Animal communications, information theory, and the search for extraterrestrial intelligence (SETI)

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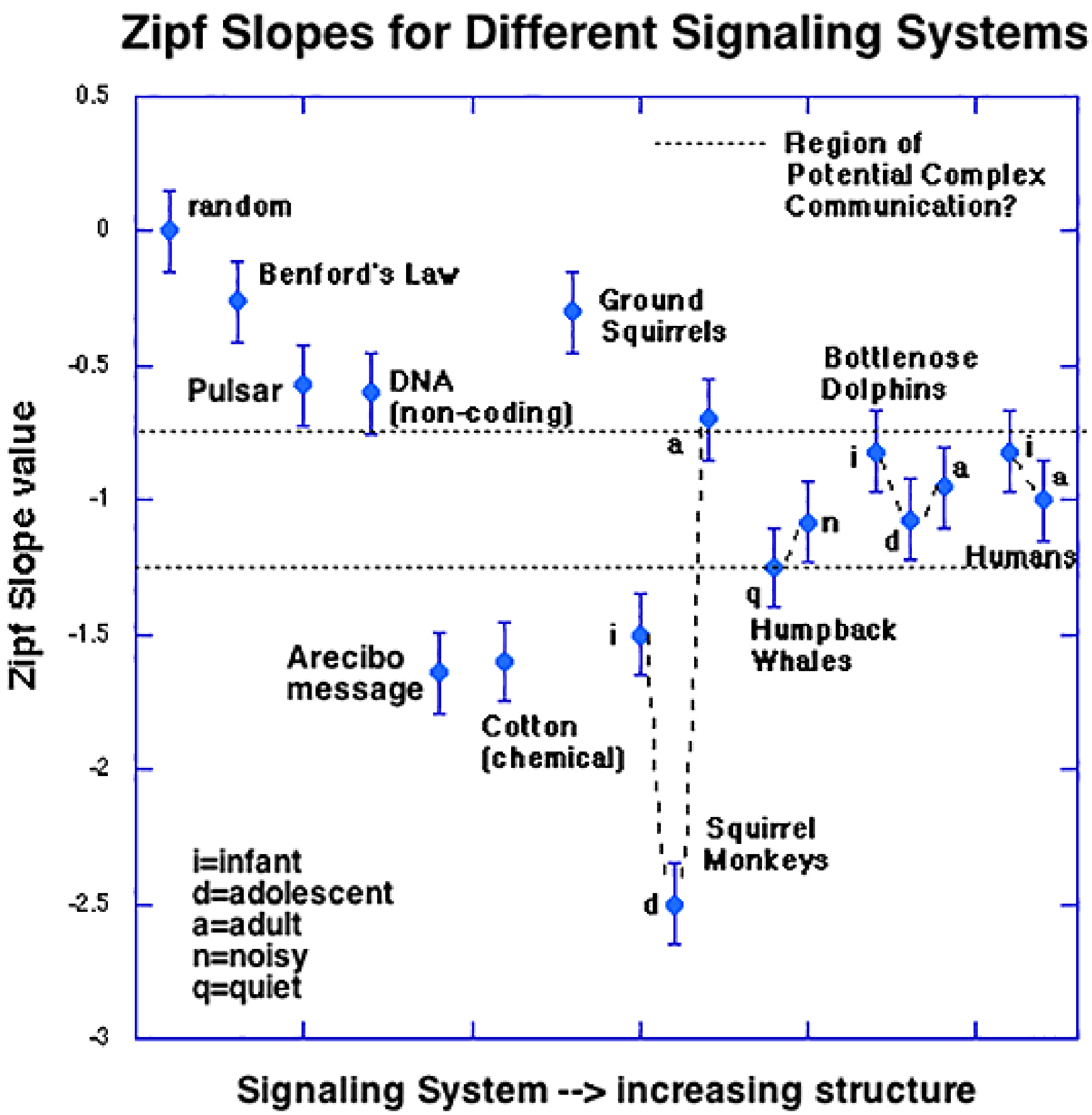
The idea that we can learn about possible extraterrestrial (ETI) communication systems by studying non-human communications on Earth is similar to the astrobiological idea that one might learn more about exobiology by studying the extremes of life on Earth. Such study was taken up by Dr. Brenda McCowan of University of California, at Davis, Dr. Laurance R. Doyle of the SETI Institute, and their PhD student at the time, the now Dr. Sean F. Hanser. Early work was also helped on by Dr. Jon M. Jenkins also of the SETI Institute at the time.

To begin this study, we selected terrestrial species that are socially complex, but largely depend on acoustic signaling to communicate – that is, bottlenose dolphins and humpback whales. We also included squirrel monkeys. The tools we chose to apply were signal classification methods (largely the K-means cluster 60-point contour) and the broad mathematics of Information Theory discovered by Dr. Claude Shannon of Bell Laboratory in the late 1940s. Originally developed to ascertain the amount of information going through telephone lines, we applied it to quantify the amount of information, in bits, that was being communicated between captive, adult bottlenose dolphins.

A linguistic relationship known as "Zipf's Law" appears to be a necessary but not sufficient condition for complex communications. In this relationship, the (base ten logarithm) of the frequency of occurrence of the various signal types (assumed to be sufficiently sampled so it can represent a probability) is plotted in logarithmic rank order, and a complex communication system will always give a -1 slope for the distribution of the signals types (letters, words, or phonemes). Although Zipf's Law applies to many systems, a communication system that is not coded must have this distribution to have the potential for complex relationships between the signals. In human languages we would call this "syntax" in the sense of rules of spelling and grammar.

We discovered that adult bottlenose dolphins obey this Zipf's Law relationship so that there could exist "syntax" within their communication system. Why would such syntax exist? For one thing, this syntax enables the recovery of errors in the transmission, which definitely has survival value. A human example might be the recovery of missing letters in a poorly copied manuscript by the use of spelling rules.



Zipf slopes for various signaling systems. This figure shows the slope of the linear regression of the log10 of the frequency of occurrence distribution of a signaling system against the log10 of the rank order (1st, 2nd, 3rd, etc. most frequent). We indicate a region around the values of the regression slope = -1 (dotted horizontal lines) where the Zipf relation may be indicative of a signaling system with potential significant communicative complexity. We point out that this diagram is indicative of what may be achieved but that, to some extent, we may be comparing "apples with oranges" in this diagram, since the sense, use, and meaning of the signals therein classified are unknown for most non-human species. Credit: Figure after L.R Doyle et al. / Acta Astronautica 68 (2011) 406–417.

We also found that bottlenose dolphin communication follows a Zipf's Law distribution of signals. On the other hand, human babies do not follow a Zipf's Law distribution to their signals and, interestingly, baby bottlenose dolphins also do not follow a Zipf's Law distribution, rather they follow the same distribution that human babies follow. In other words, baby bottlenose dolphins "babble" their whistle language. By the time they are 2 years old, they have acquired the -1 slope adult language and start to whistle like adults.

We have also applied Zipf's Law to stellar sources such as pulsars, and their signals do not obey Zipf's Law. We have then gone on to apply Shannon Information Entropy to humpback whales, and we discovered that they have enough "syntax" to recover mutual communications that have lost up to 40% of their signal content (in this case due to boat noise). This defines their language as intelligent communication, one that has many "rules" interconnecting the signals of various types, thereby maximizing error recovery.

Thus, looking upward, this gives us a very simple first tool (of several more we have developed) that can be used to distinguish a set of signals that may be received from an extraterrestrial source as to whether it is a message of a complex communication system or not. For an ETI signal, we would be measuring the degree of communication complexity. Such algorithms may be used to broaden the search for extraterrestrial intelligence (SETI) by supplying mathematical tools of information theory, tested upon terrestrial non-human communication systems, to examine the message content with a sort-of "intelligence filter," whereas, to date, only the narrow-band carrier signal has been examined.

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