Do Bottlenose Dolphins Have a Language?

Evaluating the Potential of Dolphins' Whistles to Transfer Information

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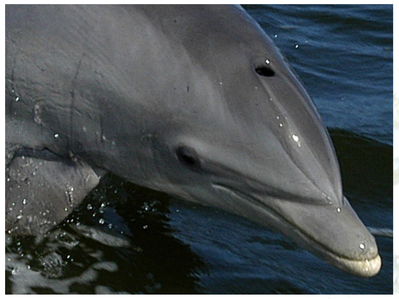
Introduction

Bottlenose dolphins, Tursiops truncates, are known to be social animals, widely communicating with each other and interacting with their environment. This has been made possible by their ability to produce a rich acoustic repertoire, as well as their exceptional sonar characteristics.

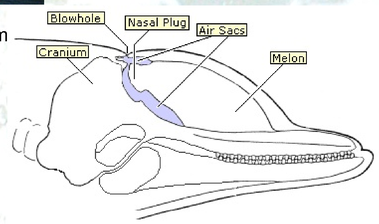
A wide range of vocalisations have been identified and linked to different behaviours of dolphins [2]. These vocalisations can be divided into three major groups: clicks, burst pulses and whistles [4]. Clicks are often used for echolocation, whilst the burst pulses are usually signs of aggression, distress or excitement. Whistles are used by bottlenose dolphins for communication in their complex fission-fusion societies [2].

The different types of whistles utilised by dolphins, along with dolphins' ability to learn artificial signals to label objects [3], raises the possibility that the whistles constitute some sort of dolphin language. As a first step to evaluate this possibility, the potential of dolphins' vocalisations to transfer information can be measured.



A bottlenose dolphine. Figure taken from [8].

Below is a schematic illustration of the anatomy of a dophin's head, where the whistles are produced. There is still a debate on whether the whistles are produced aerodynamically, by resonating the nasal air sacs, or by a "tissue vibration mechanism" [4]. Figure taken from [6].



References

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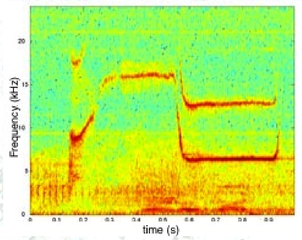
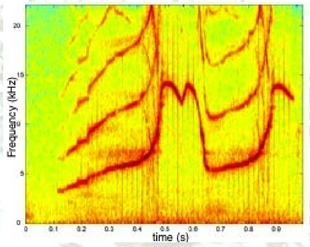
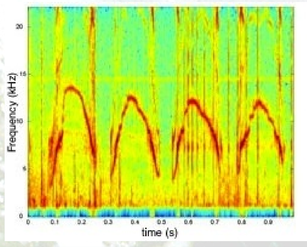
Background image taken from [8].

Whistles

Whistles have a range of frequency between 4 and 20 kHz and a duration of 0.5 to 0.8 s [2]. Various whistles have been identified and categorised for bottlenose dolphins. One type of whistles, which is known as the "signature whistle", is a characteristic of each dolphin. This whistle is constantly used by dolphins throughout years, in some cases up to ten years, in situations such as mother/calf reunion, courtship and alloparental care [2]. Signature whistles can be visualised using spectrograms. Studies have shown that the shape of the loop is unique for each dolphin [6]. Recent studies have demonstrated that dolphins use the information stored in the frequency modulation pattern of signature whistles to identify individuals [3].







Spectrogram of signature whistles of 3 different dolphins. These whistles are characteristic of each dolphin and are used for individual recognition. Figures taken from [6]

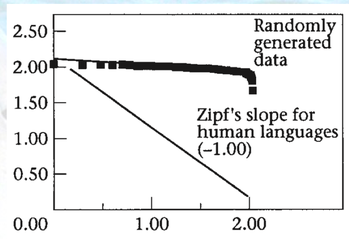
Zipf's Law

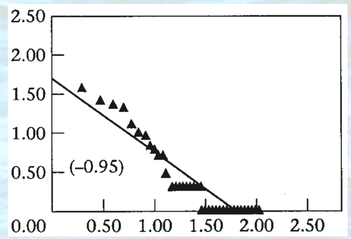
Zipf's law, which is based on the Zipf's "Principle of Least Effort", provides a measure for the potential of a system to transfer information. In his Principle of Least Effort, Zipf argues that the amount of potential communication through language can be optimised through a balance between two forces: unification and diversification [5].

In order to evaluate the potential of a system to carry information, the signals in the system should be identified and ranked according to their usage. Then, the logarithm of these ranks should be plotted versus the logarithm of the percentage of occurrence of the signals. The slope of this plot would then give a measure for the potential of the system to transfer information. In fact, a slope of -1 represents a balance between unification and diversification and suggests the system's high potential of information transfer. Studies have shown that various human languages follow Zipf's Principle of Least Effort, having a slope of approximately -1.00, consistent with the predictions of Zipf's law [5].

Potential Communication Capacity of Dolphins' Whistles

McCowan et al [5] have applied Zipf's law to dolphins' whistles. They have shown that the plot of log rank of whistles versus their log frequency of occurrence has a slope of -0.95, similar to that of humans. It was also found that the whistles of infant dolphins displayed a lower slope in the first month of their life, suggesting that their whistles had a more random nature. The slope of these whistles increased to more than -1, indicating a high amount of repetition in the signals. As the dolphins grew to adulthood, the slope reached -0.95. These results suggest that dolphins' whistles have a distribution similar to that of words in different human languages and that dolphins can learn this structure as they grow. In addition, the results indicate that the whistles have a high potential to carry information.





The plot of log signal rank versus log frequency occurrence for (Left) human languages and (Right) whistle repertoires of adult bottlenose dolphins. The close matching between the slopes suggests that there might be a similarity between the potential of these two repertoires to carry information. Plots taken from [5].

Conclusion

The application of Zipf's law to dolphins' whistles has revealed that these vocalisations have a non-random distribution and a high potential for transferring information. However, some have questioned these results, arguing that Zipf has not provided a mathematical proof for his Principle of Least Effort and thus, his law is not a reliable measure of a system's potential of information transfer [9]. Furthermore, Zipf's law does not provide insight into the organisation of the whistles and thus, cannot answer the question of whether dolphins use whistles like some sort of language [5].

Despite the ongoing discussion on the reliability of Zipf's law and its application to animal communication, it is still widely believed that information theory can provide tools to study animal communication [1, 7]. Current studies do not provide evidence for the existence of a dolphin language. Thus, further research should be done to investigate the organisation of vocalisation repertoire in bottlenose dolphins with tools provided by the information theory.

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BBSRC bioscience for the future
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