Horizontal and Vertical Echoic Angular Resolution in the Bottlenose Dolphin (Tursiops aduncus)

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Introduction

Previous experiments have proved dolphins’ ability to solve Two-Alternative-Forced-Choice-Task (2AFC-T) in two horizontal discrimination experiments and resulted 75% correct threshold at 1.60 and 1.50 degrees angular separations (Branstetter et al 2003 and 2007). A dolphin’s minimum audible angle (MAA) was obtained at 0.90 and 0.70 degrees in the horizontal and vertical planes respectively by passive listening tests (Renaud et al 1975). This study aimed to investigate and compare a bottlenose dolphin’s angular resolution (AR) ability in both horizontal and vertical orientation in reference to the dolphin’s ventral plane using 2AFC-T.

Methods

The subject of this study was an eight-year-old, female Indo-Pacific bottlenose dolphin (Tursiops aduncus), called Dumisa. Dumisa was required to wear eyecups and distinguish between two arrays of air-filled PVC rods using echolocation. The array consisted of a double rod (S+ stimulus) separated by constant 2 degrees (θw) and a single rod (S− stimulus). The separation between the S+ and S− arrays (θb) varied resulting in angular differences (Δθ=θw-θb) between 4.00 and 0.25 degrees (4.00, 3.00, 2.00, 1.75, 1.50, 1.25, 1.00, 0.75, 0.50 and 0.25 for the horizontal test, and 4.00, 3.00, 2.75, 2.50, 2.25, 2.00, 1.75, 1.50, 1.25, 1.00, 0.75, 0.5 and 0.25 for the vertical test) (Figure 1). The stimuli were positioned on the wooden arc, maintaining constant distance from the subject at all angular differences.

Procedure

During the trials Dumisa stationed in the hoop at a distance of 2 m from the stimuli and located the position of the double rod (left or right side for the horizontal and dorsal or ventral for the vertical orientation). Dumisa indicated her choice by pressing the response paddle on the respective side of the stationing hoop (right or left for Horizontal AR, while dorsal or ventral position for the Vertical AR experiment).

Each test session consisted of 24 trials and had three phases: ‘warm-up’ trials, two sets of test trials and ‘cool-down’ trials. The initial six ‘warm-up’ trials were conducted with the two biggest angular separation differences (3.00 or 4.00 degrees). If Dumisa made more than one mistake, the session was aborted. The two sets of test trials were presented in a staircase procedure with diminishing angular differences. The position of the S+ was assigned pseudo-randomly (left and right for Horizontal and dorsal or ventral for Vertical AR) and balanced over the two test sets. Finally the sessions were finished with the ‘cool-down’ trials (3.00 or 4.00 degrees) to end on a positive note.

Results

Altogether 13 different angular separation degrees were tested in a course of four experiments, two Horizontal (HAR I and II) and two Vertical AR (VAR I and II) (Table 1). Each degree was tested 60 times during 780 test trials. The dolphin’s correct performance showed the same trend for both Horizontal and Vertical AR, gradually decreased with the separation difference (Figure 5). As the task became more difficult Dumisa favoured the right side to the left (incorrect choice right: 146, left: 53) and the dorsal side to the ventral (incorrect choice dorsal: 84, ventral: 38).

Conclusion

The dolphin was able to discriminate separations as low as 1.00 degree horizontally and 1.00 degree vertically. Both experiments provided a psychometric function for the dolphin’s echoic resolution in the horizontal and vertical dimension. These results agree with previously obtained localisation abilities of both echolocating bats (Branstetter et al 2003 and 2007) and passive listening dolphins (Renaud et al 1975). In comparison to Renaud’s findings that suggested moderately better localisation abilities on the vertical plane, Dumisa’s performance on 1.00 degree separation also showed a higher number of correct trials during Vertical AR. These results support evidence that the dolphin can recognize shapes through echolocation alone (echo-imaging).

Acknowledgement

We would like to express our gratitude to the Marine Mammal Department of Ocean Park for their continuous help. We would like to thank the interns and volunteers for their hard work.

References


Table 1: Summary of Dumisa’s performance (%) on the 13 angular separation degrees during the Horizontal (HAR I and II) and Vertical (VAR I and II) angular resolution experiments.

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