Introduction to Brain and Behavior
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Lecture 18
Neural Mechanisms of Attention

Hello, and welcome to the course Introduction to Brain and Behavior. I am Doctor Ark Verma from IIT Kanpur. As you know, I work at the Department of Humanities and Social Sciences and also at the Interdisciplinary Program of Cognitive Sciences at the Institute. This is week four and we're talking about attention. In today's lecture, we'll talk about some of the neural mechanisms of how the process of attention manifests itself in the brain. Let us start with voluntary spatial attention.

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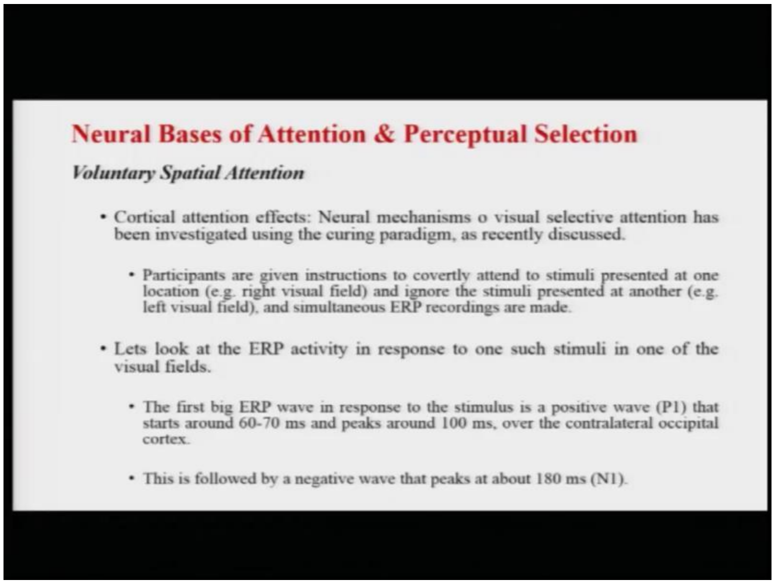

Now, there have been some of these effects with respect to the cortex or the areas that are involved in manipulating voluntary spatial attention. The neural mechanisms that, actually selective for visual attention has been investigated using the cueing paradigm as we just discussed in the last lecture. Now, in this paradigm, typically participants are given instructions to covertly attend to stimuli presented at one location that is the say for example, the right visual field and ignore the stimuli presented at another location that is the left visual field and simultaneous ERP recording summit.

Now, let us look at the ERP activity in response to one such stimuli, onset stimulus in one of the visual fields. First Big ERP wave in response to the stimulus is actually a positive wave or P1 that starts around 60 to 70 milliseconds and peaks around up to 100 milliseconds. This is typically observed or the contralateral occipital stimulus in space that we are trying to attend. This is probably one of the first peeks or first responses of the brain that are documented, which is this positive peak called the P1.

This positive peak will typically be observed on the contralateral visual fields, suppose the stimulus is in the left visual field, it will be observed in the right hemisphere. If the stimulus is in the right visual field, the activity will be observed in the left hemisphere. This one is followed by a negative wave that peaks at about 180 milliseconds which is known by the name N1. So, there are two of these important peaks that we can talk about.

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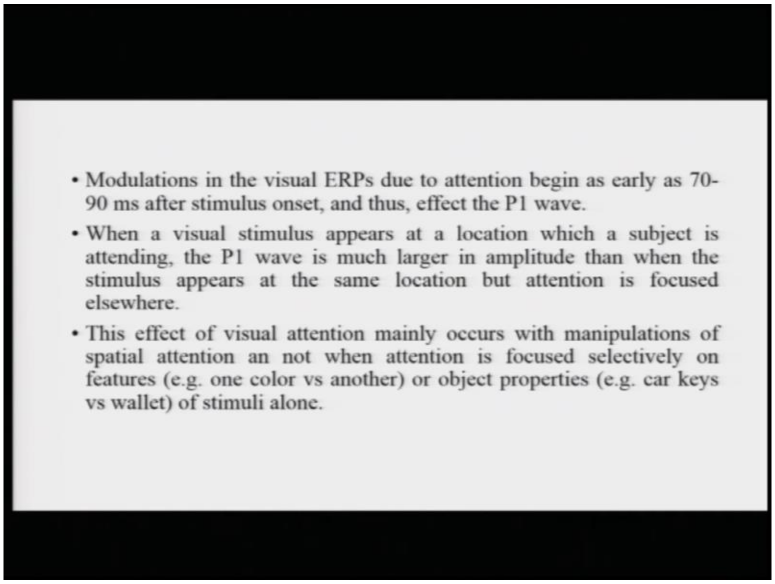

Now, modulations in the visual ERPs due to attention begin as early as 70 to 90 milliseconds after stimulus onset and thus affecting the P1 wave. So, this P1 wave is typically manifestation of modulations due to attention. Now, when a visual stimulus appears at the location in which a subject is attending, suppose, there is this region in the space which the subject is actually attending, the P1 wave is much larger in amplitude then when the stimulus appears on an uncued or unattended location.

So, this is something very important. This is something that tells us that the P1 wave is basically arising or is basically manifesting in response to a stimulus or a location in space being attended. This effect of visual attention mainly occurs with manipulations of spatial attention and not when attention is focused selectively on features. So, this is also something which you should remember that the P1 wave is an index of spatial attention. So, its basically an index of attending a particular region in space and not other features like say for example, color or shape or motion, you know of the stimuli.

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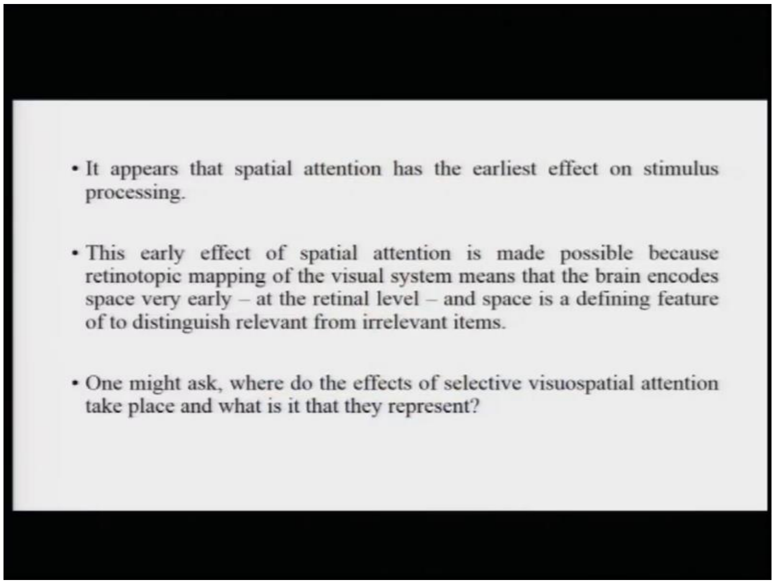

Now, it appears that spatial attention has the earliest effects on stimulus processing. The first thing we actually do about when we are processing a stimulus is to identify its location and space. So, this early effect of spatial attention is therefore made possible because retinotopic mapping of the visual system means that the brain encodes space very, very early even at the retinal level.

If you remember from the last chapter, we have talked about how the receptive fields of neurons are capable of retinotopically mapping or representing the visual space outside in the neuronal visual fields as well. So, we are basically talking about that same phenomenon.

So, again, this early effect of spatial attention is made possible because we know as we know retinotopic mapping of the visual system means that the brain encodes space very, very early even at the retina level. And that space is a defining feature or defining property that distinguishes relevant from irrelevant items. So, that is something which you will also need to keep in mind. Now, one might ask where do these effects of selective visual spatial attention take place. And what is it that they represent? So, how is this activity actually happening?

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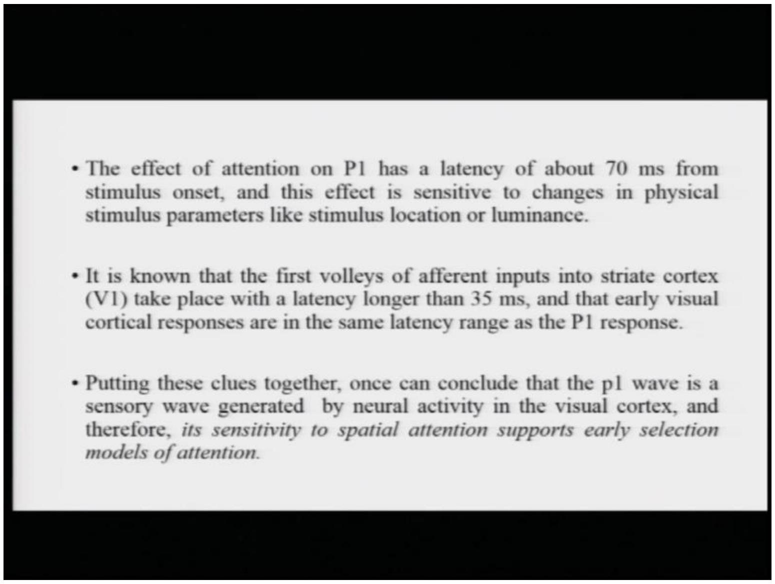

On that, the effect of attention on P1 basically has a latency. So, we know that the effect of attention on this P1 wave has a latency of about 70 milliseconds from stimulus onset and this effect is sensitive to changes in physical stimulus parameters like stimulus location. Now, it is known that the first volleys of afferent inputs, basically neurons going upwards into the striate cortex, that is the area V1 take place with the latency just longer than around 25 milliseconds.

And that early cortical responses also have the same latency range as the P1 response. So, if you kind of put together all of this information, you can conclude that the P1 wave is a sensory wave. It is a wave which talks about sensory processing generated by neural activity in the striate cortex or in the visual cortex. And therefore, its sensitivity to spatial attention supports what are called the early selection models of attention.

Remember, we have talked about Broadbent's early selection model which says that, at a very early stage, we already decide to filter out irrelevant from relevant information and only relevant information is allowed to move further to allow a more detailed processing. So, this can constitute one of the evidences in favor of that kind of account.

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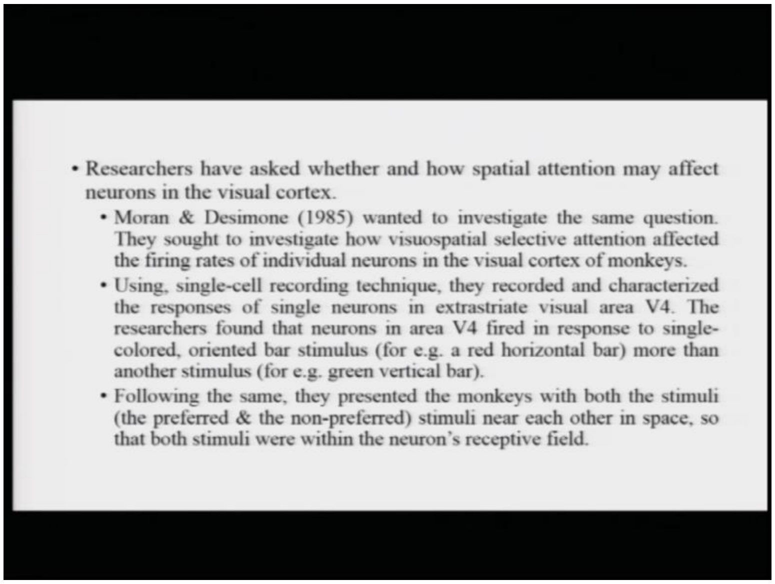

Let us move further. Now, researchers have asked how, whether and how spatial attention may affect neurons in the visual cortex? So, does it happen that the spatial attention or say for example, that whether we are attending a particular region in space affects the activity of neurons in the visual cortex? So, Moran and Desimone wanted to investigate the same question. And they sought to investigate how visual spatial selective attention affects the firing rates of individual neurons in the visual cortex of this study with the monkeys.

Now, they used single cell recording techniques and recorded and characterized the responses of single neurons in the extra striate visual area, V4. The researchers found that neurons in this area, neurons in this area V4 basically fired in response to single colored oriented bars stimulus. Say for example, let us take a red horizontal bars, which is just one color, and it is horizontal in space, more than another stimulus, so you can call the red horizontal stimulus as the preferred stimulus and the green horizontal, green vertical stimulus as the non-preferred stimulus.

So, you have two kinds of stimulus. And we know that these specific neurons, if you remember from the last chapter, we have talked about that neurons fire to very specific properties or very specific kinds of stimuli. So, this is an example of a neuron which prefers the red horizontal bar stimulus and does not prefer the green vertical bar stimulus. So, following the same kind of presentation, they presented the monkeys with both the stimuli at once, situated near each other in the space, so that both of them were falling now in the visual field of this particular neuron.

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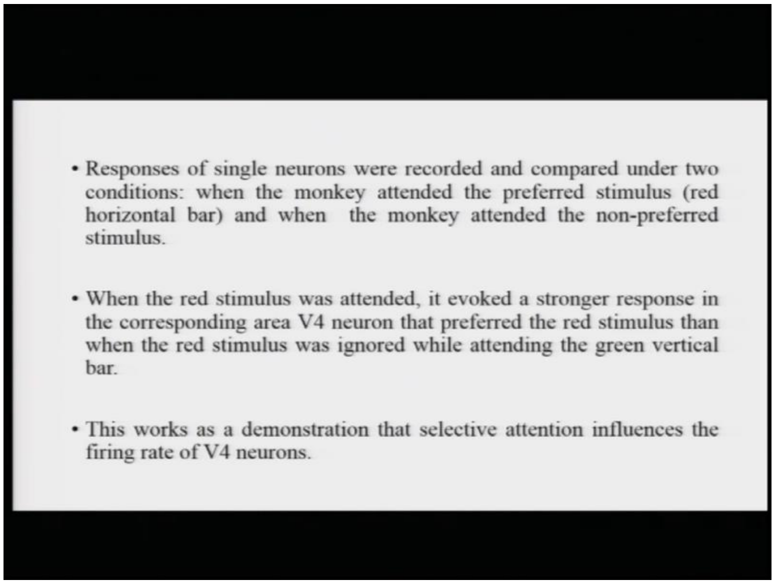

Now, what did they find? Responses of the single neurons were recorded and compared under two conditions. When the monkey was attending the preferred stimulus, versus when the monkey was attending the non-preferred green vertical bar stimulus. When the preferred stimulus was attended, it actually evoked a stronger response in the corresponding V4, in a corresponding V4 neuron that preferred the read stimulus. Then when the red stimulus was ignored or while attending the green vertical bar.

So, when you were actually attending something, it is in essence, actually increasing the firing rates of the neurons in the visual area V4. So, this can work as a demonstration that selective attention actually influences the firing rate of neurons. And you can sort of extrapolate it to say that it actually affects the sensory processing of information in the visual cortex.

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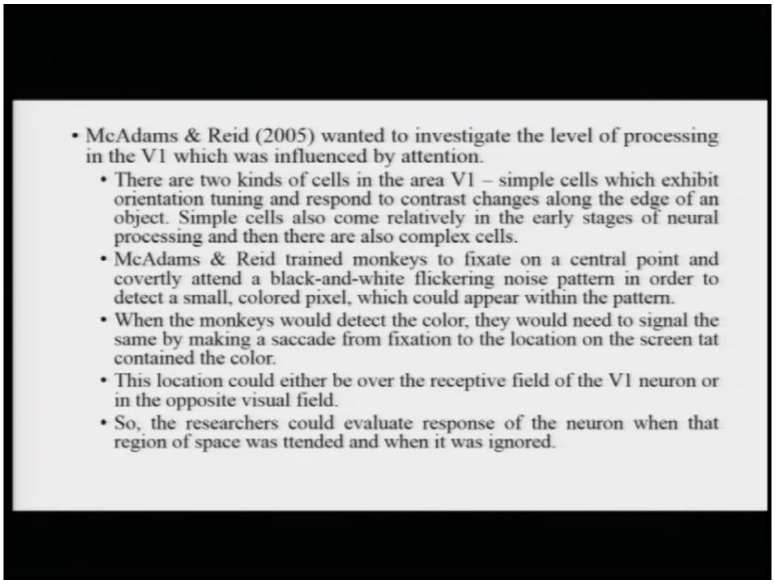

Let us move further. McAdams and Reid actually wanted to investigate the level of processing in the V1, which was influenced by attention. So, they just wanted to dig a little bit deeper and see, what is the level of processing at which, you know, attention modulates processing in this area V1?

Now, there are two kinds of cells in the area V1, simple cells and complex cells, again something that we have already talked about. Now, simple cells basically exhibit orientation tuning, and they respond to contrast changes along the edges of an object. Simple cells are also basically they come relatively in the early stages of neural processing. And then there are complexes which kind of you know, combine more information.

Basically, they combine the inputs from several of these signals as it seems. Now, McAdams and Reid trained monkeys to fixate on a central point and then covertly attend a black and white flickering noise pattern in order to detect a colored pixel. So,, you can imagine that there is let us say, a square patch, which has this flickering black and white pattern.

And somewhere in the middle of this black and white pattern, there will be a colored pixel. And what the monkey has to do is to identify this colored pixel from this black and white flickering pattern. So, this is basically what the monkey has to do. Now, when the monkey would detect the color, say, for example, monkey detects a colored stimulus, it will need to signal, signal the same by making a saccade back from the fixation location to the screen that contained the color.

So, suppose the monkey sees a red colored pattern here in the middle of this black and white flickering pattern, the monkey has to look back at the screen containing red color. Now, this location could either be over the receptive field of the area of the V1 neuron or in the opposite visual field. So, it could be either in the attended individual field or the opposite visual field.

Now, researchers this would enable the researchers to evaluate the response of the neuron when that region was face was attended, versus when it was ignored. So, this region of color, whether it was in the attended region, or it was in the unattended region, that response could be compared now.

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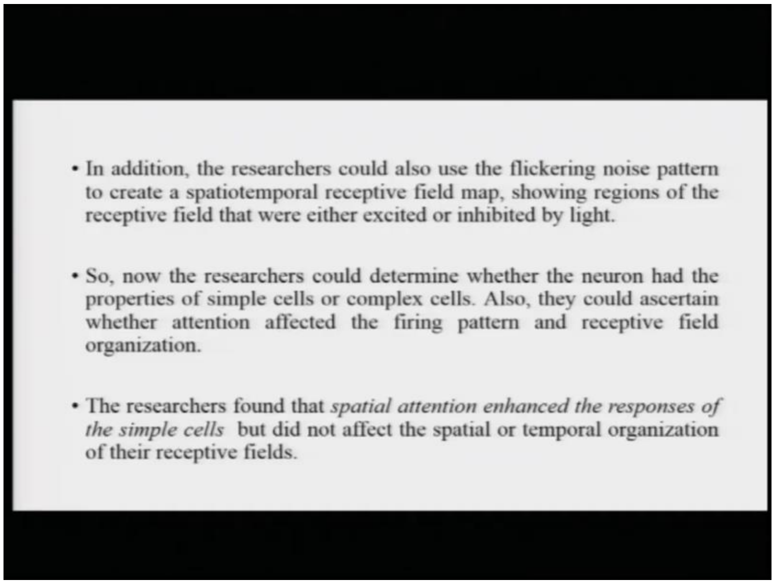

In addition, the researchers could also use a flickering noise pattern to create a sort of spatiotemporal receptive field map showing regions of the receptive field that were either excited or inhibited by light. So, they could kind of get some more information about how this particular you know region is responding. Now, the researchers could determine whether the neuron had the properties of simple cells or complex cells. They could also ascertain whether attention actually would affect the firing pattern and the receptive field organization.

What did they actually find? The researchers found that spatial attention did indeed enhance the responses of these simple cells. But it did not really affect the spatial or temporal organization of the receptive fields. So, there is no or reorganization of the receptive fields happening in response to, to spatial attention. But what is happening is that the firing rates are sort of, you know, being affected.

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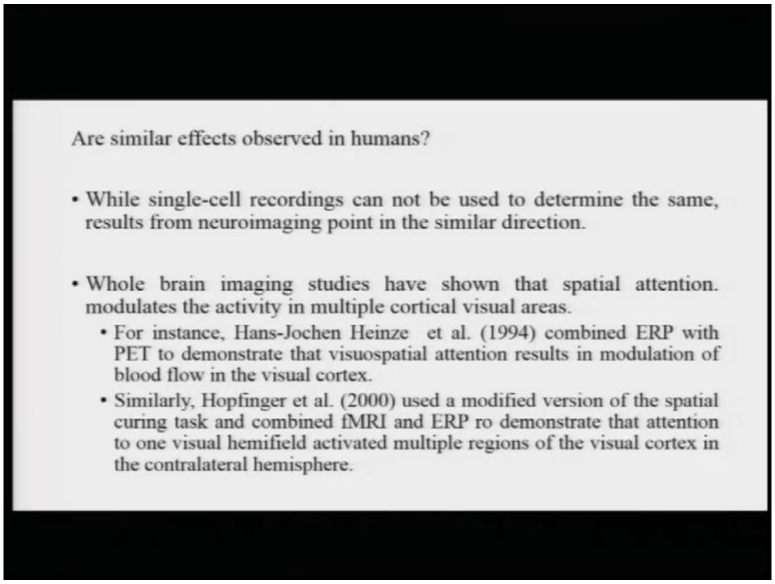

Now, this was basically in the case of monkeys and we are talking about single cell recordings. Is there any evidence that say, for example, spatial attention affects visual processing of, you know, of the human brain as well? So, obviously as you know, single cell recordings cannot really be used to determine the same, determine any kind of activity in the human brain, results from neuroimaging actually point in the same direction. So, what has happened is, whole brain imaging studies have shown that spatial attention modulates the activity in multiple, you know, cortical visual areas.

So, let us look at some of these studies. Now Hans-Jochen Heinze actually in 1994, combined ERP with PET to demonstrate that visual spatial attention results in the modulation of blood flow in the visual cortex. So, if you were paying attention to some region in space, it is actually modifying the blood flow in the visual cortex as well.

Similarly, another study by Hope finger and colleagues in the year 2000, used a modified version of the spatial cueing tasks that we have talked about in the past. And they combined fMRI and ERP to demonstrate that attention to one visual hemi field activated multiple regions of the visual cortex in the contralateral hemisphere. So, if I am attending the left visual field, multiple regions of the visual cortex in the right hemisphere are actually being activated. So, this is something you should definitely remember.

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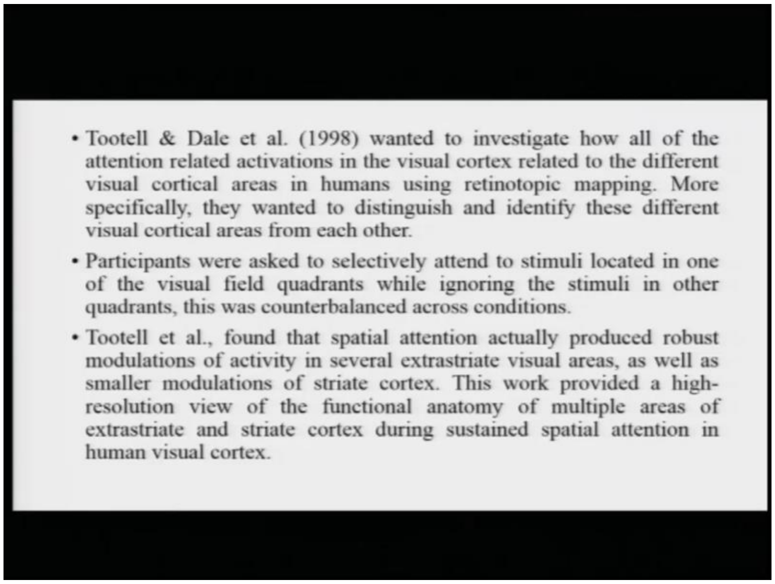

In another study, Tootell and Dale and colleagues actually wanted to investigate how all of the attention related activations in the visual cortex related to the different visual cortical areas in the humans, you know, basically are related to the different visual cortical areas in humans using retinotopic mapping.

More specifically, they wanted to distinguish and identify these different visual cortical areas from each other. So, they basically wanted to check which visual areas in the cortex actually respond differently to different kinds of attentional effects. Now, what happened in their task? In their task, participants were asked selectively to attend to stimuli located in one part of the visual field, in one of the visual field quadrants, while ignoring the stimuli in other quadrants. Say, for example, if you have this visual field, you can divide this into four parts.

This will be the upper left, upper right, lower left, lower right quadrant. So, what the task was that the participants had to attend to stimuli in one of these quadrants, while ignoring the stimulation that could be presented in any of the three other quadrants. Now, Tooteel and colleagues found that spatial attention actually produced robust modulations of activity in several extrastriate visual areas as well as smaller modulations of the striate cortex were observed. This work actually then, you know, provided a very high resolution view or the functional anatomy of various areas of the extrastriate and striate cortex during sustained spatial attention. So, this kind of, you know, could give a nice figure as to which areas of the striate are involved or are openly influenced by spatial attention.

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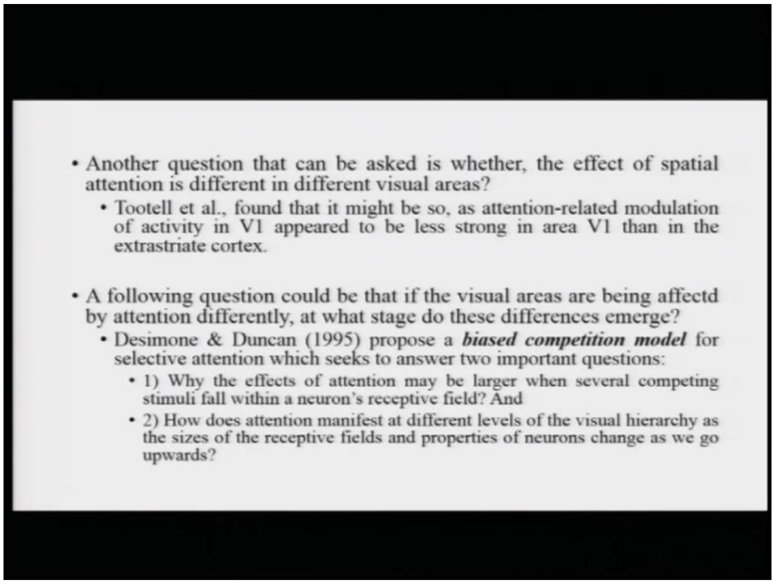

Now, we can ask some more questions. We can ask a question that says, that whether the effect of spatial attention is different in different visual areas? So, we have so far seen that spatial attention does influence processing in the visual cortical areas, both in the monkey and the human brain. Now, the question is, is this effect differential or is it broadly activates the entire, you know, gamut of visual areas that we know about? Now Toteeling and colleagues in the same study found that it might actually be the case.

So what really, they're saying is that attention related modulation of activity in the area V1 appeared to be less strong in area V1 than in the extrastriate cortex. So, basically when they were comparing the activity in different areas of the striate cortex, there is where they actually find that there is a differential effect of, you know attention related modulations, so that is established.

Now, lets move further quickly. A following question could be that if the visual areas are being affected differently, at what stage do these differences start emerging? At what stage let us say area V1 starts responding differently to area V4. Now, Desimone and Duncan in 1995, they proposed a biased competition model for selective attention. And this model is typically poised to answer at least two very important questions.

The model could answer say for example, why does the effect of attention or why the effects of attention may be larger when several competing stimuli fall within the same neurons receptive field and also how does attention manifest at different levels of the visual hierarchy as the size of the receptive fields and the properties of these neurons change as we go upwards.

Again, if you remember from the last lectures, that the visual field of you know the neurons in the retinal region the you know, the ganglion cells etc is much smaller as compared to the visual field in the of the neurons in the LGN as compared to the visual fields of the neurons in striate cortex.

So, as the visual field sizes or receptive field sizes sorry and the properties of these neurons across these three different regions change, how does this effect of attention manifests itself, does it sort of differently affect you know, the neurons in the retinal region versus the neurons in the LGN thelemine region and versus the neurons in the visual cortex? So, these are the two questions this model sort of seeks to address.

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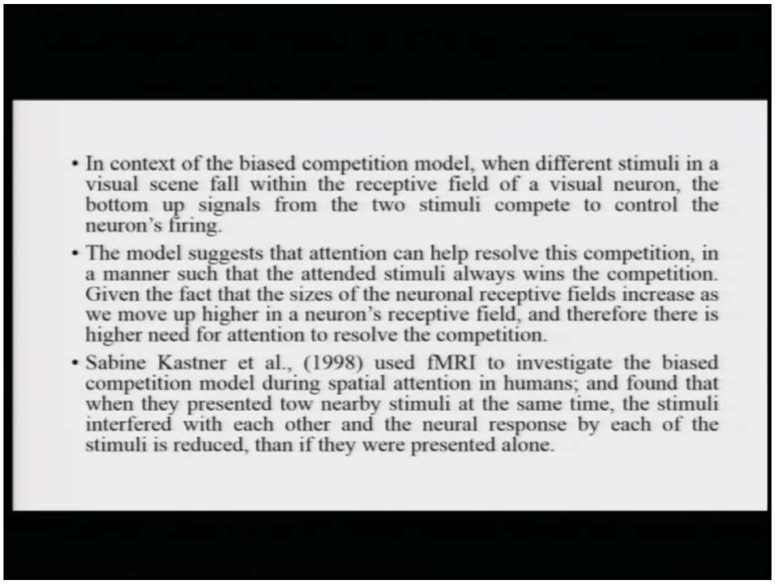

Now, in context of this biased competition model, when different stimuli are presented, you know, when different stimuli in a visual scene supposed to fall within the receptive field of say, of a particular visual neuron, the bottom of signals from the two stimuli will compete to control the neurons firing.

Suppose there is, suppose I am a neuron and there are two stimuli that are seeking my attention. So, what basically happens is that both of these stimuli will compete with each other to actually get the best of my firing or say to get the best of my attention. Now, this model actually suggests that attention can help resolve this competition. If there is some spotlight, let us say, let's go back to the spotlight metaphor.

If suppose there is some spotlight, it falls on one of these two stimuli and you know and does not fall on the other stimulus, then what will happen is, I will buy in sort of an automatic sense, I will attend or fire in response to this stimulus, much more than I will fire in response to this stimulus. So, what attention is doing is, it is actually resolving this competition.

Now, given the fact that the size of the neuronal receptive fields increase as you move higher up in the neurons in the visual processing hierarchy, therefore there is much higher need for attention as we go ahead to resolve the competition. So, basically there is more need of attention when we move upwards the visual processing hierarchy.

Now, Sabine Kastner and colleagues in around 1998, they used fMRI to investigate the bias competition model using spatial attention in humans. So, they basically wanted to check okay, whether the predictions of this model that is being proposed by you know, Desimone and Duncen is correct or its not really correct.

So, they found that when they presented two nearby stimuli at the same time, the stimuli interfered with each other, and the neural response by each of the two stimuli were reduced as opposed to when they were presented alone. So, they were, there three conditions. A stimulus A presented alone, stimulus B presented alone, and then stimulus A and B presented together. In this together condition, the responses or the firing rates of the neurons to both of these stimuli are actually reduced.

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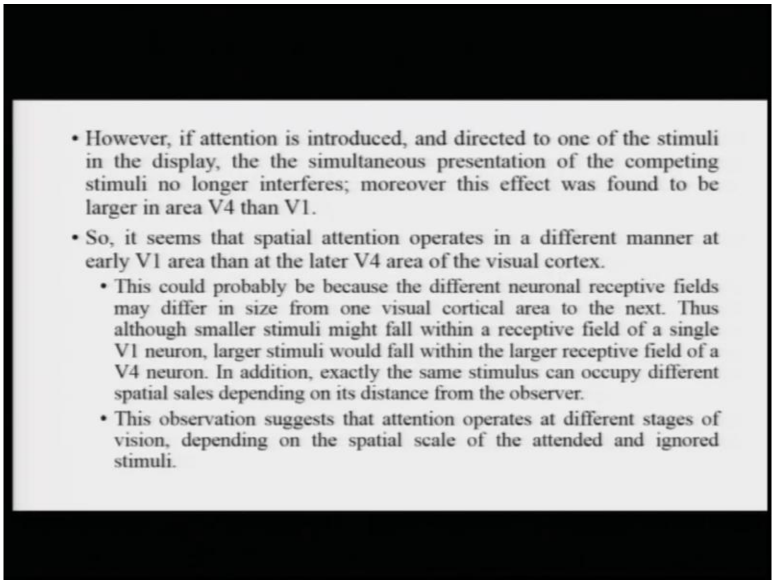

Now, if attention is introduced in the mix, if somehow at cue my attention to any of these two stimuli, or say for example, this attention is directed to one of the two stimuli in the display, the simultaneous presentation of the competing stimuli does not interfere with each other. And moreover, this is the interesting part that this effect is found to be much larger as you go up in the visual hierarchy.

So, if you go in the area V4, then you find that this effect is much larger. So, it also tells you that the role of attention in higher visual processing areas is probably much more important than in the earlier visual processing area. So, this is some kind of caveat that you should probably make note of.

Now, its so, it seems by now that spatial attention operates in a different manner. At early, V1 area than at the later V4 area the visual cortex, that is alright. Now, why should this be? This could probably be because of the different neuronal receptive fields may differ in size from one visual cortical area to the other. So, that is something we have already just talked about. Thus, although smaller stimuli might fall within the receptive field of a single V1 neuron, larger stimuli would fall in the larger receptive field of say, for example, a V4 neuron.

In addition, exactly the same stimulus can occupy different spatial scales, depending upon its distance from the observer. Suppose something is much farther than me, then the size will seem smaller and it will basically compete in the earlier areas, which has smaller visual fields versus when the stimuli is just right into my face, it will appear much bigger and will basically occupy the receptive fields of neurons from the higher regions.

Now, this observation sort of suggests that attention operates at different stages of vision depending also upon the spatial scale of the attended and ignored stimuli. So, something that is also important is the spatial scale at which you were interacting with the stimuli and that basically also you know, influences the manner in which attention interacts or attention operates with respect to these stimuli.

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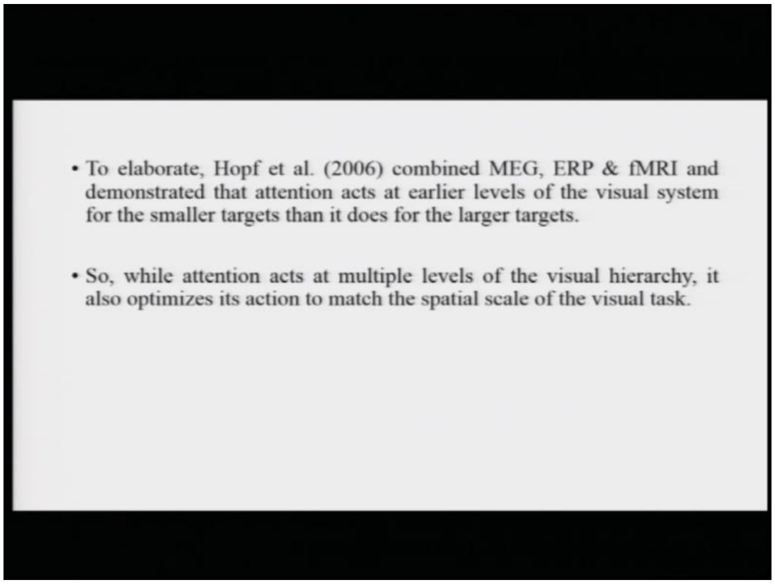

Now, to just kind of elaborate the same, Hopf and colleagues in 2006 combined MEG, ERP and fMRI. And they demonstrated that attention acts at earlier levels of the visual system for the smaller targets than it does for the larger targets. So, when small targets are being attended to, the effect of the modulatory effect of attention is observed much faster, much earlier than it does for the larger targets.

So, while it is sort of established that attention does act at multiple levels of the visual hierarchy, it also should be noted that attention optimizes its action to match the spatial scale of the visual task, whether you're dealing with small looking stimuli or larger stimuli. Also you should factor in the distance of the stimuli.

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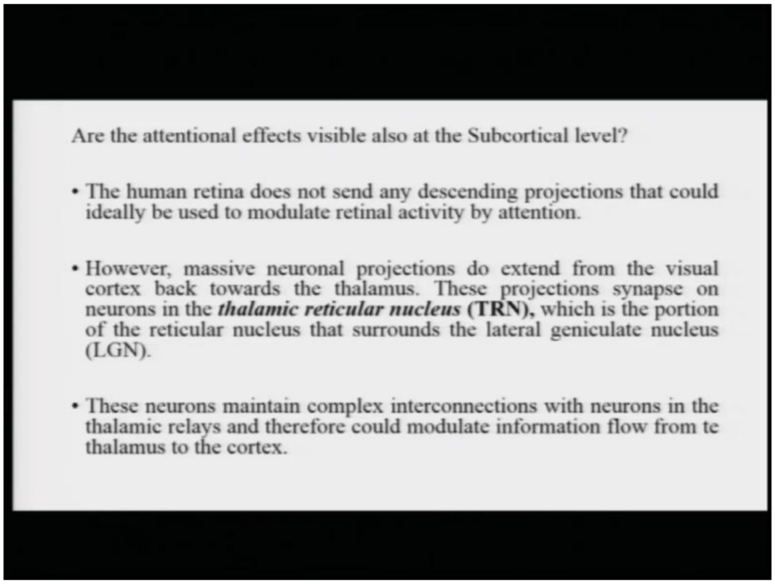

Now, are these attentional effects also visible at the subcortical level? Now, human retina typically does not send any the human retina actually does not send any descending projections that could ideally be used to modulate retinal activity by attention. But there are massive neuronal projections that extend from the visual cortex back towards the thalamus.

Now, these projections actually synapse on spatial nuclei, called the thalamic reticular nucleus or the TRN, which is the portion of the reticular nucleus that surrounds the lateral geniculate nucleus. So, this is also a bunch of nuclei, which is just around the LGN. Now, these neurons, the TRN neurons maintained complex interconnections, the neurons in the thalamic relays and therefore, in principle could actually modulate the information flow from the thalamus to the cortex.

So, whatever inputs are coming from the retina, here is where, these you know the modulation of how much information has to go further or not can be actually done. Now, this is in principle, let us see what actually happens.

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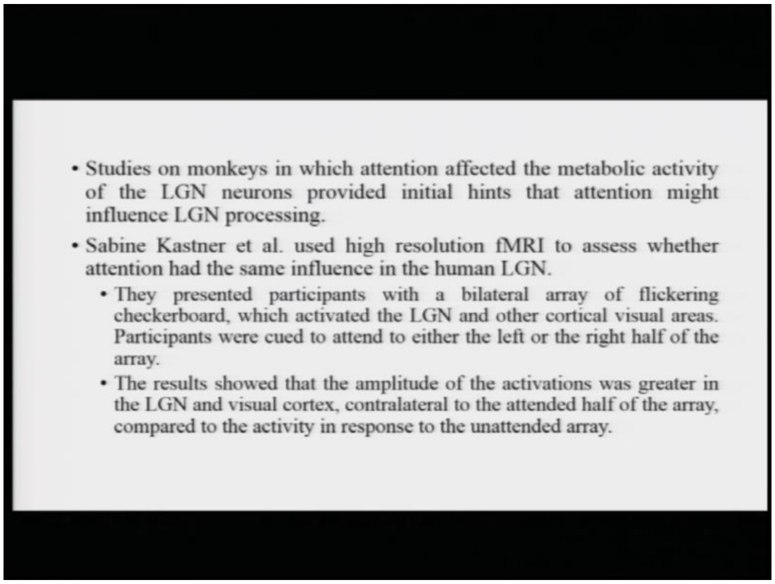

Now, studies on monkeys in which attention was shown to affect the metabolic activity of the LGN neurons provides initial hints that attention might be influencing the processing at the level of the LGN or the lateral geniculate nucleus. Sabine Kastner and colleagues used high resolution fMRI to assess whether attention also had the same influence in the human LGN.

So, what they did? They presented participants with a bilateral array of flickering checkerboard kind of stimuli, which would activate the LGN and other cortical visual areas. Participants were basically cued to attend to either the left or the right half of the array. The results showed that the amplitude of the activations was greater in the LGN and the visual cortex contralateral to the attended half of the array.

Suppose you were attending the left visual field, the LGN in, visual cortex in the right hemisphere will be more activated. Compared to the activity in response to the unattended array. So, there is going to be much less activity in the left hemisphere because this right visual field is not really attended. This is not cued. It is not really geared to grab my attention.

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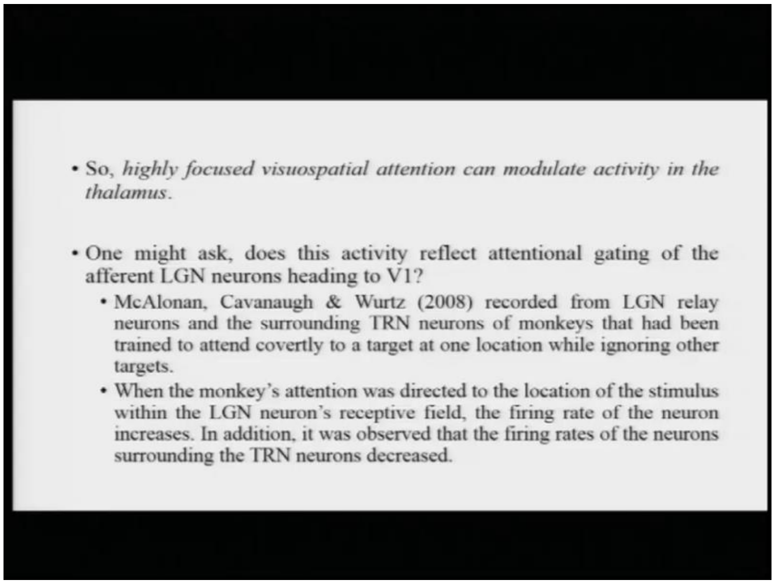

So, what can we conclude highly focused visuospatial attention can actually modulate activity even at the level of the thalamus. We have established that it modulates activity in the visual cortex. Now, we are actually saying it also modulates activity at the level of the thalamus. Now, one might ask, does this activity reflect attentional gating of afferent LGN neurons heading to V1?

So, if there is some effect of visuospatial you know attention modulating activity at the LGN, is it possible that at this level itself at the thalamic level itself, information can be created, and you know, parts of it can be allowed to go further to the higher visual cortex or parts of it might be just held back.

Now, McAlonan, Cavanaugh and Wurtz in 2008 recorded from LGN relay neurons and the surrounding TRN neurons the thalamic reticular neurons of monkeys that had been trained to covertly attend to a target at one location while ignoring the other targets. So, they had this, you know interesting bunch of monkeys and the recording from LGN relay neurons and the surrounding TRN neurons.

What did they do? When the monkey's attention was directed to the location of the stimulus within the LGN neurons receptive field, the firing rate of the neuron does increase. In addition, it was also observed that the firing rates of the neurons surrounding the TRN neurons also increases.

So, when the nucleus, when the stimulus is falling in that is LGN neurons receptive field, it is its firing rates are also increased, along with the firing rates of the TRN neurons. So, it does sort of, you know, give us a clue about that, there's something interesting is happening here.

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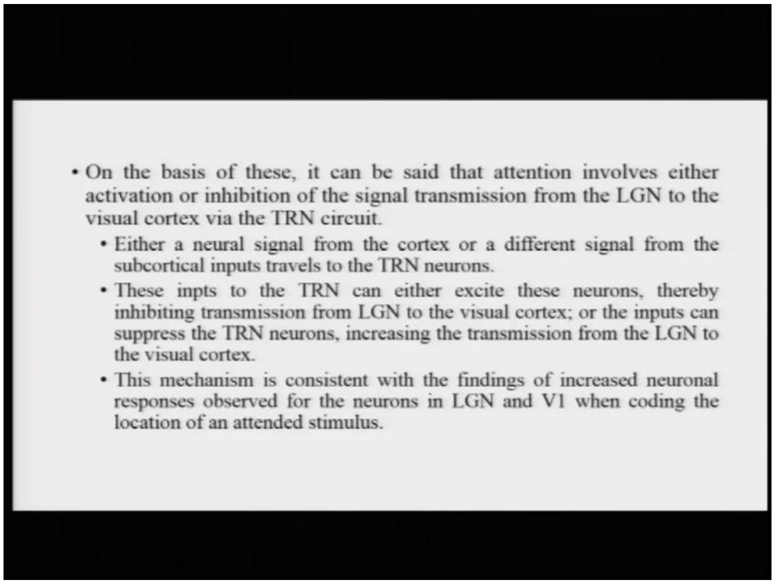

Now, on the basis of these findings, it can be said that attention involves either activation or inhibition of signal transmission from the LGN to the visual cortex via this TRN circuit. So, actually, it is possible that at the level of the thalamus, at the level of the lateral geniculate nucleus or some kind of additional gating is actually taking place.

Now, either a neural, this can happen via you know a few ways. Either a neural signal from the cortex or a different signal from the subcortical inputs must travel through the TRN neurons. These inputs to the TRN neurons can either excite these neurons, excite the neurons in the visual cortex, thereby inhibiting transformation from the LGN to the visual cortex, or the inputs can suppress the TRN neurons increasing the transmission from the LGN to the visual cortex.

Now, what you have to understand here is this TRN neuron is acting sort of as a bottleneck, which is controlling the flow of information from the LGN neuron to the visual cortex. If these TRN neurons are excited, they can sort of curtail the information flow from the LGN neuron to the visual cortex.

When these TRN neurons are supposed to be suppressed, they will allow more information to flow from the LGN neuron to the visual cortex. This is typically what we are talking about. Now, this mechanism is consistent with the findings of increased neuronal responses observed for the neurons in the LGN and V1, when they were coding you know, location of an attended stimulus. So, it sort of marries well with these other findings that neuronal responses are actually increased when the neurons in the LGN and area V1 are coding the location of some attended stimuli.

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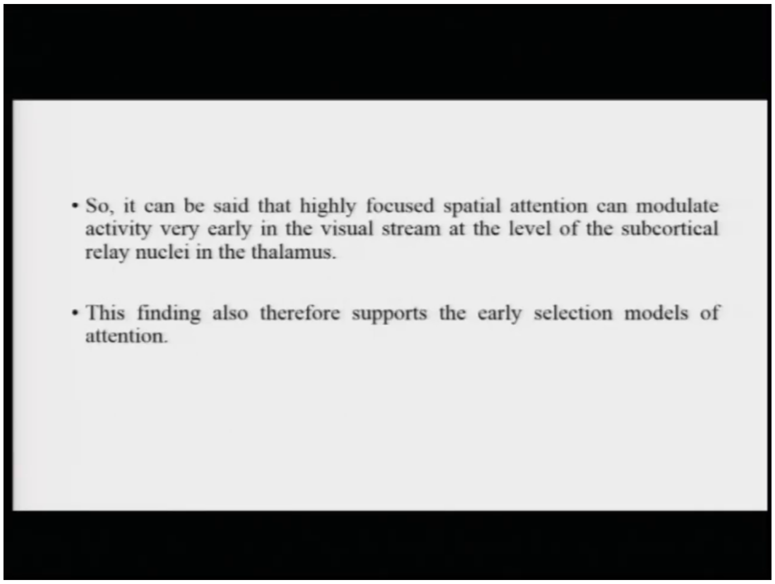

So, this is something that we can kind of say that highly focused spatial attention can indeed modulate the activity very, very early in the visual stream, even at the level of the subcortical relay nuclei of the thalamus. So, this finding, again, as we said, supports the early selection models of attention. So, I hope things are making it clear. I am sure that there is too much information being presented. But I hope you will sort of, you know, pause, understand, pause, understand and move ahead.

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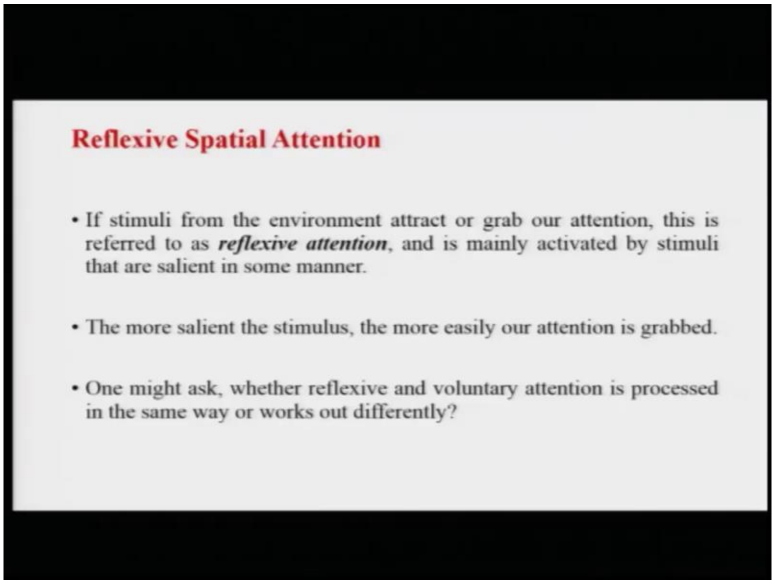

Now we have talked about, you know, voluntary or goal driven spatial attention. Let us talk a little bit about reflexive spatial attention. Now, if stimuli from the environment can automatically attract or grab our attention, this is basically referred to as reflexive attention. Reflexive attention is not something that you decide and pay attention to something. It is that while you are doing, carrying on with your own task, something suddenly, and something so salient happens that it grabs your attention.

The more salient the stimulus, the more easily your attention will be grabbed. So, the louder the noise in the periphery, the more you know, automatically your attention will be oriented to the background. Now, one might ask whether reflexive and voluntary attention is processed in the same way or works slightly differently from each other? So, let us look deeper into that.

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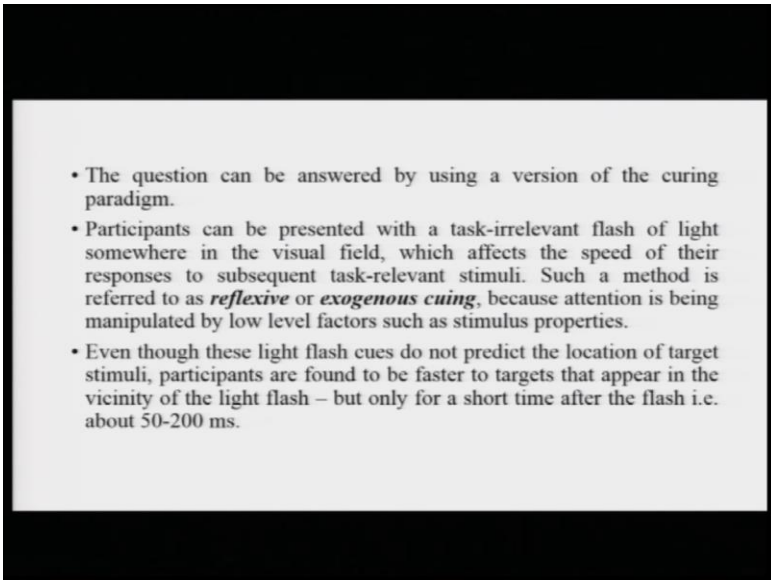

Now, the question can be answered by using a version of the cueing paradigm. Participants can be measured, participants can here be presented with a task irrelevant flash of light somewhere in the visual field, which affects the speed of their responses to subsequent task irrelevant stimuli.

Suppose, you know lets imagine a task where the task of the participant is to track in pending stream of letters, this track for the letter X and you are doing that. Suddenly there is a flash of light in either the right or the left visual field, now what that would do is that would slower down slow you down or slow down your responses to detecting whether the letter X is present in this rapid visual stream or not.

So, such a kind of a method which sort of interferes with, you know, a goal that has been set is known as reflexive or exogenous cueing. Because what is happening here is that attention is being manipulated by low level factors such as stimulus properties, flash of light, color, motion, you know, you can kind of think of any number of feature or stimulus features or stimulus properties.

Now, even though, that these light flash cues do not really predict the location of the target stimulus, participants are found to be faster for targets that appear in the vicinity of this flash of light. So, this flash of light, for all intents and purposes might be, you know, uninformative.

But as soon as there is a flash of light in some region in the visual field, your attention kind of goes there. And for some time, maybe up to 50 to 200 milliseconds, if anything else, if any other stimulus of that you might want to attend appears in the vicinity of this flash of light of all of this, basically of this exogenous cue, it kind of gets the benefit of attention having been there. So, the stimuli that are presented in the vicinity of the exogenous cue are detected faster for up to 200 milliseconds, so just remember this.

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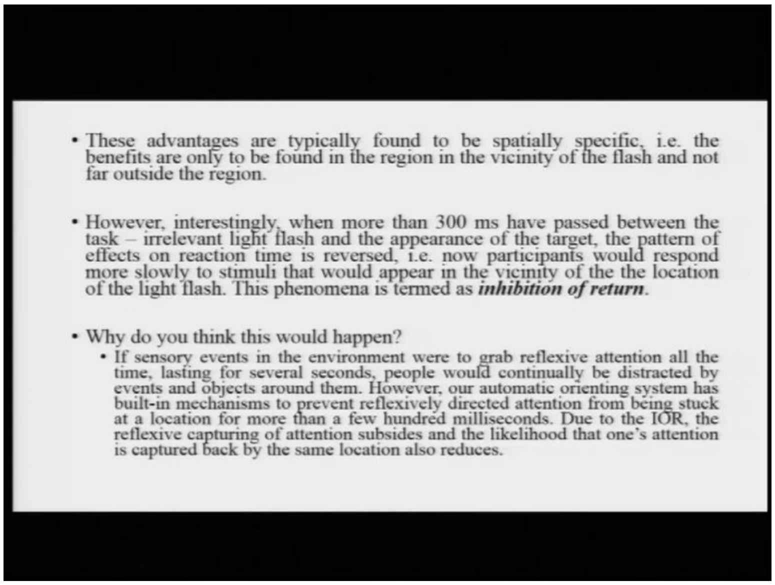

But these advantages, or these benefits are typically found to be spatially specific. So, what does that mean? It means that, benefits are own to be found only around that region, maybe two degrees of visual angle or one degree of visual angle around that exogenous cue, and not far outside. So, it does not really happen in the entire left or right visual field wherever you have presented the exogenous cue.

Now one, one thing is more interesting that once more than 300 milliseconds have passed, after the cue had been presented or this exogenous, you know, cue or irrelevant flashlight has been presented, the pattern of effects on reaction time is actually reversed. So, what happens now? After 300 milliseconds have passed, now participants who had actually responded more slowly to stimuli that appear in that, in the vicinity of the exogenous cue.

This is an interesting phenomena. And this phenomena is referred to as inhibition of return. So, if you presented an exogenous cue, up to 200 milliseconds, anything presented there will be processed faster, after 300 milliseconds have passed, the things will actually suffer from a cost or a disadvantage.

Why would this happen? Now, say for example, imagine a scenario that, you know, sensory events in the environment were to grab reflexive attention all the time, you know, different things keep popping around when you are moving on the road, when you are you know, cycling to work or something like that.

If your attention were to be automatically grabbed by so many of these stimuli that you keep seeing all around, lasting for several seconds, what would happen is that people would continuously be, you know, distracted by these number of events and objects around. So, what happens is that our automatic orienting system has this built in kind of a mechanism which prevents reflexively directed attention from being stuck at a particular location. So, it goes there, stays there for 200 milliseconds and comes back.

So, due to this inhibition of return phenomena, the reflexive capturing of attention and you know, and attention actually subsides and the likelihood that one's attention is captured back by the same location, if another flash of light appears there after 200 milliseconds kind of gets reduced. So, that is that is basically to sort of save us from all the distracting stimuli that are happening all the time in our environment.

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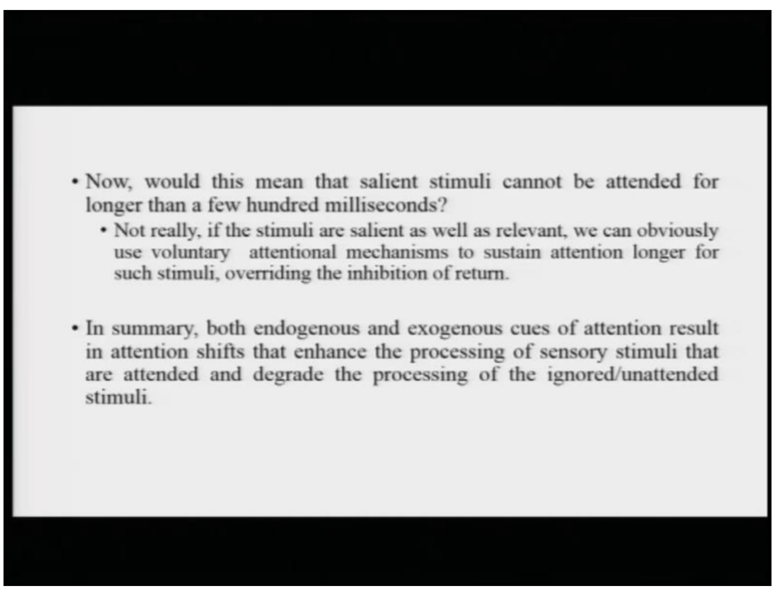

Now, does this mean that salient stimuli cannot be attended for longer than a few hundred milliseconds? No, basically if the stimuli are really salient, as well as say, for example, now you have gotten it, gotten interested in them and they have become relevant as well, they can obviously use voluntarily voluntary attention mechanisms to sustain attention at the same location for longer than 200 milliseconds that we are talking about.

So, what do we have in totality? In summary, both endogenous and exogenous cues of attention result in attention shifts that enhance the processing of sensory stimuli that are attended and degrade the processing of sensory stimuli that are meant to be ignored or unattended. Alright.

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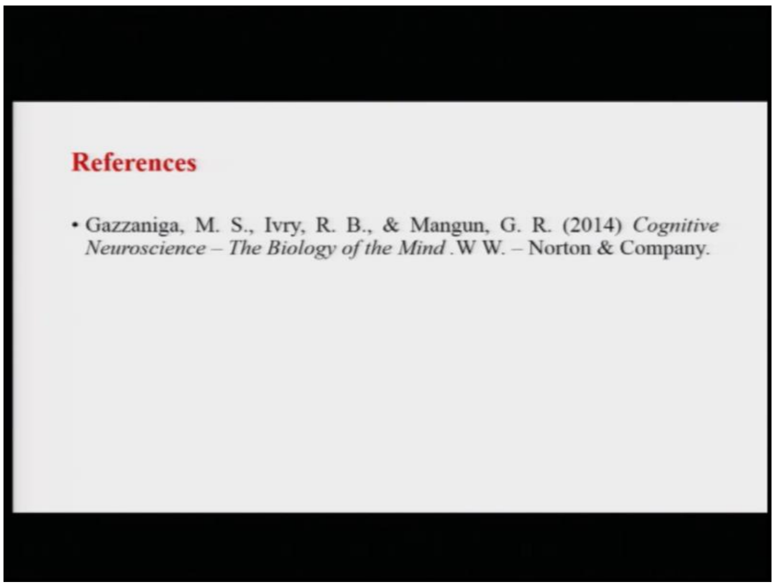

So, this is all about reflexive spatial attention that I had to talk to you about. We will meet in the next lecture and talk about some things. Thank you.