TARGET CLASSIFICATION IN THE DOLPHIN

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1. ABSTRACT

Given a multiple highlight structure of target echoes, the dolphin's ability to classify the targets by number of highlights in the echo was studied. Around 60 symmetrical, in respect to the horizontal plane, targets with different shapes, materials and sizes were tested. The dolphin was able to divide the targets into a class of single-highlight echoes and a class with multiple highlights as long as the interval between highlights was larger than around 30 μs.

KEY WORDS: dolphin; target classification; echo structure.

2. INTRODUCTION

Numerous experiments have been conducted to investigate dolphins' ability to discriminate the size, shape, material composition and interior structures of targets. Dubrovskiy et al. [1, 2] postulated that dolphins recognised the material composition and diameter of spherical targets by difference in average oscillation period of the target frequency response. The dolphin discrimination threshold was found to be from 2 to 3 kHz Dubrovskiy et al. [2]. Dubrovskiy and Krasnov [3], Golubkov et al. [4] considered the time domain characteristics of echoes from spheres and suggested that the dolphin might discriminate intervals between the primary echo and secondary echo, which is in inverse proportion to the oscillation period of the target frequency response. Hammer and Au [5] investigated the dolphin's ability to distinguish bronze, glass and stainless steel probe cylinders from the aluminium standard cylinder that had the same dimensions. The dolphin mistook the glass cylinders for the aluminium standard almost in all trials. The matched-filter responses of the steel and bronze cylinders were readily discernible from the aluminium standard. However, for the glass cylinder it was similar to that for the aluminium cylinder [5]. The Hammer and Au results [5] were consistent with early finding of Dubrovskiy et al. [2]. Dolphins do not seem to create a concept of certain material composition of the target, but rather sort out the targets by echo structure differences in the oscillation periods of the frequency response or in the intervals between echo highlights. On the other hand, the dolphin was shown capable of distinguishing steel spheres and cylinders from brass, ebonite, titanium and duralumin ones, regardless their size, Saprikin et al. [6], Belov et al. [7]. Analysis of the echoes has shown that the dolphin did not use such cues as an interval between the highlights or ripples in the amplitude spectra of the targets, Korolev and Belov [8]. The authors suggested that the dolphin might analyse a fine time structure of the secondary highlights in the echoes.

In order for a target to be identified into a certain class, the target must possess a unique feature or combination of the features that other targets lack. However, it appears difficult to translate target material features into acoustic parameters of the target echoes regardless size and shape of the targets. Given multiple highlight structure of most targets in response to the dolphin click, we chose to examine whether the dolphin would be able to classify the targets by number of highlights in the echo regardless material, shape or size of the targets. The dolphin target classification into the class with a single highlight in the echo and the class with two and more highlights in the echoes was studied.

3. METHODS

The subject was the Black Sea bottlenose dolphin (*Tursiops truncatus*). Experiments were conducted in a 28 × 13 × 4 m concrete pool. A two-response forced-choice procedure was used. A vertical net partition set a minimum distance of 5 m, from which the dolphin made his choice. Targets were presented simultaneously on either side of the partition at 1m depth and 3 m from each other. Prior to stimuli presentation, the dolphin positioned itself at the far (from targets) end of the partition. Having made its choice the dolphin approached a chosen target. The animal performed around 300 trials per session. Around 60 different targets with a central symmetry were prepared (figure 1).

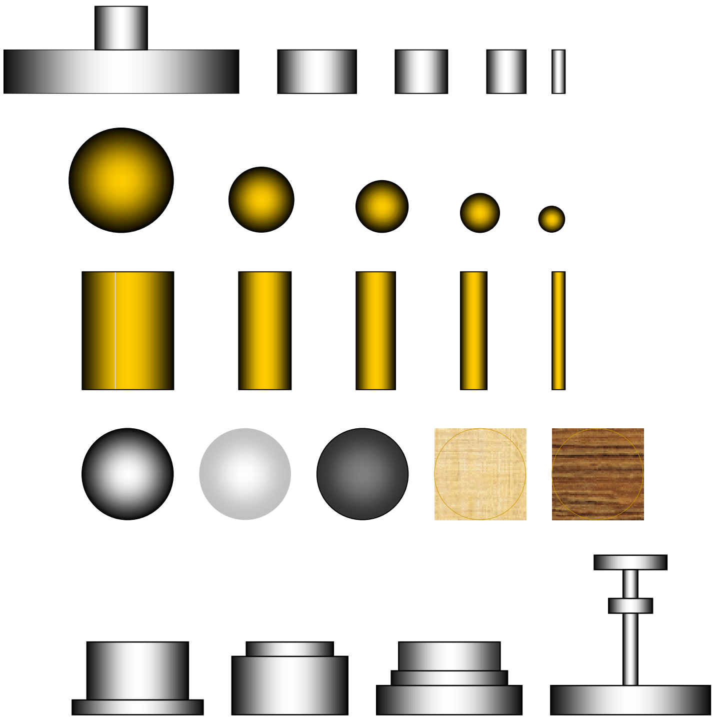

Figure 1. Examples of the targets used in the experiments. The darkness and texture of the spheres reflect different material composition.

A set of 15 foam disks of 5 to 35 cm in diameter and 0.5 cm to 3.0 cm in height was used. Small steel discs were encapsulated in the centre of the form discs to offset their buoyancy. The brass, steel, duralumin, ebonite, and lead spheres with diameters 1, 1.5, 2.4, 3, 5, 5.4 cm, 1, 1.5, 2.5, 3, 4, 5, 7.6, 9.2 cm, 3.5, 4, 5, 5.5, 7.5 cm, 2, 3, 4, 5 cm, and 2, 3, 5 cm, respectively, were also used. The spheres made out of wood, plastic, rubber and textolite of 5 cm in diameters as well as metal discs and cylinders with different diameters and heights were also tested. Several targets with more complex shapes but also with central symmetry were used. The echoes from all the targets were recorded and analysed using simulated dolphin sonar click before experiments with the dolphin started. All single foam discs returned a single-highlight echo. One of the foam disks was used as a single highlight target. Two centre-aligned disks were used to assemble the targets with two highlights. The interval between the first and the second highlight in the echo varied from 50 to 200 μs for different combination of the discs in the double-disc.

First, the dolphin was trained to discriminate between a 20-cm foam disc and two centre-aligned (similar to the double-disc shown in the first row of figure 1) 10- and 20-cm foam discs. Second, in each consecutive trial two different discs from the set were randomly chosen to combine into a double-disc. This double-disc was presented to the dolphin with also randomly chosen a single disc. Finally, two targets taken randomly from full set of objects, regardless material, shape and size, were presented to the dolphin for discrimination. The same couple of the targets was normally presented in no more than four consecutive trials and then replaced with another couple of targets. We did not want the dolphin to switch to another discrimination cue, which it could have found in case of a longer presentation of the same couple of the targets. For the same reason, in most of trials, one of comparison targets had a single highlight and the other had two or more highlights in echoes. A standard target was the one with a single highlight. One of the objectives of the study was to determine a minimum interval between the echo highlights, at which the dolphin could differentiate the targets with double-highlight echoes from targets with a single-highlight echo. This threshold interval could be treated as an estimate of the dolphin sonar time resolution.

In some trials, however, both comparison targets had double-highlight echoes. The dolphin was rewarded for an approach to any of the targets. The minimum interval between highlights in one of the comparison targets, at which the dolphin would stop identifying a target as being a double-highlight, was determined. We assumed that as long as the dolphin perceived both targets as the ones with double-highlight echoes, the percentage of discrimination should be around 50%. When the interval between highlights in one of the targets was smaller than the sonar time resolution, the target should be treated by the dolphin as one with a single-highlight echo. As a result, the discrimination should increase above 75% level.

4. RESULTS

It took the dolphin only several trials to learn the difference between the 20-cm foam disc and a double-disc combined of the 10- and 20-cm discs with distinctly one and two highlights in the echoes. The dolphin readily distinguished a single foam disc from a double-disc for any combination of the discs in a double-disc and any diameter of a single disc. It signified that it did not pay any attention to the intensity of the targets and amplitude ratio of the first and second highlight in the double-disc echo. The dolphin was able to discriminate between any novel targets

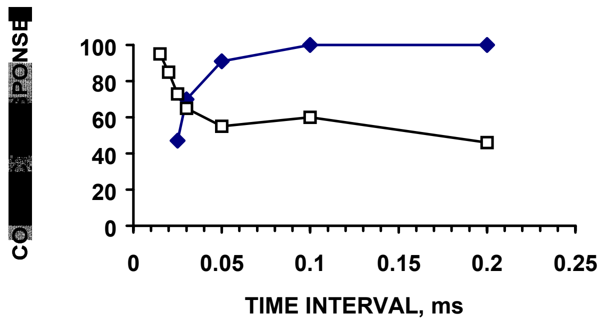

Figure 2. The dolphin's discrimination between single- and multi-highlight targets as a function of the interval between the first and the second highlights in the target echo (plot 1). Plot 2 describes the dolphin's discrimination between the targets with multi-highlight echoes, as a function of an interval between the first and the second highlights.

from the full set of targets, as long as one target had a single highlight in the echo and the interval between echo highlights in a comparison target was larger than 25-30 μs (figure 2, plot 1).

When comparison targets both had double-highlight echoes, discrimination was above the 75% level only if the interval between the first and the second highlight in one of the targets was smaller than around 30 μs (figure 2, plot 2). If this interval defines a time resolution of the dolphin sonar then the dolphin discriminated and classified the targets in the time domain.

5. CONCLUSIONS

The Black Sea bottlenose dolphin is capable of target classification by number of highlights in the target echo. The dolphin did not generate search image of the target based on material composition, shape or size, but rather dealt solely with the acoustic parameters of the echo. The minimum interval between the first and the second highlights in echoes of 25 to 30 μs, which separate for the dolphin the class of targets with a single-highlight echo from the class of targets with multi-highlight echoes, can be considered as an estimate of the dolphin sonar time resolution.

REFERENCES

[1] N. A. Dubrovskiy, A. A. Titov, O. S. Krasnov, V. P. Babkin, V. M. Lekomtsev, G. V. Nikolenko. Investigation of resolution of echolocating system of the Black Sea bottlenose dolphin. Tr. Akust. Inst.,Moscow, 10: 163-181, (1970).

[2] N. A. Dubrovskiy, O. S. Krasnov, A. A. Titov. Discrimination of solid elastic spheres by an echolocating porpoise, Tursiops truncates. In: Proc. 7th Intern. Conf. Acoust., Budapest. (1971).

[3] N. A. Dubrovskiy, O. S. Krasnov. Discrimination of elastic spheres according to material and size by the bottlenose dolphin. Tr. Akust. Inst., Moscow, 17: 9-18, (1971).

[4] A.G. Golubkov, M. V.Yershova, A. R. Zhezherin & V. B. Fradkin. Experimental study of maximum range of discrimination of spheres by marine animals. 4th All-Union Conf. on Bionics, Moscow. Vol. 1, pp. 27-28, (1973).

[5] C. E. Jr. Hammer & W. W. L. Au. Porpoise echo-recognition: an analysis of controlling target characteristics. J. Acoust. Soc. Am. 68L 1285-1293, (1980).

[6] B. A. Saprikin, B.M. Korolev, E. C., Dmitrieva, M. C. Fedenko, E. D. Borisova. 1977. Physiological journal USSR, T. 63, N3, 1083-1087.

[7] [B. I. Belov, B. M. Korolev, B. P. Morozov. 1983. Recognition of the class of equivalent objects in different condition by the bottlenose dolphin. X All-union acoustic conf. Moscov, 28-30.

[8] [8] B. M. Korolev and B. I. Belov. 1991. Classification of material composition of small-size targets in the bottlenose dolphin. XI All-union acoustic conf. Moscov.