Virtual Reality
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Lecture - 20-2
Evaluation of VR Systems

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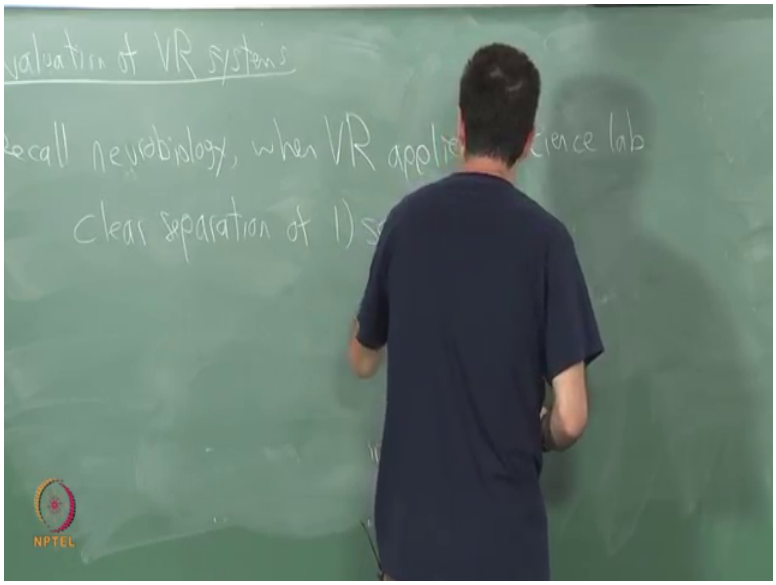

Actually evaluation VR system so, in other words, how do we know whether you are making progress right, you made one experience, I have improved it, I have made something better, are you sure right? So, how do we know? Remember that when we talked about we talked about neurobiology in the very beginning lecture and perceptual psychology as well; we have where VR was applied in a lab to study how organisms are affected by that. We talked about VR applied to insects such as a cockroach; we talked about it applied to rodents as well, so major applying it to a mouse. All the way up to perceptual psychology which corresponds to applying virtual reality to humans all right.

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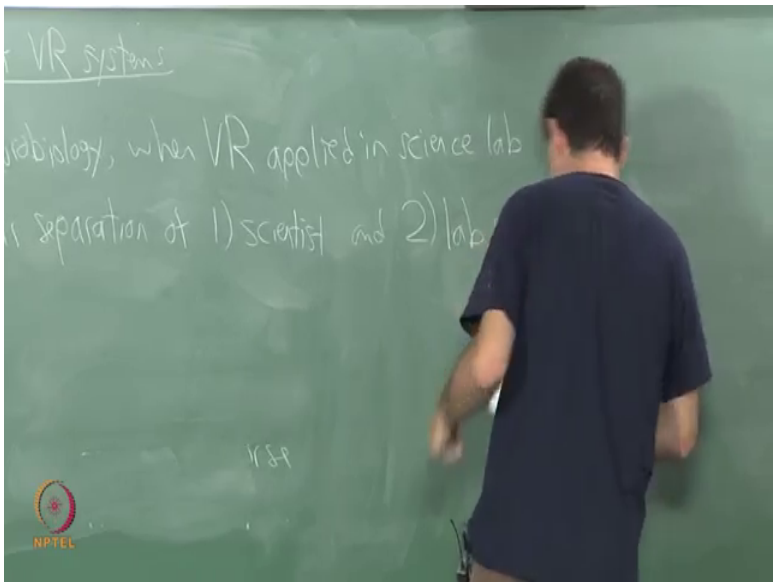

So, when we do that there is very clear separation of the scientist and the laboratory subject. However, if you are an engineer or developer of virtual reality systems, but in this case you may commonly be moving back and forth between these two without even being very much aware of it right. So, just be aware that every time you try your experience you become the laboratory subject, and then you go back and try to be the scientist again right. And it becomes even worse because you know the scientists might at least in principle, it is supposed to be dispassionately trying to determine whether some hypothesis is true or false.

So, they really would just like to know what is the truth. The developer would like to be done with their task have everything work well, and either it is part of a business or a class project, whatever the case may be are just making a good experience, so they have a vested interest in having the hypothesis come out, so that they have made something good right. So, that is another kind of problem. So, they are already even as a scientist if they were there quite a bit biased for the outcome to be in their favor right all right.

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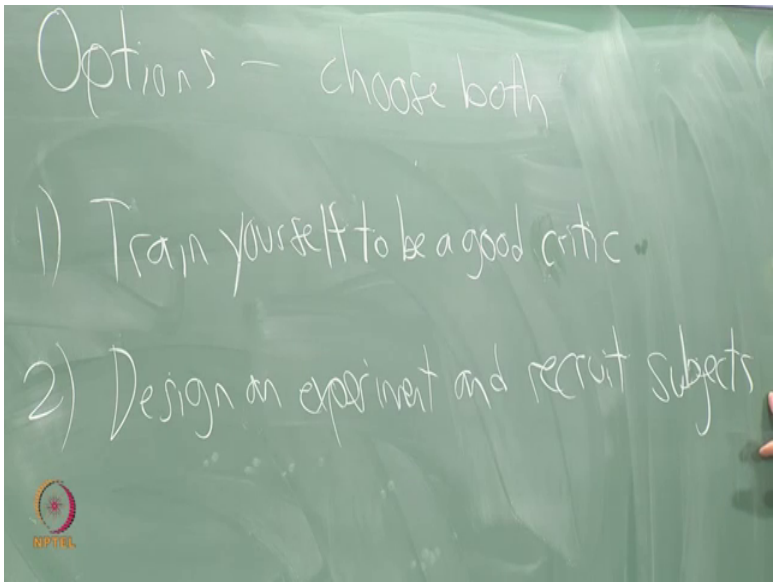

So, what options do you have? I will mention two options. One train yourself to be a critic, I say good critic or maybe a bad critic in the sense of train yourself to be very negative and hostile towards your own designs it is difficult to do maybe. Two, design an experiment and recruit test subjects right. So, recruit people to try. Which one should you choose? I suggest choosing both of them right

So, obviously, the first one is the laziest one right. So, train yourself and then you can evaluate what you are doing with very quick frequency and without doing a lot of extra work. Number 2 may require significant amount of extra effort and work and so you end up doing this depending on how much your life depends on it right. So, what exactly you are doing, you build entire company around this, you had better do a lot of experimentation and testing are you building your entire career basing it on this then do a lot of testing. If it is just something for fun to share with your classmates then fine let a few of your classmates try it, and get some feedback and then may be enough to make you happy. So, choose both.

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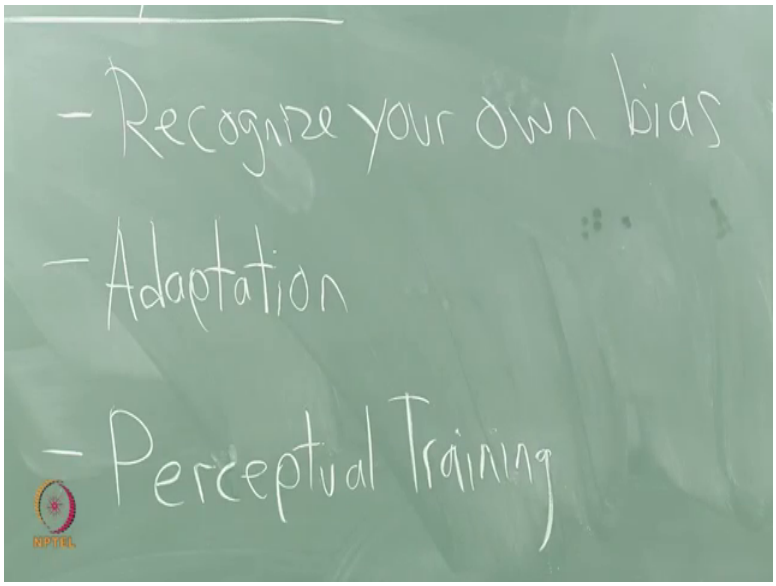

Let me give some advice under these two cases. So, what if we choose number 1? So for yourself, we give some key points one thing is recognized your own bias, we recognize your own bias. So, one of the things I will say about that is you are going to know more about what you are trying to do, what is the intention of your experience than anybody else right.

So, if you know what you are trying to do, it may be the case that you have some kind of motion occurring, and you know that the object is moving not you. But if someone tries it, and they do not know either way, they may think that they are the one that is moving, and then they get sick and you complain why are you getting sick and then and then and then you say well you know it looked like I was moving and then the creator might say well, well duh of course, you are not moving the object was moving did not you get it you know. So, it will actually affect the outcome of sickness here in the simulator sickness based on what interpretation your brain is giving. So, you have to be very careful about that.

The other thing which I already mentioned is you might be very proud of what you have made or lazy all right. So, you have done, you want to be done with it, you do not want a bunch of feedback that says do it all over again right or (Refer Time: 06:05). So, you had like to think that you are done right, so that is your bias right. You are either proud or

lazy, you do not want to redo it or you are happy of what you have made you are biased by that. And only you understand what it is supposed to do.

What else adaptation this is from perceptual psychology. So, you might perceptually adapt. So, you may have made some bad choices, there may be some errors in your system. You have learned to adapt to those they do not bother you anymore maybe you have made something that is horrible from us from a vestibular mismatch perspective, but you have made so many horrible experiences before they do not bother you anymore right. So, you adapt to it.

The more experience you have in general with virtual reality the harder it may become to detect the flaws. So, you may need fresh subjects. One way to fight against that of against the adaptation is to put yourself through what I would call perceptual training. It is like training a detective to look for clues at a crime scene right. Look for the clues, try to try to find the things that you would ordinarily miss and look for them and then as you develop experiences make sure you are finding them again. So, try to try to see the flaws that maybe were invisible before.

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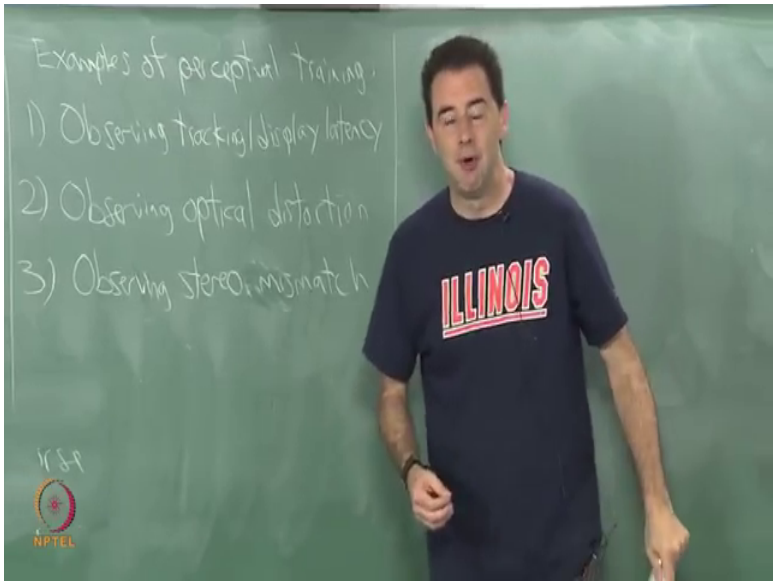

I am going to give some examples of this that I myself experienced. So, one observing latency, so tracking and display latency ok. So, suppose you have some head tracking and maybe something gotten messed up right. So, it is hard to tell you had like to verify that. Here is what I like to do; I like to look at a vertical line about 2 meters away in VR.

So, it is comfortable, it may be a doorframe or our side of a window and then I go like this. So, I move my head back and forth at about 2 hertz. If I shake too much at a higher speed, then the headset might start to move with respect to my head, and I do not want to do that. If I move too slowly then I might not perceive latency anymore. So, I picked a kind of intermediate speed well like this.

If I move too far of an angle then I might also have problems, because of optical distortions things like that. So, if I just move like this small angle at about 2 hertz, then I can adjust with some keys let us say the amount of prediction that is going on in the tracking to try to compensate. Ideally it should all be working fine maybe there should be effectively no latency, but you can then move the keys and you can show yourself what does it look like? When there is 40 milliseconds of latency or 100 milliseconds of latency. What does it look like if I overshoot I try to predict and I end up arriving the images end up arriving 50 milliseconds ead of where they should be right. So, you train yourself to look for that, and then try to 0 in and get it to match as closely as possible as it does to the real world.

And again you can go to the real world and look back and forth or something try to match it you are using the vestibular ocular reflex then do it in VR and see if it looks right. When I started working on VR in 2012, I could only see latency down to about 40 milliseconds when I first started playing with these systems. After about a year and a half and perceptually training myself I could detect latency down to about 2 milliseconds. So, so, I think that is very close to the limits of human perception that is very important.

So, all of a sudden I have trained myself to be a verifier of whether or not the latency has been handled correctly. So, you should do that, rather than training yourself to just adapt to the latency, and have your brain convinced that that is fine right. And then you may have some discomfort or maybe fatigue or may be simulator sickness at the end because you have not trained yourself to look for it.

Another one observing optical distortion remember that we have lens aberrations with a high field of view lens. So, what you need to do to see optical distortions and any kind of problems with those is you have to be looking through the sides of the lenses. Now, you could just go like this, move your eyes to the side, try to look around, but why not use your vestibular ocular reflex. So, what you do is you look at an object in VR; you fixate

on it and then move your head back and forth a lot. And in fact better than picking an object, go to a place where there is a lot of rectilinear structure where there are vertical and horizontal lines maybe in a nice room, I thought as I look around in this classroom, look at the blackboard I see I see lots of structure vertical and horizontal lines.

So, do that and then move your head back and forth, so that you are looking out of the sides of the lenses. If there are optical distortion issues, you will see a significant amount of warping or swing in these vertical lines so to look for that. If you go do that, try that in the lab, you will find that. Even if you compensate forward in software, you still cannot compensate for all of it because your pupils when you use your vestibular ocular reflex like this are translating away from the center of the lenses. So, you are moving across different parts of the lenses.

Another one observing stereo mismatch so, I am supposed to be showing perfect stereo rendering for the right and left eyes. What if I got it wrong? So, what if for example, I have I have everything matched perfectly except I have decided to draw a butterfly, but the butterfly only shows up for the left eye. You think you would notice? You might not; your brain will still fuse everything together in one coherent picture.

So, the way to do it, how would you do it? Well, close your right eye, and look through the left, and then close the left eye and look through the right and see if you get different pictures very simple, but people usually do not do that right, so that is, so that is one thing you can do, close one eye and then close the other and compare the images that you get right, so very simple. So, there are many, many procedures like this, you may need to be clever about them as you suspect different kinds of flaws in your system questions about that all right.

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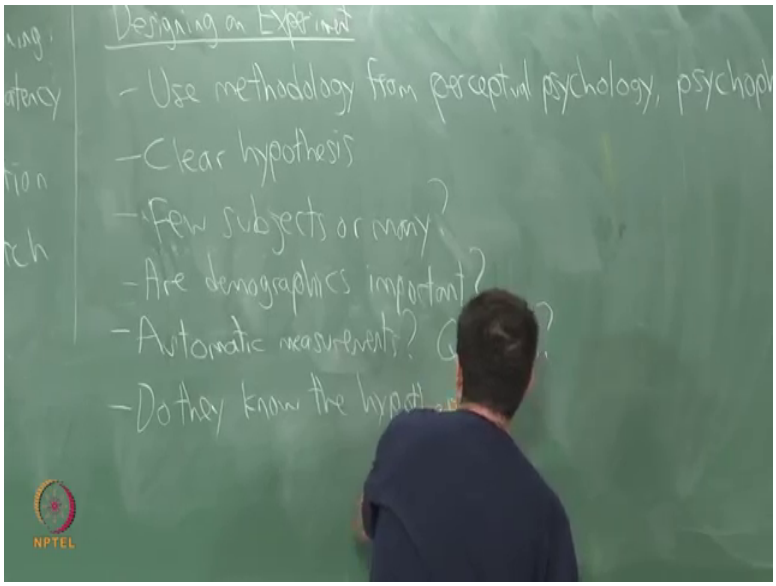

So, now that is for yourself what about designing an experiment. Now, there are plenty of books and courses just entirely on this. And we have to design experiments when there is human perception involved. So, if that is the case, I highly recommend, you read about and use methodology from perceptual psychology, you should believe this from the things we have talked about in this in these lectures for this course especially the area of psychophysics.

Let me just give some highlights you definitely need to have a clear hypothesis right, be very, very clear about what it is you are trying to establish not just always my system pretty good, you know I guess try to come up with very very clear hypothesis about what you are trying to reason about. You have two methods of locomotion for example method a, method b which one is more comfortable from a simulator sickness perspective, which one is more effective in terms of way finding you know are you actually building a kind of map of the environment while you navigate around or not or is it become too confusing and disorienting. So, formulate the hypothesis very clearly.

Do you need I am a few subjects or many maybe 100 of subjects? You do not always need a lot of subjects for some experiments in psychophysics; it may be just that three or four subjects is enough. It may be based on a simple phenomenon maybe, the response time of your vestibular ocular reflex and you do not need to have 100s of subjects to determine that. It may be very very similar very very close range of small amount of

variation let us say from human to human, you just need to measure it. So, you need a few humans to make sure that you have gotten the measure accurately you have done things correctly. So, perhaps you do just enough to believe the data and not be overwhelmed by one or two outliers right versus some kinds of phenomena especially when we talk about simulator sickness you may need to studied over a very large number of people.

Related to this is our demographics important. Who is going to be using your experience, and does it matter you know men and women may have different um different experiences, and may be different results based on gender, may be different results based on age, may be different results based on the amount of experience in terms of sitting in front of giant displays all right. So, if you have a group of people who have been playing first person shooter games for the last 5 years very regularly, they may have a different response to the kind of stimuli that cause simulator sickness, they may be quite immune to it in a lot of cases.

Can you take automatic measurements, can you take automatic measurements or do you have to ask them how they feel right? Did you like that experience? Did it make you sick? Maybe you can measure the galvanic skin response which has to do with the conductivity across their skin which I measure whether or not they are sweating which may then give an indication of whether or not they are starting to get sick. So, they are different things you could measure or at least it may have some measurement of their emotion while they while they use the system there are also other measurements you may be able to take that may give in indication of simulator sickness maybe how they move their head, how they are balancing is affected you may be able to measure that.

If you do not have to tell them to give you a response in some kind of questionnaire, you might have an advantage, of the automatic measurements can directly correlate with the hypothesis that you are trying to resolve. So, automatic measurements are do you have to ask them questions. You have to make a question here. Do they know what you are trying to measure, which do you think is better, should they know the hypothesis? No way, right whatever they know about it they may be trying to help you right or they may be the kind of evil subject they may try to harm your experimental right, they may say I know what they are trying to measure, I am going to keep answering the opposite you know so.

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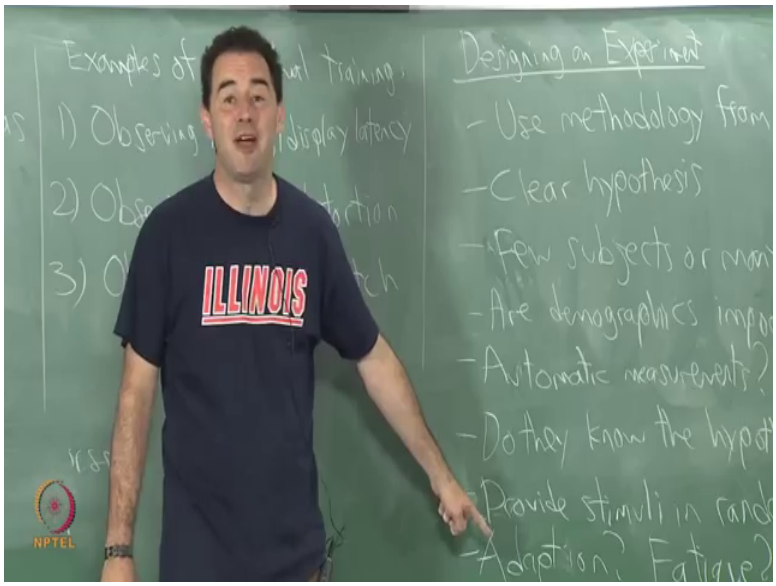

So, it is best they do not know, part of that is you should provide this is very common in psychophysics and perceptual psychology provide the stimuli in random order right. Like for example, when we talked about perception of equal loudness, do you want to start off soft and just gradually increasing it maybe better just present them with sounds at random levels.

And then have them indicate whether it was louder or softer right if you are trying to determine that could maybe ask them if its equivalent, but then I guess there is the difficulty of how much time has gone by since they have heard the base stimulus. So, if you have the opportunity, it is better to present the stimuli in the experiment in some kind of random order without them having any idea of what you are trying to measure.

Another one is adaptation. Adaptation is that an issue or fatigue right. So, it may be the case that as they are doing the experiment, they adapt or maybe you have had the same subjects coming back day after day. Well, you might need some fresh subjects or maybe they become fatigued right. If they become fatigued, then they will have different responses near the latter part of your experiment. Good thing you use random order at least right if you have if you save the best for last you know then that ordering and there increase of fatigue will affect the outcome.

So, these give you some general ideas of the kinds of things to pay attention to in designing your experiments. It is not at all easy and it is especially difficult for engineers,

but there are people who have studied us they do this, all the time they write books on it you can get advice you can talk to perceptual psychologists at your university, and get ideas on what you should be doing here any questions about this? All right I have one final reference that I think it is very helpful for general research scientific questions whether it is engineering or perceptual psychology aspects.

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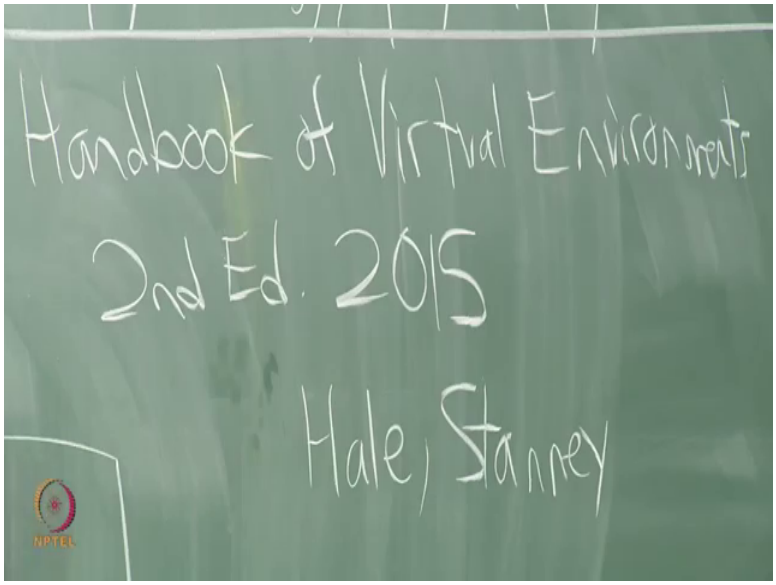

And it is the Handbook of Virtual Environments. Make sure you get the second edition which is from this year 2015. It is an edited series by Hale and Stanney. It is a very thick book, an enormous collection of survey papers that survey many different aspects of virtual reality or virtual environments. So, I am sorry as I find it an excellent source for all of the current up to date scientific literature at least up to probably 2014 and then the and then the book was made. But this is a great source, you can find many references in there and then search for references, that reference references that are that are newer after that and you can find a huge access to the literature on that.

So, that is all for the course let me just remind you of what we went through we start off I start off giving you a definition of virtual reality that emphasized that it is engineering plus some organism that is being subjected to artificial stimuli. So, remember the organism is a key part of that. So, and in the case of most of what we talked about in the class you are the organism that is participating in it. So, make sure that you take that into account in whatever you evaluate. I gave you a bird's eye view where we talked about

the hardware, the software, and the software mainly involved in alternate world generator which today are mainly it is most popular to use game engines, but who knows what the next generation is going to produce, there should be virtual reality engines that make it very easy for developers to develop experiences, game engines are not ideally suited for that right now, but they are trying to adapt them.

And I gave an overview of perceptual psychology. Then we went into geometric transforms and models right. So, how to model these alternate worlds and transform them, so that the right information appears on the screen. Then we talked about light and optics. We got into the physics of it. And then once you understood optics and light, we talked about lenses, and then optical systems that are engineered to make for example, a head mounted display, but then we got into the human eye as an optical system. And then we went into the physiology of the human eye, we went into photoreceptors which are like the input pixels, we talked about the optical system of putting a display in front of your face and going from pixels to photoreceptors.

And then we went into human perception and physiology. We went from photoreceptors to talking about the retina, the neural structure that is part of the eye which goes from the photoreceptors to the ganglion cells; the information is communicated along the optic nerve arriving into the visual cortex. So, then we got up to the levels of perception. We talked about hierarchical processing of the brain, and the whole visual system.

And then we had perception of motion right. Part of that is complicated by the fact that our eyes move. So, we covered the motion of our eyes we covered perception of motion we have covered perception of depth. And I emphasize that there are many other kinds of perception like perception of scale, perception of color. So, now, that you understand that template you can study other aspects of perception. We then described systems of tracking, because we have to track the motion of the human head and perhaps more of the human body in order to make up a perfect kind of correspondence between the physical world and the virtual world.

Then we get into rendering for the visual case. Much of that was standard computer graphics kinds of concepts, but there are many particular aspects to be concerned with when we get to virtual reality. For example, aliasing becomes much worse because of the

changing viewpoint that we have and because of the stereo perspective that we have. So, this becomes a serious and difficult issue

Then we talked about audio for virtual reality. And we have covered many of the same kinds of concepts that we did for visual there are rendering issues, there is human physiology issues, there are perception issues, we covered these for audio. We could have done the same for haptics and touch or forearm, for smell and taste whatever other senses you want to bring into the virtual world we talked about we could talk about these as well in the same kind of style. The vestibular organ was also mentioned because it is very important especially in the case of vestibular mismatch it also is what helps power the vestibular ocular reflex which is very important.

And then finally, we ended by getting into interfaces some of these higher level aspects going across locomotion, manipulation, system control and social interaction. And then I concluded by giving you an overview of how to evaluate VR systems whether it is yourself especially emphasizing perceptual training, and then the design of experiments involving human subjects and that brings us to the end.

Thank you very much.