Neural Science for Engineers
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Lecture - 36
Control of eye movements

Hi, in the previous session, we discussed about vision, and I speak specifically about vision because there was a lot of emphasis put on why the eye are not a camera, and we discussed the mechanisms by which photons are processed within the visual apparatus starting from the retina and all the way back to the visual cortex and associated cortices.

So, the story of the world as we see through the eye is actually built within the brain, that is something which you should understand and that there is processing happening at each individual step of the apparatus starting from the amount of light which gets into the eye which is regulated by the diameter of the pupil, two there are some mechanisms which we study now and at each level of the retinal processing system, at the optic nerve within the colliculus, there are specific things which happen.

Some of these are known to us because we have found out, we as in humans have found out how this data is getting processed from parts of the retina to various parts of the optic tract, then back to the colliculus center and up to the occipital cortex. But you can imagine that there is a lot more to be done to have a more comprehensive idea of how we perceive things visually.

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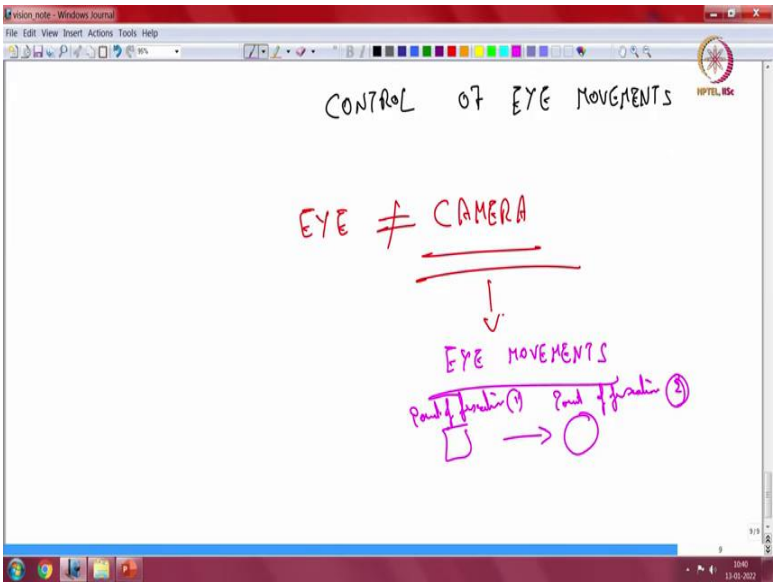

So, an integral part of the system is the control of eye movements. Now, here again, I will have to use the idea that the eye is not equal to a camera, and we will substantiate it by again using eye movements as an example. So, when we use the term eye movements, it would indicate that the purpose is from one point of fixation to the next point of fixation.

So, that would be the logical way in which we think about eye movements. So, why do you need eye movements? Because you need to see different things and to perceive different things at a very base level; perceive things as a threat so these are things which you would imagine that the eye has to be used to scan the immediate environment and you know that would be the purpose of eye movements if you would imagine, but that kind of movement would not require the kind of complexity which I am about to describe.

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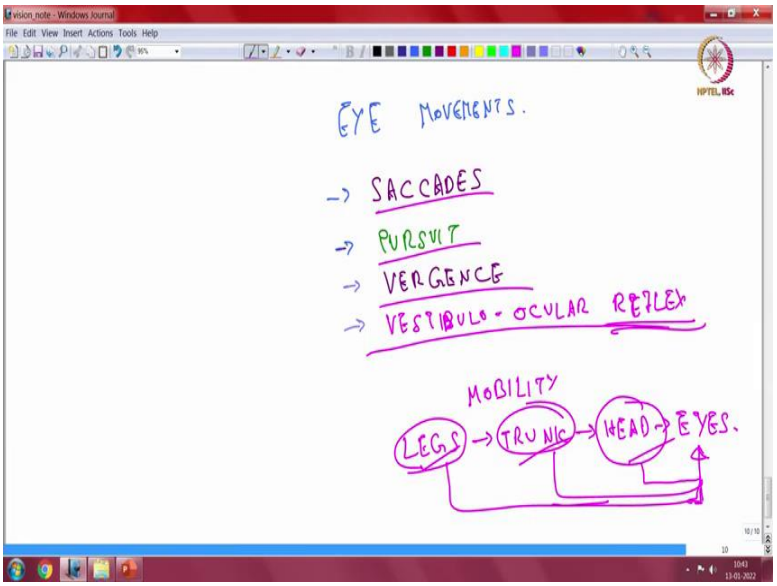

So, when we study eye movements, we study some set of things. So, those set of things is what is listed over here. So, the first are called saccades and then, you have pursuit, then you have vergence and an extension sort of this is the vestibulo-ocular reflex. So, that is a reflex and the others are not actually reflex mechanisms, they have different properties and we discuss the properties and then, try to figure out if you can make sense of why the eye need so much of different kinds of movements to perceive the environment around.

Now, human beings are mobile and the sense bipedal and mobile and we have a torso leg now, legs mobility in a human being. So, mobility in a human being is you have a trunk, a head and eyes. So, you would actually you know if you just control legs or the trunk, you should be able to control the movement of the eyes.

We also have the problem of head for which reason you need to have eye movements as separate from movements of the leg, trunk, or the head. So, why do you need so much of individual movements? You know these are individual movements which are recognizable, and I would demonstrate to you how recognizable these are.

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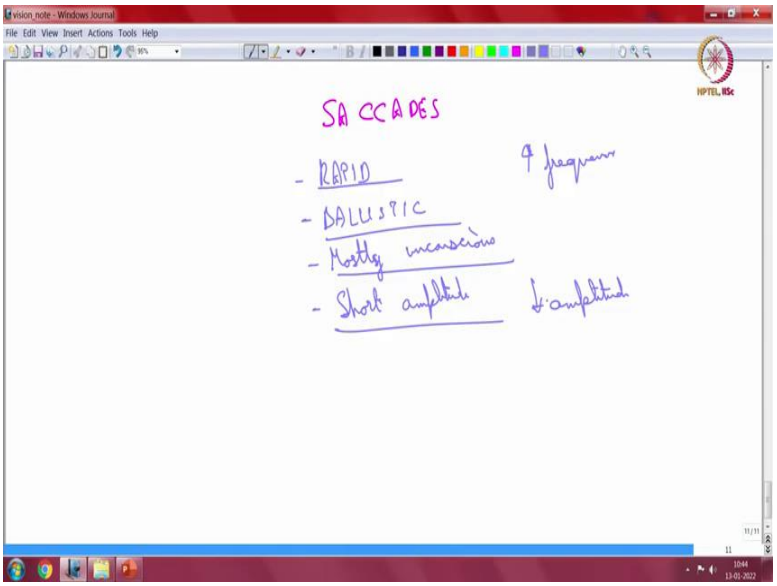

We start a discussion with saccades. Rapid, I think it is called ballistic, mostly unconscious, relatively short amplitude. So, rapid in a sense, it is very fast. So, you have high frequency, low amplitude, amplitude movements and it is within a, what we could call as a visual scene.

So, in a visual scene, say you are looking at some object, you are still continuing to look at the object, but the eye does not statically view the object, the eye does these micro movements and it is those micro movements which are called as saccades so, that is where I think I should give you an example.

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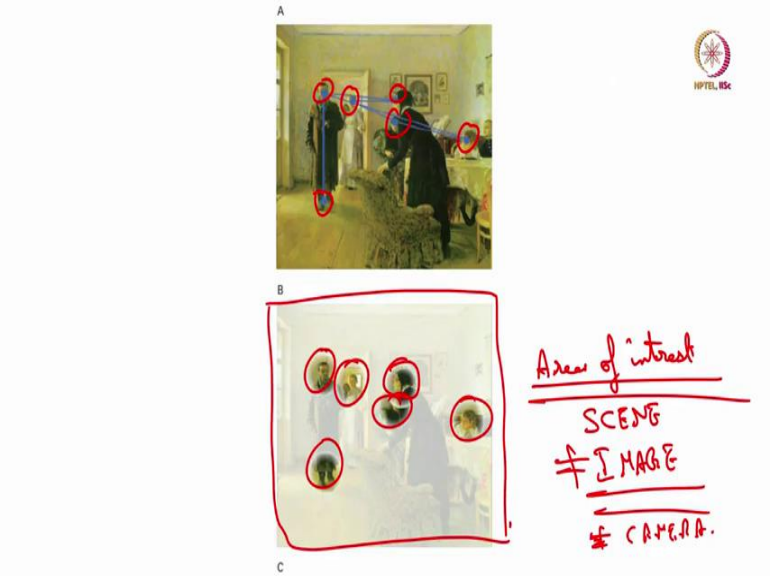

So, this is the example taken again from candle.

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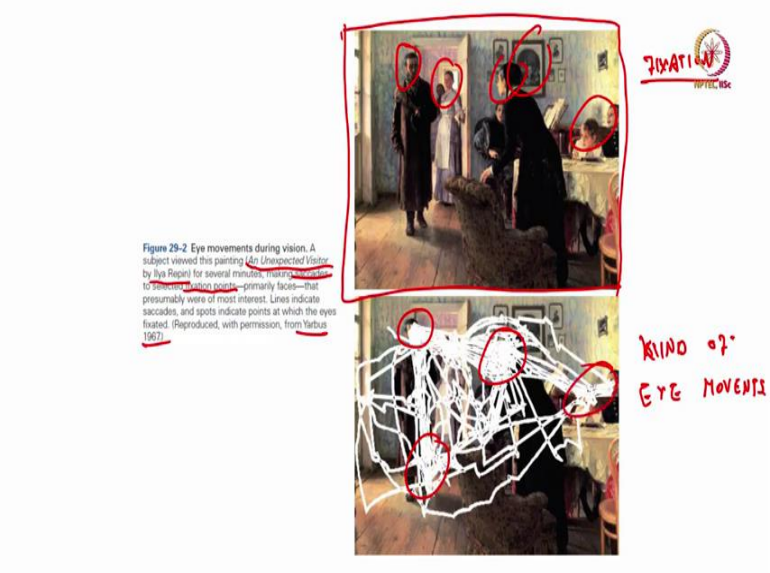

This is Yarbus 1967 in which somebody tried making out fixation points. So, you know you can map, they have done some method by which they can determine fixation and given a scene, say scene is an individual picture so, this is an individual picture which is there and then, you try to find out how the eye goes about doing its analysis and this is the kind of eye movements which are there.

Now, it does not mean that you know it is all saccades. What I mean to say is that all of these are integrated movements, you cannot split, for the purpose of understanding and obviously, for the terminologies which have been developed, I split it into two.

But what I meant is you know you do not capture the image for analysis in the head, you know you do not have a giga pixel, image generated from all the retinal processing and line recognition, feature recognition, object recognition, multi-object segmentation and then, you do processing no, it is the other way around.

So, in the given photograph, you can make out that the individual objects are scrutinized to varying extent based upon the interest and what the purpose of the entire exercise is. This is an artistic image I think so, this is an unexpected visitor by somebody and so, it saccades for selected fixation points and each individual point is not viewed as a point you know you have these micro movements which exist over there.

And these are the sort of nodes which are happening and within those nodes, there are very small individual movements. So, this is the saccades which is happening within the eye, and you can actually map it into something like this. So, you can make out that you know these are the points of interest. Generally, faces are points of interest because we as human beings are key to look for faces in an image or in a scene, a scene is dynamic, and you are key to look at individual faces.

So, what is shown over here is the importance of the eye in trying to you know this entire image is split into areas of interest. So, there are areas of interest within any scene not image. This is one of the reasons why I was using that it is not a camera.

And remember, this is not that you know first generate the image and then, you do the saccades. The saccades are used at the time of generating the image and that is a key difference when we think about something like that.

So, that is the proof of saccades. You can observe somebody who is looking at an object, unconsciously and you can make out this minor flickering movements of the eyes so, those are the saccadic moments. I will just describe these movements and then, we will go to the analysis part after that. So, saccades is one kind of movement.

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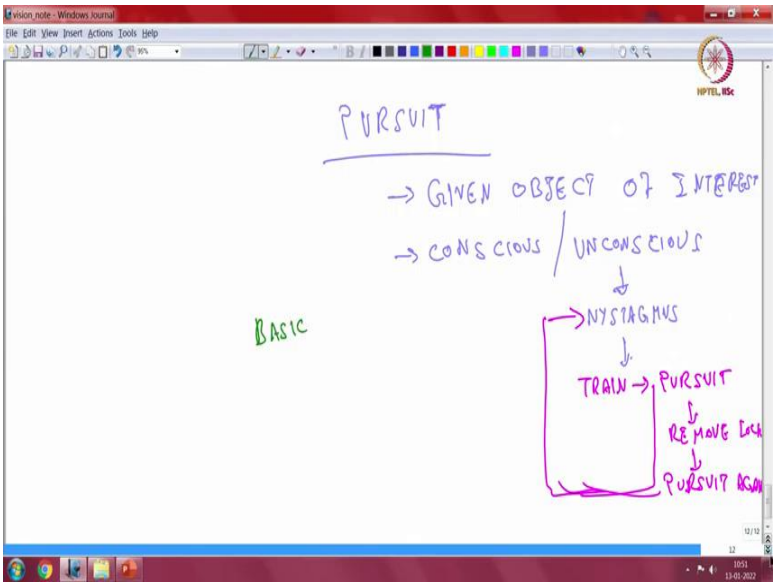

Now, next set of movements is pursuit. Pursuit is common sense you know. You have an object which is moving, and I keep my eye fixated on to the point and that is through the mechanism of pursuit. So, wherever the object is going, fixing the eye, I can track the object, no head movement and that is pursuit. So, you can do it in multiple directions and that act actually is coordinated by the different muscles.

So, a mechanism of that is you know and remember that the object although in my hand, need not be the same so, you can have an object moving in your visual scene and the eye makes a conscious effort to pursue the object and so, pursuing is on a given object of interest and remember it can be conscious or unconscious.

So, you can unconsciously pursue an object say for example, and that is the phenomenon of nystagmus. You are in a train, and you know you are looking at objects outside of the train and then, the objects are moving obviously, at a very rapid pace and so, you pursue, remove, lock and pursue something else.

So, all these sequences would result in nystagmus. So, nystagmus can happen in nature, and it can also happen in various disease states which we study. So, that is what I meant by unconscious. Conscious of course, in which you are consciously pursuing, keeping your head stiff, you are consciously asking your eyes to look at an object.

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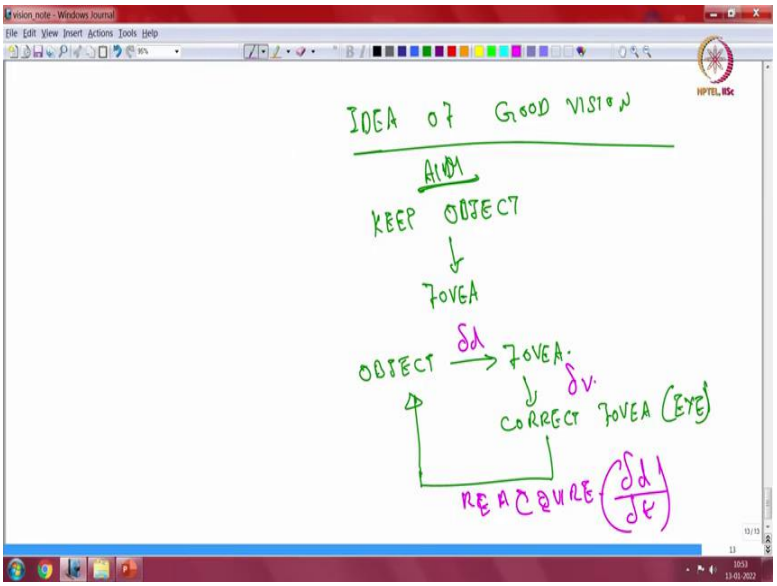

Now, if we analyze how a pursuit goes down so, how would pursuit be you know computed? So, the basic idea of good vision is to keep object of interest in fovea. So, that is the aim of the entire mechanism. So, you need to keep an object which is there in your visual scene within your fovea.

So, when said object goes away from the fovea, which basically means the eye to reacquire the object. So, that would form the mechanism. So, you have a small change which is happening within the object which is not on the fovea, and you can compute the distance, the distance would give the velocity so, the distance which has moved in unit time and then, that gives the velocity and that would give you the amount of distance in unit time. So, that gets computed and that is how you do the pursuit.

So, two mechanisms are different. Remember saccades are small, micro movements, small amplitude, they do not go span across the entire visual field. Visual field if you remember is the amount of space which can be seen through the entire eye. So, there is a lot of area which can be covered. The eye has a smaller part and then, you can look at extremes and cover the entire span. So, within that visual scene, you have pursuit which can fix it on a given object.

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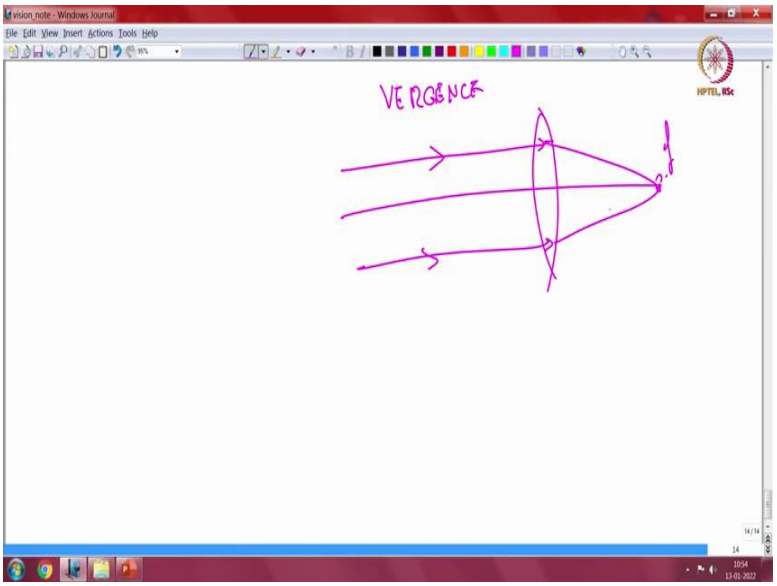

Now, we look at vergence. We know that you have a lens and then, at around you know an object from infinity would converge to the focal point. So, when it is at infinity so, how do you ensure that something which is very close by gets fixed to the focus point, you ensure that; I need two eyes actually.

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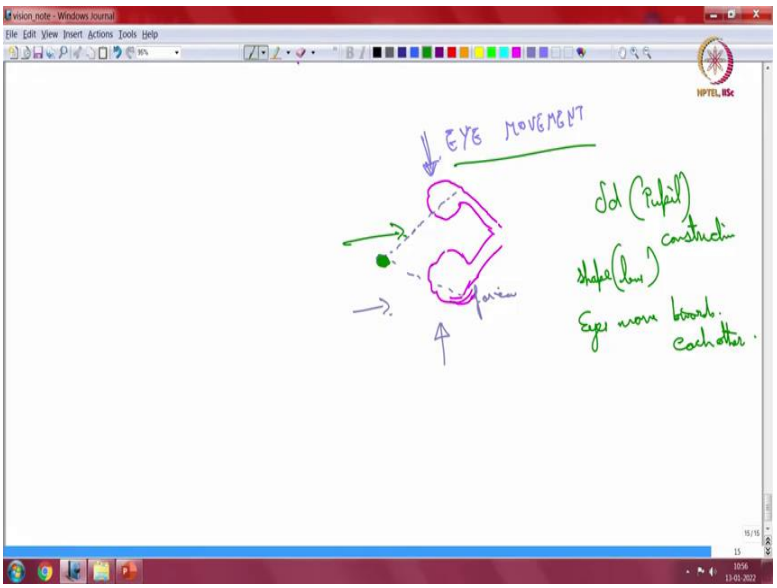

So, that happens when you converge both your eyes. So, visual access will be here to the fovea for an object and as the object comes closer, the eyes go closer to each other and so, this is eye movement.

So, as an object moves closer to the eye, you have eye movement which helps in focusing. So, along with the eye moment, there are other things which is changing the diameter of the pupil, which is constriction, then the lens changes its shape, then eyes move towards each other.

See both pursuit and vergence are sort of common-sense things. So, how do you see something close by? So, you have an object which is distant and then, when it is coming closer to you, your eyes have to move closer to each other so that you still retain fixation at the point. So, pursuit, vergence, these are simple to recognize.

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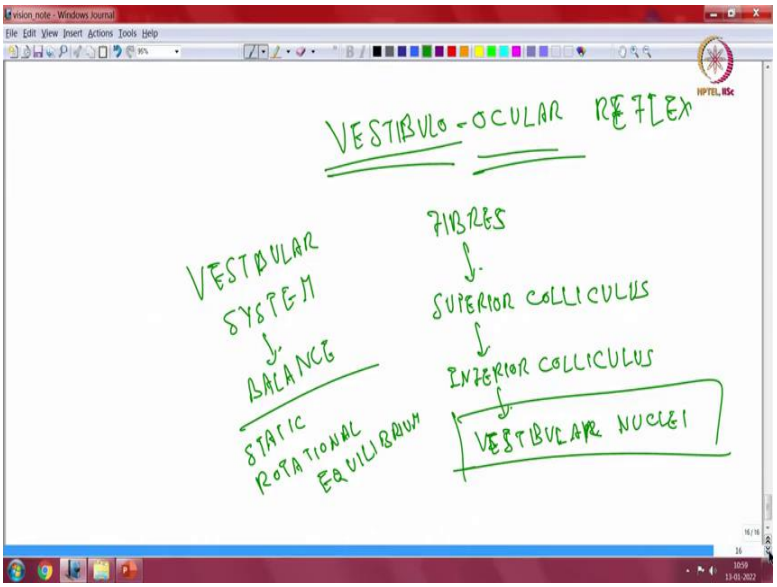

Now, an extension of the logic is the vestibulo-ocular reflex. So, when the head moves, still you know fixation on a given object so, here I am using the camera, I am turning my head, it is the inverse of fixation.

So, in inverse of fixation because in pursuit what happens is you are pursuing the object. Here, it is the other way around I am ensuring that my eye, the gaze, eyes remain focused on a particular object in spite of my head moving in various directions. So, that is sort of inverse of that.

Now, the mechanism is mediate to the vestibulo-ocular reflex. Remember somewhere in the discussion on pathways, I said that there are a lot of components of fibers which go

to the superior colliculus and then, inferior colliculus and then, there are pathways to the vestibular nuclei.

So, vestibular nuclei is vestibular system is something related to balance, I think I should be covering it sometime later now. Balance is you know the sense of static and rotational equilibrium.

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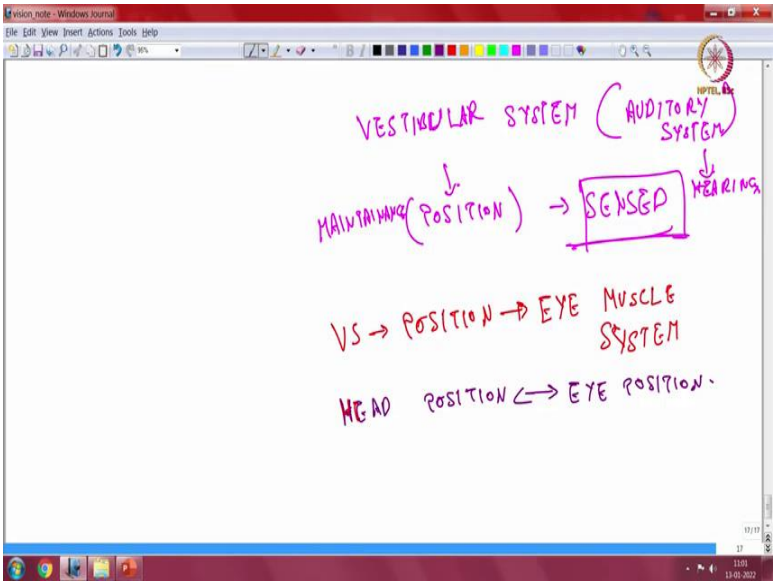

So, the vestibular apparatus is one of the mechanisms of position. Vestibular system is for position maintenance. So, the function ensures that you know whatever position you want to achieve, it is perceived, I use the term perceived or sensed.

So, you would sense your position with this one. So, it is closely related to the auditory system which is hearing. So, you would have heard somebody friends, family, somebody who suffered from a cold and then has this giddiness episodes and things like that so, that sort of indicates how this close they are closely related within the body and then, sometime later I will discuss the mechanisms of that.

So, coming back to our current discussion so, what the vestibular system does is it gives position information, and that position information is transferred to the eye muscle system. So, head position is connected to eye position, ok that is simple. So, you when you move your head, there is something which happens, which tells the eye to move in whatever direction which is necessary to ensure that gaze does not get affected.

So, these are various kinds of systems which are in place and these systems are for different kinds of purposes. So, the objective is to visualize something. So, it is an active process. So, active process in the sense that it is based on neuronal input, it is not passive from the outside.

So, there is some processing happening within your head and that determines how the eye looks at from one place to another place. Why I said neural mechanism and not conscious is say suppose there is a bright light in your field, the natural tendency is to look at that bright light and so, those are unconscious mechanisms.

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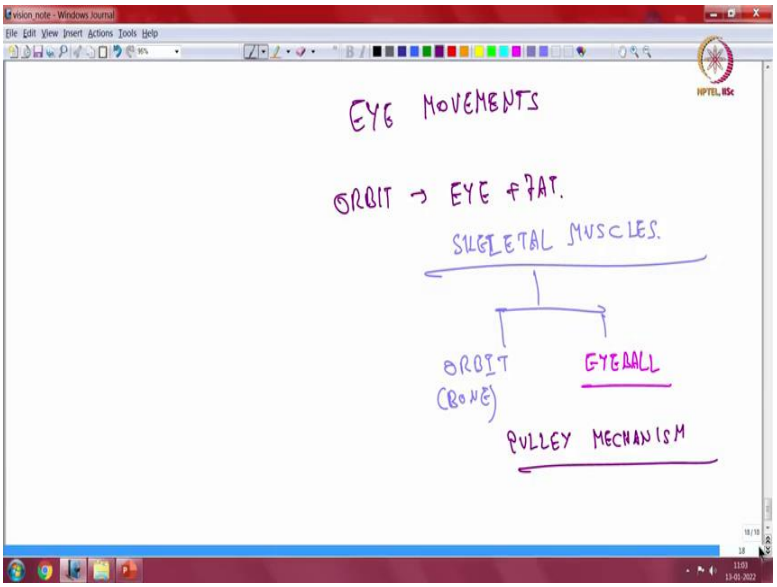

Now we come to the question as how it is mediated? How are eye movements mediated and in our discussion for of anatomy, I told you that the orbit has eye, there is some fat, which sort of cushions the entire movement set and then, you have got skeletal muscles.

Now, skeletal muscles which basically, one part is connected to the orbit which is bone, and another part is connected to the eyeball which is to the outer coverings of the eyeball. So, the mechanism is actually a pulley mechanism. So, muscle contracts and the eye moves to one direction and that is how this the mechanism is implemented.

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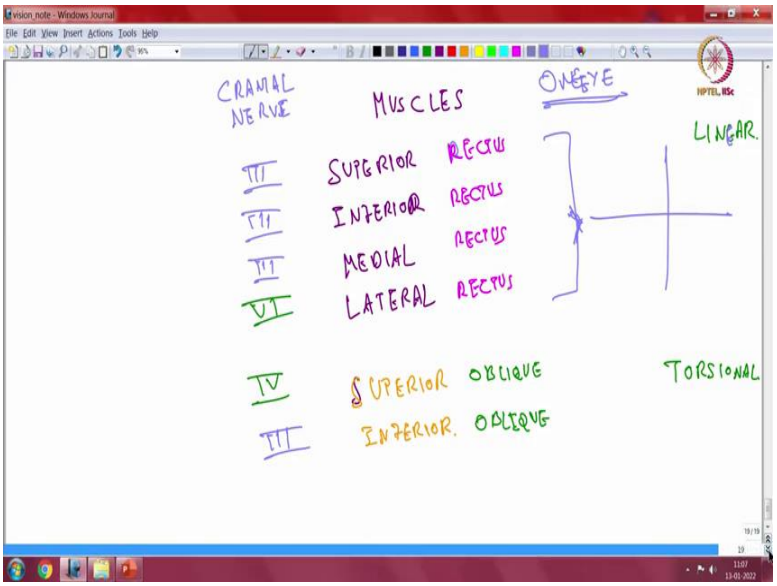

So, what are the kinds of muscles which are involved a brief discussion. So, you have muscles, superior, inferior, medial, lateral. So, these are four directions, and these are oblique directions. So, we will name the muscles superior rectus, inferior rectus and this is superior oblique, inferior oblique.

So, many muscles are involved you know there are 6 muscles which are responsible, these are linear, and these are torsional. So, linear is direction. So, this is lateral rectus for my right eye, medial rectus, superior rectus, inferior rectus then, superior oblique and inferior oblique. So, we will denote the now.

So, all of this stuff is superior cranial nerve IV, lateral rectus is cranial nerve VI, all the rest of it is III. So, that is the cranial nerves. A very busy explanation, it is not necessary for you so that is the reason I went through it in this fashion. So, for a given eye, there are four cardinal places.

So, given eye, this is lateral rectus, in which movement happens like this, medial rectus, superior and inferior rectus and superior oblique, inferior oblique. So, torsional movements and linear movements.

So, these are the mechanisms and each of these mechanisms is for one eye. So, one eye in the sense that, you need to yolk what you call synchronizing muscles and when you

see any object you obviously, notice that both of your eyes move synchronized with each other.

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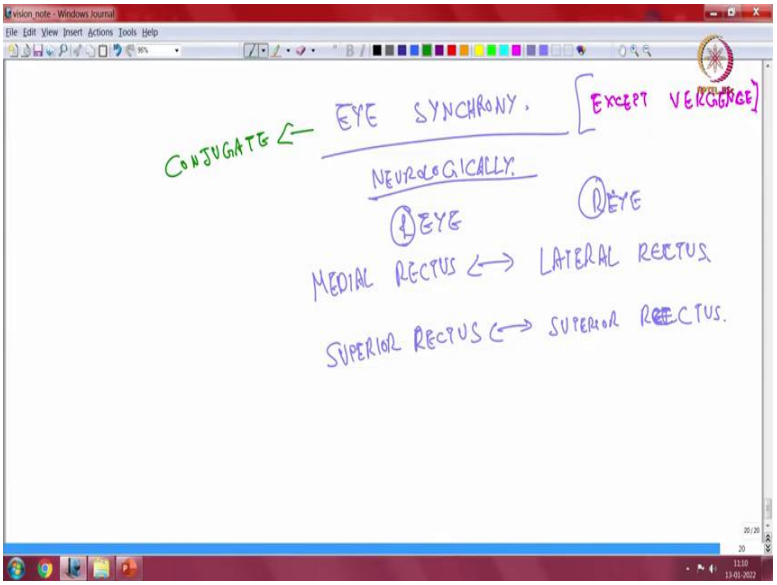

So, eye synchrony is done neurologically. So, how is that done? So, you have the medial rectus of the left eye with the lateral rectus so, medial rectus and lateral rectus of the other eye so, right eye, left eye. So, right eye and left eye, right eye medial rectus is connected neurologically. So, you connect neurologically the left eye medial rectus with the right eye lateral rectus and that ensures that you have synchronous movement of the eyes towards one direction.

Remember, there are so many notions over here. So, you have visual field which is related to the object which is there in space to which you have a half symmetric retina not half symmetric, it is four quadrants and because of the lens, you see inverted images on the retina, what I am here speaking about is gaze, gaze in which movement of the eye happens in one direction and that is by synchronizing different muscles in individualized. So, that is what has been told.

Superior would require superior of both sides to be connected. So, anyway I am not going into greater detail, there is a lot of yoking which happens between these oblique muscles which again I think I will have to refer back to right its sanely, you can check up how those things, but the objective is not to mention, this is not a biology class or a

medicine class in which I would need to emphasize on that. The idea is to convey that there is eye synchrony, individual eye movements.

Now, eye synchrony does not happen in except vergence. So, vergence is disconjugate movement so, the others are called conjugate. So, say eye synchrony is called as conjugate movements. So, conjugate movements is when the eye moves symmetrically for various things, even saccades a conjugate, pursuit is conjugate, a vestibular-ocular is obviously conjugate, the vergence is disconjugate or because you need to bring the eyes closer towards each other. So, the key thing is it is all based neurologically.

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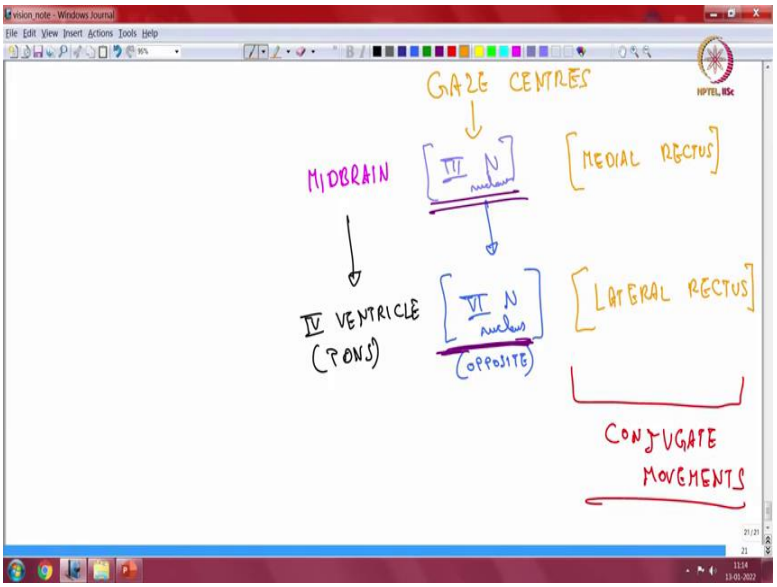

So, to give you an example in the midbrain is the III nerve nucleus, III nerve nucleus goes to medial rectus. Now, so, from the mid brain, it goes into the floor of the IV ventricle with somewhere in the pons where you have VI nerve nucleus so, there is a connect and this is to the opposite side.

So, one side medial rectus is connected to other side lateral rectus, and all of this results in conjugate movements. So, that is howyou have paths from each of these nuclear and it is all hardwired, you do not learn these things, it is all hardwired within the brain and that is how you switch from various parts in the brain, mid brain and pons through dedicated fibers into the internal longitudinal bundle and the nuclei are in different places.

And from each of these things, there are fibers which go to specific nucleus. So, when you activate the III nerves nucleus, there is immediately activation in the opposite side VI nerve nucleus.

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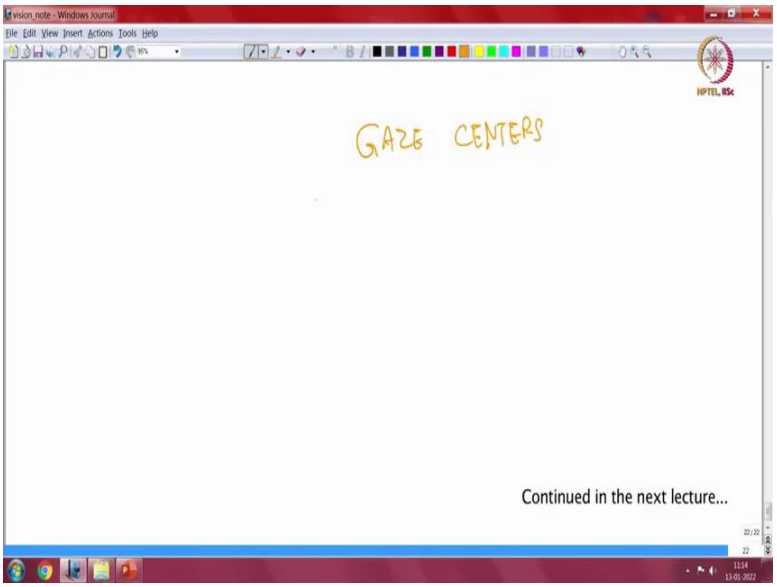

Now, if you look at a higher level, you know the next level is what is called as gaze centers. So, gaze centers, we will continue in the next session.