AUDITORY RESPONSES OF STARLINGS, ENGLISH SPARROWS, AND DOMESTIC PIGEONS[1]

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A NATURAL corollary to our studies of pitches of bird voices at the Laboratory of Ornithology at Cornell University is a study of the range of bird's hearing. A few first experiments have been made and while they are far too few to warrant making deductions, still they seem to point to certain little suspected tendencies. Hence this preliminary report.

The methods used in these experiments are similar to those used by Pavlov in his classical animal experiments. We are indebted to numerous persons for aid and suggestions. Dr. H. S. Liddell, Professor of Physiology at Cornell University, advised with us and was most generous with his knowledge and experience in similar experiments. Dr. Arthur A. Allen helped us in numerous ways, with advice and with occasional observations. Dr. Elsa G. Allen helped with the observations, as did Eugene Gerberg; and Kenneth Bennett built and serviced the electrical equipment under the direction of the junior author.

Our first test was made on four captive Starlings (*Sturnus vulgaris*) and it showed that while they are sensitive to about the same high frequencies as man, their range of sensitivity is not nearly so extensive, and that their response to sounds falls off rapidly for frequencies below 1,200 cycles per second (c.p.s.); no response at all being observed to sounds of 650 c.p.s. or lower. Hence, while man has a range of sensitivity of some nine octaves, Starlings appear to have a range of less than five; and this loss is in the lower or middle range at frequencies where man's ear functions acutely.

The exact range of human hearing is rather indefinite; various investigators estimate it differently. However, the authors, both persons with normal hearing, find that at about 16,000 c.p.s. on the high side, and around 20 c.p.s. on the low, the sensation of hearing disappears. These figures can be used as good approximations. Six hundred c.p.s., where the Starlings apparently do not hear, is in the second octave above middle C on the piano, and about the center of the most used human notes. The lowest note on the piano keyboard is 27 c.p.s.; the highest, at the extreme right, is 4138; and the tone called "middle C," which in musical notation is placed on the line between the bass and treble staffs, has a frequency of 259. This is the C at the approximate center of the piano keyboard. To comprehend how insensitive Starlings are to tones that man hears well, we have but to observe that these birds do not hear middle C nor the C an octave above it. Only the four highest octaves on the piano are audible to them; but they are also

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sensitive, as will be elucidated in the following discussion, to about two octaves above the piano range.

The birds were kept in a large two-compartment cage. The larger compartment was outdoors; the smaller was roofed over; the compartments were adjoining; and the birds had free egress and entrance. The observer sat concealed behind the smaller compartment. The birds could feed only on a tray in the smaller compartment. This tray was kept plenteously supplied and was so wired that the observer could, at will, cause a slight electric shock to penetrate the birds' feet. A loud speaker was set up in the inner compartment, wired to an oscillator and amplifier. In this manner pure tones of any desired frequency could be emitted.

When the birds were on the tray a predetermined frequency was given forth by the speaker; a few seconds thereafter the electric shock button was pressed. Unless the birds left the tray before the electric shock they naturally received its full force. In making the early tests, while training the birds to respond, the oscillator was set for a sound of 2,000 c.p.s., a frequency which they heard well. Seven days after beginning these tests the first response was noted. In order not to make the birds too tray-shy at this period, the tests were made but once daily. The birds soon became conditioned to the sound and would leave the tray the instant it appeared. After six more days it was possible to raise the predetermined frequency, though care was used not to do so in any regular sequence. This was done so that the birds should not become conditioned to any particular note.

The birds were allowed to feed only when an observer was present, for the tray was covered and inaccessible for feeding at all other times. This insured the observer action when he was present. However, there seemed to be a constant struggle going on in the birds themselves after they once learned that the tray carried a pain-giving shock, and only excessive hunger could tempt them to the tray. In the Starling experiment one bird rarely came to the tray and fed mainly on food which the other birds, in their eagerness to get food, dropped from the tray. This bird finally died of starvation; seemingly the fear of the tray being so great that rather than submit to this terror the bird allowed itself to starve. In the later experiment with English Sparrows we also lost one bird in this manner.

It was found that between 14,000 and 15,000 the Starlings' responses were less acute. They would cock their heads and listen for a second before leaving the tray. Above 15,000 they made no response, whatever. At 15,500 they would go on eating contentedly. Further tests were made up to about 20,000 c.p.s. with negative results. Apparently these four Starlings did not hear above 15,000.

After determining the high point, the sounds from the loud speaker and oscillator were gradually brought down. At 1,000 c.p.s. response was good, but below that point it diminished rapidly, though there was

some response down to 700. Below that figure there was no response whatever. The birds would come into the compartment while the speaker was on, obviously not hearing it, for by this time they were extremely nervous and afraid of the tray and even of the compartment in which the tray was located. They would stand on the tray eating, quite oblivious to the speaker, which produced a powerful 600 c.p.s. tone.

As a check on the Starlings' deafness to tones between 600 and 700 c.p.s., a violin was secured. The fundamental of the E string of the violin is 652 c.p.s. However, the harmonics of the E string are quite strong. A 600 c.p.s. pure tone on the oscillator, loud speaker set-up, brought no response; playing the E string on the violin softly brought little or no response; but if it were played loudly the birds left the tray hurriedly in the same manner as they did formerly. This suggests that when the E string on the violin was played vigorously they perceived the harmonics which would be well within their auditory range; but that they do not perceive, at any time, the fundamental tone of the E string.

It is interesting to note that a study of the song of the Starling made from oscillograms taken in nature show no frequencies in the song below 1,100 c.p.s. (Brand, 1935; 1938) 1,100 c.p.s. was found only once; 1,375, the next lowest note in the song, appeared several times. Thus it would seem that the sounds produced by the Starling are in the range where their hearing is very acute.

Our next experiment was with five English Sparrows (*Passer domesticus*). It took these birds about the same time as the Starlings to become conditioned. However, after a week of learning we were able to proceed. The results were similar to those with the Starlings. The range, 11,500 on the high side, 675 on the low, was much less than human range and mammalian range in general, but all sounds responded to were within the range of sounds the bird normally produces.

The third experiment was with Domestic Pigeons (*Columba livia*). Here again, though we found the Pigeons' hearing went an octave or more lower than the other birds, the subjects showed no hearing responses at frequencies easily audible to man. The range of Pigeon hearing was 7,500 on the high end, and they lost all sensitivity below 200. Two hundred c.p.s. is not a low note being about the G below middle C on the piano.

It is much too early to come to any definite conclusions from these very meagre experiments. Many more species must be tested and more data accumulated before anything definite can be said, but the indications are that birds hear over a much more limited range than mammals. Whether this is true of all or most birds is still to be discovered. Further investigation in this field should prove most fruitful.

Summary

Starlings showed a positive range of hearing 700 to 15,000; the English Sparrow range was 675 to 11,500; and the Pigeon, 200 to

7,500 cycles per second. All the birds showed decreasing sensitivity as the extremes were approached. Thus the Pigeons did not seem very sensitive to sounds below 500, though they could hear until 200 was reached, and the Starlings showed decided loss of sensitivity about 12,000, though they continued to hear till 15,000. Comparing the apparent hearing of these three species of birds to human hearing, we find that man hears about four octaves lower than Pigeons and five lower than Starlings and English Sparrows. At the high end of the hearing range, man normally hears at least as high as the two latter species and about an octave higher than Pigeons. The species tested are evidently deaf to tones in the moderate and low range of hearing, tones that man hears extremely well.

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