Introduction to Brain & Behaviour
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Measuring Structure and Function Together in the Brain
Lecture 10

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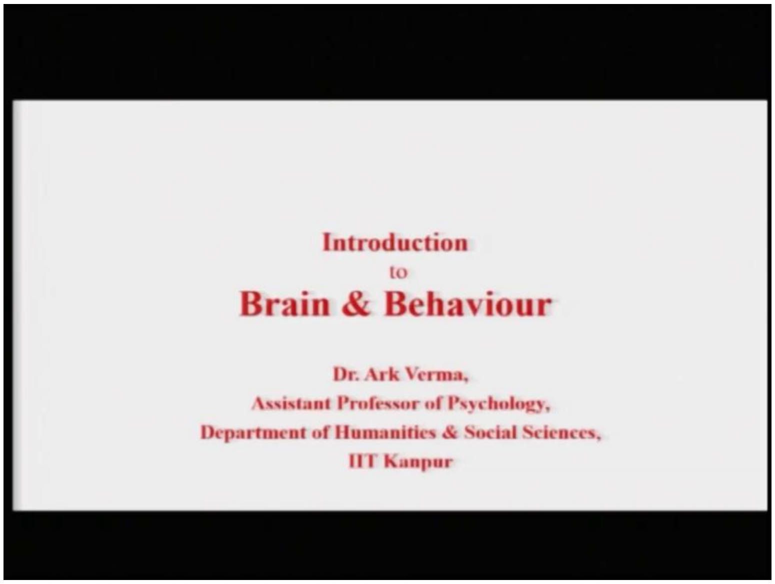

Hello, and welcome to the course, Introduction to Brain & Behavior. I am Dr. Ark Verma from IIT Kanpur. As you know, I work at the Department of Humanities Social Sciences and also at the Interdisciplinary Program for Cognitive Sciences. This is the second week and we have been talking about certain methods to measure the structure and the functioning of the brain. Till now, we have talked about methods that measured the structure or the function.

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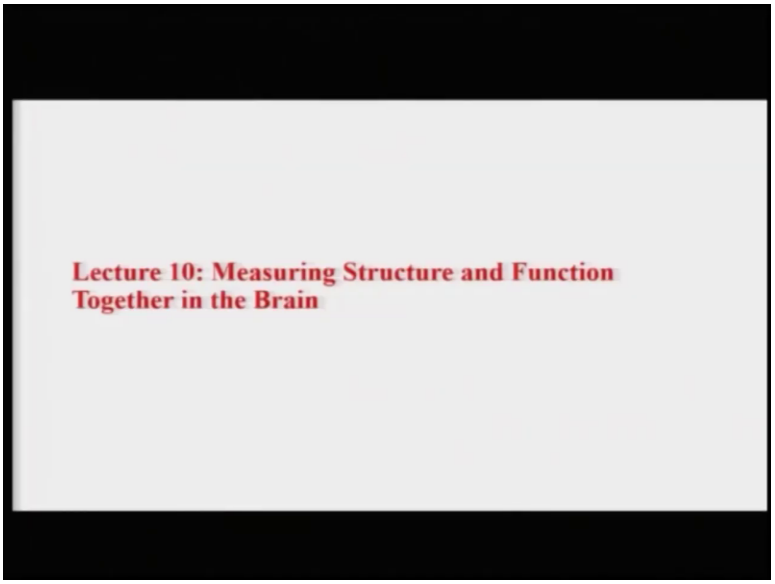

In today's lecture, we kind of try to look at a couple of methods which combine the structure and function measurements of a normal brain.

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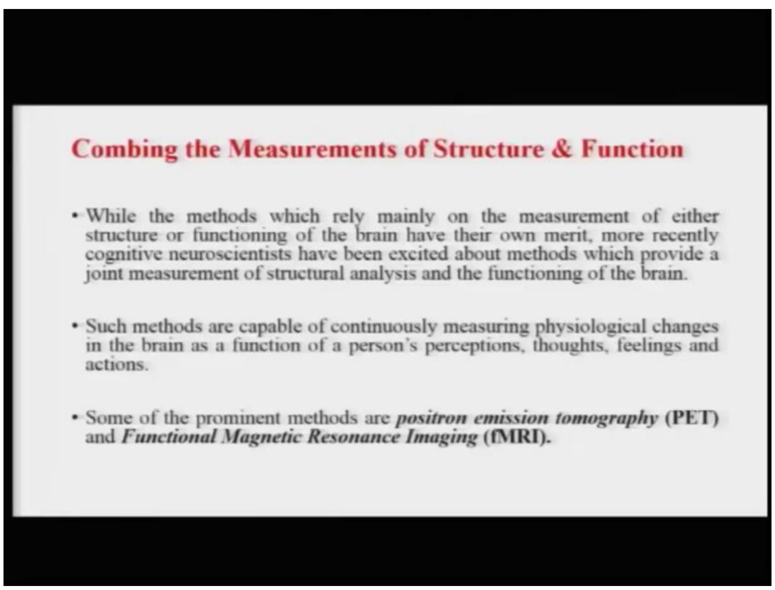

Now, while the methods that rely mainly on the measurement of either the structure of the brain or the functioning of the brain, like say, for example, the CAT scans or the MRIs, versus the EEGs and the MEGs, both of these kind of methods have their own merit and they reveal obviously, invaluable information. But more recently, cognitive neuroscientists have been excited about methods that provide a joint measurement of the structural analysis of the functioning human brain.

So basically, we are talking about knowing exactly what areas of the brain are involved in what cognitive functions or what areas of the brain are triggered or giving a response to particular stimulus presentation, or particular experimental manipulations that the researcher might be carrying out. So that is a very, very, interesting and a fascinating insight into the functioning brain that a neuroscientist, neurologist, psychologists for that matter have really been looking forward to.

Such methods are capable of continuously measuring physiological changes in the brain as a person's perceptions, thoughts, feelings and actions vary with respect to the stimulation that is provided. Some of these prominent methods are the positron emission tomography method, which is the PET and the functional magnetic and resonance imaging method, which is called the fMRI.

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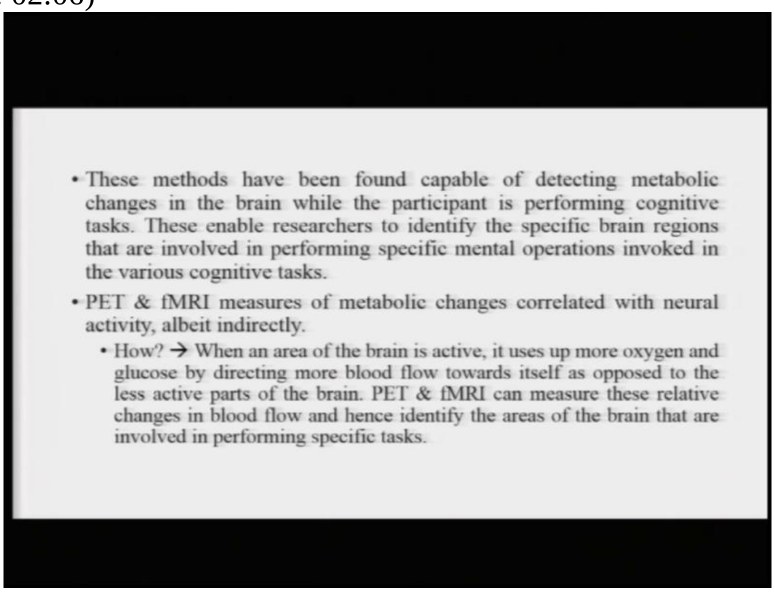

Now, these methods have been found capable of detecting metabolic changes in the brain while the participant is actually performing these cognitive tasks. These changes enable the researchers to identify specific brain regions that are involved in performing specific mental operations invoked in the various cognitive tasks that you ask him to do. The PET and fMRI measures of metabolic changes are then correlated with neural activity albeit in a slightly indirect method.

Now how do you do that? When an area of brain is active, it uses up more of the oxygen and glucose by directing more blood flow towards itself, as opposed to the less active parts of the brain. Both PET and fMRI can measure these relative changes in blood flow, and hence, be able to identify the areas of the brain that are involved in performing these task. Let us talk about the positron emission tomography or the PET method.

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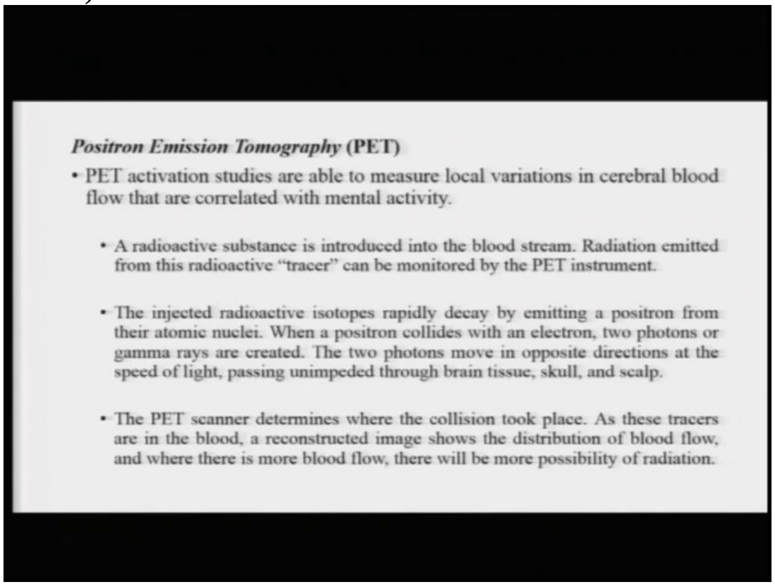

The PET activation studies have been able to measure local variations in cerebral blood flow that are correlated with mental activity. What happens here is that a reduced active substance is introduced into the bloodstream by an injection. The radiation emitted from this radioactive tracer can then be monitored by the PET instrument. Now what happens is that this injected radioactive isotope rapidly decays by emitting a positron from their atomic nuclei.

When a positron collides with an electron, two photons, or gamma rays are created, which move in the opposite direction with the speed of light, passing unimpeded through the brain tissue, skull and scalp. Now what the PET scanner does is it determines where all this collision is taking place. As these traces are in the blood, a reconstructed image of these collisions basically gives us the distribution of blood flow.

And wherever there is more blood flow, there are more possibilities of these collisions happening or more possibilities of where this radiation is coming from. So typically, when a person is doing a particular task and the areas of the brain which are involved in those tasks will receive more blood flow, hence the tracer will be able to travel there. And when the image is being drawn on the basis of these traces, it basically gives you the image of areas that are involved in doing these tasks.

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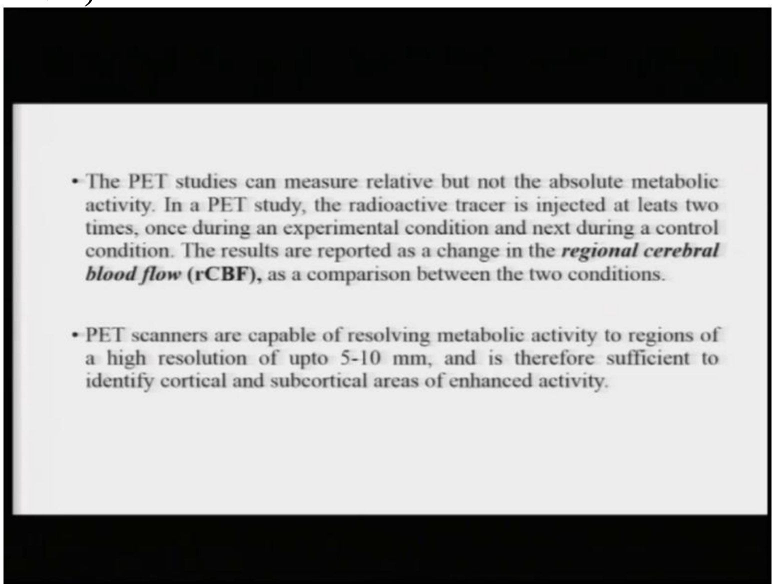

Therefore, the PET studies can measure relative but not the absolute metabolic activities. In a PET study, typically, this radioactive tracer has to be injected at least two times, once during an experimental condition, so that you know which areas were invoked while doing the experimental task. And once, during a control condition with which you will compare the activity of those specific tagged areas. This, the results basically or the dependent variables that are obtained from PET are basically reported as a change in the regional cerebral blood flow or rCBF, as a comparison between the experimental condition and the control condition.

PET scanners are therefore found capable of resolving metabolical activity to regions of high resolution of up to 5 to 10 millimeters and is therefore sufficient to identify cortical and subcortical areas of enhanced activity.

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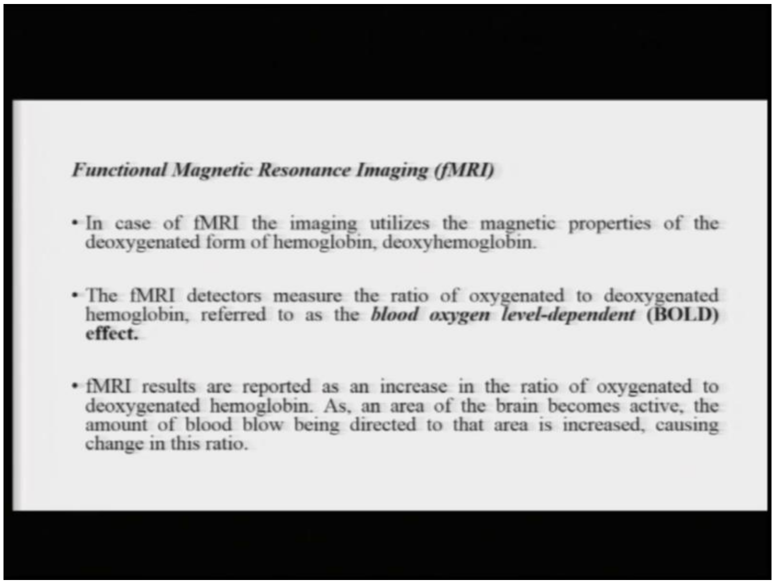

Let us talk about functional magnetic resonance imaging. In the case of fMRI, the imaging basically utilizes the properties of the deoxygenated form of hemoglobin, which is called deoxyhemoglobin. The fMRI detectors, basically what they do is that they measure the ratio of oxygenated to deoxygenated hemoglobin, which is basically measured as blood oxygen level-dependent effect or the BOLD effect. fMRI results are therefore reported as an increase in the ratio of oxygenated to deoxygenated hemoglobin.

As an area of the brain becomes active, the amount of blood flow being directed to that area is increased causing change in this ratio, which is therefore measured under the pooled effect.

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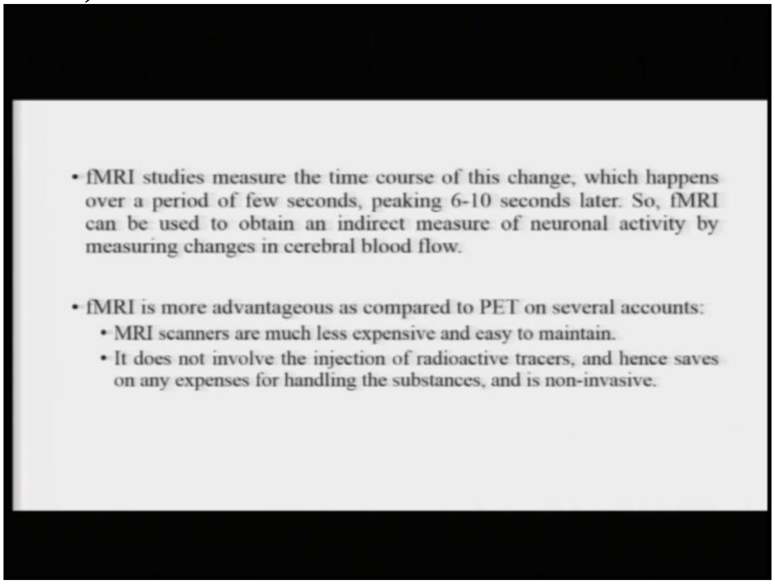

Now, fMRI studies are capable of measuring the time course of this change, which however happens very slowly over a period of few seconds, peaking up to about 6 to 10 seconds later. So, what the fMRI can be used for basically is to obtain an indirect measure of neuronal activity by measuring changes in the cerebral blood flow to that region.

So in some sense, you can say that fMRI might not really be the best method to get a very good temporal resolution of activity of the brain, but it can give you a very reliable and a good method of obtaining the spatial resolution of a neural activity in the brain. Now, fMRI is slightly more advantageous as compared to the PET method, based on a couple of accounts.

Say, for example, MRI scanners are much less expensive and much less hassle to set up, easier to maintain and also fMRI is basically, does not really involve handling radioactive substances, so that also saves a big huge chunk of the cost. Finally, a very important method which is very helpful in getting more and more participants for fMRI studies as compared to PET studies is that fMRI is a non-invasive method. It does not involve injecting anything inside your body, which a lot of participants might not be very comfortable with.

So for these reasons, as a neuroimaging method, fMRI has been more extensively used as opposed to the PET method.

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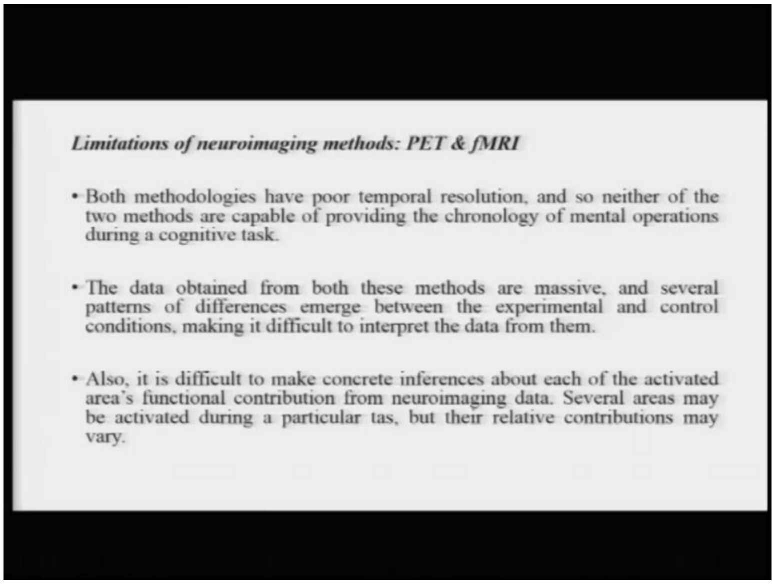

Now, we have talked a little bit about both PET and fMRI. But together, both of these methodologies have some drawbacks by themselves as well. Say, for example, both of them have a poor temporal resolution. So neither of the two methods are really capable of providing the chronology of mental operations during a cognitive task. The data that is obtained from both of these methods are massive. There is a huge amounts of data that are generated.

And when you look at huge amounts of data, there is a possibility that several patterns of differences will emerge between the control and experimental conditions, and would become really difficult for experimenters, researchers to really make sense of so many of these differences and to attach significance of interpretation to so many of these differences that are available.

Also, it is slightly difficult to make concrete inferences on the basis of each of these activated areas, because the relative contribution of each of these areas is very hard to assert. At best, the measures are correlations of a neuronal activity versus the cognitive task that is going on. So already it is not causation. So it is very, very difficult to really draw very concrete and significant claims on the basis of both PET and fMRI studies. And that could be one of the reasons why several researchers are still not very comfortable in interpreting whatever comes out of these fMRI studies.

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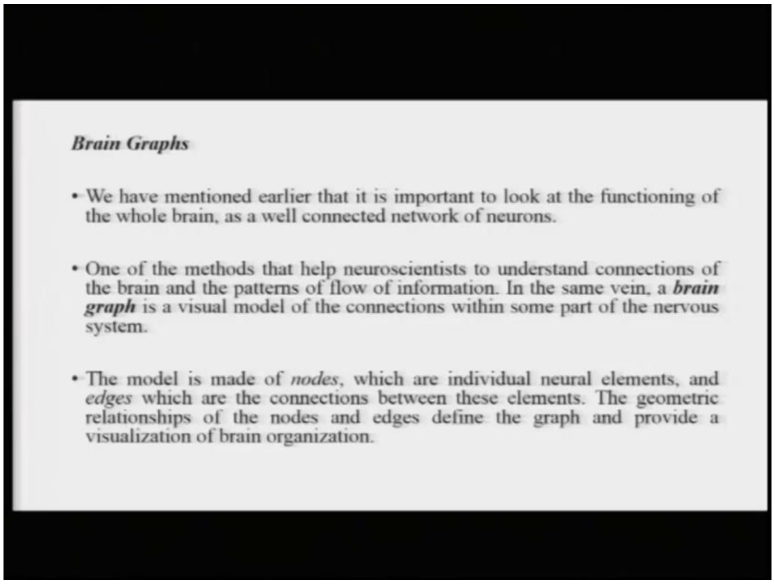

And talk of a couple of other things, or other kinds of methods that are useful. Say, for example, off late scientists have been looking at what are called brain graphs. And brain graphs are basically visualizations of the connections and patterns of connectivity of the brain. So basically, the model is made up of nodes, which are individual neural elements. We are going to talk about the mess neurons and edges which are connections between different neurons. Now, the geometric relationship between these different nodes via these edges typically define and sort of lay out the graph and provide a view of the brain organization during a particular task.

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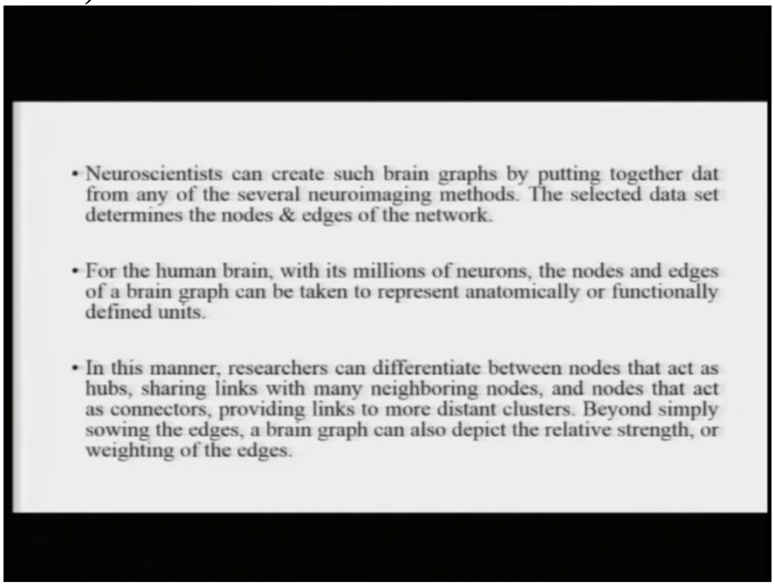

And how this is done is basically, a neuroscientist can create such a brain graph by putting together data from several neuroimaging methods, from any of the several neuroimaging methods, lots of data can be pooled in, lots of data can be pooled together. And some of these graphs can be cooped up, can be device, basically to get a visualization of which areas together were involved in doing what cognitive function.

So for the human brain, there is millions of neurons, the nodes and the edges of a bar graph can be taken to represent anatomically or functionally defined units. Say, for example, you will see in a lot of literature that we are going to come across in further chapters that there are these networks that neuroscientists have identified. So this is the supervisory attention system, this is the frontal network, this is the maybe face recognition network, word recognition network and so on. And so, a lot of those insights basically come from drawing these kinds of visualizations like the brain graphs.

Now, in this manner, basically what happens is researchers can differentiate between nodes that act as hubs, sharing links with many neighboring nodes and nodes that act as connectors providing link to many distinct clusters. So, once you sort of have a visualization of the connectivity in the brain, you can sort of see that okay, which is the area that is connected to so many other areas. And so it might be acting as a hub of relaying information.

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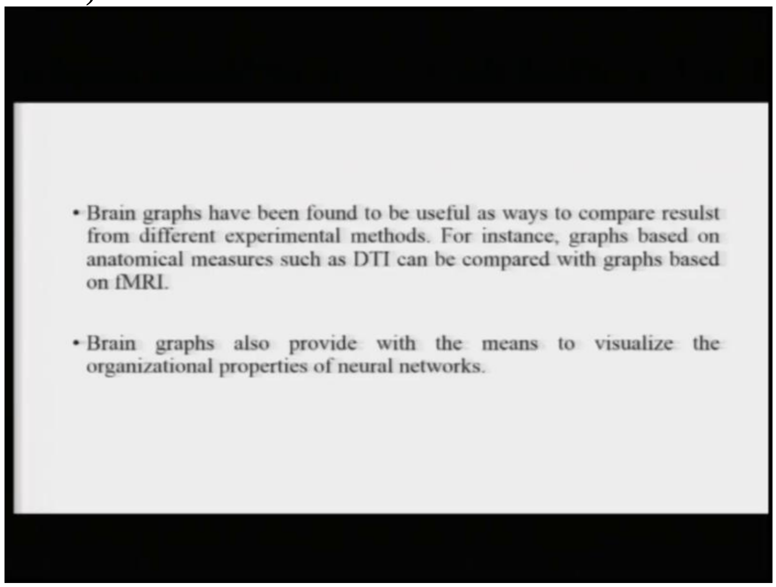

Say, for example, the thalamus projects to so many of these sensory processing areas, that is probably one of the reasons why that insight sort of has come that okay thalamus acts as relay station between information that is coming down from the down from spinal cord, midbrain etcetera, and conveys it to different areas of the cerebral cortex.

So, some of these kind of conclusions can be actually drawn from these brain graphs. Now, they have been found very useful as ways to compare the results from different experimental methods. Say, for example, graphs can be compared from anatomical measures such as DTI and fMRI. And therefore, they can sort of provide good way of putting together results or being able to make slightly broader conclusions based on the connectivity patterns that are derived from several of these methods.

Brain graphs also provide us with means to visualize the organizational properties of these neural networks, how do they change, what are the dynamic patterns of connections, what are the weightings of these neurons, which region is more important, which region is less important. All of that can be visualized using these brain graphs. One of the other and recently probably most popular methods of doing neuroscience is this aspect of doing computational modelling.

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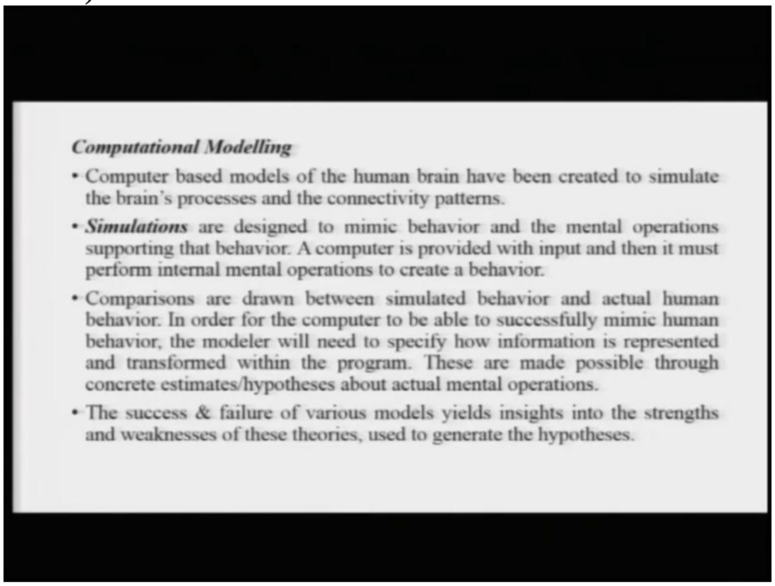

Now computational, computer models of the human brain have been created from a long time to simulate the brain's processes and its connectivity patterns. Simulations are computer programs that are designed to mimic human behavior or the behavior of the brain and the mental operations that support that behavior.

A computer is typically provided with input, and then some output is expected which should be very similar to the output that the human brain generates. Then what you can do is you can draw comparison between the simulated behavior that you seeing in this computer system and the actual behavior of the person. And by doing these comparisons, you can actually learn as to what might be happening in the actual human brain.

Now, this is very interesting because in order for these simulations to succeed or to perform anywhere closer to the actual human behavior, the computer modeler or the person who is designing these programs will actually need to specify very, very specific aspects of the functioning, all the detailed steps one by one in all its details, because only then the model will be able to produce the behavior which is anywhere similar to human behavior.

So, they will need to specify how information is represented in the brain, what are the mental operations, in what sequence do they happen and how do they kind of transform the input to reach the stage where the output can be generated. The success and the failure of various models yields basically insights into the strengths and weakness of these theories that have been used to generate the, basically what happens is that a lot of these computational models are actually derived from theories about human behavior.

Say, for example, there can be a theory that says that okay, I am going to give a theory which will decide, or which sort of estimates how the process of face recognition happens in humans. And the theory will basically say okay, these are the areas of the brain that will be connected. This is how they will process the input, in this manner, in this thing and this is how the output will be generated.

So, a computer programmer or a computational neuroscientist, as they are called, can actually build up such a model and try and see to what extent the model is replicating the output that is given by the human participant. And that in that sense, whether the model actually is capable of giving very close output or very far off separate output can kind of provide insights into whether these theories which are being built in, into these models are correct or incorrect.

So, computational modelling is therefore, a very, very interesting and a very popular method of understanding how the brain's processes might be operating, what are the connectivity patterns of the brain and how does the brain probably function.

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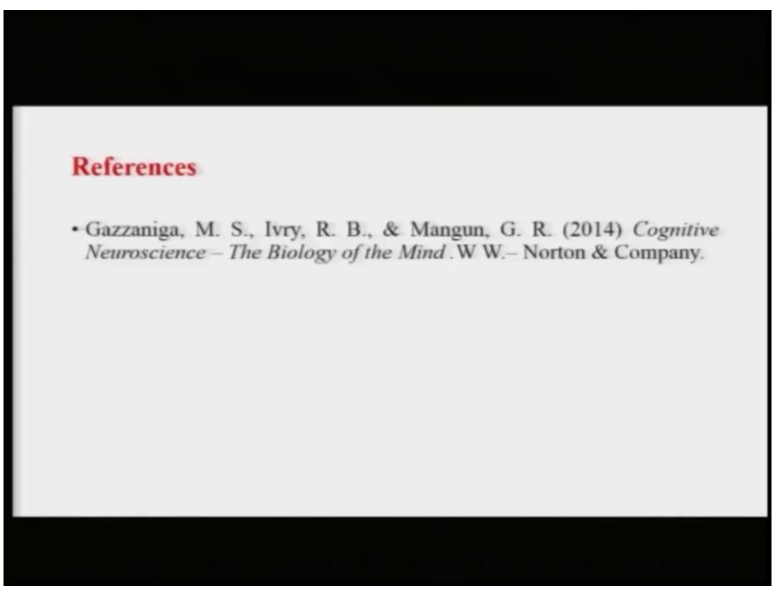

So, I think this is all from my side. We have sort of finished the chapter on methods of cognitive neuroscience. We will start with looking at specific cognitive functions and the areas of the brain from the next lecture. Thank you.