Cognition and its Computation
Prof. Rajlakshmi Guha
Prof. Sharba Bandyopadhyay
Biotechnology and Bioengineering
Indian Institute of Technology, Kharagpur

Lecture - 49
Lessons from Animal Communication

Hello. So, we have been discussing about speech and language. You have learned about speech production and speech perception and you have also learned about language acquisition in the very beginning. And, throughout we have said that animal models can play a big role in terms of our basic understanding of speech and language.

Although, we have always said that speech and language is a uniquely human capability which is very true in the sense that the possible number of ways we can communicate with speech is infinite. So, we can create infinite number of sentences and describe any new possible kind of phenomena or situation or feeling or anything to another person through speech.

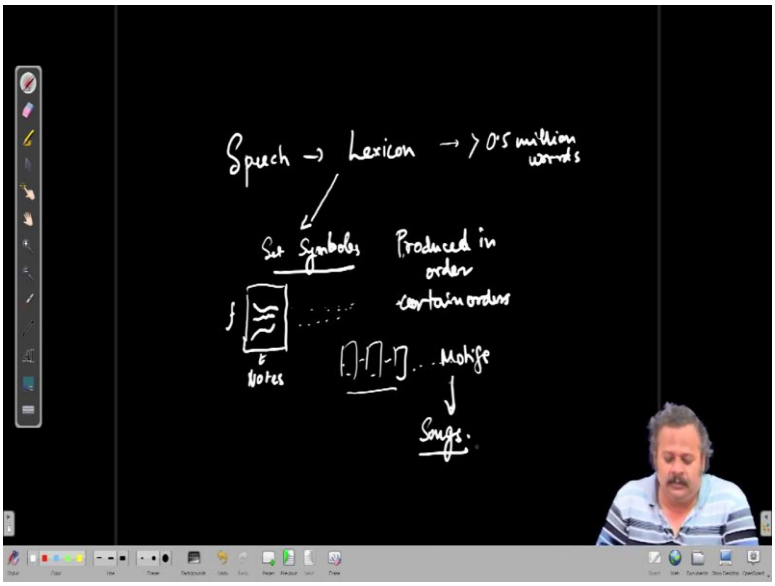
But, animals on the other hand have a very small repertoire of communication symbols or sounds, and also the usage of those sound symbols are actually limited to a very few specific kinds of situations. We talked about the example of the honeybee last time and also about rodents and primates and song birds for their courtship and meeting behavior, meet selection and so on.

So, although limited to that particular kind of situations where the vocalizations of the other species are used to communicate, since they are rudimentary forms of communication, although nowhere close to humans they can form a basis for investigating how those forms of communication develop and are achieved and how to what extent are they similar to humans.

And, based on that we can actually design studies for disorders in communication and in those particular types of particular species and investigate the mechanisms at the neural level that are involved in producing the kind of disability. And, hence that will allow us to understand ways to circumvent them and actually revert those such disabilities or bring cures about such disabilities if possible.

So, it may sound like a stretch that bird song is akin to human speech, of course, it I mean some of us may be even laughing at this sentence which is actually fine. But, if we think of some of the important features of speech, that is apart from the huge repertoire that.

(Refer Slide Time: 03:52)



So, speech actually has lexicon or the dictionary which is huge. So, our in English we have probably more than half a million words with many that have similar meanings and most that are unique and many that are unique also and of opposite meanings and so on with different kind of relations in the meanings. And, we have a very well specified grammar for us to understand sentences and form sentences.

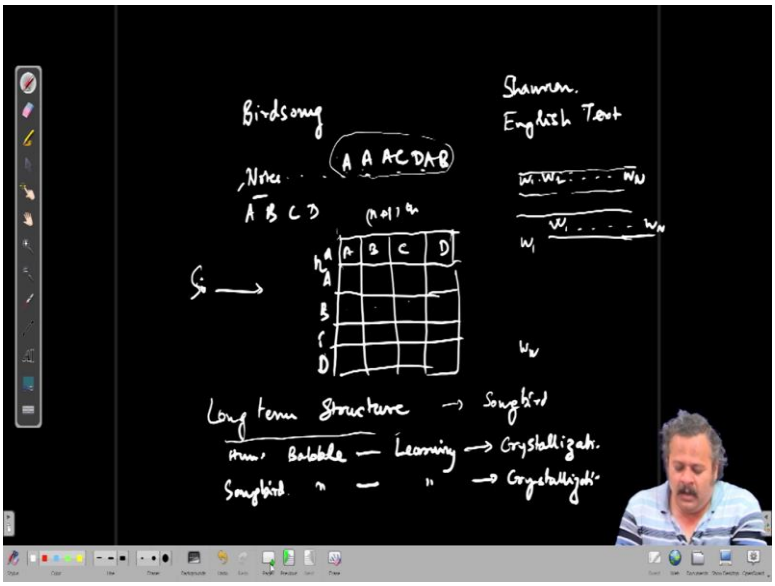
The similarly in the song bird the there is a sort of set of symbols which are quite complicated, set of symbols. So, what we mean here set of symbols is basically spectrographic component. So, if we take those symbols, those utterances by the bird that are separate as units, we call them nodes in the song bird.

And so, if I this is time and this is frequency representation as we have done for speech, we can have a similar kind of representation where the white lines depict where high energies are and the black regions have low or no energy. So, there are different kinds of nodes with very complicated structure of the energy variation as a function of frequency and time as I have shown in this one particular note. And so, there are a large number; obviously, not even cannot even be compared to the size of the human lexicon.

And, now these large number of nodes when produced are actually produced in order by song birds, only in certain orders that too. So, this shows that actually the there is dependency among the types of nodes that are present and these set of nodes together form syllables in the song bird, the symbols then form together form motifs and syllables then for motives and then the motives form songs.

And, there are only a few types of songs or a limited repertoire of songs that are present in the song bird in each kind of song bird. But, the type of symbols that are used, they are large and they can be combined to form many different songs. The interesting thing is the birds produce learn this song much like humans from their tutor or a con specific that is an adult which keeps on producing the songs for this is used for courtship. And, the baby birds learn from that adult con specific in their nest which is usually the father.

(Refer Slide Time: 07:54)



So, birds bird song has a particular structure saying that if we take up the notes and ordered them, then not every order is possible. Let us say it is A B C D are the four notes, then we find that it is A A A C D A B kind of thing that is being produced let us say for example, which means if I take the all possible songs that are produced, we will and they follow similar trends.

Then, if we look at how one particular symbol follows another particular symbol, we may find that there is a higher probability of a particular symbol being produced after another symbol. So, if the nth symbol in a song and n plus 1th symbol in our song of the

song bird are combined to find out whether A is followed by B A A or B or C or D, A B C D or B is followed by A B C or D.

Then, we have this matrix which can be called the transition matrix or the not like a Markov chain transition matrix, but matrix that tells us what is the probability of observing B followed by B or A followed by A or D followed by C and so on. And, it is found that in the song bird these matrices have typical structures, that is actually also true in rodent calls, rodent vocalizations and also in prime non-human primate vocalizations.

And, but the unique thing about the song bird is that they are they actually learn the sequence from the father. And, they may be made to learn other sequences and they can be taught to discriminate certain grammars, which is the unique thing about birds. So, if we look at human speech, what Shannon had shown early on is that if we take English text and take all the possible and he actually took a large set of sentences of human speech and from books, basically text.

And so, they are words followed by word 1, word 2 up to word capital N. And so, let us say the these capital N words are the lexicon, then we can have a similar transition matrix for word 1 to word N, that is what is followed by what in what probabilities. And, what Shannon showed is that as we go along a sentence, the entropy or the variability or the uncertainty of the word that comes at the second position or third position or fourth position gradually decreases, which means that there is an inherent structure or dependence of on average of the possible words that follow other words.

So, if we think of these uncertainties as in a quantitative manner, the weight is quantified by something called entropy which can be taken up in a computational neuroscience course. In the reading material, you will be given a brief understanding of entropy, so, that entropy reduces.

So, and if we look at the song bird and rodent calls and even non-human primate call sequences, this entropy reduces showing that there is dependence in successive nodes that are produced. So, of course, that does not mean it is language, but that also means that that kind of ordered sequence is they are capable of producing the ordered sequence.

And, now if in a disease model which have a particular disease that is being replicated in the animal model then, we can actually now see if such structure is changing or not in

that model and if it is equivalent to what is happening in the humans in this rudimentary sense, then we can get pointers for identifying the neural mechanisms involved in these disorders.

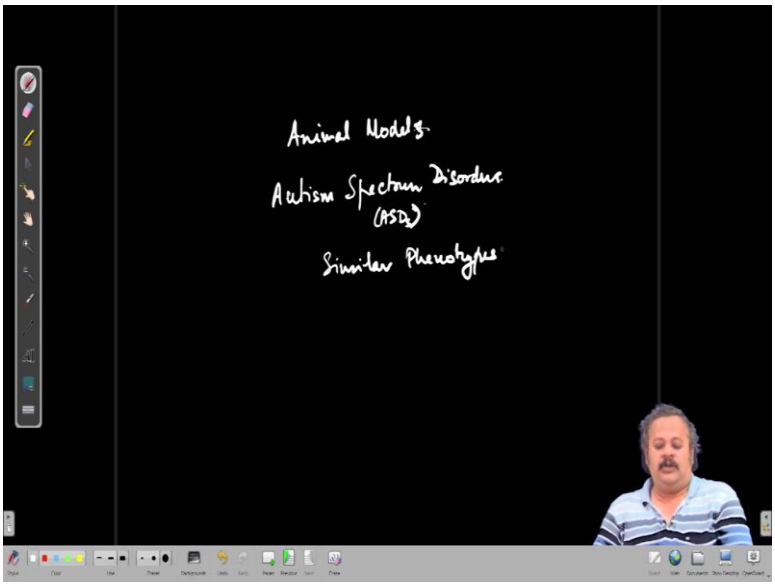
So, the next idea here is that while there is structures shown by Shannon in English text, there is also, this these are studies done later, there is also very long term structure or long term correlations in speech and that long terms correlation is also present in baby babbles.

And, interestingly this long-term structure is present in song bird and also a babbling period that song birds also have before they start to produce the version of the song they are learning from the adult in the nest. And so, just like there is long term structure or long-term dependence is present in babble and that there is the fact that there is babble in human as well as song bird preceding the learning phase. So, this phase is the learning phase when it starts to imitate the parents and others around.

And, in the song bird case it is only the father in the nest or the adult in the nest male adult in the nest and then there is crystallization of words and there is crystallization of songs in the song bird. So, there are certainly a very clear parallels of learnability and stages of development in speech and language in humans as there is even though at a rudimentary level in the song bird.

So, the song bird can serve and has actually served as an important model to understand the neural mechanisms in behind production of speech.

(Refer Slide Time: 15:45)



That is why animal models serve an important role in terms of understanding the neural mechanisms behind speech and language. And, in later years in the recent past, more recent past because the song bird is not a mammal, the focus really shifts towards mammalian models. And, that is why people are looking into the same kind of features in mice or rodents and even in the non-human primates.

So, we already know that from many models of autism spectrum disorders which is a commune which has part of it is communication disorder. So, in ASDs model in the different species like in mice or non-human primate, there is a distinct change in the set of vocalizations that are produced how much vocalization that is produced. So, there are evidence that is point there is evidence that is pointing to the fact that we can have a similar kind of phenotypes of the disorders in animal models of this disease.

And so, given the parallels of learnability and the stages of development, although the song bird is important we still do not have parallels in a mammalian system about the learnability. And, also more of the structure learning, being able to separate structure, differentiate structure as birds can do which we still do not have evidence in mammal, mammals other than humans.

So, it becomes important to understand many other aspects of speech or language in the animal models also. So, with this we will conclude the lectures on the use of animal

models or what we can learn from animal models for about speech and language. And, in the next lecture, we will take up disorders in speech and language.

Thank you.