Cognition and its Computation
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Lecture - 05
Frontal Lobes Cognition

Hello, welcome. Today, we are going to talk about the Frontal Lobes and Cognition. We are going to discuss a little in details about the different areas of the frontal lobe, we will talk about the prefrontal cortex primarily, its functioning and its role in cognition.

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So, to start off with I will just show you a model of the brain and the areas where the front lobe is located. We have already discussed about this earlier in our previous class. And, as you all know that this is the cerebral cortex the uppermost layer and the outermost layer of the brain.

And, they it has a wrinkly appearance primarily because of the gyrus and the sulcus, the gyri and the sulci. And, they are divided the whole cerebral cortex is divided length ways into two cerebral hemispheres. And, the two hemispheres the right and the left hemisphere are connected to each other by the a bundle of fibres known as the Corpus callosum. And we know we already are aware that each hemisphere controls the opposite half of the body.

And this hemisphere, this these both two hemispheres they are divided on each side into four lobes. So, the lobes as you already know are; this is the frontal lobe this is the parietal lobe, this is the occipital lobe. And on both the sides here and here on both sides are the temporal lobes. Each lobe has important functions, we have discussed about the lobal functions earlier. So, today we will focus mainly on this seat of anatomy or as it is known as the seat of cognition that is the frontal lobes.

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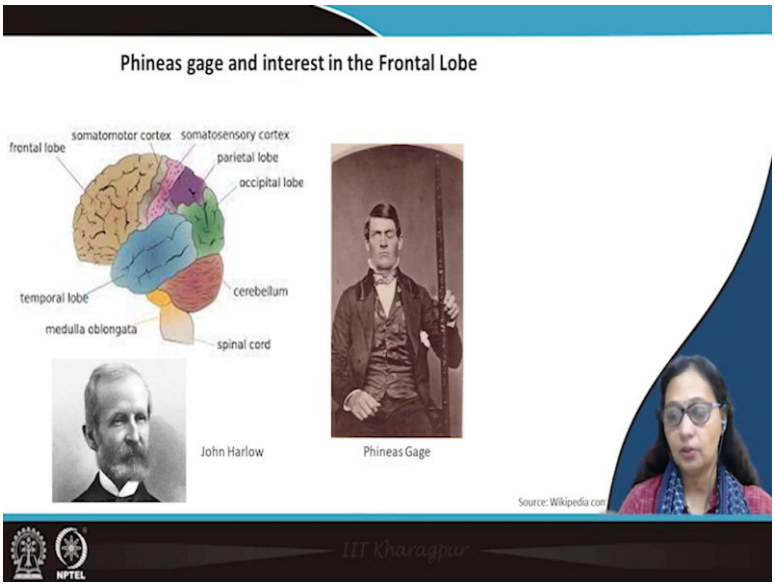

Interest in the frontal lobes had not arrived or before the last century actually it started with the incident of Phineas Gage, and what happened to Phineas Gage? Phineas Gage was a construction engineer who met with an accident while working on the railway tracks. Due to an explosion a 43 inch long 1.25 inch diameter iron tapping rod penetrated Gage's left cheek. So, if you assume that this is where the eyes are.

So, it went through the left cheek over here and tore through the brain and exited the skull from here on the right side before landing 80 feet away. So, it entered from here, and it tored away from here. Gage survived the incident and was conscious for some time. In fact, he could also recognize his colleagues and talk to them before he was taken to the hospital. And in a couple of month's time, he was back from the hospital with apparently everything normal. So, he was fit to return to work he joined back on his work.

And, when I say normal; his cognitive abilities his motor abilities none of it was affected. And so he could focus his attention he could remember people he could recognize people he there was no deficit in his language functions. So, apparently he seemed normal when he returned back to work. Of course, he had lost his left eye due to the accident, but rest of it seemed fine. Now, Harlow, John Harlow who was a speaking physician noted that he had a problem with estimating size and amount of money, but he had no problem estimating time.

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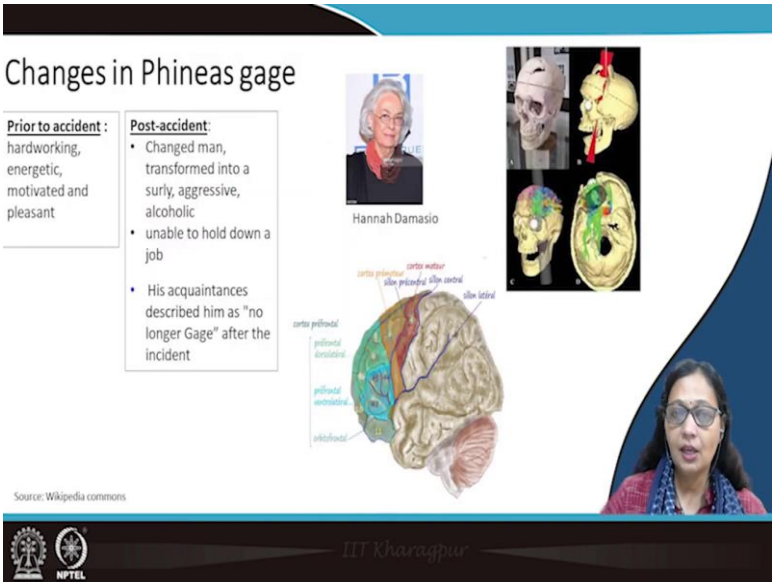

So, this is this was the only change that Harlow noticed initially. A couple of months later, when Harlow saw Phineas Gage he got a different picture of Gage as in the Gage seemed to have changed as a person over time prior to the accident, Gage was hardworking, sincere, energetic, motive, motivated and a very pleasant young man sociable young man, but after the sick accident people described him as a changed man. He had become surly aggressive, alcoholic and he was unable to hold on to a job.

He had got into gambling and relationships and his acquaintances people who had known him from before said that he was no longer Gage after the incident. After around 100 years later, in 1994, Hannah Damasio and her colleagues studied Gage's skull. Thankfully, the skull had been preserved and using modern neuroimaging techniques they tried to reconstitute the accident and the probable areas of injury in Gage's brain.

And, this study was published in science in 1994, they showed that the damage involved both the left and right prefrontal cortexes. So, this area of the brain. So, this area of the brain both these areas both on the left as well as the right prefrontal cortex seem to have been affected due to the accident. And this caused a deficit in decision making and emotional processing for Gage.

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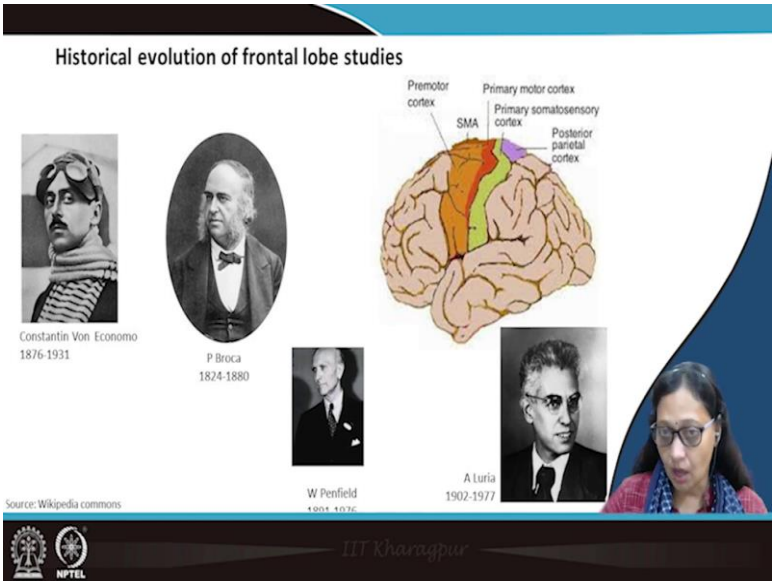

So, this implied that the frontal lobes was not a silent area as was as had been thought for the last couple of centuries, but they were involved in personality changes as well as multiple cognitive activities. So, now, looking at the historical evolution of frontal lobe studies with the development of new histological and anatomical techniques by Karl, Von Economo and Brodmann and the growth of experimental psychology, interest in the frontal lobes increased in the post renaissance.

Now, in 1861 Paul Broca we are all familiar with Paul Broca and his work in language articulation; and he pointed out Paul Broca pointed out that the frontal lobe of the brain was the seat of articulation of language and Frederick Tilney, a neurologist he suggested that the 20th century would be the century for the frontal lobes; that is, there would be a lot more of research on the front lobes and we would get to know a lot more.

Unfortunately, Tilney was proved wrong and for most part of the 20th century, frontal lesions associated with stroke, with trauma, tumor, seizures, infections, neurodegenerative diseases like dementia and neuropsychiatric illness like schizophrenia

were completely neglected. And, there was hardly any systematic attempt to study cognition or behaviour. Then, in 1954, penfield stated that the frontal lobes have major three anatomical divisions.

He spoke of a motor strip. So, he spoke of a motor strip that involved the fine coordination of movement. Please do not go this is a very basic rudimentary model of the brain and I am trying to just show you the areas so that you have a tentative idea, but please do not go by the colourings specifically. So, this area of the frontal lobe.

So, this area he said that this tentatively the blue area is the motor strip that was Penfield spoke of was responsible for fine coordination of movement a pre motor area where he said that this was more of a an area where people you plan motor movement for the organization of movement and a pre frontal region. So, this is the primary region for thinking and coordination. And around 1970, Alexander Luria we have spoken about Luria earlier and you know he was an innovative Russian Psychologist, he also started focusing his attention on frontal lobe functions.

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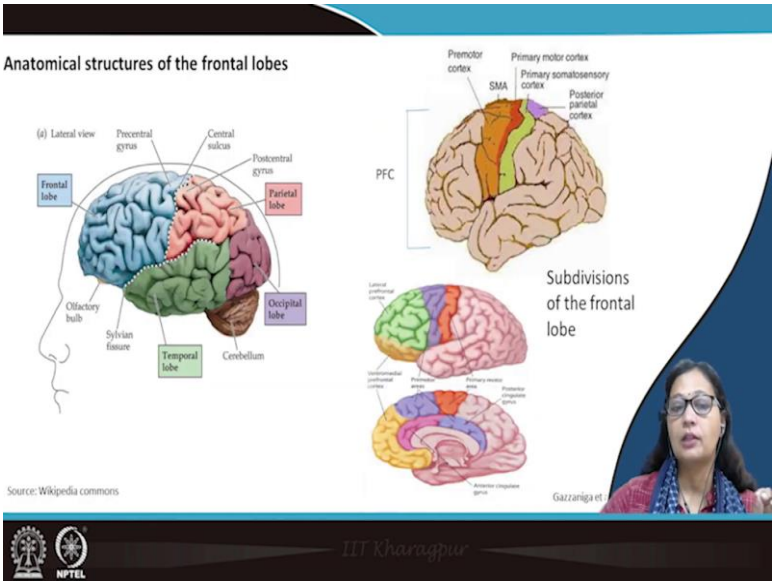

And his theories were based on war victims and clinical patients that he had surely to seen during his clinical experiences over time. Now, coming to the anatomical structures of the frontal lobes. For the last few decades, the role of the frontal lobes in cognition have been highlighted and particularly the prefrontal cortex. So, this area has been a an area for research for cognitive neuroscience. The frontal lobes constitute more than one

third as you can see till here; it is more than one third of the brains cortex and this region has multiple connections with the other cortical regions as well as the sub cortical regions.

So, within. So, deep within it has multiple associations anatomically the frontal lobes are bounded by the central sulcus. This is the central sulcus that separates them from the parietal lobe. And the sylvian fissure this is the sylvian fissure that runs across over here as you can see. This fissure it divides it or it separates it from the temporal lobe and the corpus callosum that is within separating them from the subcortical structures.

The frontal lobes are divided into major functional divisions. So, that is motor or premotor cortex. So, this is the area of the motor and the premotor cortex and the prefrontal cortex is for more is more with the decision making and organization activities. Now, these the motor and the premotor areas are distinctive functional units; whereas, the prefrontal cortex is a more complex unit requiring for the subdivision.

Now, the left and the right frontal lobes are also differentiated. The left frontal lobe is more specialized in language related functions; and the right frontal lobe is more related to social cognition and emotional processing. If you remember Broca spoke of an area for articulate language functions in the left frontal lobe which is known as the Broca's area or which is the Brodmann area 46.

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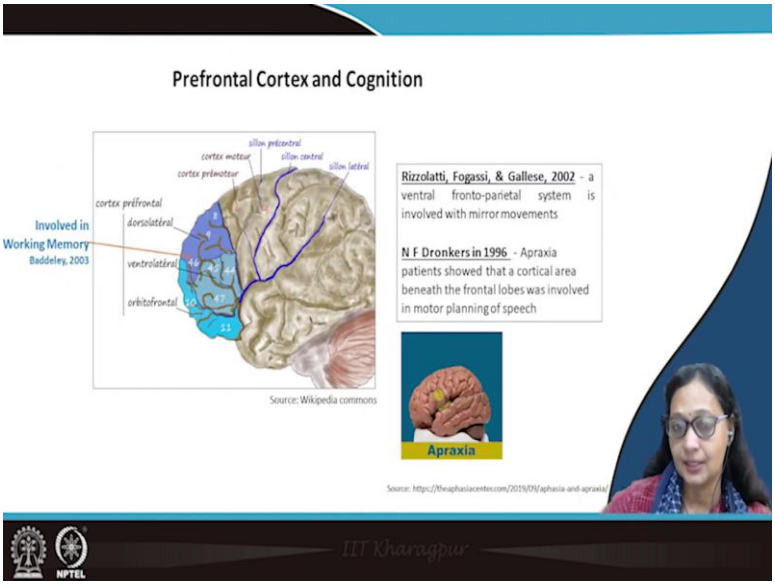

Now, FMRI studies suggest that self reflection, reading emotional expressions of others and many other aspects of social cognition are activated more on the right instead of the left frontal regions. Now, coming to the prefrontal cortex and its role in cognition, the association cortex of the frontal lobe is also known as the prefrontal cortex. And this is a late developing region of the neo cortex, in humans it is almost one third of the whole neo cortex.

This cortical area has gone through the largest expression expansion during evolution and individual maturation. And its late maturation is due to the late myelination of its axonal connections. The PFC or the Prefrontal Cortex is divided functionally into broad regions and these are the lateral PFC, the ventromedial PFC and the orbitofrontal PFC. So, you already are familiar with the lateral side. So, this is the lateral side, this is the dorsal side and inside this is the ventral side and the medial surface is within.

So, now let us look at the specific areas of the PFC. The ventromedial areas of the PFC. So, that is the area that is within. So, if you open this. So, the area that is within inside this part is developed early and evolved and are involved in the expression and control of emotional and instinctual behaviours; while, the lateral PFC are late maturing areas and are involved in higher executive functions.

The dorsolateral PFC so, this part the dorsal that is the front and the ventral is the back. So, the dorsal part of the dorsal lateral PFC is the highest cortical area that is involved in the motor planning at organization and regulation. The dorsolateral PFC lies in the middle frontal gyrus of humans that is in Brodmann area 9 and 46. And, important function of the DLPFC is the executive functions such as working memory, cognitive flexibility, planning, inhibition and abstract reasoning.

Though, it must be remembered that the DLPFC is not exclusively responsible for the executive functions, but it is more of a coordination between multiple areas that are responsible for executive functions. The ventrolateral PFC receives so the ventral side. So, again just to remind you once again the dorsal side is the front is the top of the brain here the ventral side is the lower part of the brain. So, the ventrolateral would be this area of the PFC this side of the PFC.

The dorsal would be the upper part. So, the ventrolateral PFC receives motivational and emotional information from the orbitofrontal cortex. Now, where is the orbitofrontal

cortex? So, this is assume the face here. So, these are the orbits of this is where the orbits of the eyes would be. So, just the frontal area of the orbits is the orbitofrontal cortex. So, this is where the orbitofrontal cortex of the PFC lies ok.

Now, the orbitofrontal cortex of the PFC the VLPFC receives motivational and emotional information from the orbitofrontal cortex and subcortical areas. So, that is from the areas that are within. Now, let me see I can open this for you. So, it would be from the subcortical areas within the orbitofrontal; the dorsolateral PFC sorry the ventrolateral PFC receives information. And this information can be used for elaborate decision making of or design of co directed behavior.

The ventral visual pathways provides detailed information on object identity, colour and shape to the petrolateral PFC. So, you can well understand how it helps in the decision making and the goal design behavior. So, it helps to identify things it helps to take a decision based on the specific properties of an object situated in the medial portion of the PFC, the highly in interconnected ventromedial PFC. So, this would be this area. So, I will just remove the prefrontal cortex and this area within the middle here.

So, this would be the ventromedial PFC and this as you can well understand is serves as a region for binding together large scale networks. So, there are networks from all across the brain. So, from all parts of the brain ok that subserve and emotional processing decision making memory self perception and social cognition in general the dorso p dorsomedial PFC. So, that is the upper part, but in the centre.

So, in the medial region is a region that acts as an interconnect between the cognitive control areas and affect trigging area triggering areas; and plays a role in both generating as well as regulating emotions. So, it has a very close connection with other limbic structures and that is why it is important in generating the emotion as well as the impulse control or the self control of emotions. The orbito frontal cortex we spoke about the orbito frontal cortex it is here these areas.

Is a region in the frontal lobes of the brain that is involved in the cognitive process of decision making. In humans, it consists of the Brodmann area of 10, 11 and 47. Now, looking at some research by you know famous neuro neuroscientists in this area. Alan Bagley in 2003 showed a dorsal prefrontal parietal system involved in working memory; we are aware of Alan Bagley’s work in working memory.

And he showed that Brodmann area 46 was responsible for verbal working memory in the left side. So, we already know that the language functions dominate on the left hemisphere. And on the right side, the visual working memory Rizzolatti Fogassi and Gallese in 2002 showed that a ventral frontal parietal system. So, this is sorry. So, this would be a dorsal system this is a ventral system. So, the a ventral frontal parietal system.

So, this area, but ventrally ok is involved with motor movements. Now, we also know Rizzolatti and his colleagues worked on mirror movements or mirror neurons. So, we know that it is also a very important area for social cognitioning, social cognition. N F Dronkers in 1996, with his study of apraxia patients showed that a cortical area beneath the frontal lobes was involved in motor planning of speech.

Now, this is one image that I have used from the apraxia centre and aphasia centre and they were you can look it up in details from this source that I have also mentioned below.

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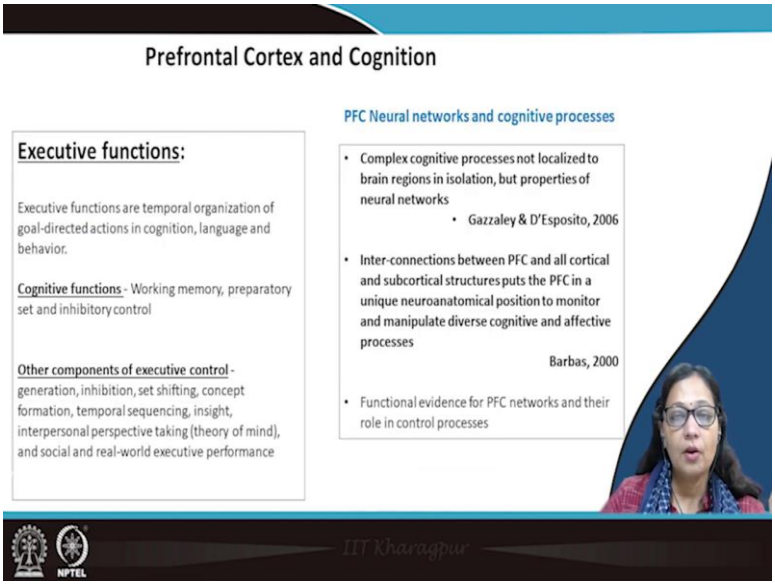

Now, coming to the prefrontal cortex and cognition whenever we are talking about free frontal cortex and cognitive processes we cannot talk without you know we cannot do away without talking about executive functioning. So, what are executive functions.

These executive functions are a term used to describe the neuro psychological functions of the frontal lobes and these incorporate many distinctive cognitive processes. So,

executive functions are a temporal organization of goal directed actions in cognition language and behavior; because it is when we are talking of goal directed actions that require planning and coordination, the temporal sequence the organization and integration of the temporal sequence of neural inputs is very very important.

And this is activated by multiple cognitive functions like working memory preparatory set and inhibition control and inhibitory control. And these are coordinated these are in a in a nutshell the executive functions that are coordinated by the prefrontal cortex. Some other components of executive functions or executive control include generation inhibition, set shifting, concept formation, temporal sequencing, insight, interpersonal perspective taking.

That is understanding how others are thinking it is often known as the theory of the mind and social and real world executive performance. So, thoughts into actions generating thoughts into actions and how quickly and how efficiently that can be done shows how well the cognitive processes or the executive functions are working. So in fact, when we are looking at neuro degenerative diseases like dementia, we would try and test the executive functions in that individual.

In fact, we also do the same for TBI, Traumatic Brain Injury patients to see how quickly and efficiently how optimally an individual is being able to inhibit a process take on another, switch a task take on another decision plan how the individual is planning and executing it into an action. So, we are going to talk about this later in the section on neuro psychological testing and cognitive testing coming back to this again.

Gazzaley and D Esposito in 2006 pointed out that complex cognitive processes are not localized to brain regions functioning in isolation, but they are properties of intricate neural connections. Similarly, in 2000 Barbas had suggested that the interconnections between prefrontal cortex and all cortical and subcortical structures puts the prefrontal cortex in a unique neuroanatomical position to manipulate and monitor diverse cognitive and effective processes.

So, its positioning anatomical position is effective for its coordination and management of the cognitive and effective processes. Primarily, because the neural networks from the PFC to the premotor and motor areas to the other subcortical areas and to the various other cortical areas like the parietal areas the temporal units, these the cingulate which is

a very important area as Cummings has suggested in understanding PFC. So, a cingulate is an area that is subcortically placed and is very important area of the frontal lobe.

It is also very important for cognitive processing. So, the anatomical the neuroanatomical position of the prefrontal cortex along with its associations gives it an opportunity to coordinate multiple diverse cognitive and effective processes. Along with the availability of high end neuroimaging techniques, we have also found out that there is accumulating functional evidence for PFC networks and their roles in cognitive processes.

So, anatomically not only anatomically, but the functionally also we have been able to identify the you know the role of the PFC networks in cognitive processes.

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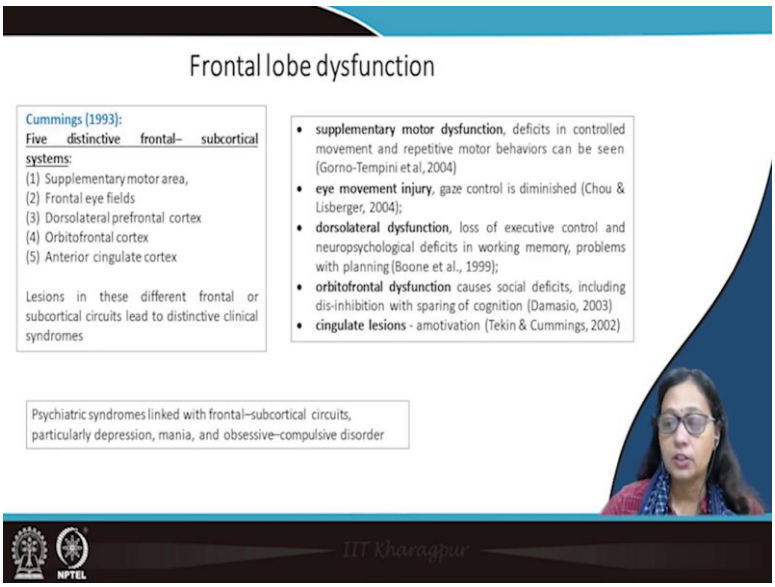

Now, coming to frontal lobe dysfunction. We spoke about the frontal lobe functioning, now what happens if there is an injury or if there is a lesion in a specific area of the front lobe? So, Cummings in 1993 suggested that there are five distinct frontal cortical, subcortical systems where which you are already familiar with most of it.

So, one is the supplementary motor area, the frontal eye fields, the dorsolateral PFC the orbitofrontal cortex and the anterior cingulate cortex. I was just talking about the anterior cingulate; within and he suggested that within each circuit specific neurochemical systems transmit their functional activity. And lesions in these different frontal loss subcortical circuits leads to distinct clinical syndromes.

So, what happens? So, in supplementary motor dysfunction deficits are noticed in controlled movement and repetitive motor behaviors. In eye movement injury gaze control is diminished as is easily understandable; dorsolateral dysfunction in dorsolateral dysfunction there is a loss of executive control and neuro psychological deficits are seen in working memory problem and problems with planning.

So, there is a loss of planning and coordination with a dorsolateral dysfunction; with an orbitofrontal dysfunction social limitations are seen. So, there are social deficits including disinhibition and lack of or sparing of cognition. So, there are problems with cognitive areas this was worked on by damasio and as you already know antonio damasio had classic research in the area of decision making and emotional processing and how each can influence the other.

Now, lesions in the anterior cingulate causes a motivation; this was worked out by Tekins and Cummings in the year 2002. So, psychiatric syndromes have also been seen to be strongly linked to these frontal subcortical circuits, especially psychiatric syndromes like depression, mania and obsessive compulsive disorder.

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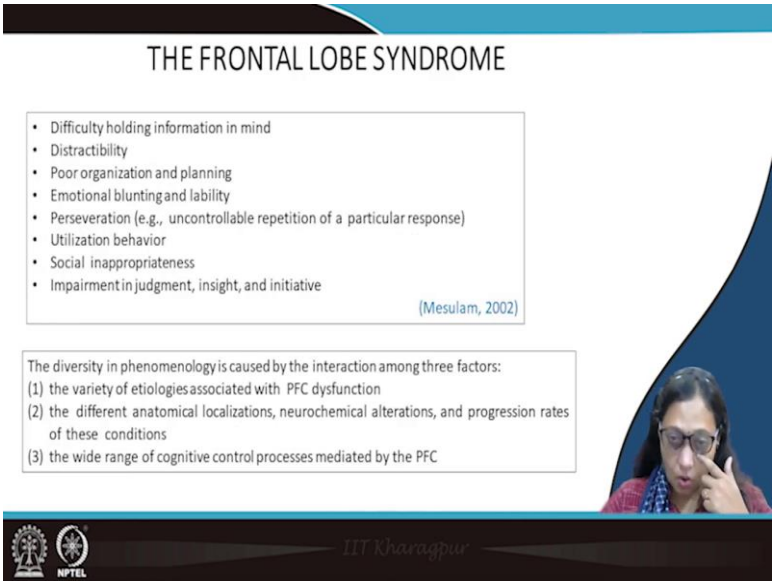

Now, when we are talking about the frontal lobe syndrome it has been seen that aspects of the behavioral manifestations of frontal lobe damage.

As seen through clinical reports since Phineas Gages personality transformation show that there is a diversity and variability of symptoms between patients. So, it may the manifestation may be very different over individuals. So, the frontal lobe syndrome is not a particular symptom that is seen, but it is a constellation of behavioral changes that evolve in different patterns of patients with the prefrontal cortex lesions.

So, as described by Mesulam in 2002, it includes difficulty holding information in the mind. It includes distractibility poor organization and planning, emotional blunting and liability and perseveration, utilization behavior, social inappropriateness and a loss of judgment insight and initiative. We have already spoken about a motivation earlier; the diverse phenomenology is due to the interaction of three factors.

Number 1, the variety of etio etiologies associated with PFC dysfunction like stroke, front temporal dementia, tumors, traumatic brain injury, epilepsy, attention deficit and hyperactivity disorder or schizophrenia or perhaps even with normal aging; the other is the different anatomical localizations the neurochemical alterations and progression rate of these conditions. And, the third is the wide range of cognitive control processes that are mediated by the PFC.

So, the phenomenology can be because of these independent factors or because of the interaction of these different factors. And as seen in degeneration of the orbital frontal cortex in FTD presenting it presents itself with emotional dysregulation and socially inappropriate behavior; while just a nearby area of the dorsolateral PFC lesions from middle cerebral artery stokes leads to executive function deficits.

So, on the one hand the degeneration of orbitofrontal cortex in FTB presents emotional dysregulation and socially inappropriate behavior, while dorsolateral PFC lesions which again these are all functional units remember in a very close network that leads to acute executive function deficits. This clinical disparity is the resultant of structurally and functionally dissociated neural networks. And that mediate these distinct control processes. This one more area that needs to be spoken about when we are talking about frontal lobe syndrome.

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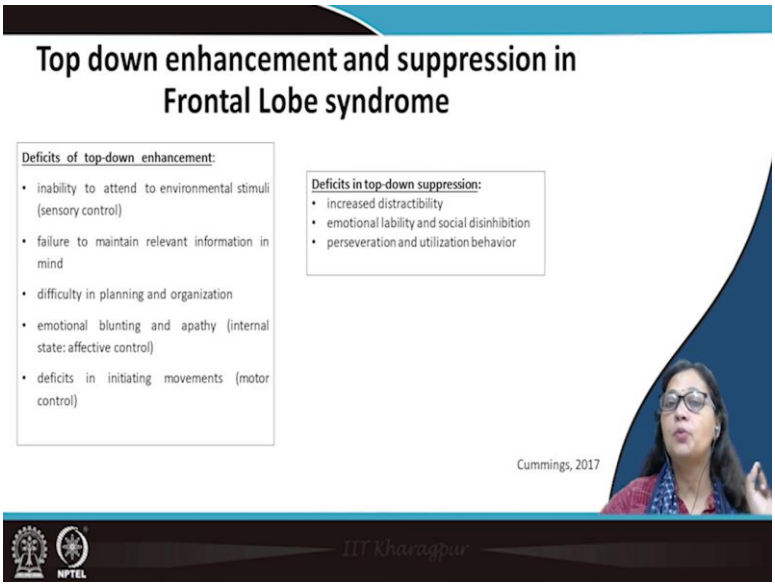

And this is top down enhancement and suppression. So, Cumming's speaks about this and he says that the deficits of top down enhancement in neural processing result in an inability to attend to environmental stimuli that is there is a lack of sensory control, failure to maintain relevant information and difficulty in planning and organization. So, that is the cognitive control and emotional blunting and apathy that is a loss of effective control along with a deficit in initiating movements that is again a loss of motor control while.

So, this is we spoke about top down enhancement in contrary when it there is a top down suppression it leads to increased distractibility in processes of sensory control and cognitive control, emotional liability and social disinhibition is in effective control and perseveration and utilization behavior in motor control.

Finally, the role of a histologically unique neuron this is when we are talking of front lobe we must talk about the spindle cell. And the role of this histologically unique neuron cannot be done without when we are talking about the frontal loads in humans. And this is this was first described by von economo and von economo was is classically known for his phenomenal work in the area of encephalitis.

And, he spoke about these spindle shaped cells that are found in layer 5 b of the ventral frontal anterior cingulate and the anterior insular regions of the right frontal area. And

research in this with these cells have shown that they have an implication in social cognitive para paradigms in frontal lobe research, in frontal lobe area.

So, in this session we have covered a lot perhaps you know an extensive area and functioning of frontal lobes. I have tried to make it as simple as possible. I will share with you the text for easy reference. And it has, so in a nutshell we can see that there is a lot of research that has been done in the last century and is still continuing with in frontal lobe anatomically with frontal lobe areas for understanding the cognitive processes. Primarily with emotional processing and executive functions, decision making, planning, coordination and other executive functioning.

Now, an approach of recent research in cognitive neuroscience is to attempt is an attempt to explain the PFC function through a unifying theory. So, we hope. So, far research has been independent and autonomous of course, with equals from others, be it neuroanatomically, be it from the perspective of disorders or with overall cognitive functioning from psychology and social cognition, but there the attempt is to explain PFC functioning through a unifying theory.

So, this is a very very important area to be studied extensively if we are trying to understand cognition because when we are going to talk about measurements of cognition, be it electro physiologically, be it through radiology studies or be it through cognitive tests. This is the area and this areas is functioning is what we shall try and capture through our testing. So, that is enough for today.

Thank you.