Virtual Reality
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Lecture – 9-3
Human Vision (eye movements)

Alright, I want to now get to the next problem which is eye movement. So, I talked a little bit about the fact that the eye can move. So, in the picture, that I drew before where the eye was facing the screen; that is all very nice, but a lot of trouble is caused by the fact the eyes can move. And our eyes are moving all the time without us being consciously aware of it.

You can command your eyes to move, but when you are not commanding to your eyes to move, they are moving a lot anyway and they are moving very often doing all sorts of things. And I want to classify the different types of eye movements. Before I do that, I will first just explain the different eye muscles just to start off.

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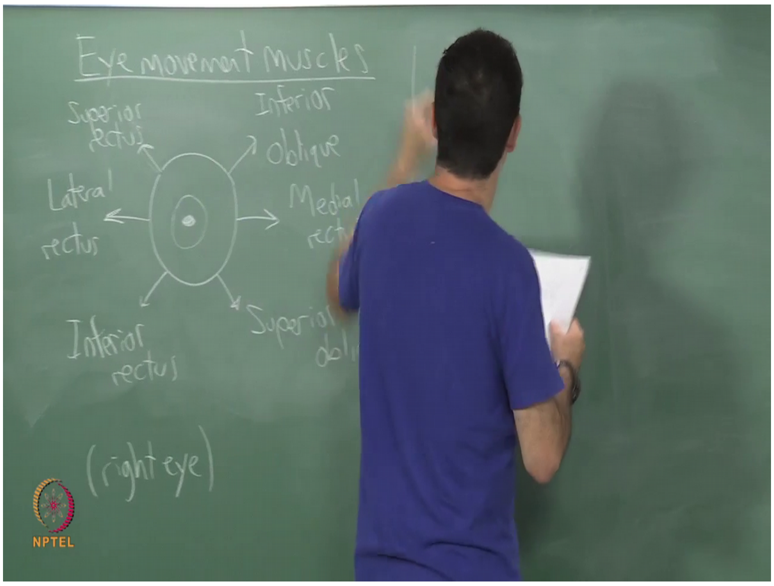

Eye movement, let us take imagine the eyeball and you are looking you straight at the eye. It is drawn iris perhaps.

So, for each eye, there are six different muscles, that are able to contact or extend and that will allow your eye to rotate. The ways that they will pull on the eye, there are side ones, there is lateral rectus and medial rectus. So, two eye muscles for side to side, this enables you to do your motions with your eyes. So, you can go back and forth like this, right? Some of these side motions may be necessary for binocular vision for stereo when you move the depth of under distance of an object that you are focusing on; however, you may also just want to move from side to side both eyes together in a coordinated way. Let us see which eye is this, lateral I believe this is the right eye because lateral should be off the side and medial should be into the centre.

So, I believe it is the right eye, put my label in the wrong place there because I am not going to be able to I am. So, I going to be able to put my remaining muscles. So, there also some muscles off on the diagonal 4 of them. There is a superior not going to go too far on these kinds of things it just to look like an anatomy class and were not going to have to worry about too many Latin names. But inferior oblique, down here superior oblique, and down here is inferior rectus. So, if the eye is a rigid body how many degrees of freedom does it have for rotation, right? Just as a rigid body before we think of any constraints, 2?

Student: 2.

Really as a rigid body? How many degrees of freedom does a rigid body have of rotation?

Student: (Refer Time: 03:59).

3, degrees of freedom right so, translation part is 3 rotation part is 3. So, there are actually technically 3 degrees of freedom of rotation. And there are 3 pairs of muscles that can pull the eye back and forth.

So, it can achieve 3 degrees of freedom of rotation; however, you are most familiar with it being 2 degrees of freedom probably seems like 2 degrees of freedom because we can look up and down, and we can look side to side. But also when you are converging, it turns out there is a little bit of roll happening. So, roughly speaking there are 3 degrees of freedom, but there mostly constrained to a 2-dimensional surface of rotation. So, it is close to 2 dimensional, but you can make arguments for being slightly 3 dimensional. Let us say right; so, there is kind of a thin band for the third dimension of rotations.

So, it does have all of this. So, extra bit of freedom, but you cannot do absolutely wide motions also there is very tight coupling between the eye muscles, from eye to eye as well. You cannot very easily or maybe in any way start to look having your eyes look in different directions or and so, so there they definitely designed to be coordinated alright.

So, these two side ones lateral rectus and medial rectus are free on your eyes back and forth. And for pitching up and down and a little bit of rolling these other 4 muscles are used. Types of eye movements so, eye move we put this in one over here called eye movement muscles.

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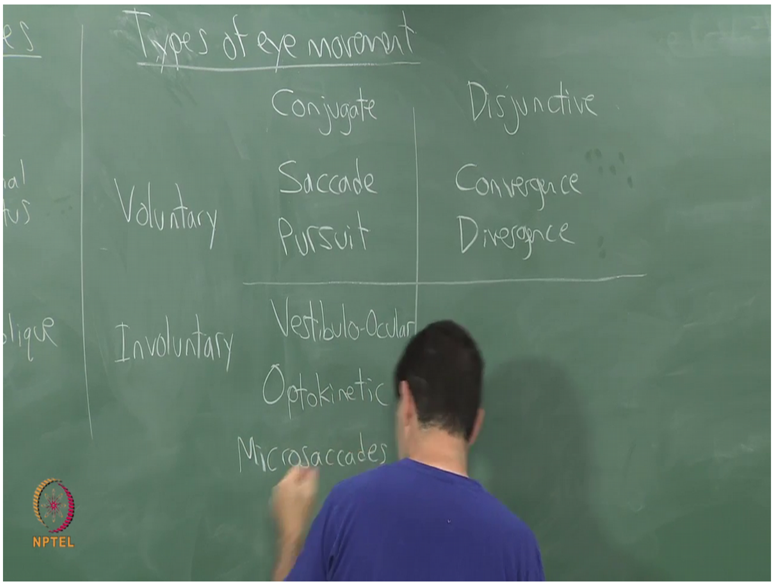

And then I will say types of eye movement, types of eye movement. Let me just make a nice 2 by 2 table here. I put down some names, and then I will I show you a couple of short videos. And then I will explain these different modes. So, here I will call the motions conjugate, and here I will call them disjunctive.

So, conjugate will mean that both eyes are moving together for, whatever the purposes of the movement they are moving together and disjunctive means, that they have a there they are executing separate motion somehow there not there not doing the same motion. And over here for this row I will have a voluntary; which means that you can consciously control it or involuntary, if you have little or no ability to control it, alright.

So, on the conjugate side we have saccades and pursuit sometimes called smooth pursuit. On the disjunctive side we have convergence, which can be coupled together with the other one that goes here which is divergence. They are just opposites of the same thing. These are the motions that happen when we are trying to match stereo.

Maybe that looks like it should be conjugate, because they are trying to come together to make stereo, but geometrically in terms of the transforms that are being applied, these are different transforms, right? They are like mirror images. So, as far as involuntary we have vestibulo ocular, vestibulo ocular, and optokinetic and one more here microsaccades.

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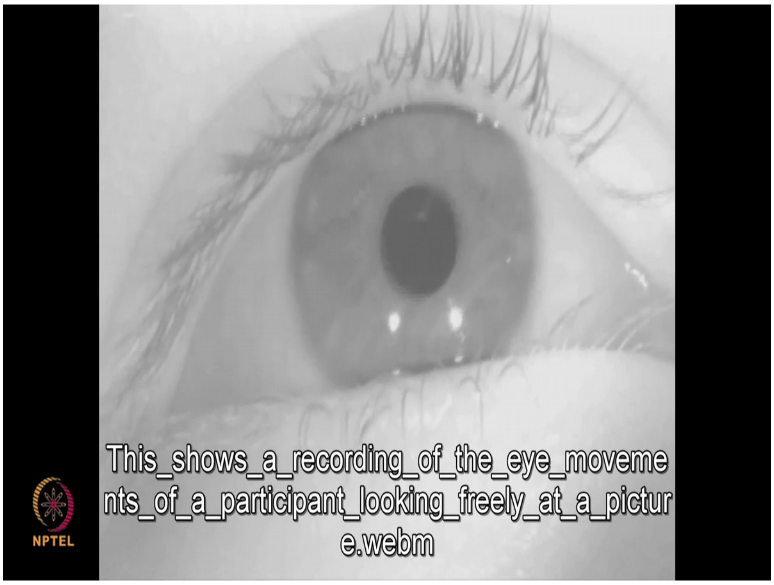

So, this is an eye looking at a picture. So, these are a saccades the eye is looking around at different places. So, you are pointing the fovea, at a bunch of different locations, we do this all the time when reading, looking at pictures looking at people, close up, and you may hardly be aware of the different motions that are occurring here. So, that is an example of saccades.

And then this is how a smooth pursuit looks; when your eye is following a moving target, right? It does look smooth compared to the last one right. In the last case the eye seems to be jumping from place to place quickly trying to fixate to. It is like taking a bunch of quick photographs for the first one. This one is more of trying to maintain a stable image on the retina as something is moving.

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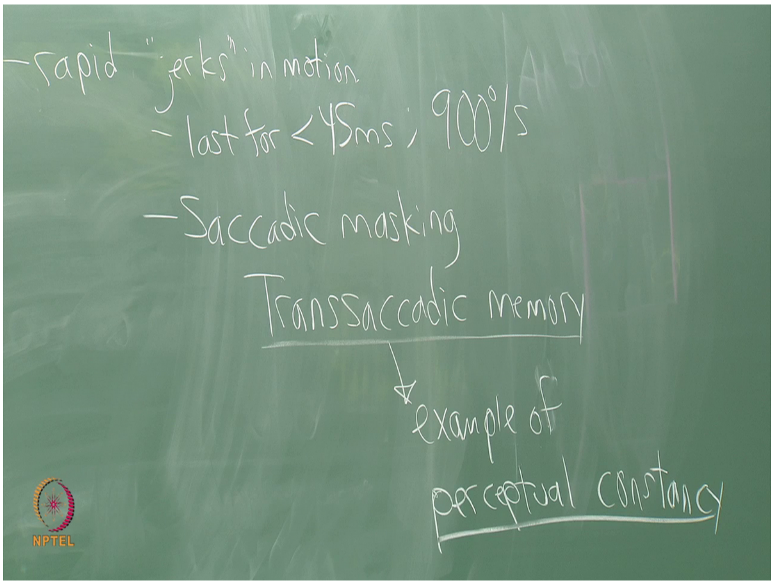

So, one saccades. So, they involve rapid, rapid jerks in the motion. And so, these jerks, they last for less than 45 milliseconds, and during that time they may be as high as 900 degrees per second. So, very fast motions are occurring. And as I said that one of the main reasons for doing this while I showed you the video I said that it improves a visual acuities; like, you are taking a bunch of high resolution photographs.

If you like for your for your brain, and to try to take in the whole picture, because you cannot take in a high resolution image with a very high field of view all at once; our eyes are just not designed like that you get the feeling that it is like that, because your brain is doing some kind of repair work to assemble everything together and give you, what feels like a high resolution high field of view image of the world.

But it the eye does not actually have that based on the way the eye movements occur, the way the fovea is designed the photoreceptor density, all of these things are coming together, now, and you do not have that there is a fascinating thing that happens here which is there is a saccadic masking; which is that the brain is actually hiding these jerk intervals from your from your memory or from your perception.

So, even though these jerky eye motions are happening, you do not perceive them at all. And even your perception of time is somewhat altered from them. So, because of this you have what is called trans-saccadic memory, which is a special case of a very general phenomenon on that people know in perceptual psychology it is an example of what is called perceptual, perceptual constancy.

So, what does that mean? Um you perceive what seems to be a single stationary image, one in actuality when performing saccades your eye is moving around all over the place. I had a very a very interesting opportunity, I am I was at Ludwig Maximilian university in Munich about a month ago, and I visited a virtual reality lab there where they had a well-designed eye tracker, hooked up to a system that would actuate a camera with very low latency exactly as someone is moving their eyes.

So, what you could do is you could have someone sit there they start moving their eyes around doing the normal saccades and then you can look on a screen, and see what the camera sees, when it is mimicking exactly the motions of the eye during saccades that does not sound interesting. So, when you see these motions it is it looks like an absolute mess you know the image is changing constantly there; should be all kinds of blurring as you as it turns very quickly.

I found it very difficult to make sense out of the images that come from that. By just having a camera that menacing mimics exactly the motions of the eyes and saccades. We do not perceive that; I would doing saccade motions all the time, but we perceive the world as being stationary yet, it would be a significant engineering challenge to then take that video from the cameras moving all over the place and try to stabilize it in the same way you could do it with I am use and so forth, but you have a lot of work ahead of you just to stabilize that image the brain is doing the work already in stabilizing. Let us say, the time sequence the video that is that is coming into our photoreceptors, alright? So, I find that very interesting.

So, that is one of the one of the motions is saccade, I am going to talk about pursuit next and then I will take a break in a bit and then I will talk about the remainders after that.

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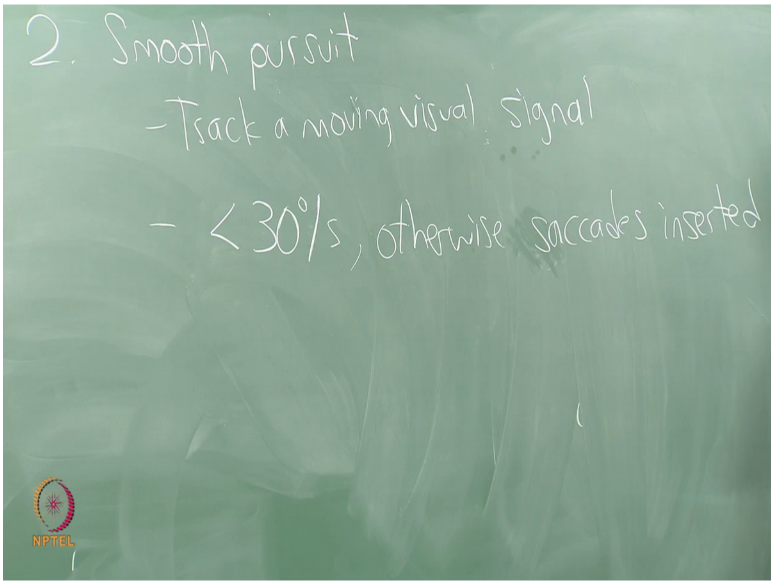

So, two smooth pursuit. So, in this case you track a moving visual signal. So, I could take this notebook and move it back and forth and my eyes are tracking it using smooth pursuit. Now I might also rotate my head some to help that process out. So, so you cannot combine, and very naturally we do combine sometimes head motions with these smooth pursuit motions, but that is going to lead also to the vestibulo ocular reflex which is coming next. But let us just separate them out very carefully.

So, even if you hold your head still there is smooth pursuit. So, if for example, you may be watching a tennis match, or football match you watch the ball go back and forth or of course, a cricket match. And you watched the watch the ball moving, and your eyes are tracking that right; same thing for a car going by on the street.

So, these motions are significantly slower they are less than 30 degrees per second. And if you trying to track something that is faster than that with your eyes, what will happen, is that some saccades will get mixed in. So, the eye will have to jump ahead to catch up. So, sometimes so, say otherwise saccades are added, saccades are inserted. The main reason for doing this is to reduce motion blur.

So, you can this attempts to give a more stable image on the retina as you moving as not you are moving, sorry, as the object that your tracking or whatever features there are is they are moving to make that appear to be a stable image, to make it look motionless as far as your retina is concerned, right? Questions about that? Yes.

Student: Sir (Refer Time: 15:56) coming the surrounding, right?

That is very interesting. I think, that is that is correct, yeah, motion blur be in the surroundings; however, if you tracking it your fovea is aimed at the object of interest that is where you are getting the highest visual acuity, and there is attention your attention is focusing on that, right? And so, yes, but the focus is not the attention is not there. So, it is not a problem. It is very interesting question though why do not we try that during the break why do not we do some smooth tracking experiments.

And see if you notice some kind of blur that is another question do we would you can you design an experiment where you perceive the blur um, but. So, the brains relying on attention to let us say not worry about that another thing that happens which I didn't get to the stereo part yet, but if I converge my eyes to this bottle for example, then everywhere else there are double images.

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It is called diplopia, right? Do you notice that very often? Not really, but now try it put something up there and then at the periphery, you notice there is multiple images it is very obvious once you know to look for do not look directly at it, because when you focus on something else, but you will converge to something else, but if you just converge on something close. And then I see two professor mony is there out of the side of my eye. So, you know it works very naturally like that. Anyone else? Alright, thanks