ACOUSTIC THEORY OF THE PARROT

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The syrinx of the parrot represents a special development for the purpose of sound production, the avian larynx being unfit for vibratory functions because of its long arytenoids. Among other things the syrinx of the parrot is able to produce whistling sounds of a practically sinusoidal nature. On the other hand, it may be used to effect step-like changes in the cross-area of the end of the trachea, where the latter bifurcates to form the two bronchi. In this process the wind-pipe probably is never completely closed: there is merely a cross-area modulation.

The syrinx is a modification of the final, lowest ring of the trachea in which two lateral, oblong openings have been created that are closed by a membrane. The two membranes are made to vibrate by the expelled airstream; they may vibrate freely because the syrinx is situated in one of the several airsacks of the parrot. The action of the syrinx is controlled by three paired muscles, so in total by six muscles.

When the cross-area of the trachea is changed in a step-like way the steps may follow each other at comparatively regular intervals so that a periodic and melodious basic sound is created. Sometimes, however, the steps come at irregular intervals so that we cannot speak of a periodic excitation.

When the parrot excites its syrinx in a step-like way, damped oscillations of its trachea are visible in the oscillogram. The vocal tract of the parrot begins at the opening of its beak, passes through the stiff larynx and ends at the syrinx. Its acoustic behaviour is that of an organ pipe closed at one end, to wit at the position of the syrinx, of which only the length may be adjusted by muscular action between, say six and nine cm. Consequently, the relation between the frequencies of its formants is fixed, the formants of this type of organ pipe being odd multiples of the lowest formant. Oscillograms show that the parrot mainly operates with the first formant of its trachea, the amplitudes of the odd multiples being very low.

As the parrot is able to realise nasal consonants in spite of the fact it has no nasal cavity of any importance we might re-think the problems of nasality.

Probably the parrot produces fricatives and plosives by means of its tongue and larynx.

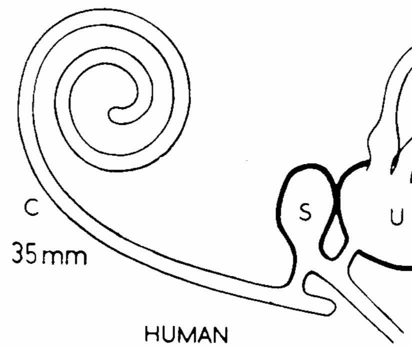


Fig. 1.

In many respects the auditory system of the parrot is less complicated than that of man (see Figure 1). The human ear possesses an auricle, an external meatus, a drum, three ossicles, two muscles, a 35 mm long cochlea with a clear distinction between inner and outer hair cells.

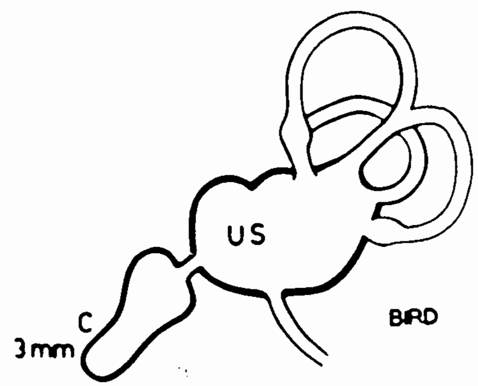
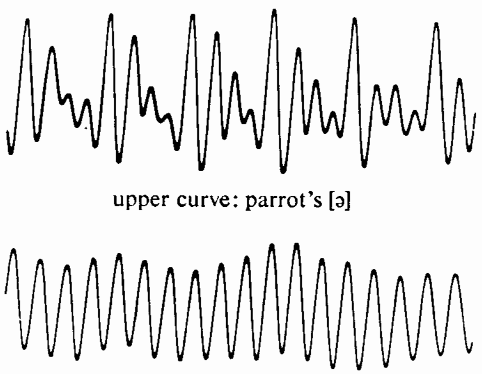


Fig. 2.

The parrot has no auricle, only one ossicle, one muscle, a rudimentary cochlea with a length of a mere 3 mm, missing the distinction between inner and outer hair cells (see Figure 2). Moreover its scala vestibuli is filled with a damping pad instead of, as in man, completely with fluid. Nevertheless the parrot has in some way 'processed' human speech waves and, as a matter of fact so satisfactorily, that it is able to deceive the human listener with the imitated speech sounds it reproduces with its 'apocryphal' vocal apparatus. So we see that the well-developed cochlea of the mammals was not a *conditio sine qua non* for the acquirement of speech by man. We must not, however, rely on our ear in judging the vocal performance of the parrot as it becomes increasingly clear by studying the speech of the parrot by objective means, preferably via the oscillogram. The fact that, in principle, the parrot is a one-formant talker, is revealing. It is still a moot point exactly how the parrot selects

the human formant it is able to imitate. We might even speculate that the bird is not able to separate human $F1$ from human $F2$ which is typical of a mechanism that differentiates a time-function with respect to time and afterwards measures (that is, indicates) zero-crossings.

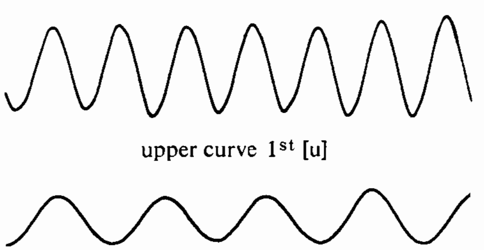


upper curve: parrot's [ə]

lower curve: warbled whistle

Fig. 3.

A typical way for a parrot to reproduce the neutral vowel [ə] is to realise only $F2 = 1500$ Hz as a damped oscillation of its trachea, (see Figure 3).



upper curve 1st [u]

lower curve 2nd [u] of the word [kukuk]

Fig. 4.

In Figure 4 we see how the parrot reproduces the vowels [u] from Dutch *koekoek* ([kukuk]) as two whistled practically sinusoidal waves with different frequencies corresponding to the correct intonation.

One particular parrot we investigated permitted itself to realise in some passages, the human [i] as an one-formant damped oscillation with a very irregular repetition rate so that, during that [i], intonation was absent. During these passages the parrot showed the same irregular basic sound that is so characteristic of human oesophagal speakers whose larynx has been surgically removed. Interestingly enough, this short absence of intonation during some vowels of the parrot escapes our attention: we still have the illusion of continuity, of wholeness.

Also the fact that the parrot is a one-formant speaker escapes our attention, whereas we do not notice either that quite often he simply skips several consonants. Nevertheless, the human listener has the illusion of wholeness. Interestingly enough, in running speech a HUMAN talker also creates illusions of wholeness in the human listener, in spite of the fact that he greatly reduces the contrast between the formants of his vowels, makes assimilations, omits complete sounds etc., etc. As a recent paper by Warren and Warren 1970 shows, a human listener is very easily fooled: even if complete syllables in a tape-recorded sentence are replaced by some buzzing sound, he will not even notice it and still 'hear' the contaminated syllable as an auditory illusion. He will be aware of the buzzing sound but not be able to locate its exact position in the sentence. This supports my vision that all speech recognition by humans comes down to having auditory illusions: the things a human talker permits himself in free running speech are of the same nature as the parrot permits himself when speaking as best as he can.

Probably in his natural habitat the parrot does not imitate other animals. In my opinion the parrot belongs to the type of birds that are born without an inbuilt programming of their vocal behaviour and merely follow their natural urge to imitate the sounds of the beings that take care of them in the nest when very young. My experience with breeding budgeringars does not contradict this hypothesis. They even took me for a big budgeringar when they started feeding my finger-nail from their gizzard (crop). Budgeringars taken away from their mother at a very early age remain silent unless we stimulate them by speech.

Parrots are best understood by people speaking the same language the birds imitate because these people may base their illusions on the scantiest acoustic information.

I have made a tape-recording of a parrot that is one of the coöperators of the Institute of Phonetic Sciences of the University of Amsterdam, singing a Dutch nursery rhyme. After that it sings, with a heavy Dutch accent, an English song called "Dances Romances". This accent, of course, is the accent of the person who trained the parrot.

The experience gained by trying to reconstruct the nature of the speech apparatus of the parrot from the corresponding oscillograms is helpful in the phonetic study of human speech defects. In that way the study of a queer bird, the parrot, may be benificial to the study of another queer bird, man.

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REFERENCE

Warren, R.S. and R.P. Warren
1970 "Auditory Illusions and Confusions", *Scientific American* 223.6:30-41 (December).

DISCUSSION

ABE (Tokyo)
Why do you think parrots don't imitate sounds in their natural habitat? And why do they talk the way they do only in captivity?

MOL
I speculate that parrots possess an inbuilt instruction to adopt the sounds they hear from their parents. In captivity they take humans for their parents.

TRUTENAU (Legon, Ghana)
First I should like to note that Prof. Mol's parrot creates a much more perfect auditory illusion than many expensive synthesizers.

One should like to hear more of his ideas on nasality. I have always considered nasality to be essentially a result of extreme damping, which could of course originate from other than nasal cavity walls.

MOL
I completely agree with Dr. Trutenau's idea that extreme damping is a very important cue for nasality. The site of the source of this damping is comparatively arbitrary. When there is room enough for a nose, like in man, the nose provides the damping.

IIVONEN (Oulu)
Do you possibly see some contradiction in your evidence with the parrots to the statements made by Dr. Lieberman concerning the ability of ancient man to speak?

MOL
No. On the other hand I am not impressed by Dr. Lieberman's statement that ancient man would never have been able to speak English. Even though I see no disadvantage in that. Today, too, there are languages with only one or two vowels.

ADAMS (Haberfield, Australia)
Considering these differences between the production of human and avian speech, how do you account for the impression of intonation received by the listener in utterances made by the parrot?

MOL
Intonation of the parrot is carried by those passages during which it is not being interrupted. There are many vowels that are fairly periodic, in that way giving rise to an overall impression of intonation.