Computational Neuroscience

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Week – 01

Lecture - 03

Welcome. So, this is our third lecture in the Computational Neuroscience course. So, we are in the first week in where we are doing introduction to neurons and we have discussed in the previous two lectures the structure of neurons and also the structure of networks and synapses. And we have got some idea of what an action potential is and how that is a currency of computation and communication that is it is transferred from one neuron to another and based on what computation is performed the next neuron produces an action potential or a train of action potentials and that is conveyed on further. So, in order to delve into the whole idea of spiking neurons and how they encode information which will be the goal of our course and how neural systems learn based on inputs and input activity and output activity. We need to put things in a bigger perspective where we will now be discussing the basic structures of the brain where all this computation will be going on because we will be might be referring to some of these structures as we go along in the course.

So, to start off as we had discussed earlier in the if you look at the cerebral cortex the or the entire brain together the outside is covered with the cerebrum and there are multiple ways in which people make sections or scientists make sections either the sagittal section to the right or coronal sections in the middle and in green on the left the transverse sections and we if we make different sections we will be able to see different structures within the brain and depending on how we section the brain we get to see many different kinds of structures. So, overall if we talk of the brain the two main structures without any sectioning or without any slicing that we can see is the overlying cerebrum as we said and a smaller structure which is also a very important structure which is the cerebellum as you can see in the slide on the right hand side. So, in the central nervous system these two are there and along with it as you can see from here in this region and which is continued in this part in this place is a continuation of the central nervous system which is the spinal cord. So, we will not be talking too much about the spinal cord in our lectures, but please do not disregard it as something vestigial or anything you are already aware of how important the spinal cord is and is the path of

input information from variety of peripheral structures into the brain.

And so now if we go through if we look at the entire cerebral cortex or the cerebrum you will see that there are multiple different kind of sulci and gyri. What we mean by sulci and gyri are that the sulci are the indentations that are formed in the brain structures and they separate different gyri that is the regions that contain the cortical structures in them. So for example, this whole region here that I am drawing in my red is a region which is a gyri and the central part in this which is an indentation that separates the gyri is what we call the sulci and the particular sulcus that I have marked is what we call the central sulcus and it separates two very important parts of the brain or the different lobes as you can see on the right hand side this is the central sulcus and the frontal lobe is anterior to the central sulcus and the posterior to the central sulcus is the parietal lobe. Another very important sulcus which differentiates the temporal lobe from the other structures so this is the lateral sulcus which runs parallel along separating out parallel to the transverse axis transverse plane and that is called the lateral sulcus and this lateral sulcus separates out the temporal lobe from the parietal and the frontal lobes. And at the back at the very back of the brain is what is the occipital lobe which is the main structure for the visual processing.

So primary visual areas and visual association areas are present in the occipital lobe and they are also separated from the others by another sulci and within the temporal lobe and in the parietal lobe and in the frontal lobe there are many different gyri each of which contain various different structures or various different processing centers like in the superior temporal gyrus it contains the area that processes auditory information. Similarly in the beside the post central gyrus the region is somatosensory input region and then in the pre central gyrus over there is processing of motor information and premotor information beyond that in the frontal side. So overall what we are saying so far is that if we look at the cerebral cortex or the cerebrum there are these four main lobes which are the occipital lobe, the temporal lobe, the parietal lobe and the frontal lobe and within them different sulci separate out different structures and even different sulci separate out these different lobes also and different structures are present within the gyri. And so if we go a little further and cut out a section what we see is a clear picture of how the arrangement is present in the sulci and gyri as you can see in the image on the left which is a real section of human brain where we see a large part of it is white in color in the middle and also in the regions above. So these regions that are white in color are actually what we call the white matter and similarly we have what we call the gray matter in the overlying regions.

So these are the these struck these are the gyri that we were seeing from outside and the indentations that we have those are the sulci. So I hope that the previous picture and this

picture together provide you a fair idea of the sulci and gyri and where the different structures exist. So the cell bodies that are present in this gray matter areas in the different gyri is what the different regions are made up of. So these are regions with neuron cell bodies and it contains a layered structure which is what we say is the cortical layers layer 1, 2, 3, 4, 5, 6 as we had discussed in our previous lectures and below that or actually the different gray matter areas are above sitting on the white matter area which are essentially fibers of passage or axons that are connecting different regions different brain structures with other brain structures. So the whole region of white in the brain that we are seeing here are basically fibers a bundles of fibers or axons that are projecting from one particular region to another region by making synapses on the region to which they project.

So this is basically for the cerebrum part. The cerebellum is also similar in nature. It also has gray areas and a gray matter and white matter areas but it has a more gray matter region compared to what we see in the overall brain. So in the other than the overlying cerebrum region we have inside or rather inside sitting inside the cortical regions are further more structures that connect the periphery to the cortical regions through various different elements or structures. And so if we look at the if we start from the very bottom actually if this is where the spinal cord has started and in this region is where the brain stem is which is the lowest sort of region in the hierarchy starting from the periphery and beyond the brain stem there are pons and the medulla and beyond that is the midbrain and then beyond that is the thalamus.

So if we look at the picture on the right hand side it is more clear with the medulla of longata and the pons in the in this brain stem midbrain region in the in between those two regions and the midbrain ends where the thalamus starts off in the center and this thalamus is the gateway into the cortical region. So it is an obligatory station from through which the inputs from the various lower cortical structure lower subcortical structures go through to reach the cortex. So basically I mean mostly all the inputs that reach the cortex that come in as inputs into the cortex are via the thalamus as we will see this is the stereotypical structure throughout the different sensory pathways and even other regions. So beyond this there are other structures that we can see which has to do with more limbic processing and that we will take up in a different slide later on about how the amygdala, hippocampus and other structures are involved in terms of in this whole picture. So the structure above here that is in white that is shaped like a crescent and sitting just underneath the cortex is the corpus callosum and it is essentially a pathway that connects the two hemispheres of the brain.

So most or all the connections that are made from the one side one hemisphere of the brain to the other hemisphere of the brain are through the corpus callosum. And so if

when we talk about the whole brain so we have talked about the different lobes and now if we go into a finer detail of the areas that are involved in processing different kind of information then we have the various the primary sensory regions can be seen here if we start with the visual regions at the back here is the visual cortex in the occipital lobe and surrounding the visual cortex just outside it in this light blue color is the as the secondary visual area or it is actually also called the visual association area. So a huge number of non-primary visual areas are present in this secondary large secondary visual area and what we mean by the primary visual area is that it gets the first inputs from the visual system from the subcortical structures that is from the thalamus as we had discussed. So beyond that then in as we said in the along the superior temporal gyrus we have the primary auditory area in light green shown there and in a darker shade we have the auditory association area surrounding it. And further surrounding the whole region is the Wernicke's area which is the posterior and on the back side is the posterior speech area and that is involved with processing speech and in the Broca's area in the anterior region in the frontal lobe is the anterior region for generation of speech.

Now in terms of the somatosensory system as you can as we mentioned earlier just behind or anterior to the central sulcus is the primary somatosensory region that is the region that gets inputs from the thalamus of the somatosensory system and outside that are the secondary somatosensory areas which are not clearly marked here but that overlays with our speech area in the Wernicke's I mean the interacts with the speech area in the Wernicke's region. Just anterior to the central sulcus is the primary motor area as shown in the violet color and neurons there are involved in providing inputs to the subcortical structures to drive different actions. And so this primary motor area has heavy interconnection with the somatosensory system. It is connected to the other sensory systems also but primary and the motor and somatosensory have much heavier interconnections because of the nature of the involvement of the two systems when we are performing a motor action. So, anterior to the primary region is the secondary motor areas and the premotor areas where motor planning takes place that is how the different sequence of actions will be performed that is planned and then it drives the primary motor area to produce the action through the subcortical structures that control our muscles.

And right in front of this region is the prefrontal cortical region which is the executive region of the brain which is in the frontal lobe and in the prefrontal region of it that is the most anterior part of the brain. And there are a number of different sub regions in the prefrontal cortex which are involved in variety of different executive functions like working memory, like decision making, like flexible behaviour, like attention and so on. All these higher order functioning are controlled from the prefrontal cortical regions in the frontal lobe in this region. And so there is a very important region that is actually not

visible here and tucked inside under the Broca's area is another part of the prefrontal cortex which is the orbitofrontal cortex which is involved in flexible behaviour. So this is broadly what the different regions of the brains are.

And as we will see there is a certain nature to this organisation or certain principle by which all these systems are organised and which aids in information processing. And gradually we will see how these pathways of the different sensory systems are organised, how they project to the finally to the prefrontal regions for executive functions for decision making and how based on that decision motor action is produced through the motor planning area or the premotor area, supplementary motor area and then the primary motor cortex and then down to the muscles. So this is the broad overview of the structures that we have and in this lecture we will start stop here and later on start with the ideas of information processing in the brain in these different pathways how the systems are organised to process information by using spiking activity of neurons at different stages and how percept of the sensory world forms in our brain and how then we make decisions and then perform an action and so on. Thank you. .