Warblers in the Tower of Babel

Songbirds have been found to have language skills so far seen only in humans, says
s ananthanarayanan

HUMAN communication, through speech, is a class apart from forms seen elsewhere in nature. Ants and bees are known to communicate, as are schools of fish and birds in flight. Animals, the dolphin, the whale use sounds, but the evidence is only of those used as signals, not as an intelligible combination of sounds in the sense of a language. Kentaro Abe and Kai Watanabe of Kyoto University in Japan report in the journal, *Nature*, that the *Bengalese Finch* has the ability to distinguish syntactical variations in birdsong. Such distinction, of the ordering of components of the sounds, amounts to a form of grammar and is different from the use of sounds as mating calls or to announce the discovery of food or warning of danger.

Grammar is the set of rules that govern the formation of phrases in a language. Basic similarities in the structure of most languages have raised two kinds of theories – one, that all languages have a common origin; and the other that grammar is something that is wired into the brain and the human species would develop languages that follow a basic and in-built "Universal Grammar". One feature of UG is the distinction in all languages between verbs and nouns and then some patterns in how they are placed. But features such as these are at a "higher" level of language, which presuppose reference to things and actions in communication.

Of course, even reference to *danger*, leading to a form of behaviour may involve the use of nouns and verbs, but UG, if there is one, may be more basic than even this. Forms of computer languages, which have *variables* and *functions* also provide examples of grammar while enabling the computer to understand how values are to be manipulated.

But a distinguishing feature of humans that they have well developed languages, with a grammar that is acquired very early in the life of an individual, which enables him/her to form nearly infinite kinds of sentences with a limited set of words. At the core of this ability is the adherence to the rules of grammar and the ability to recognise at once a violation of the rule or to fill in words or phrases, where needed, for the grammar to be right.

How the human child acquires this *rule of wide application*, from exposure to the language for just two or three years, has been a question and subject of research. It has been found that once a language is learnt,
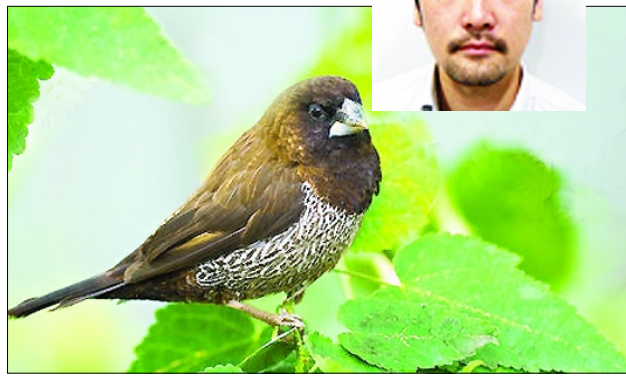
A study by Kentaro Abe (top, inset) and colleagues at Kyoto University has determined that the Bengalese Finch has the ability to distinguish syntactical variations in birdsong. Such distinction, of the ordering of components of the sounds, amounts to a form of grammar.

there are specific portions of the brain that get activated if the person hears a syntactical anomaly and it is believed that some of these regions in the brain would be involved in working out which sentences are not grammatically correct. There may even be a system of a phrases being passed through these regions for "vetting" before a sentence is formed, in ordinary composition. But as evidence of such discrimination is found only in humans, there has been little scope for detailed laboratory study using animal models.

Songbirds

A promising area is the case of birdsong, which has language-like features of sounds of different pitch placed in succession or, alternately, interspersed with periods of no sound, etc. Specific songbirds, particularly the *Finch*, have been extensively studied and it is found that they have defined forms of song peculiar to groups of birds that roost together and it has been shown that birdsong is learnt by fledglings, usually from an older male songster. Birds raised in isolated groups also speedily acquire the songs of the larger group once they are exposed.

It is of interest that some species of songbirds, including the Bengalese Finch which the Tokyo scientists studied, have songs of a syntactically complex structure, the

when the song had been played 200 times, there was no longer an increase in the number of call responses, indicating "habituation". Even if the song was now replaced with a recording of one of the birds' own songs, there was no increase in the number of response calls. But if the song was replaced with a new one from others of the same species, the rising numbers of response calls started, till there was habituation. The conclusion is clearly that habituation is song specific and this can be a tool to examine the birds' ability to recognise changes in songs played to them.

This analysis with Bengalese Finches was done using first a real birdsong and then the birdsong again, with the sequence of the tones or "syllables" changing but keeping the number and composition of the syllables the same. Birds were first exposed to a particular song so that it had become "habituated". Then, in the test, the birds were subjected to the habituated song for five minutes, immediately followed by the "sequence modified" song for five minutes. The difference in the call response numbers in the two five-minute periods was an indicator of whether the change in the song had been noticed. The test was done with the same version of the original song and the sequence modified song with 17 male and 17 female subjects and the result was that there was a significant increase in the call response numbers.

It was thus found that Bengalese Finches could identify subtle changes in the sequence of tones making up the songs. However, not all modifications of the sequence could be identified. What is more, the sequence changes that could be detected and those that could not were the same in all the birds, including those raised in the experimenters' aviary and those obtained from a bird supplier.

The study was then continued, to identify the changes in the sequences that caused the difference. It was found that novel syllable sequence, rather than a particular linear sequence, were what caused the distinction. The sequences of tones were then engineered to present a variety of "non-adjacent dependencies", to mimic grammar rules and tests showed that Bengalese Finches could positively internalise the rules and respond when new sequences followed the rules or violated them.

Changes in brain

These well-defined features of pattern recognition by the Finch make it possible to look at changes in the bird's brain when those familiarised with a syntax rule were exposed to sequences that broke the rule. It has been found that the portion that gives the song recognition ability is one called the "frontal nidopallium". This agrees with earlier findings that injuring this portion of the brain affects song recognition in Canaries and the Zebra Finch as well. The findings also parallel what is known of the parts of the human brain, where damage results in selective language impairment. These findings thus provide an animal model for carrying out studies that cannot be done on human subjects.

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sequences of notes and pauses being variable, but still not random – which indicates a level of organisation that is similar to the structure of human language. But the question is, do songbirds recognise and distinguish specific variations of birdsong? Is there any *computational* ability?

There has been a record for some time that the *European Starling* can be trained to distinguish between different sequences built out of two tones. For instance, if the tones are A and B, then the starling can tell the difference between the sequence "AB AABB AAABBB…" and the sequence "AB, ABAB, ABABAB…" The Tokyo scientists collected more data of such ability in the case of the Bengalese Finch, using more complex tone sequences, more subtle differences to be distinguished. The sequences were developed according to a syntactic rule and the ability to detect a deviation from the rule was investigated.

The method used was a habituation / dehabituation procedure. Birds were kept in soundproof cages and exposed to specific birdsong of the same species, though a speaker. The birds responded with a short vocalisation, or call, when they heard birdsong. During the first few minutes of playing passages of song, the birds responded every time the song was played, with increasing numbers of call responses. But

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STUDIES of genes in the X chromosome of *Drosophila* have shown that they are arranged in a linear order, each gene having a fixed position along the length of the chromosome. A gene's allele occupies a corresponding position in a homologous chromosome. Such a postulate arose out of the observation that a) the many genes in *D. melanogaster* could be divided into four, and only four linkage groups corresponding to the four haploid chromosomes, and b) the evidence that linkage with respect to two pairs of genes, when incomplete, was incomplete in a characteristic frequency that could be interpreted as a function of the constant spatial relationship between linked genes. AH Sturtevant devised a test whereby the position and linear order of a third gene could be determined with reference to two other genes on the same chromosome. Because three genes are used simultaneously, the test has become known as a three-point cross.

If it is assumed that the correct serial order of three hypothetical genes is *abc* and that the distances between the genes are reflected in the frequencies with which crossing over takes place between them, then a test cross of the heterozygote + + +/*a b c* to the triple recessive *abc/abc* can yield a certain pattern of possible phenotypes.

Again if it is assumed that crossing over occurs, the non-crossover group would be the largest in number. A region of a single crossover would arise from a chromatid exchange in the region between genes *a* and *b* and another region single crossovers from an exchange in the region between genes *b* and *c*.

The frequencies of the two types of single crossovers will, in general, depend upon the linear distance between *a* and *b* and *b* and *c*. The double-crossover group will contain the smallest number of individuals. This results from the fact that the occurrence of a crossover between any two genes is a statistical function of distance. The simultaneous occurrence of crossovers in two adjacent regions would thus be the product of the individual single-crossover probabilities and would, therefore, be considerably less than either alone.

An experiment carried out in maize will illustrate actual use of the three point cross. The genes brown midrib (*bm*), red aleurone (*pr*) and virescent seedling (*v*) are located in chromosome 5 and the data obtained from linkage studies are as follows:

$$\text{Parents}\quad \frac{+\ \ +\ \ +}{+\ \ +\ \ +} \times \frac{bm\ \ pr\ \ v}{bm\ \ pr\ \ v}$$

$$F_1\quad \frac{+\ \ +\ \ +}{bm\ \ pr\ \ v}$$

$$\text{Test-cross}\quad F_1 \times \frac{bm\ \ pr\ \ v}{bm\ \ pr\ \ v}$$

Test-cross progeny:

+ + +	232	Noncrossovers = 42.1 per cent	Parentals
bm pr v	235		
+ pr v	84	Single crossovers between	
bm + +	77	bm and pr = 14.5 per cent	
+ + v	201	Single crossovers between	
bm pr +	194	pr and v = 35.6 per cent	Recombinants
+ pr +	40	Double crossovers between	
bm + v	46	bm and pr, and pr and v = 7.8 per cent	
	1,109		

From the above groupings, each composed of equally occurring complementary types, certain facts are readily deduced. The non-crossover types, of course, are those that preserve the original parental gene groupings; the least frequent groups have the lowest probability of occurrence and represent the double crossovers. This group also provides information as to the linear order of the genes. With respect to *bm* and *v*, the gene *pr* has shifted positions with its allele and is, therefore, between 6m and *v*. The order of the three genes is *bm pr v*. The two remaining classes constitute the single-crossover types, one class representing the crossovers taking place between *bm* and *pr* and the other those between *pr* and *v*.

In calculating the genetic distance between two genes, *all* crossovers (single and double) that have occurred in a particular region must be taken into consideration to construct an accurate representation of the genetic map from crossover data. The map distance between *bm* and *pr*, then, is not 14.5, but 14.5 plus 7.8, or 22.3. Similarly, the total crossover frequency for the *pr-v* region is 35.6 + 7.8, or 43.4. The total distance from *bm* to *v* would be 65.7, because units of the map can be successively added to indicate genetic distance. So, except for very short regions in which double crossing over is rare, the map distance is greater than appears from the single-crossover frequency.

Through the accumulation of genetic data on the frequencies of crossing over, it has been possible to construct genetic, or chromosome, maps in which the serial order of the genes and their genetic spacing have been accurately determined. In addition to a mutant name and an abbreviated symbol, each gene, or locus, is designated by a number, which is obtained by summing up the crossover values for all known intervals to its "left".

Only those regions of the chromosomes that possess detectable mutant genes can be mapped. It has also been found, as a general rule, that the shorter the map distance between two genes, the more accurately can they be located. The reason for this lies in the fact that when two genes are more than 10 to 20 map units apart, double crossovers can occur and these result in a spuriously low frequency if they are not taken into account. A more accurate genetic map can be made, therefore, by the addition of successive short intervals than by utilising intervals between genes that are widely separated on the chromosome.

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A haul of exoplanets

Originally scheduled to end in mid-2009, the Corot mission has been extended to 2013 and is sending back a mine of information, writes binay malakar

ASTRONOMERS across the world have detected more than 550 "extrasolar planets" – those around other stars than our sun — since the hunt began in earnest around 20 years ago. These are more diverse in character than anyone can imagine; while some need years to circle their stars, others do it in less than a day. They come in all sizes, from gaseous giants twice as large as Jupiter to small planets comparable to earth and everything in between.

Led by the French Space Agency's Centre National Detudes Spatiales, in conjunction with the European Space Agency, Australia, Belgium, Germany, Spain and Brazil, the Corot mission involves a 27-cm space telescope that searches for exoplanets with the so-called transit method that actually measures the tiny decrease in the brightness when an object passes in front of a star. Corot has already detected 25 extrasolar planets and has identified another 400 possible candidates that are in the process of being confirmed. To determine whether these are actually extrasolar planets, the Corot team uses ground-based telescopes around the world for follow-up observations.

The mission's two objectives are to search for extrasolar planets with short orbital periods, particularly those of a large terrestrial size, and to perform asteroseismology by measuring solar-like oscillations in a star. It was launched on 27 December 2006 and subsequently reported first light on 18 January 2007. It detected its first estrasolar planet, Corot 1b, in May 2007. The mission was originally scheduled to end two and a half years from launch but apparently flight operations were extended to January 2010 and then to 2013.

Into its fifth year of operations, Corot has detected hundreds of candidate planets, many of which are subjects of ongoing studies to pin down their true nature, and 15 confirmed planets across the full size range. The 10 new exoplanets discovered (the announcement of which was made recently) are Corot 16b through to 24b and c. The inventory includes seven "hot Jupiters", some of which are unusually dense and/or on unusually elongated orbits. There is much to be learnt from these recently discovered systems about the way giant planets form and evolve, a planet smaller than Saturn

(Corot 22b) and a system of two Neptune-like planets (Corot 24b and 24c) orbiting the same star. The densities of these planets, which are all gaseous, span a wide range, from values similar to that of Saturn, the least dense planet in the solar system, to higher values comparable to the density of Mars. Ever since the early days of exoplanet astronomy, different kinds of planets have been

COROT SATELLITE
① Camera & electronics
② Baffle
③ Telescope
④ Proteus platform
⑤ Solar panels
Source: CNES

An international team, including Oxford University scientists, has discovered 10 new planets. Amongst these is one orbiting a star perhaps only a few tens of million years old, twin Neptune-sized planets, and a rare Saturn-like world.

discovered: gaseous giants larger than Jupiter and smaller, rocky bodies, down to masses comparable to earth's. The new set of 10 planets exhibit a rich list of very interesting properties.

When the hunt for planets around stars other than our Sun began, achieving detection was the primary goal. After almost two decades of research, great technical progress, and the discovery of several hundred exoplanets, the focus has now shifted to a more analytical approach. Astronomers exploit the joint power of space-based facilities, such as Corot, and high quality data from the ground in order to pin down the characteristics of a large number of planets. With this data at hand, it is possible to tackle fundamental questions concerning how exoplanets form and what kind of objects emerge from the various formation scenarios. The new results announced on 14 June this year at the second Corot symposium in Marseille, France, highlighted, once again, the diversity of properties observed within the "zoo" of exoplanets.

The host stars also exhibit rather mixed properties, ranging from a 10,000-million-year-old – twice as old as our sun – in

the case of Corot 17b, to a rather young (about 600 million years old) counterpart in the case of Corot 18b: its mass is 3.47 times that of Jupiter's, time period is 1.9007 days, radius is 1.31 times Jupiter's and eccentricity is 0.08. Observing a planetary system with such different ages is particularly useful when testing different scenarios of formation and evolution.
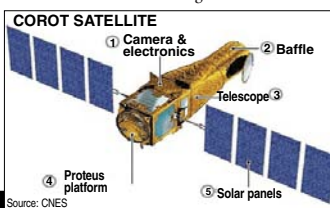
Two of the planets (Corot 16b and Corot 20b) lie on highly elongated orbits and explaining their survival represents a challenge from the dynamical point of view. The double system of Neptune-like bodies is rather peculiar, and it will be monitored in the future to determine if it harbours other planets as well.

Although the study of exoplanets is relatively new, there is a lot of data by which one can characterise the details of worlds orbiting other stars and Corot in particular is making a crucial contribution. To understand the conditions in which planets form, one needs to catch them within the first few hundred million years. After that, memory of the initial conditions is essentially lost. In the case of Corot 18b, different ways of determining age give different results, but it is possible that the star might be only a few tens of millions years old. If this is confirmed, we could learn a lot about the formation and early evolution of hot gas giants by comparing the size of Corot 18b to predictions of theoretical models.

Another system of particular interest is Corot 24, which is around 4,400 light years from us and consists of a star just a little smaller than our sun, orbited by two transiting planets. The first of these planets is three times larger than earth and takes 11.8 days to complete an orbit. So these planets are similar to Neptune in size but much hotter.

Corot 22b is a rare example of a planet similar in size to Saturn. Located around 2,000 light years from us, it takes about 10 days to orbit its star, which is slightly hotter than our sun. So far data about the upper limit on its mass is available, which is enough to determine that its density is not much more than that of Jupiter, which means it has a predominantly gaseous composition, although it could contain significant quantities of rock and ice.

Once Corot detects a transit, additional observations are made from the ground using a number of telescopes all over the world. Although astronomers cannot see the planets directly, they use space- and ground-based data to measure their sizes, masses and orbits precisely. That is why, among all known exoplanets, those with transits yield the most complete information about formation and evolution.

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