Sounds inside the respiration system of *Tursiops truncatus*

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Summary

Experiments verified that in periods of active echolocation, the sound pulses inside the nasal canal of a bottlenose dolphin either were absent or considerably weaker than outside this canal. In the right nasal canal, sounds were registered that were not heard from the outside. Apparently could be considered as internal noises accompanying the process of echolocation pulse generation. As a rule, they were narrow-band sounds, sometimes with an obvious amplitude modulation which is characterised by side frequencies, non-multiple to the main frequency. Practically all internal noises coincided in time with the process of echolocation. The presence of these sounds is evidence in favour of the hypothesis of a pneumatic mechanism of sound generation in dolphins.

Key words: sound, echolocation, dolphin, hydrophone, generation

Introduction

Sound signals produced by dolphins for echolocation can be recorded outside the dolphin. These signals are expected to be accompanied by sounds in the respiratory system if the hypothesis of the pneumatic nature of sound generation is valid (Airapet'yantz & Konstantinov, 1974).
Investigation of the patterns of internal and external sounds production may allow conclusions about the mechanisms of sound generation in free swimming dolphins.

Materials and methods

A complex set of devices allowed us to penetrate inside the respiratory system of a dolphin with a miniature hydrophone and to register sounds simultaneously inside the respiration system (above and below the inner valve at the level of the osseous partition of nasal canals) and outside, at two points on the dolphin's head (near the rostrum and in the region of the right outer acoustic duct). Sounds were recorded while the dolphin used echolocation to locate fish during feeding. The hydrophone, that had been placed into the respiration system of the dolphin was a cylinder of piezoceramics, 2 mm in diameter and 3 mm high. It was mounted on the end of a fine (1.5 mm in diam.) shielded conductor.

The device to insert the hydrophone in the spiracle and to position it, is shown in Figure 1. The hydrophone (1) is fixed in the necessary position with a rigid 1 mm diameter stainless steel wire (2). To achieve this, the hydrophone's shielded conductor was tightly tied to the wire (2) and was held together with two suction cups (3). These were fixed on the dolphin's body (behind the blowhole), while the hydrophone itself was inside the spiracle. This device (Fig. 1) allowed us to insert one or two hydrophones into the

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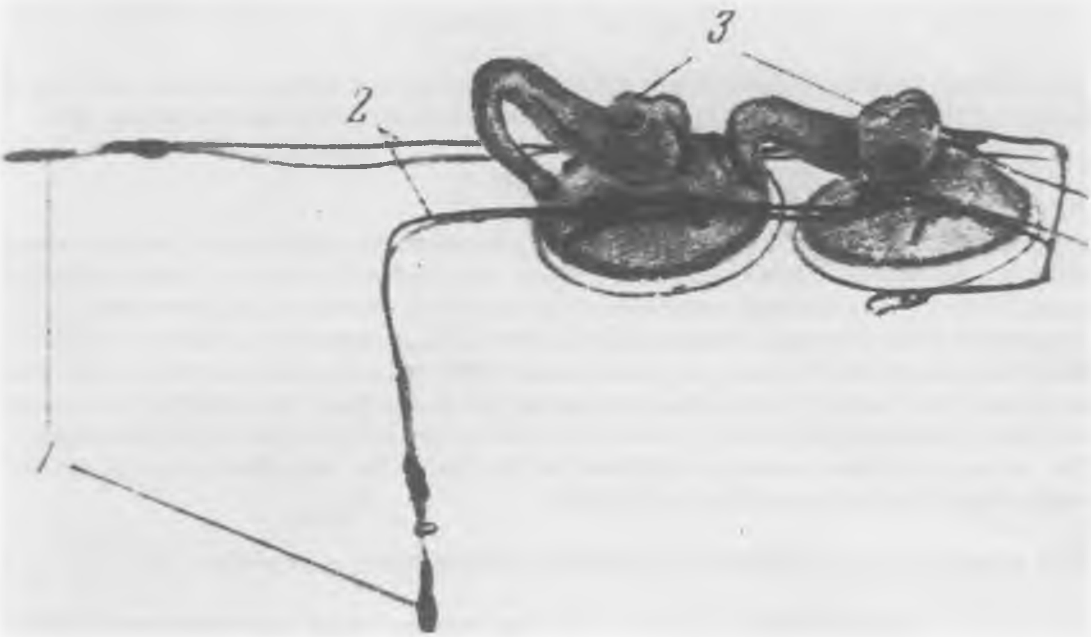

Figure 1. Device allowing insertion of the hydrophone inside the spiracle of dolphin.

spiracle. In order to insert only one hydrophone, it was necessary to curve only one wire at a right angle (as shown in the figure). Then a second hydrophone, fixed to a second wire can be located above the melon. Alternatively the second hydrophone can be set at any point on the head of a dolphin by a separate suction cup. Figure 2 shows the process of insertion of one hydrophone into the dolphin's spiracle during a breath. A third hydrophone fixed near the rostrum had the same construction as the one inserted in the spiracle. The fourth hydrophone, a piezoceramic sphere (15 mm diameter), was secured to the skin near the right outer acoustic duct. All hydrophones are connected to a three-channel radio-controlled tape-recorder in a waterproof housing, attached to the dorsal fin of the dolphin (Romanenko & Chikalkin, 1974).

The insertion of the hydrophone 6 cm into the spiracle seemed painless and did not evoke unpleasant sensations in the dolphins. The dolphins tried to remove the hydrophone by blowing air through the spiracle. This behaviour was shown only 2 - 3 times in each case and it was followed by normal feeding behavior in the pool. The size of the pool was 12.5 x 6 m, the water depth was 1.2 m.

Results and discussion

The miniature hydrophone was inserted alternatively into the right and left nasal canals. During periods of active echolocation, registered by hydrophones located on the head of a dolphin, sound pulses inside the nasal canal were absent or considerably weaker than the sounds recorded outside. This indicates that the larynx was not the source of the signals used for echolocation as supposed by Gurevich (1972, a, b). Moreover, sounds were recorded inside the right nasal canal that were not registered by the

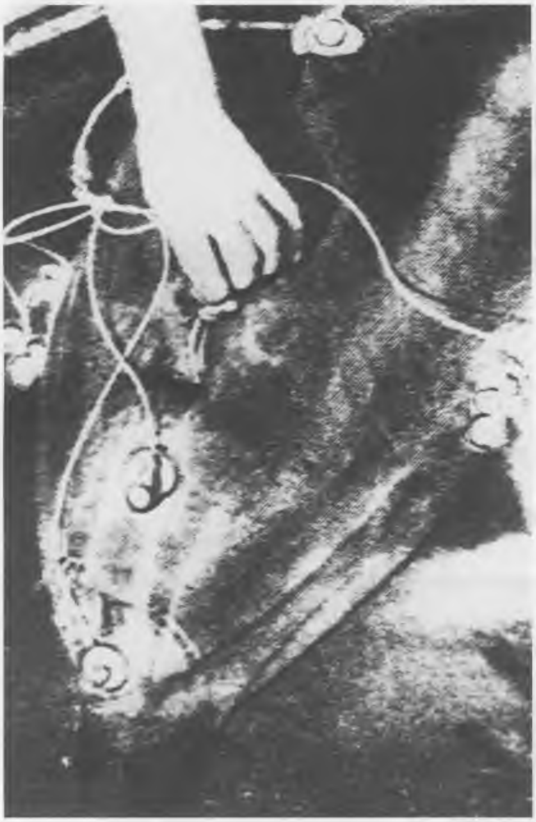

Figure 2. Insertion of the hydrophone in dolphin's spiracle.

hydrophones outside. This internal noise occurred simultaneously with echolocation pulses. Internal noise had the characteristics of whistles, but differed considerably from communicative whistles. The internal sounds were usually narrowband, sometimes showing amplitude modulation characterised by side frequencies which were not multiples of the main frequency (see Fig. 3a). The communication whistle sonogram is shown for comparison in Figure 3b. In Figures 4a and b, the oscillograms of internal noise and of communication whistles are shown. The communication whistles have, to a considerable degree, a harmonic character, whereas the internal noise looks like a series of one- or two-period pulses which can be interpreted as a signal with an amplitude overmodulation. Figures 5a and b show internal noise against the background of faintly perceptible pulse series and the corresponding series of echolocation sounds registered on the dolphin's head near the rostrum. On the abscissa of Figures 3 - 6 the time is plotted.

It is worth emphasizing that all internal sounds were registered in the right nasal canal. In the left nasal canal no sounds were registered. Unfortunately, there was no possibility to undertake multiple tentatives of sound registration in the left nasal canal to elucidate whether sounds could be heard here during echolocation. The scarce data which are at our disposal allow us to draw only a preliminary conclusion that the area of the left nasal canal below the muscle barrier had no relationship to echolocation while the right nasal canal, without doubt, had a relationship to echolocation.

Practically all internal sounds coincided in time with the process of echolocation. Only in 2 of 17 cases internal noise was not heard during echolocation (possibly very feeble and not heard). It is not excluded that internal sounds are of aerodynamic origin and accompany the process of air transportation within the structures responsible for echolocation sounds generation. However, another explanation is also possible. Internal sounds could be due to a considerable pressure difference on the two sides of the muscular partition and may be generated when the air passes the muscular partition to compensate for pressure differences. This explanation is supported by measurements of the air pressure in the dolphin's breathing system as shown in Figure 6 (Dargolts *et al.*, 1981). The air pressure (1) in the nasal canal between the internal muscular partition and the ex-

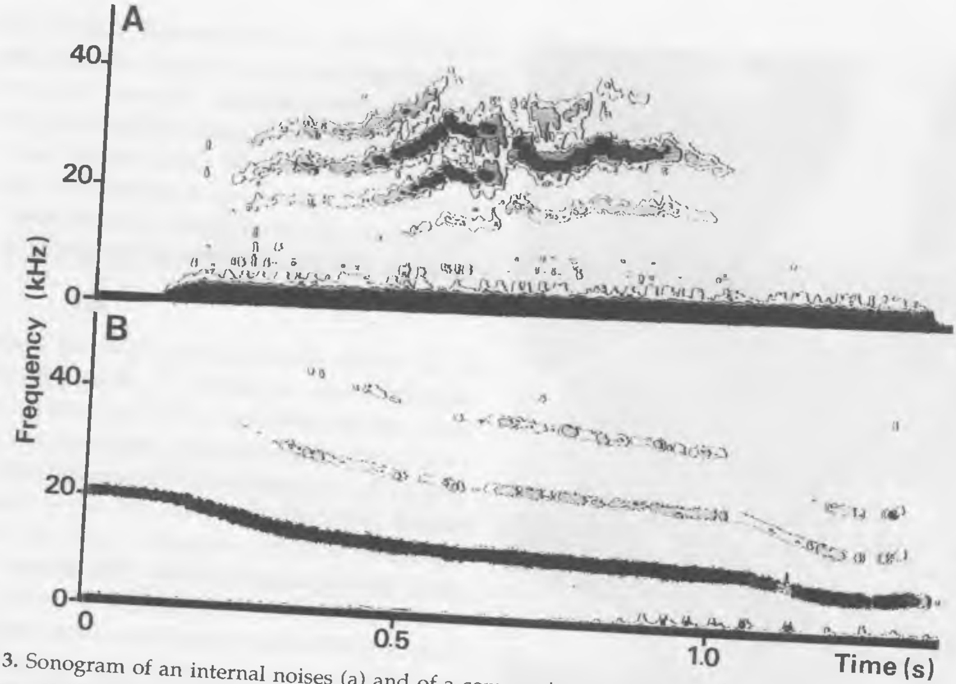

Figure 3. Sonogram of an internal noises (a) and of a communication (b) sounds.

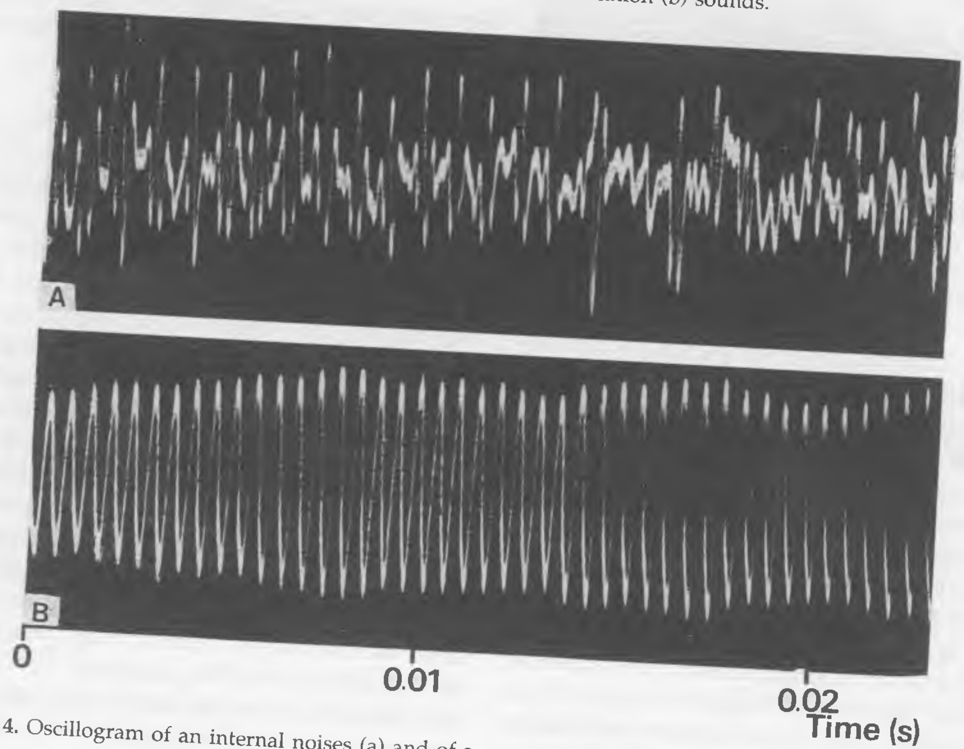

Figure 4. Oscillogram of an internal noises (a) and of a communication (b) sounds.

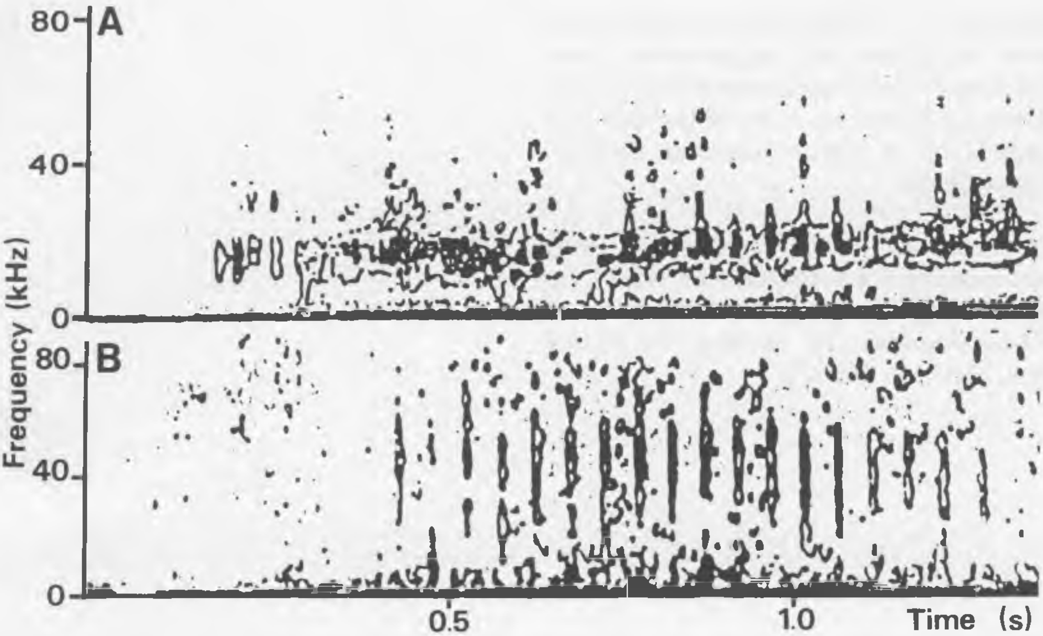

Figure 5. Sonogram of internal noises against the background of a pulse series (a) and of the same pulse series registered on the dolphin's head (b).

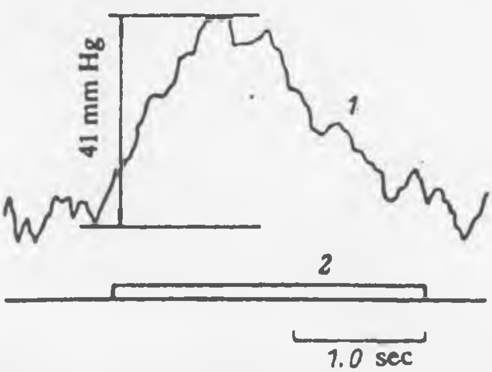

Figure 6. Air pressure inside the dolphin's nasal canal during echolocation.

ternal nare was increased by 30 - 50 mm Hg during echolocation (2).

Further investigations must reveal the true nature of the internal noise. At present, however, the presence of these sounds in one way or another are witnesses in favour of the pneumatic mechanism of echolocation sound generation in dolphins.

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