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

Lecture - 25
Executive Circuits

Welcome. So, this is the last lecture on our Brain Circuits to give you brief overview of the circuits that are involved in the final lectures about Cognition and various aspects of cognition. And, so this particular lecture has to do with the executive function circuits or the executive circuits.

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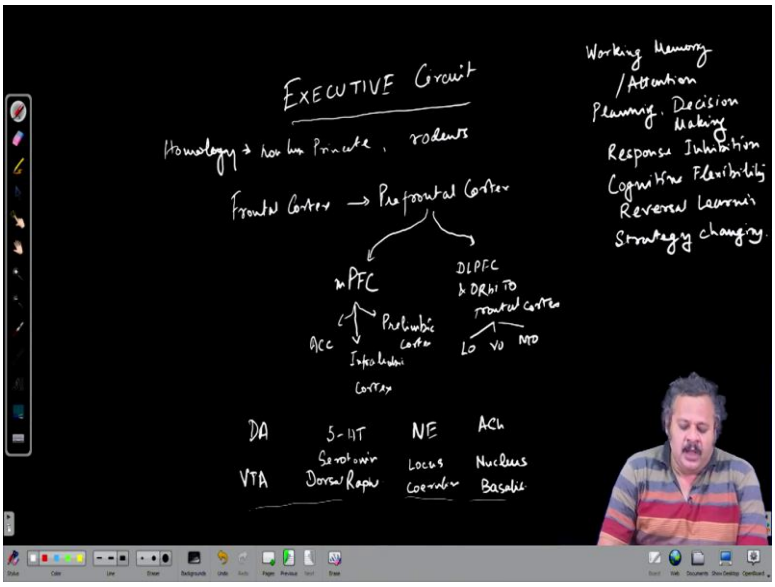

So, this circuit or this the structures involved in executive function are present in a highly evolved state in humans, but there are homologies in terms of structure in primates a non-human primates and other mammals and even rodents which allows us to study these particular functions in some rudimentary form or at least in principle to understand how we execute different kinds of behaviours.

As the name executive circuit suggests it is the prime center of control and there are a number of executive functions that are controlled by the elements of the circuit. The

primary seat is thought to be in the frontal cortex you know I mean it is in the frontal cortex and particularly, the pre frontal cortex which is a part of the frontal region.

And, there are sort of two aspects to it or two sides to it. One is the m or medial prefrontal cortex and the other is the dorsal lateral PFC and orbital frontal cortex orbital frontal cortex. So, this region has again three parts based on their location and actually also functionally and that is the lateral orbital, the medial orbital and the ventral orbital.

So, the m PFC on the other hand also has distinct parts. They are primarily the anterior singlet cortex which is on the medial end of the prefrontal cortex, then there is the infra limbic cortex and the pre-limbic cortex. So, this kind of division or the subdivisions of the prefrontal cortex are based on the functional aspects of executive functions and so, what are some of the executive functions?

So, the working memory that is involved in attention is one of them planning, decision making, response inhibition, cognitive flexibility, reversal learning, strategy changing these all come under cognitive flexibility. These are some of the executive functions and we although we say that it is the prefrontal cortex that is the structure involved in executive function, and is in executive circuits there are of course, many other regions that are involved in the executive functions.

And, they have to do with essentially how inputs are provided into the prefrontal cortex from association areas and emotional areas or from the limbic system like amygdala and the hippocampus. And, also even from the motor regions and that is mediated primarily through the striatum. And, the other very important parts are the modulatory regions in the midbrain that are heavily involved in the executive function and the four primary neurotransmitter that are involved are dopamine as we have learnt earlier from the ventral tegmental area projects on to the prefrontal circuits.

Then there is the dorsal raphe nucleus providing serotonin or 5-HT serotonin, then nor epinephrine provided by locus coeruleus and also acetyl choline that comes from the nucleus basalis in the basal forb. So, all these four structures that provide the neuro modulation based on dopamine, serotonin, norafyn and acetyl choline are involved in a combinatorial way and sometimes in with only a specific way that are projecting on to different parts of the prefrontal cortex to modulate behaviour or executive behaviour.

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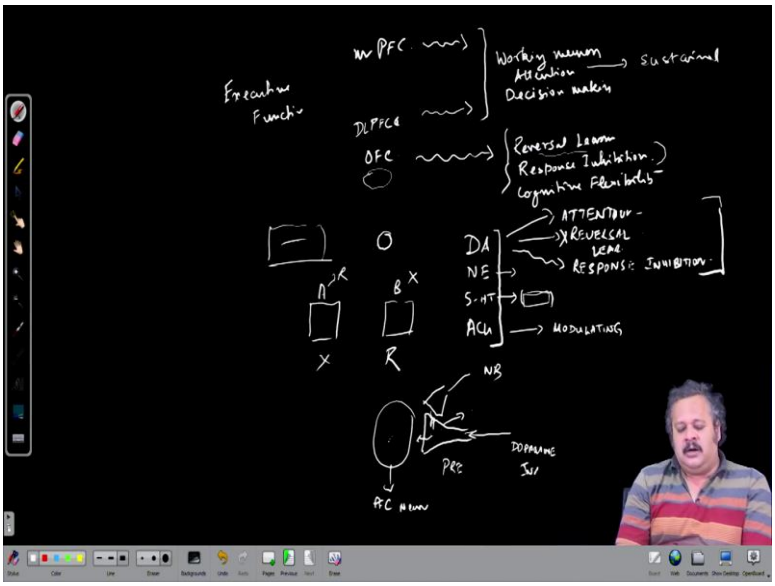

So, in terms of the executive functions if we look at the m PFC and the dorso lateral prefrontal cortex and the OFC parts the primary ways these are involved are this is involved in working memory and attention decision making whereas, the OFC is primarily involved mainly with the reversal learning and response inhibition.

So, when we talk this is basically cognitive flexibility. So, when we talk of working memory and attention and the involvement of DLPFC and m PFC when we go into details of how attention and working memory come into play in terms of computing the or the computational aspects of attention, we will see that there are neurons in the prefrontal cortex that reflect working memory through sustained or persistent action potential firing which represent neural correlate of working memory.

So, those kind of neurons can be found in the PFC and it is the involvement of attention in a particular task is based through this working memory being intact in the sense that other inputs coming into the working memory have to be stopped in the sense. So, if we are performing a task that requires attention let us say we are reading a particular book and then there is a loud sound on the side that starts off.

So, the this sounds come into working memory and the job to sustain this attention requires the help of a response inhibition that is I want to; I want to stop myself from going into the direction of the sound and paying attention to it as to what is going on and so on. So, it is for a full task it is not that individually m PFC or DLPFC or OFC is

working. It requires coordination among them. So, to have sustained attention, we require response inhibition also.

Similarly, for flexibility we let us say if we talk of reversal learning if h let us say we are given a reward for a particular stimulus A and we are not given a reward for a particular stimulus B.

And, let us say we are performing this task where sometimes the stimulus A comes, sometimes the stimulus B comes and we have to get the reward for the stimulus A and suddenly there is a switch which often happens and which requires flexibility on our part that is the B stimulus becomes rewarding now, and A is non-rewarding. Earlier A was rewarding and B was non-rewarding.

So, in order to process this information in order to understand that there has been a switch we have to have attention going on through the process and realizing that this switch has happened. So, if we talk of reversal learning it is not completely devoid of attention, but it may be true that lesions of the DLPFC lesions of the m PFC can lead to attentional deficits, but not reversal learning deficits as much.

So, it is not going to be exclusively just that reversal learning is changed if we make a lesion in the OFC, but primarily its role is in reversal learning or cognitive flexibility, but it does not mean that we do not need the other parts for these kinds of executive functions. So, it requires the involvement of all these elements. And, in this process we require the inputs from the different mid brain structures are required in terms of how well we can perform the these functions.

So, in terms of the involvement of dopamine nor epinephrine, serotonin and the nucleus basalis acetyl choline we know that all of these are actually involved in the executive functions, but some of them have primary role in specific tasks or specific types of executive functions.

And, so, in order to do that what we know is first of all 5-HT is more or less involved in all kinds of executive function that is a serotonin in attention and in decision making, in working memory, in strategy shifting that is set shifting task all of them require serotonin because removal of serotonin or rather if we have; if we have antagonists for serotonin pic receptors in the prefrontal cortex then there are deficits in all of these tasks.

Even reversal learning, response inhibition and attention and set shifting that is strategy changing and decision making. So, nor epinephrine is also involved primarily in the response inhibition part and where we learn from a sudden changes in the context and we have to inhibit ourselves from responding to stimuli that are not that require us from stopping us from doing a particular thing. And, similarly the nor epinephrine is also involved in reversal learning.

On the other hand, the dopamine circuits the dopaminergic elements are primarily involved in attention in the frontal cortex, but not in reversal learning. So, dopamine is involved in attention and not in reversal learning, but dopamine is crucially required for response inhibition.

So, it requires a very careful parsing out of these different aspects in order to do the experiments where we exclusively parse out the effect of dopamine on attention which we will be discussing in our attention lectures of how it is computed. Similarly, to parse out reversal learning from response inhibition because reversal learning may involve response inhibition, but all of reversal learning is not response inhibition.

So, that also requires careful a differentiation of the different kinds of behaviour that we are talking about. So, in that sense we know that after understanding that response inhibition requires dopamine whereas, reversal learning does not that seems to be contradictory, but we will see that actually in terms of flexible behaviour how we can separate these two out.

And, so, the dopaminergic inputs to the medial PFC as well as the OFC both are important because attention is not mediated by OFC and the response inhibition is mediated by OFC. Similarly, acetyl choline is primarily involved in modulating all these neurotransmitter because of the presence of nicotinic acetyl choline receptors in the pre-synaptic terminals. So, that causes that regulates the release of the different neurotransmitter.

So, the cholinergic in inputs that come on to synapses if there are receptors in the pre synaptic terminal of a neuron. So, this is pre synaptic terminal of a neuron which is providing input to a neuron here in the prefrontal cortex let us say PFC neuron. And let us say this is a dopaminergic input from VTA or another glutamate allergic input from somewhere else.

So, the cholinergic inputs coming from the nucleus basalis, they can actually bind to nicotinic receptors or which are the ionotropic receptors of acetyl choline and they modulate the release of this particular neurotransmitter. And, so, as many many studies have looked at acetyl choline and its involvement in executive function and it has been shown it is particularly important in attention not only through it is inputs on to the prefrontal cortex, but also into the sensory areas.

So, the as we can see the four different dopamine four different neuro modulatory inputs from the midbrain namely from VTA locus coeruleus and raphe nucleus and the nucleus basalis all have a role to play in the terms of producing executive function. Similarly, the different parts of the prefrontal cortex and the striatal circuits involved require specific inputs to produce a goal directed behaviour. I mean, that is the basic point of executive function that is to produce a goal directed behaviour.

So, it also requires sensory inputs coming in from the sensory regions via the amygdala or directly that requires association in terms of performing a behaviour. And, so, although the prefrontal cortex is the mediator or the executor that is controlling executive function, it requires many other regions involvement directly or indirectly in order to produce the different kinds of executive functions that we talk about.

And, we will discuss more in detail when we go into how we do decision making in terms of actual neuron based neural firing based output from input to output and based on how attention modulates our perception, and how we sustain attention and how we actually do reversal learning in our later lectures.

Thank you.