it is either present at a clearly supraliminal level or it is completely absent. So far, this procedure has been used successfully with pigeons and rats (Blough, 1958; Gourevitch, 1960) in determining absolute thresholds in a variety of sensory modalities. In our study, cats were the experimental animals, and the stimuli to be discriminated were a steady tone and a frequency-modulated tone. We expected to have to modify the initial training procedure described by Blough because of differences in species and in the type of threshold to be determined. However, we decided to follow his procedure as closely as practical until modifications clearly were required.

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METHOD

Subjects

The subjects were four mature cats with no previous conditioning experience.

Apparatus

Figure 1 is a schematic of the training apparatus. The training cage, which contained two levers and a food dipper, was constructed of hardware cloth and was as open as possible so it would not interfere with the sound field more than absolutely necessary. This cage and a loudspeaker through which the auditory signals were presented were located in a soundproof room. A low-frequency oscillator (LFO), with an output of 3 cps, was connected through an electronic switch to the frequency-modulation control of a beat-frequency oscillator (BFO). This BFO was set to a frequency of 1000 cps at an intensity 60 db above the normal cat threshold. When the electronic switch was on, the signal from the LFO modulated the frequency of the BFO signal over a 200-cps range so that a "warbling" tone with a 3-per-sec repetition rate was heard. When the electronic switch was off, the 1000-cps tone was steady.

The programmer contained the components necessary for the control of the auditory stimulus and presentation of the reinforcement.

Counters were connected to the programming apparatus for measuring the animal's responses under the various stimulus conditions, and for counting the reinforcements.

Procedure

Briefly, a feedback loop was used in the tracking procedure so that the animal's responses controlled the nature of the stimulus (warble or steady tone), and the stimulus, in turn, controlled the animal's responses. In our study, the animals were trained to press the A-bar when the warble tone was present and the B-bar when the steady tone occurred. When the steady tone was present, the B bar presses were reinforced with food; when the warble tone was present, the A-bar presses were reinforced by a tone change to steady.

MAGAZINE TRAINING AND BAR PRESSING

Before magazine training, we conducted food-preference tests with several foods. We liquified these by blending them with water so they could be presented with the dipper.

canned cat food	kidneys
bonita	veal heart
salmon	condensed milk with
beef liver	an equal
pork liver	amount of water

OPERANT CONDITIONING SYSTEM

Fig. 1. Major components used in the conditioning. See text for details. (The audio frequency oscillator and the circuit by-passing the BFO were not used in the present study.)

The bonita, salmon, and milk were about equally preferred, with all other foods well below. We decided to use the milk because it was much easier to prepare. The milk was an adequate reinforcer for all animals but one; for this one animal, bonita blend proved satisfactory.

To augment the auditory cues of the food-dipper mechanism, a signal light over the dipper was illuminated when the dipper was raised. Under a 23-hour deprivation schedule, the animals readily learned to come and eat whenever the dipper was raised. However, we found that the dipper's normal position should be down, because if it remained up, the cat returned and licked it repeatedly between bar presses.

Training in bar pressing was conducted initially with only one bar present. The usual shaping-up procedures were followed. A 4-sec food presentation interval was found suitable; with longer intervals, the animals sometimes continued bar pressing after the dipper raised. After responses to one bar were well established, the second bar was positioned in the cage and the first removed. Later, both bars were positioned in the cage and presses to either were reinforced with food. Bar positions had to be adjusted so that the cat could not press both bars simultaneously.

DISCRIMINATION TRAINING

To establish differential responses to the warble and steady tones, we presented the

food reinforcement only for a B-bar press in the presence of the steady tone. After presentation of the food, we presented the warble tone, which could be changed to a steady tone by an A-bar press. Thus, A-bar presses were reinforced by the steady tone which acquired reinforcing properties through its association with the food, whereas B-bar presses were reinforced by the food. To insure that the animal was not merely responding alternately to the two bars, the tone remained steady after two-elevenths of the food reinforcements, and the animal did not need to return to the A-bar. With a CRF schedule, discrimination training progressed so rapidly that all animals were placed on variable-ratio schedules (*b*, Fig. 2) after a very few sessions.

RATIO TRAINING AND PUNISHMENT CONTINGENCIES

Initial variable-ratio schedules required 2 to 4 presses on each bar, and we had planned to increase the schedule to a final stage requiring 2 to 6 presses (*c*, Fig. 2). Figure 2 shows that the introduction of the VR schedule caused a temporary decrease in the proportion of the correct B-bar responses because of the animal's tendency to change to the B-bar only after a single A-bar press.

We quickly saw that a major problem would arise in establishing sufficient stimulus control of an animal's responses. Lack of such control was evident from the extensive

Fig. 2. Proportion of correct presses for each bar by a representative animal. Letters at bottom of figure indicate experimental conditions: *a*, CRF schedule on both bars; *b*, VR Schedule (2-4 presses) on both bars; *c*, VR increased (2-6 presses); *d*, interpress TO's (0.5 sec) introduced on A-bar; *e*, interpress TO's introduced for B-bar; *f*, interpress TO's increased to 0.75 sec; *g*, interpress TO's increased to 1.0 sec; *h*, bar lights added; *i*, interpress TO's increased to 1.50 sec; *j*, houselights extinguished during TO's; *k*, bar lights dimmed; *l*, bar lights removed. See text for details.

"overpressing" behavior, *i.e.*, the tendency to continue to press the A-bar after the warble tone changed to steady. After several unsatisfactory attempts to solve this problem, we realized that the reason for this lack of control was interference of the cat's bar-pressing behavior (together with the noise of the bar) with its attending to the auditory stimulus. Although three modifications of the procedure did not correct the overpressing, they did serve to point up the fundamental problem:

- (1) Since the overpresses might indicate that the tone change (warble to steady) was not reinforcing, the time between the tone change and primary food reinforcement was reduced. A CRF schedule was established for the B-bar while the VR schedule was continued for the A-bar. With this change in procedure, the tone change was followed more closely by the food reinforcement. Because this was ineffective, a punishment contingency was introduced.
- (2) The punishment contingency took the form of a return to the start of the sequence after an overpress. For example, an overpress caused the warbling tone to be re-established, and the animal again had to press the A-bar the proper number of times to cause the tone to change and institute the B-bar condition. This procedure also was ineffective, apparently because the rate of responding on the A-bar was often so rapid that the re-establishment of the warble-tone condition appeared to be undetected.
- (3) In order to emphasize the punishment for overpresses, a time out (TO), signaled by extinction of the houselight, was added to the re-establishment of the warble-tone condition. During the 10-sec TO, presses were ineffective. This punishment reduced the number of overpresses, as well as the A-bar response rate. However, the animal's B-bar rate remained high. We realized that threshold testing would suffer, because an animal would be expected to note not only a change of tone from warble to steady but also from steady to warble.

The solution which is obvious in retrospect then became clear. Reducing the bar-pressing

rate would solve the problem of the lack of stimulus control when the animal was inattentive because of its bar-pressing activity. Blough has reported the same problem; he solved it by making any presses on the B-bar ineffective if they followed an A-bar press by less than 0.2 sec. Thus, the animal was forced to hesitate before it switched from the A-bar to the B-bar. Because noise of the bar pressing interfered with the auditory signal in the present situation, we decided that the best solution would be to force the animal to hesitate between each press on each of the bars. Instituting a TO after each press established the delay between presses. As initially established, this contingency merely made presses during the TO ineffective, and the punishment was simply an increase in the number of presses required. Thus, the animal could emit a series of rapid responses, hesitate for the TO period, and again emit another series of rapid responses. Eventually, this behavior would be reinforced. We therefore decided to force the animal to hesitate between *each* press by subtracting from the accumulated correct presses all responses occurring during the TO's. Thus, the animal was forced to hesitate between each response for the length of the TO.³ The animal whose behavior is represented in Fig. 2 and 3 was trained with this final procedure (*d* and *e*, Fig. 2).

The length of the pauses between presses needed for the animal to attend adequately to the auditory signal was not known. We planned to start with TO's of 0.5 sec and increase them gradually to 1.5 sec. Although this was done for several animals, including the one shown in Fig. 2 and 3, training time was great, and many animals exhibited tendencies toward extinction. Figure 2 shows that the level of performance of TO's of 1.5 sec did not materially improve over that exhibited by the animal with 0.75-sec TO's. Thus, the somewhat shorter TO's apparently would serve adequately. Furthermore, Fig. 3 shows that the proportion of response latencies exceeding the time-out interval averaged only about 0.80 for the A-bar responses, even after extensive training. This is also strong argument for using shorter time-out intervals.

One other modification was found helpful. As the VR's increased and the TO intervals

³Because presses during TO's served to delay the reinforcement, this procedure is, in effect, a DRL schedule.

Fig. 3. Proportion of bar presses exceeding the interpress TO's. For experimental conditions indicated by letters at bottom of figure, see Fig. 2.

were lengthened, many animals tended to press the bars indiscriminately and to extinguish if food reinforcement was delayed by inappropriate responses. As a result, changes had to be introduced very gradually. We found that adding a light mounted over each bar as a visual cue increased the rate at which the various stages of training could be introduced and also combated extinction (*i*, Fig. 2 and 3). The A-bar light was illuminated when the warble tone was present; and the B-bar light, when it became steady. However, each light was extinguished during TO intervals. In effect, then, each light was illuminated only when a press would "count." At the final training stage, the lights were dimmed over a period of several sessions and finally removed completely. However, in order to signal the TO's after removal of the bar lights, the houselight was extinguished during TO intervals for both bars (*h*, Fig. 2).

For the cat whose performance is represented in Fig. 2 and 3, the effect of adding the bar lights was negligible since they were introduced quite late in the training. Their removal also had no appreciable effect on the performance. However, the performance of other animals, for which the lights were introduced earlier, improved markedly. One caution should be added. We discovered that if the basic auditory discrimination was not established before the introduction of the bar lights, removal of the lights produced marked interference with the animal's auditory discriminations. Apparently, if the light and auditory cues are introduced at the same time, the lights gain primacy, probably because of their locations near the bars.

DISCUSSION

On the basis of our results, two modifications of the preliminary training (Blough, 1958) appear to be desirable for this type of stimulus discrimination by cats. These are the use of supplementary light cues, both to signal the correct bar and to signal the TO's; and the interpress TO's. The stage of training at which these modifications might most profitably be introduced must be determined empirically. However, in the absence of specific data, since both of these modifications improve the stimulus control of the animal's responses, they probably should be introduced as early as possible, either coincident with or shortly after the initiation of the VR schedules. For the animal whose performance is represented in Fig. 2 and 3, and for the other animals so far trained, the VR schedules were increased to their final values before these modifications were introduced. The training time has been extensive: Fig. 2 represents 114 sessions, for example. Although earlier introduction of the modifications appears to shorten the training time, exactly how much time might be saved is impossible to specify.

Two observations may be made in evaluating how useful this conditioning procedure is for determining auditory thresholds. First, the procedure is clearly not so traumatizing as avoidance conditioning. Second, the time required to train the animal to the point at which thresholds can be determined is much greater than that required with avoidance conditioning. Even if revised procedures reduce the training time, the preliminary training time clearly will greatly exceed that for

avoidance conditioning. However, even with its lengthy training time, this procedure should prove superior to avoidance conditioning in two types of studies. First, as mentioned earlier, in a study in which thresholds are determined *repeatedly*, the lengthy training time might justify itself because of the "neurotic" behavior almost certain to develop with avoidance procedures. Second, as Sidman (1959) has pointed out, this procedure is ideal for delineating sensory and motor deficiencies. For these types of studies, the Blough technique has much to recommend it.

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