SIZE AND RELIABILITY OF FREQUENCY-DIFFERENCE THRESHOLDS DETERMINED WITH OPERANT TRACKING PROCEDURE¹

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Auditory frequency discrimination thresholds have been determined by a "tracking procedure" at five frequencies and two intensity levels for a group of four cats. Intra-animal thresholds were found to be quite stable, and there was good inter-animal agreement among three of the four cats. Although quite stable, the tracking thresholds were larger than those which had been obtained using an avoidance procedure. However, because of the several differences between the tracking procedure and avoidance conditioning procedure, no conclusions can be drawn concerning the efficacy of the different types of reinforcement in determining the ultimate limit of the animals' discrimination ability.

Blough (1958) and Gourevitch (1960), among others, have recently reported the successful use of a tracking procedure for the determination of absolute thresholds for rats and pigeons in a variety of sensory modalities. In a previous paper, preliminary training procedures with such a technique, designed to condition cats so that frequency discrimination thresholds could be determined, were reported (Elliott, Frazier and Riach. In press). The present paper reports on the size and reliability of the difference thresholds so obtained, and compares these thresholds with those obtained using avoidance conditioning procedure.

PROCEDURE

Tracking Procedure

The preliminary training procedure was designed to train the animal to press one bar (A-bar) when a frequency modulated (warbling) pure tone was heard, and to press a second bar (B-bar) when the tone was steady. Correct A-bar presses (in the presence of the warbling tone) were reinforced when the warble tone became steady; after this, correct B-bar presses (in the presence of the steady tone) were reinforced with food. VR reinforcement schedules were used for both responses. After the discriminial responses were satisfactorily established, the procedure was altered so

that discrimination thresholds could be determined.

For obtaining such thresholds, the stimulus control apparatus for the warble tone condition was altered so that each A-bar press resulted in a small decrease in warble size and each B-bar press resulted in a small increase. As in the preliminary training, A-bar presses also caused the warble tone to become steady on a VR schedule. No change was made in the steady tone procedure. With such a procedure, correct A-bar presses, indicating detection of the warble, caused it to decrease in size; B-bar presses in the presence of the warbling tone, however, caused the warble to increase in size. Thus, when the warble tone was present, the animal's responses drove it toward threshold.

When threshold testing was instituted the animals exhibited extremely large fluctuations around threshold, even after many testing sessions. These large fluctuations appeared to result primarily from the tendency of the animal, once the warbling tone was driven below threshold, to ignore the auditory signal. The reason for this behavior appeared to lie in the preliminary training procedure. During preliminary training the tone changed from steady to warble only after food reinforcement. The animal, consequently, was not trained to switch directly from B-bar responses to A-bar responses. To correct this, the preliminary training procedure was re-instituted and modified so that 50% of the time correct B-bar presses resulted in a change of the tone from steady to warble. In this manner the animal was trained to detect changes of the tone from

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steady to warble, as well as changes from warble to steady. After the additional training, the cats exhibited satisfactory threshold behavior.

Thresholds were determined for five frequencies at octave intervals ranging from 250 cps through 4000 cps, and at two Sensation Levels (SLs) for each frequency, *viz.*, 40 db and 60 db, relative to normal cat thresholds of audibility.

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

Avoidance Procedure

The procedure followed in determining discrimination thresholds using avoidance conditioning has been described in detail elsewhere (Elliott, Stein and Harrison, 1959). Briefly, the procedure was this. The animals were conditioned to respond to differences in frequency between tone pulses by moving across the barrier of a double grill cage. Pulses were 400 ms in length with 200 ms separations. At the start of each trial, the standard tone pulses of the particular test frequency were presented continuously. At random time intervals, varying from 30 to 60 sec, comparison tone pulses of a higher frequency were introduced in place of every other one of the standard tone pulses. After eight cycles of the two frequencies, an electric shock accompanied by a buzzer was administered through the floor grid of the double grill cage until the animal crossed the barrier. If the animal crossed the barrier before the eight cycles were completed, no shock was administered and both tones were turned off for a few seconds to signal the trial's end. After the animal responded reliably to the alternating frequencies, difference thresholds were determined with a decreasing method of limits in

which the animal was required to respond correctly to two out of three trials before the frequency of the comparison tone was decreased toward that of the comparison tone. At any one session only a single threshold was determined. Ordinarily such a threshold determination required approximately 30 min.

RESULTS

The warbling tone was always set well above the animal's threshold at the start of each testing session. A sample of the animal's performance during a testing session is shown in Fig. 1. Once threshold level had been reached, the animal maintained the warble at a fairly constant level.

Fig. 1. Sample record of cat's performance.

Individual thresholds were defined by the midpoints of each ascending and descending series. The median of the thresholds which were obtained during the last 20 min of each 30-min testing session was determined, and this defined an animal's threshold for the testing session. There were five testing sessions for each SL for each frequency, and Table 1 shows the intra-cat range of thresholds for these five sessions. In Fig. 2 and 3 the relative difference thresholds for each of the animals are indicated. Cats 2, 3 and 4 had similar thresholds for all tones except the

Table 1
Range of Weber Fractions for Each Cat (over five sessions).

Freq.	40 db SL Cat					60 db SL Cat				
	1	2	3	4	Mean	1	2	3	4	Mean
250	.03	.04	.04	.02	.03	.04	.03	.02	.01	.02
500	.03	.02	.02	.01	.02	.02	.02	.01	.01	.02
1000	.03	.01	.01	.01	.02	.01	.01	.01	.01	.01
2000	.07	.02	.02	.01	.03	.02	.01	.01	.01	.01
4000	—	.05	.05	.03	.04	.05	.02	.02	.01	.02

Fig. 2. Relative frequency difference thresholds for each animal at each frequency.

4000 cps signal at an SL of 40 db. The thresholds of Cat 1, however, were consistently larger, particularly at the higher frequencies. This animal's threshold of audibility was determined, therefore, after discrimination testing was completed to discover whether it was partially deaf. The thresholds of audibility, however, were found to be normal except for 15 to 20 db losses at 8000, 16,000 and 32,000 cps. Subsequent histological examination of the cochlea revealed no abnormalities.

Fig. 3. Relative frequency difference thresholds for each animal at each frequency.

Figure 4 compares the relative difference thresholds obtained in this study with difference thresholds obtained using an instrumental avoidance procedure (Elliott, Stein and Harrison, 1959). It will be seen that, generally, the avoidance procedure resulted in smaller thresholds. The shape of the curves as a function of frequency, however, are quite similar.

DISCUSSION

With the exception of Cat 1, there was a gratifying degree of agreement among the

thresholds of the different animals, and satisfactory intra-animal reliability. Such good agreement suggests that the tracking procedure could be used to detect relatively small changes in the functioning of the auditory system. Furthermore, such determinations could probably be carried on for long periods of time without the development of the hyperactive "neurotic" behavior that has been found to result from long-continued determinations of auditory functioning with an avoidance procedure.

Fig. 4. Comparison of relative difference thresholds obtained with tracking and with avoidance procedure.

It is clear, however, that the tracking procedure as used in this study, does not result in thresholds as small as those found with the avoidance procedure. There are many possible explanations for this, and it is impossible with the data at hand to determine which are the correct ones. First, it should be noted that with the avoidance conditioning procedure separate tone pulses varying in frequency were used, while in the tracking procedure a continuous frequency-modulated tone was used. These two types of discrimination may certainly account for some of the differences obtained. Second, the reinforcing conditions utilized in the two procedures may not be optimal in either case, and it would be unjustified to suggest that punishment *per se* results in "better" thresholds than does a reward. A parametric study would have to be run before any such conclusions would be justified. Certainly, in the present study with the tracking procedure the animals were not maintained at a high drive level. If, for example, they had been maintained at 90% body weight rather than fed *ad lib* after each testing session their performance might have

improved and the thresholds might have been closer to those obtained using shock. Another difference to be noted is that the tracking procedure requires greater activity on the part of the animal than does avoidance conditioning (in which the animal sits quietly between trials). The bar pressing activity, together with the noise associated with the bar, could conceivably interfere with the animal's ability to attend to the stimulus, at least when the stimulus was relatively weak. However, in the present study, the tones were well above threshold, and such an interpretation may not be valid.

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