Laryngeal descent is not uniquely mammalian

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Abstract

The hyo-laryngeal complex moves caudally during speech in humans [1] as well as during non-verbal vocalization in non-human mammals [2]. Little is known about this structure or its role in avian vocalization. Using anatomical data from dissected birds, Homberger [3, 4, 5] predicted the movements of the hyoid skeleton. White [6] showed cineradiographically that the larynx of the rooster descends during vocalization. Here we present the first quantitative data on changes in the dimensions of the oropharyngeal cavity, produced by the up-and-down movement of the larynx and lateral movement of the hyoid cornua, in relation to fundamental vocal frequency in a songbird, the Northern Cardinal (*Cardinalis cardinalis*). By studying the movement of the hyoid skeleton and larynx we hope to eventually understand its acoustic role in song production.

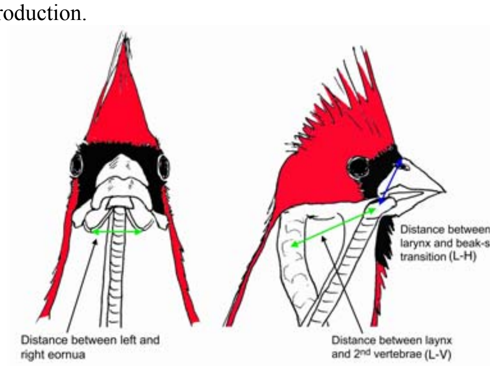

Fig. 1: *Distances measured in the frontal and lateral view of the cardinal to determine the motion of larynx and hyoid during song . In frontal views we measured the lateral movement of the hyoid cornua. In lateral views we measured the vertical and horizontal movements of the larynx as changes in its distance from fixed anatomical reference points indicated (drawing by S.A. Zollinger).*

1. Introduction

Birdsong is a complex communication behavior that requires the coordination of several motor systems. The sound produced in the syrinx at the base of the trachea is modified by the upper vocal tract. Caudal movements of the hyoid and larynx enlarge and deepen the oropharyngeal cavity, but the nature of these movements and their possible role in song production have not been studied in songbirds. Here we quantify these movements and examine their relationship to the frequency of the bird's song.

2. Methods

We used cineradiographic imaging at 30 frames per s to monitor movements of the hyoid and larynx in 3 singing adult male northern cardinals (*Cardinalis cardinalis)*. Digital video output from the fluoroscope in the diagnostic imaging system was recorded simultaneously with song on S-VHS tape and analyzed using video analysis software. Three cardinals sang a total of 8 different syllable types. In this poster we summarize results for several of these syllables for which we have the most data. The relatively high level of ambient noise in the x-ray facility restricts the kinds of spectral analysis that are feasible.

3. Results

3.1. Movement of the larynx and the cornua

The larynx movement includes a large up-and-down component (distance between skull-beak transition and the larynx) as well as a back-and-forth component (distance between the second vertebrae and the larynx). During some syllables, the larynx moves caudally as much as 12 mm from its original pre-phonatory position. This is about 13% of the total body length (measured between top of the head and base of the tail feathers). Additionally the larynx moves forward up to 18 mm. The *cornua* of the hyoid skeleton each move up to 5 mm laterally. A small up-and-down vector is also present but was not measured. The movement of the hyoid skeleton opens the oropharyngeal cavity.

3.2. Rhythmic oropharyngeal motor patterns accompany song.

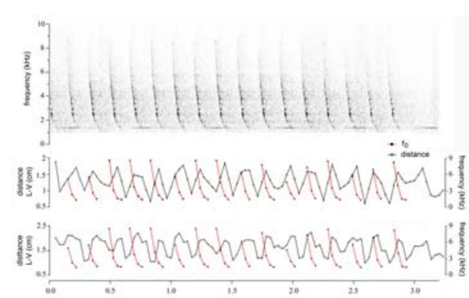

fig.2

Fig. 2: *During the initial portion of this downward sweeping syllable, the larynx is being retracted backwards and downward, increasing the size of the oropharyngeal cavity. The direction of laryngeal movement reverses part way through the sweep, causing cavity volume to decrease with decreasing sound frequency for the remainder of the syllable. Note that oropharyngeal motor pattern continues for one cycle after end of syllable train.*

During phonation the oropharyngeal cavity expands in a cyclical and relatively stereotyped pattern.

3.3. Cavity size is correlated with low f0

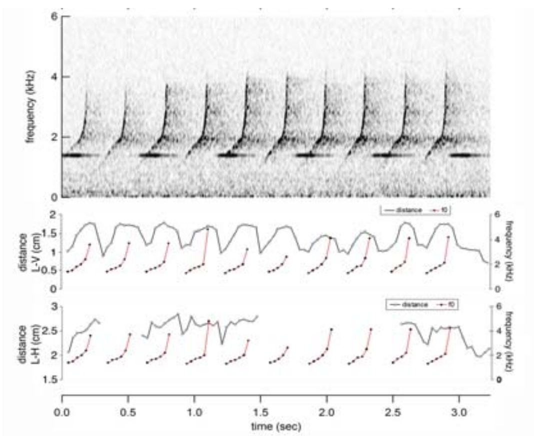

Fig. 3: *The larynx retracts rapidly downward and backwards during the initial gradual upward FM portion of syllable type e. The oropharyngeal cavity attains its maximum dimensions during the final steep upward FM sweep. Tones at 1.5 kHz were produced by x-ray machine.*

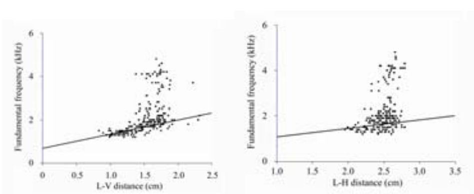

Fig. 4: *(a) Initial low frequency, gradually rising FM 'foot' of syllable e (Fig 3) has a strong positive correlation with the backward movement(L-V) of the larynx (regression line for f0<2 kHz; R^2=0.57, F=226, p<0.0001; regression >2 kHz n.s.). (b) Lowering of larynx (L-H) occurs rapidly at beginning of syllable resulting in a steep but weaker correlation with f0 < 2 kHz (regression line for f0<2 kHz; R^2=0.27; F=91; p<0.001). The oropharyngeal cavity is maintained near its maximum volume during the final steep FM part of the syllable and so is not correlated with f0.*

4. Conclusions

1. The dimensions of the oropharyngeal cavity undergo large rhythmic changes in synchrony with sound production. Cavity size is increased by a motor pattern that simultaneous moves the larynx and hyoid downward and backward as it moves the hyoid cornua laterally, confirming Homberger's predictions [3].

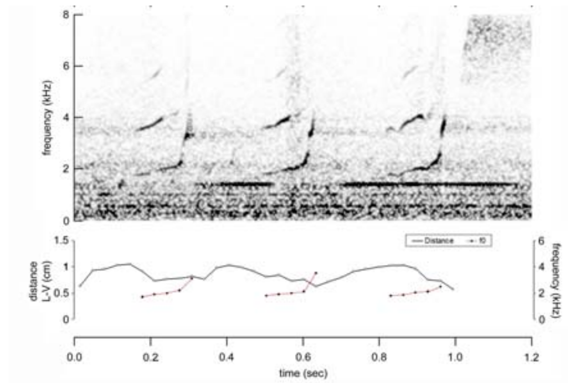

Fig. 5: *During these renditions of the syllable e the oropharyngeal motor pattern was shifted relative to phonation so that the larynx was moving forward instead of backwards during the beginning of each syllable (compare with fig 4).*

2. Below about 3 kHz, the dimensions of the oropharyngeal cavity usually have a significant positive correlation with the syllable's fundamental frequency. Cardinals produce these low frequencies on the left side of their syrinx. At higher frequencies this correlation is typically weak or absent.

3. Although our preliminary data are compatible with the oropharyngeal cavity functioning as a resonance filter, possibly suppressing harmonics of fundamental frequencies below about 3 kHz, its acoustic function and relationship to other parts of the supersyringeal vocal tract, such as beak gape, remain to be determined..

5. References

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