AUDIBILITY THRESHOLDS OF THE BLUE JAY

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ABSTRACT.—The audibility thresholds of two Blue Jays were measured behaviorally using operant conditioning and psychophysical techniques. The jays responded to pure tones between 0.25 and 10 kHz. Their thresholds are similar to those reported for seven other passerines. This indicates that passerines are somewhat less sensitive than man in the detection of sounds in the 1 to 4 kHz range and considerably less sensitive than man to sounds above and below this range.
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THE field study of avian vocal behavior usually involves arbitrary decisions about the audibility of a call to the birds being studied. The present study grew out of the suspicion that Blue Jays (*Cyanocitta cristata*) were not hearing calls that were audible to the observer. Is man more acute than birds at detecting a bird's call? In order to compare avian and human auditory sensitivity, the pure tone hearing thresholds of each must be known. We adopted standard operant conditioning and psychophysical procedures to measure the Blue Jay's hearing. The standard function for humans was published by Sivian and White in 1933, and audibility thresholds for several other bird species have been reported (Trainer 1946, Schwartzkopff 1949, Dooling et al. 1971, Dooling and Saunders 1975, Heinz et al. 1975, Sinnott 1975).

METHODS

Two hand-reared Blue Jays approximately 1 yr old were the subjects in this study. (Two other jays died before testing was completed; data from these jays were discarded.) The birds were maintained at 80% of their *ad libitum* body weight throughout the experiment on a diet of Gaines Kibbled Dog Food (General Foods Corp., White Plains, N.Y.), Tasty Dinner with Fruit (8 in 1 Pet Products, Inc., Brentwood, N.Y.), and sunflower seeds. Each bird was housed in a small wire cage, 35 cm on each side.

The experimental cage (Fig. 1), constructed of 0.5 in hardware cloth, also measured 35 cm on each side. A food trough was mounted at perch level in one corner of this cage and a water dispenser mounted diagonally opposite. A 2.5 cm long brass bar which was 0.2 cm thick and 0.75 cm wide projected into the cage such that when the bird was perched in front of the food trough the bar was just in front of and level with the bird's bill. This bar could be rotated around its long axis approximately 20 degrees in either direction. When fully rotated, it activated a microswitch.

Mounted on the wall of the experimental cage and in front of the bar was a Permoflux PDR-600 earphone. Its frequency response curve is determined between 0.25 and 20 kHz. The earphone was positioned so that the bird's right ear was directly in front of the earphone when the bird grasped the bar in its bill. To ensure that this position was maintained while the bird was twisting the bar, a piece of hardware cloth was placed on the side of the bird's head opposite the earphone to keep the bird from moving its head more than 2.5 cm from the earphone (Fig. 1).

The experimental cage was hung on one wall of a double-walled audiometric chamber (Industrial Acoustic Corp. Series 1200, Model No. 60). One 5 W bulb illuminated the feeding trough and another the bar. Together they provided enough light to monitor the bird's activity on closed circuit television.

Behavioral training.—The general procedures and techniques for auditory testing of animals used in this study are described in greater detail by Moody, et al. (1976) and Stebbins (1970). The specific procedures used for the jays were as follows. Early in training, a bird was placed in the experimental cage and reinforced whenever it pecked the brass bar. The reinforcement was a small piece of its regular food weighing between 0.025 and 0.050 g. Later in training, reinforcement was given only for twisting the bar far enough to close the attached microswitch. A reinforcement was always preceded by a 2 kHz

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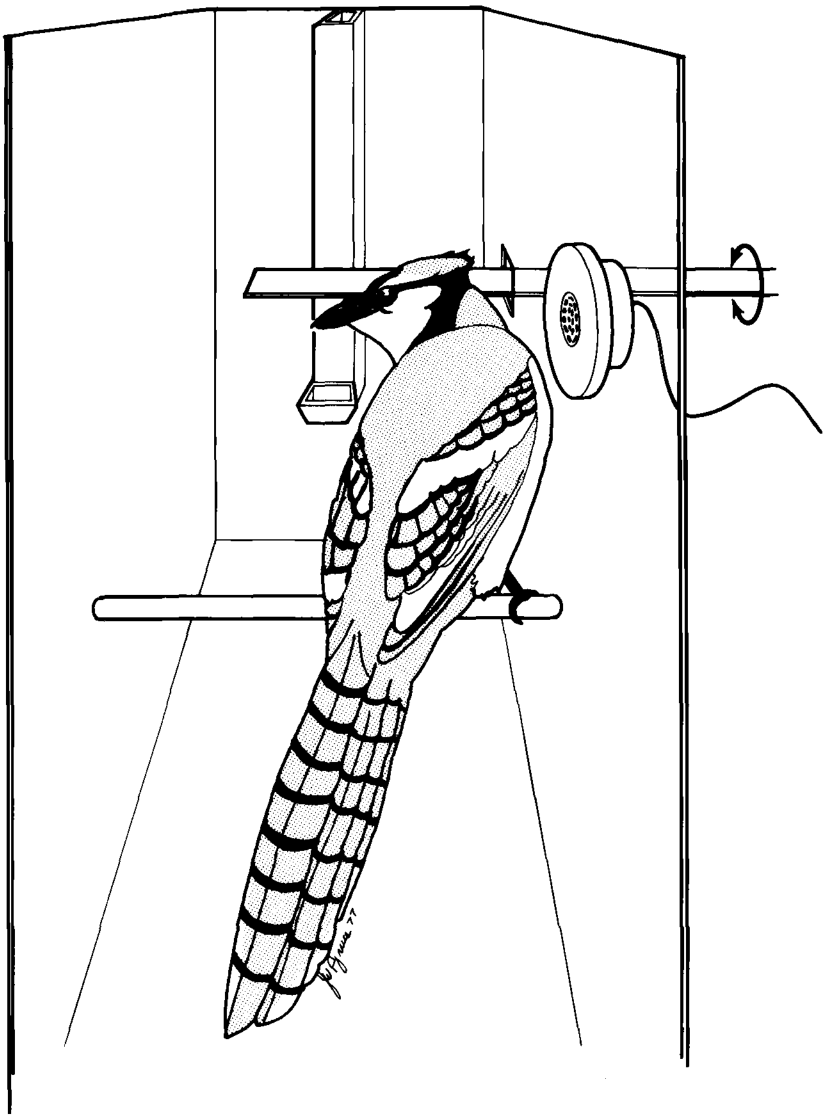

Fig. 1. The experimental cage. When the jay perched in front of the food trough, the bar was level with its bill. When the jay twisted the bar its right ear was in front of the earphone.

tone of 75 dB SPL and 0.3 s duration. Eventually, the bird was reinforced only if (1) it twisted the bar and held it in that position until tone onset, and (2) it released the bar while the tone was on. Tone onset was programed to occur at random between 0.5 and 2.5 s after the bird began twisting the bar.

Release of the bar before tone onset triggered a 5-s lights-off period or "time-out." The time-out functioned as a mild form of punishment in that it delayed the opportunity for reinforcement until the lights came back on. Late release of the bar after the tone ended was also followed by a time-out period. Only when the bar was released while the tone was sounding would the feeding mechanism be activated. On some days a bird would earn as much as 2 g of food in one session of training or testing (approximately 75 reinforcements). The rest of its daily ration of 6 g per day was provided in its holding cage 30–90 min after the session ended.

To determine whether the bird's behavior was under the control of the auditory stimulus rather than some other cue, a catch-trial contingency was introduced. On approximately one-third of all trials ran-

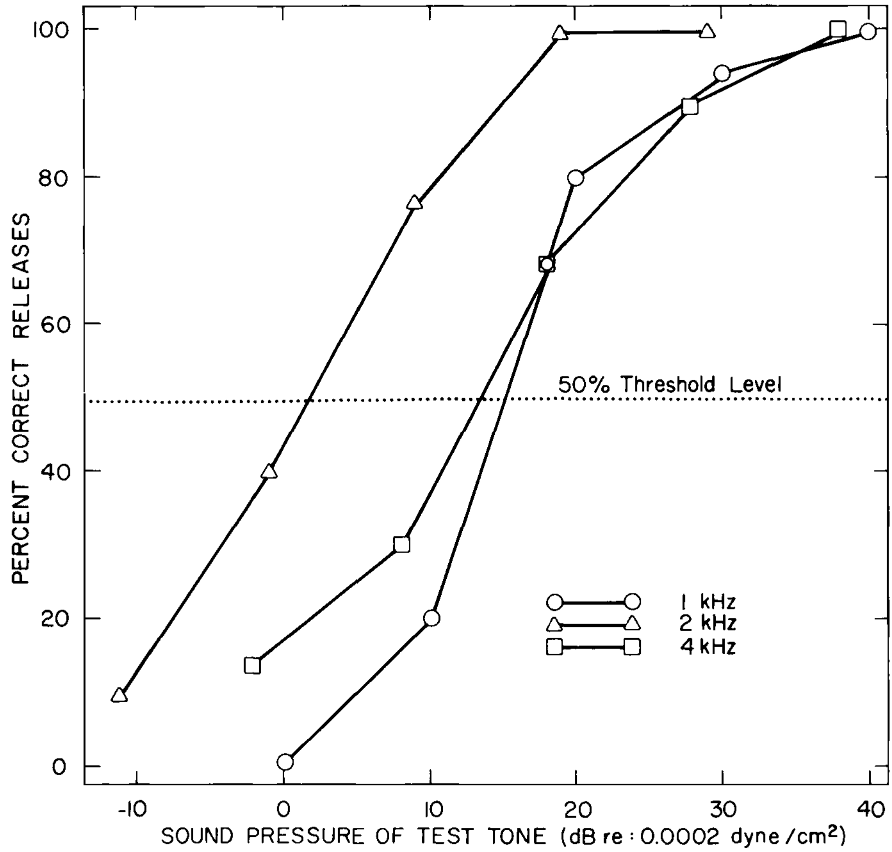

Fig. 2. Three psychometric functions of bird "Y's" behavior during testing at 1, 2, and 4 kHz. The hearing threshold at each frequency is read directly from the graph at 50% level of correct releases.

domly determined, tone onset was delayed for 0.3, 0.6, or 0.9 s. If the bird released the bar during this delay, a time-out period followed. This incorrect or premature release was, however, tallied as a "correct guess" since were it not for the delay in tone onset, the bird would have released the bar while the tone was sounding. Only when the catch-trial rate of "correct guesses" was below 10% was threshold testing begun, for at this level the bird was judged unable to anticipate the onset of the tone, or use any other cue but the tone to gain the food reward. If the catch-trial rate was greater than 10% during any one testing session, the data from the session were judged unreliable and discarded.

Threshold determination.—The auditory threshold at any given frequency is defined as that sound pressure level to which a response occurs 50% of the time. One of the standard procedures for determining auditory thresholds is the Method of Constant Stimuli (Stebbins 1970: 4–5). First, a rough estimate was made of the bird's threshold at a given frequency by decreasing the tone intensity until the bird failed to respond. Next, 5 intensities of the tone each 10 dB apart and which bracketed that threshold (3 above, 2 below) were presented randomly to the subject (15–20 presentations per intensity level). The subject's frequency of response to each stimulus intensity is calculated and the results are graphed (Fig. 2 presents some typical functions). From the resulting graph, the stimulus intensity at which the response frequency is 50% is read and this point defines the threshold. It should be noted that only two intensities, the one above and the one below the threshold, are actually used in determining the subject's hearing threshold. The presentation of the higher intensities ensures that most of the trials elicit responses from the subject, thus avoiding an unduly difficult discrimination and the possibility of extinguishing the response during the testing session.

Measurement of the sound field.—A calibrated 0.5 in condenser microphone (Bruel and Kjaer Model 4134) connected to a recording wave analyzer (General Radio Model 1900A) was placed at the various

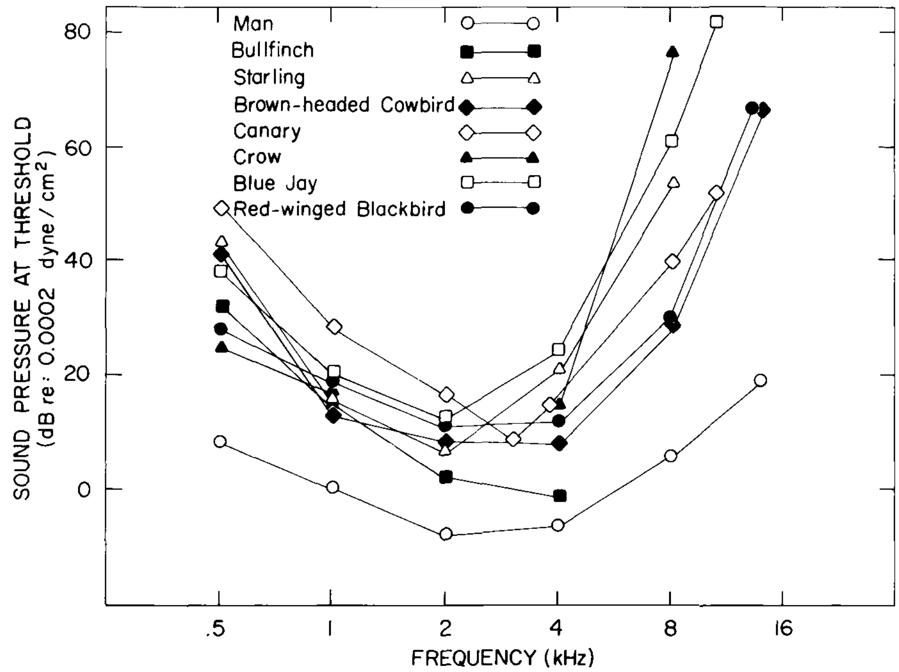

Fig. 3. Audiograms of man (Sivian and White 1933) and seven passerines: Brown-headed Cowbird (Sinnott 1975), Bullfinch (Schwartzkopff 1949), Canary (Dooling et al. 1971), Crow (Trainer 1946), Red-winged Blackbird (Heinz et al. 1975), Starling (Trainer 1946), and Blue Jay (this study).

positions in the area normally occupied by the bird's right ear while the bird was twisting the bar. Sound pressure levels (corrected for a free field) varied within the area by as much as 6 dB, so an average value was used for each calculation.

RESULTS AND DISCUSSION

Each bird's threshold was tested twice at seven different frequencies ranging from 0.25 to 10 kHz (Table 1). The birds did not respond to higher frequencies, and pure tones below 0.25 kHz could not be produced at sufficiently high sound pressure levels with the available equipment. Both jays were most sensitive to 2 kHz tones. One of the jays was consistently more sensitive than the other to all frequencies. Comparable differences between individuals, especially at "best" frequency, have also been reported by Dooling et al. (1971) for Canaries (*Serinus canarius*), Schwartzkopff (1949) for Bullfinches (*Pyrrhula pyrrhula*), and Heinz et al. (1975) for Red-winged Blackbirds (*Agelaius phoeniceus*). The small sample size does not permit statistical confirmation of the hypothesis that Blue Jays have higher audibility thresholds in their midrange than man. Nevertheless, the data do add to the body of evidence that passerine birds, in general, have higher thresholds than man (Fig. 3). Dooling et al. (1971: 705) have pointed out the considerable similarity in the audiograms of three different passerine species—the Canary, Starling (*Sturnus vulgaris*), and Bullfinch. Sinnott (1975) reports similar overlap in the Red-winged Blackbird and Brown-headed Cowbird (*Molothrus ater*). The curves of the Common Crow (*Corvus brachyrhynchos*) (Trainer 1946) and the Blue Jay are consistent with these observations (Fig. 3). Each of these seven passerine species has a narrow range

TABLE 1. The hearing thresholds of two Blue Jays (dB re 0.0002 dyne/cm^2)

kHz	Bird "Y" 1st Test	Bird "Y" 2nd Test	Bird "G" 1st Test	Bird "G" 2nd Test	Average value for both jays
0.25	37	45	46	44	43
0.50	29	41	45	37	38
1.0	15	19	26	18	19.5
2.0	2	4	24	16	11.5
4.0	13	29	28	24	23.5
8.0	56	58	66	64	61
10.0	79	83	86	82	82.5

of maximum sensitivity to sound between 1 and 4 kHz; the thresholds of individual birds in each species overlap within this region and there is a sharp decline in sensitivity to higher frequencies. The major point to be noted from Fig. 3 is that the average passerine hearing threshold within the range of their maximum sensitivity is approximately 18 dB higher than man's. Also, the range of their maximum sensitivity is much narrower than man's.

The implication of these differences in midrange hearing thresholds is that man can hear a bird's call considerably farther than a passerine can. Theoretically, because sound attenuates 6 dB for every doubling of the distance it travels, a man might hear a passerine's call up to eight times farther than the passerine itself. Practically, the situation is much more complex. There may be some overlap in audibility thresholds of some men and passerines because differences of 10 dB in man occur between "normal" individuals (Newby 1968). Furthermore, since sound energy is attenuated by the ground, vegetation, and the wind in ways that are not easily generalized (Aylor 1972, Lyon 1973), there may be differences in the magnitude of the sound energy reaching the ear of a bird perched high in a tree and that of a man standing below it. Nevertheless, assuming that an average observer and bird are approximately the same distance away from another bird, and that the attenuation effects of the ground, vegetation, and wind are about the same for both, and that the background noise level is not high enough to mask the signal for both, then calls that are characterized by the human observer as being "faint" or "very far off" are probably inaudible to the passerine bird above him.

Obviously, the differences in the hearing thresholds of men and birds are the results of different selective pressures operating on the individuals of each species (Morton 1975). The field biologist must not overlook these differences when making observations that might be affected by them.

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A **computer program that analyzes bird banding and recovery data** has been developed to compute great circle distances and compass directions from one point to another on the earth's surface. The input data are the latitudes and longitudes of the points, according to the U.S. Fish and Wildlife Service and Canadian Wildlife Service data format. For any grouping of such distance and direction data, the program also computes the mean distance and direction, the latter by the method appropriate for circular data. Measures of dispersion are also given, as is a statistical test (the Rayleigh test) for a "preferred" mean direction, and other quantities useful for other statistical analyses. Geographic locations between 19° and 59° north latitude and between 52° and 125° west longitude may be printed on a rectangular coordinate system 8.0 × 12.1 in (20.3 × 30.7 cm) in size, with an indication of the frequency of data at each plotted point. This coordinate system is such that a transparent overlay of a U.S. Army map of this portion of North America may then be placed atop the computer printout. A detailed description of the program is available at no charge from its developers: **Jerrold H. Zar and William E. Southern, Department of Biological Sciences, Northern Illinois University, DeKalb, IL 60115.** Copies of the source program and/or deck (in FORTRAN IV) may be obtained, at cost, from the department of Computing Services, Northern Illinois University.

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