Introduction to Brain and Behaviour
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Lecture 20
Networks of Attention

Hello, and welcome to the course Introduction to Brain and Behavior. I am Doctor Ark Verma from IIT Kanpur. This is week four of the course. And today, we will talk about networks of attention.

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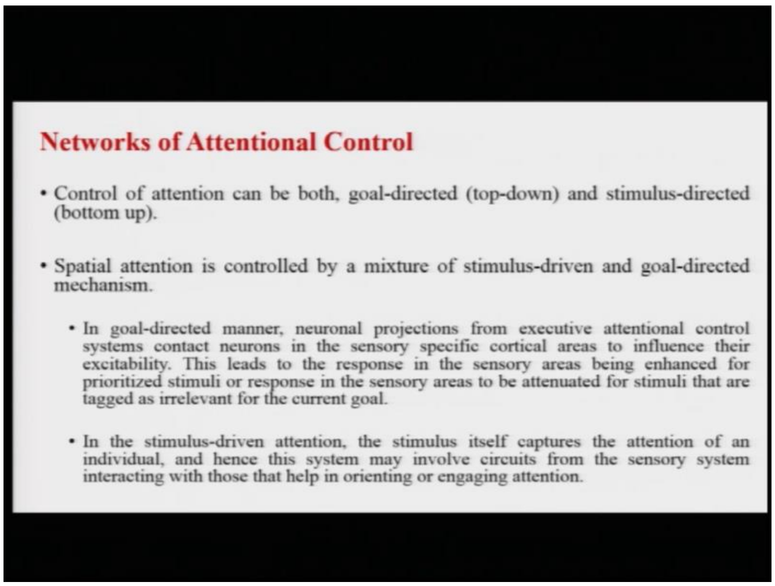

Now, control of attention, so far been talking about areas of the brain that are responsible for different kinds of attention processes. In today's lecture, we will actually talk about how these different attentional processes are regulated or controlled. So, the control of attention can be both goal directed that is topped out, when you are looking for something like in the visual search phenomena, or it could be stimulus directed, that is bottom up, which means that it is being controlled by the stimulus properties or stimulus features.

Spatial attention is controlled by a mixture of stimulus driven and goal directed mechanisms. Let us look at, when it is controlled by the goal directed manner, the neuronal projections from the executive attentional control systems may contact neurons in the sensory specific cortical areas to influence their excitability.

So basically, when you are looking for something in a region of space, what is happening is that different neuronal predictions from these executive attentional control systems, we will talk about which areas are these in a bit, they contact neurons in the sensory specific cortical areas to influence their excitability.

Suppose, I am looking for something in this region of space. I am through the executive control areas, telling the sensory areas to pay extra attention to this specific region in space. This would therefore, as I said, lead to the response in sensory areas being enhanced for prioritized stimuli at attended locations or response in the sensory areas to be attenuated for stimuli that are tagged as irrelevant for the current role.

For something, say, for example, if I am looking at, if I am looking for my car keys on my table, and I come across, say, for example you know you know some other object let say, my wallet, I am probably not really you know going to be very interested in that. In the stimulus driven variety, the stimulus would itself capture the attention of the individual and basically the flow of commands will be more bottom up.

So, what will happen is, the system will involve circuits from the sensory systems interacting with those in the orienting or engaging attention system. So, basically if there is something that is popping up from the visual speed, visualant scene, it will automatically grab my attention and it will automatically orient or engage my attention toward that specific stimulus or towards that specific feature.

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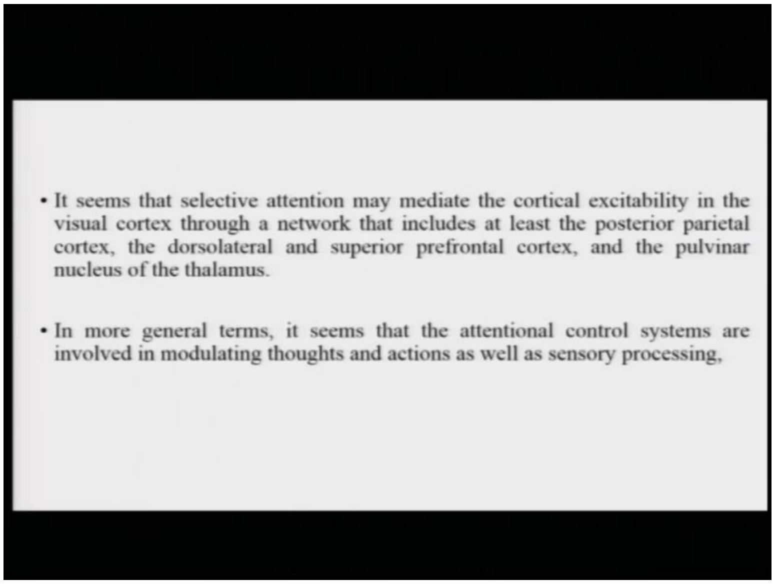

Now, it seems that selective attention may actually mediate the cortical excitability in the visual cortex through a network. That, at least you know contains the posterior parietal cortex, the dorsolateral cortex, and the superior prefrontal cortex and the pulvinar nucleus of the thalamus. So, these four five regions are probably where the attentional network control is happening. In more general terms, it seems that the attentional control systems are involved in modulating our thoughts and actions as well as modulating sensory processing.

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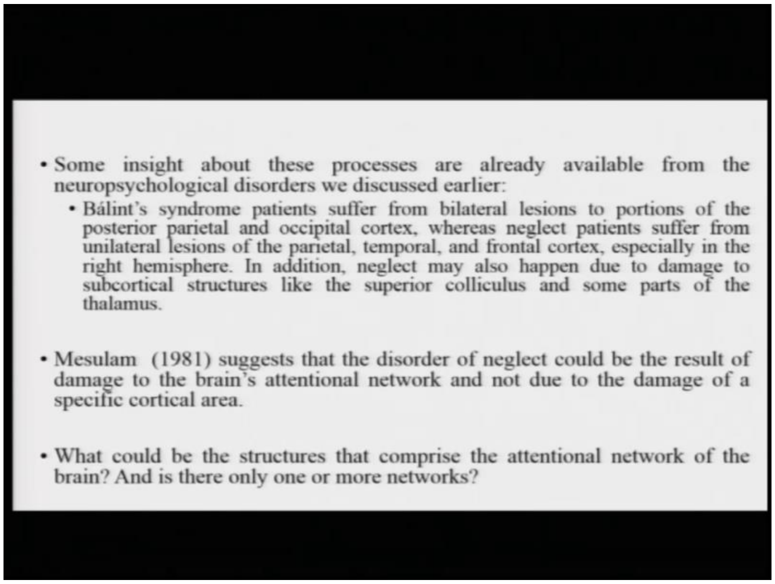

Now, let us look at some insight. Now, some insight about these processes are already available from the neuropsychological disorders that we have, you know discussed in the initial lectures of this week. You would already know that Balint's syndrome patients suffer from bilateral lesions to the posterior parietal and occipital cortices. Whereas patients of unilateral spatial neglect suffer from unilateral lesions of the parietal temporal and frontal cortices, especially in the right hemisphere.

You also know that in addition to these areas, neglect may also happen as a result of damage to subcortical structures such as the superior colliculus or some other parts of the thalamus. Now, Mesulam in 1981 suggested that the disorder of neglect could also be the could actually be the result of damage to the brain's attentional network rather than to rather than due to damage to a specific cortical area. Now, what could be these areas that comprised the attentional network of the brain? And is there just one attentional network or many attentional networks?

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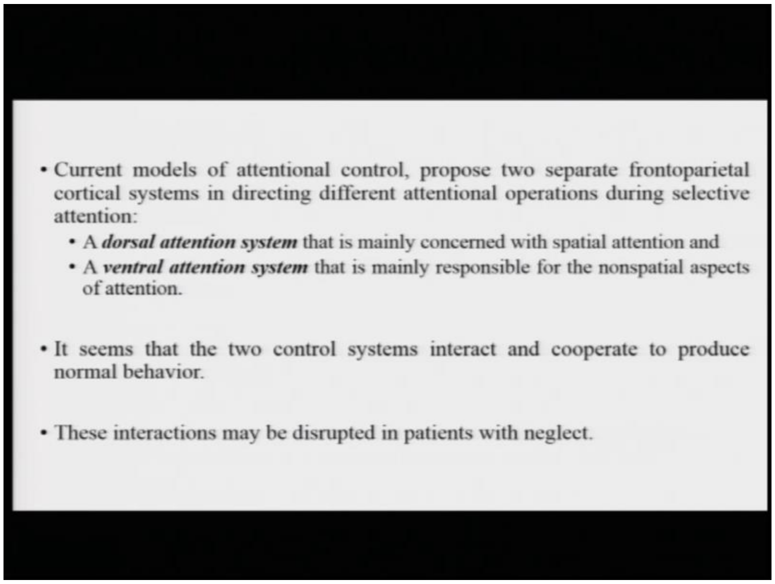

Current models of attentional control proposed two separate frontoparietal cortical systems and basically that are involved in directing different attentional operations during selective attention. So, first network is the dorsal attention system and the second network is the ventral attention system. The dorsal attention system is mainly concerned with regulating spatial attention, whereas the ventral attention system is mainly responsible for non-spatial aspects of attention, such as, say, for example, the stimulus driven or reflects a variety of attention.

Now, it seems that these two control systems definitely interact with each other and they cooperate to produce normal behavior. These interactions might be disrupted in patients with neglect. And that is where you see the pattern of deficits that they experience.

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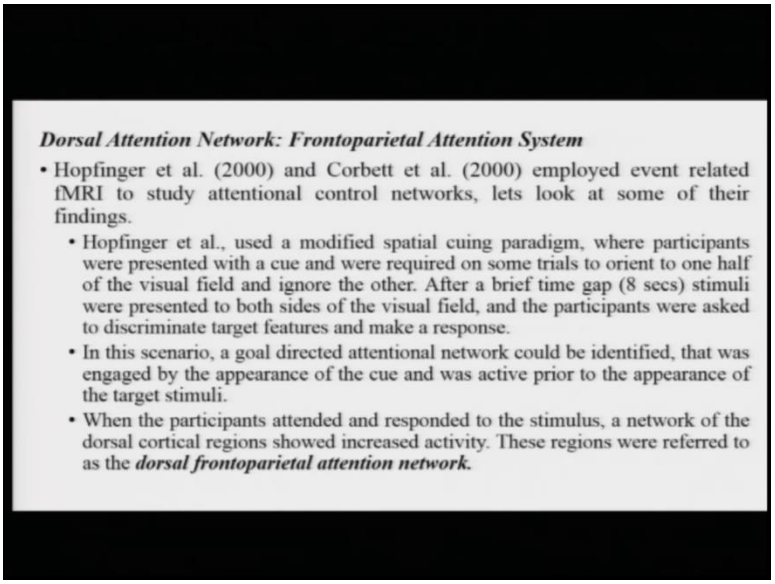

Now, let us talk a little bit more in detail about this dorsal attention network, or the front parietal attention system. Now, Hopfinger and colleagues in 2000, and Corbett and colleagues in 2000 employed event related fMRI to study these attentional control networks. Let us look at some of those findings. Now, Hopfinger and colleagues used the modified spatial cueing paradigm where participants were presented with a cue and were required on some trials to orient to one half of the visual field and ignore the other.

Suppose you will get a cue, maybe let's say an arrow in the middle that tells you to focus only on the left visual field and completely ignore the right visual field. After the cue, around after let us say eight seconds stimuli were presented to both sides of the visual field, left as well and right as well. And the participants were asked to discriminate target features and make a response.

In this scenario, a goal directed attention network could actually be identified, that would engage that would be engaged by the appearance of the cue and was active prior to the appearance of the target simply, now how is this happening?

As soon as the cue is there, the goal directed or the dorsal attention network is now engaged, it is becoming vigilant over this entire area of the visual field and it is basically scanning for the, or waiting for preparing itself to respond to the target that is going to come there. When the participants attended and responded to the stimulus, a network of these cortical regions will show or has actually shown increased activity. These regions were basically referred to as the dorsal fronto parietal attentional network. So, the region that is sort of preparing to attend this entire visual field in a goal directed map.

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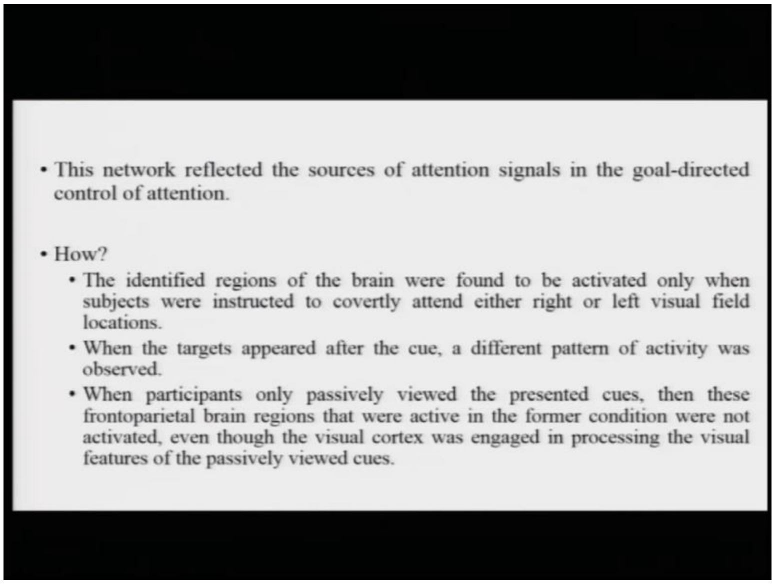

So, this network basically reflected their sources of attentional signals in the goal-directed control of attention. So, how are we making this claim that this network of regions is the one that should be candidates have this dorsal fronto parietal attentional network? On the basis of three things. First, the identified regions of the brain were found to be activated only when the subjects were instructed to covertly attend either the right or the left visual field. So, this is basically becoming activated in response to a particular spatial location that you have to covertly attend.

Second, when the targets appeared after the cue, a different pattern of activity was observed. So, this set of areas is just getting activated, pre target, so this is that you have to remember. Now, when participants were only passively viewing the presented cues, they were not asked to respond, then the fronto parietal brain regions that were active in the formal condition where they were actually asked to be vigilant and respond were not found to be activated.

Even though the visual cortex was anyways being activated, because any stimulation you present that is visual, the analysis of visual features will anyways take place. So, these sets of findings sort of led us to the conclusion that this is a network of regions that is basically responsible for voluntary or goal directed orientation, spatial attention.

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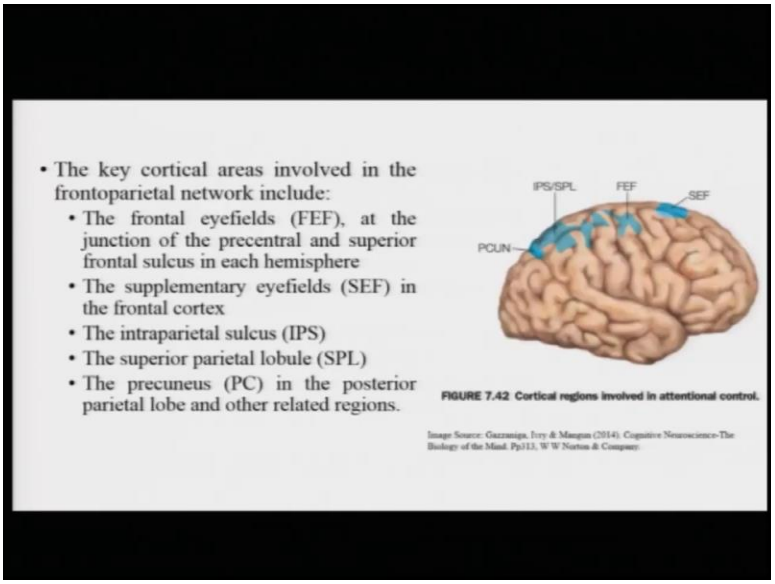

Now, what are these key cortical areas? The key cortical areas in the fronto parietal network include the frontal eye fields, at the junction of the precentral and the superior frontal sulcus in each hemisphere, the supplementary eye fields, the intraparietal sulcus or the superior parietal lobule, and the precuneus in the posterior regions of the parietal lobe and some of the other regions.

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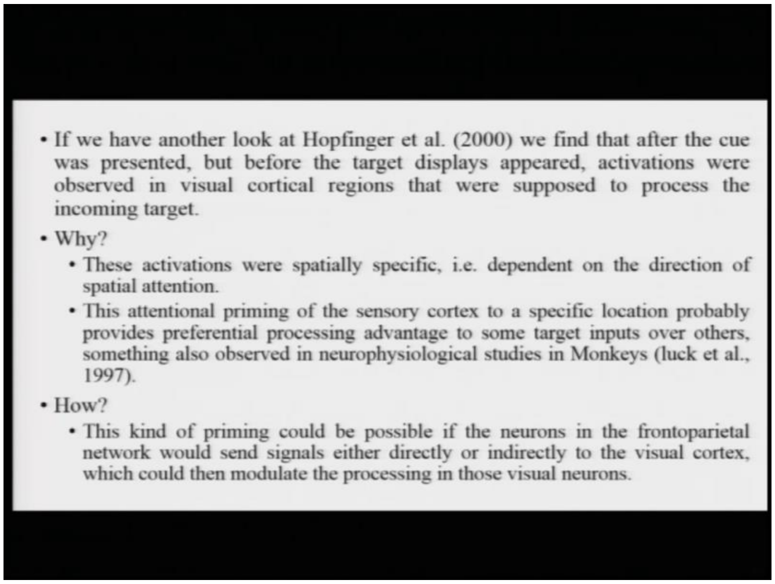

Now, if we have another look at Hopfinger and colleagues study, we will find that the cue that after the cue was presented, but before the target displays appeared, activations were also observed in visual cortical regions that were supposed to process the incoming target. So, some kind of a preparationary response is happening there. Why could this activation be? These activations are found to be spatially specific that is dependent on the direction of spatial attention, which as you know, is being modulated by the cue.

This attentional priming of the sensory cortex to specific location to this entire visual field that you are going to attend probably provides this preferential processing advantage to some target inputs over others. Something that has also been observed in neurophysiological studies in monkeys. Now, how is this attentional priming happening?

This kind of priming could only be possible if neurons in the fronto parietal network could somehow send signals either directly or indirectly to the visual cortex, which can then modulate the processing happening in there or proceeding to happen in those visual neurons.

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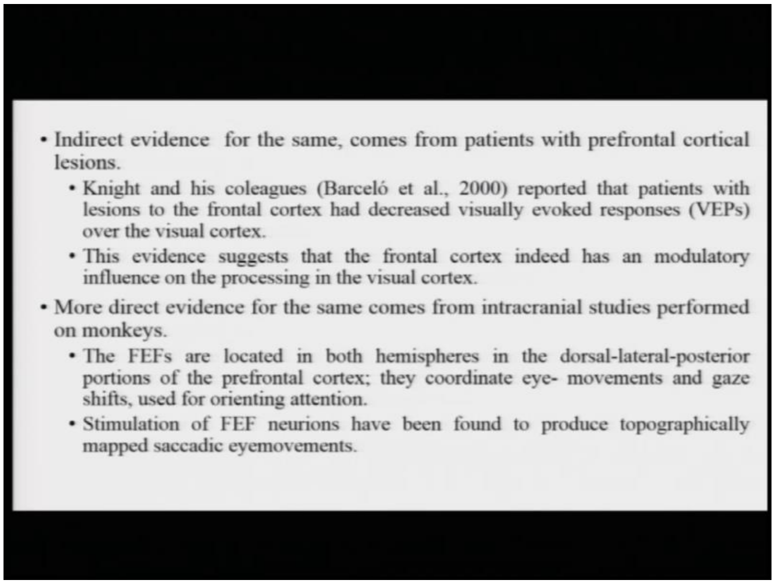

So, let us look at whether that actually happens or not. Now, indirect evidence for this kind of thing happening comes from patients with prefrontal cortical lesions. Knight and colleagues have found that patients with lesions to the frontal cortex actually have decreased visual evoked responses, or visual evoked potentials, or the entire visual cortex A.

And this evidence can be taken to suggest frontal cortex, indeed, probably acts as a modulator that influences the processing in the visual cortex. So, in some sense the frontal cortex is modulating the processing that is going to happen in the visual cortex, it can either prepare it for activity, or it can either suppress that activity in some sense.

Now, more direct kind of evidence for this kind of thing happening comes from intracranial studies that are performed on monkeys. Now, what happened? We know that the frontal eye fields are located in both hemispheres in the dorsal lateral posterior portions of the prefrontal cortex. These frontal eye fields are actually involved in coordinating eye movements and gaze shifts used for orienting attention. So, over attention if I have to move my eyes towards a particular object or shift my gaze, this is where the frontal eye fields actually play a part.

Now, stimulation of these neurons from the frontal eye fields have actually been found to produce topographically mapped saccadic eye movements. So, basically depending upon which region of the frontal eye field will stimulate, will decide which exact region in the visual space my eyes will move to. This is an important point please note.

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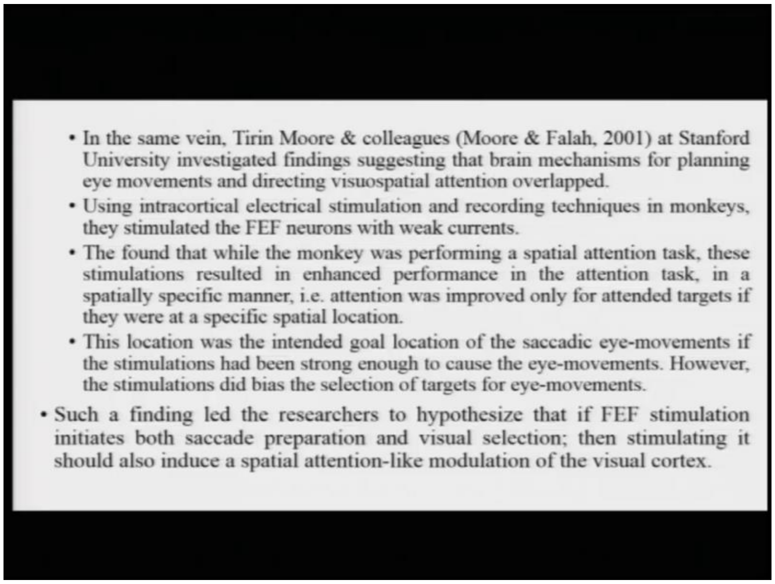

Now, Tirin Moore and colleagues at Stanford University investigated the findings suggesting that brain mechanisms of planning eye movements and directing visual spatial attention sort of are overlapped. What did they do? They used intracortical electrical stimulation, and they recorded, and recording techniques in monkeys.

And while they were actually stimulating the frontal eye field neurons with weak currents. So, what did they find? They find that while the monkey was performing a spatial attention task, these stimulation, these weak stimulation that occurred resulted in enhanced performance in the attention task in a very spatially specific manner.

So, the advantage was not across the entire visual field, where the attention was improved for only those locations where the attended targets, if the attended targets were found to be at very specific locations. And what were these specific locations? These specific locations were the intended goal location of saccadic eye movements produced by the weak FEF stimulations.

So, for example if you are stimulating the frontal eye field with some weak current, and this is the region in space, where the saccade is going to land, what is actually being found is that this is the region which experienced enhanced processing or enhanced attention. So, basically what is happening is even before the eye has actually moved there the covert attention is oriented at that location and is leading to some of these, you know, enhanced processing advantages.

So, this kind of finding led the researchers to hypothesize that if the frontal eye field stimulation initiates both saccade preparation and visual selection, then stimulating the frontal eye fields should also produce or induce a spatial attention like modulation of the visual cortex. So, this kind of just follows from this set of results.

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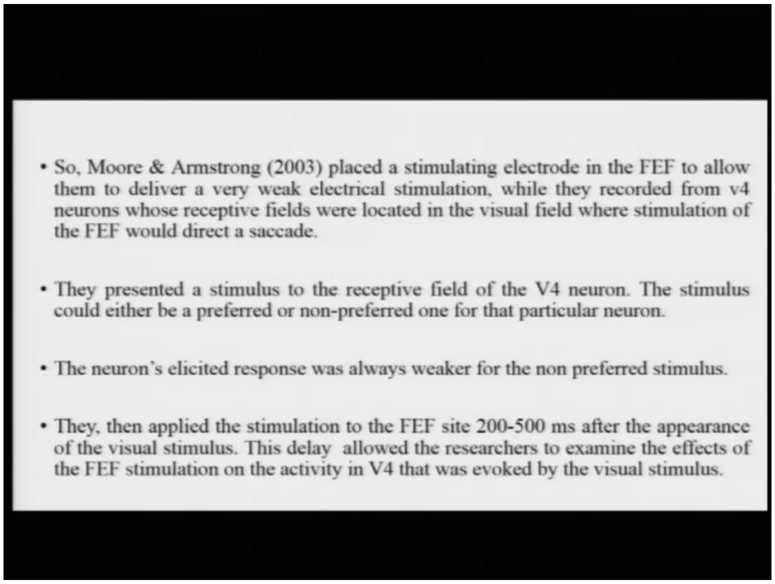

Now, to test this hypothesis, Moore and Armstrong in 2003, placed a stimulating electrode in the frontal eye fields to allow them to deliver a very weak electrical stimulation. While they are recording from the V4 neurons whose receptive fields were located in the visual field where stimulation of the FEF would direct a saccade. So, suppose this is the region, again going back to the same example. This is a region where the FEF simulation would lead a saccade to be, this region was supposed to be lined in the area V4 in the receptive field of a V4 neuron.

Now, what did what did they do further? They presented the stimulus to the receptive field of this V4 neuron. The stimulus could either be a preferred stimulus or the unpreferred stimulus for that neuron. Remember, the red horizontal stimulus versus the green vertical stimulus, let us suppose, again that the red horizontal stimulus is the preferred stimulus.

Now, the neurons eliciting response was typically always weaker for the non-preferred stimulus again. They then applied the stimulation, weak stimulation to the FEF side 200 to 500 milliseconds after the appearance of the visual stimulus that is where they applied the FF stimulation. This delay allowed the researchers to examine the effects of the FEF stimulation on the activity in the V4 neuron that was actually being evoked by the visual stimulus.

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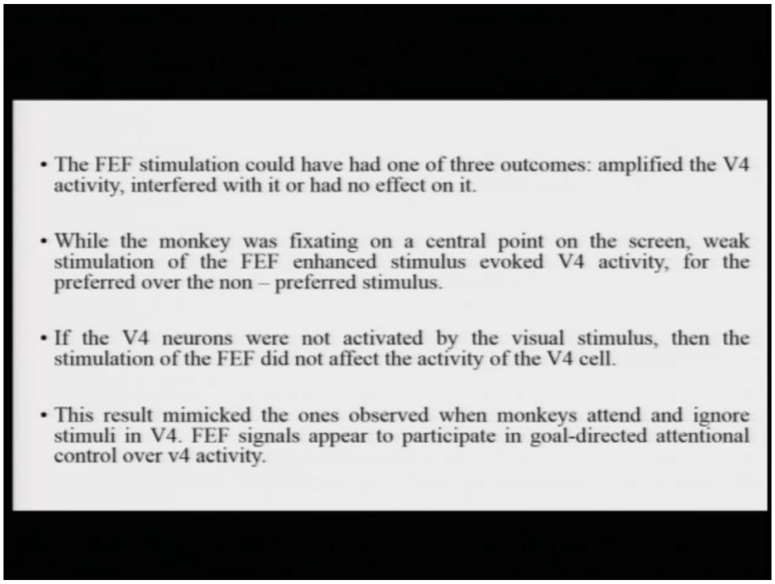

Let us look at what happened. This FEF stimulation could have either of the three outcomes. Either it will amplify the V4 activity interfered or slowed it or had no effect on it. What is indeed found was that while the monkey was fixating on a central point on the screen, a weak stimulation of the FEF enhanced stimulus evoked V4 activity.

So, if you stimulate the frontal eye field neurons, that is basically enhancing the firing that is happening in the V4 neurons in response to this visual stimulus, and obviously that happened more for the preferred or the non-preferred stimulus. So, basically what we can see is while we are stimulating this frontal eye field area, this is a way to enhance attentional processing or enhanced sensory processing at the area where the saccard was supposed to land.

Now so, if these V4 neurons were not activated by the visual stimulus, suppose you are talking about the non-preferred stimulus here, then the stimulation of the FEF neurons did not affect the activity of the V4 cell at all. So, if you look at this result, this mimics the ones observed when monkeys attended and ignored stimuli in V4, FEF signals appeared to participate, therefore, in goal directed attention control over V4 activity.

So, when you are actually voluntarily actively looking for something or you know, then basically what you can expect is the area V4 activity will be increased or the neurons in the area V4 of the visual cortex will experience heightened activation.

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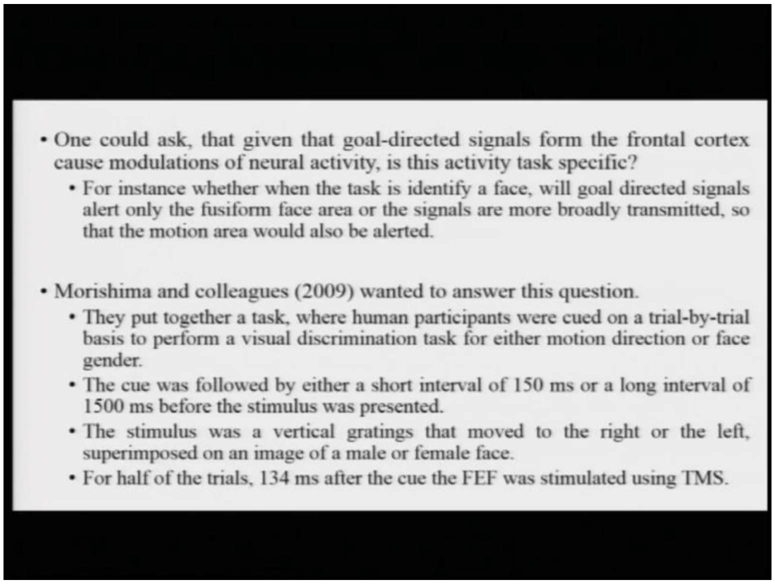

Now, one could ask that given that goal directed signals on the frontal cortex can modulate neuronal activity, is this modulation task specific or it is a genetic modulation of the entire areas? For instance, if the task is to identify a face, will the goal directed signals alert only the fusiform areas or they will alert you know the entire visual, the entire extrastriate cortex.

Now, Morishima and colleagues in 2009, they wanted to investigate and understand this question better. So, what they do they put together a task where human participants are queued on a trial to trial basis to perform a visual discrimination task for either detection of motion direction whether something is moving upwards or downwards, for example or face basically or look at say for example, whether it is a male face or a female face.

So, gender discrimination, motion direction discrimation, so moving stimulus and face stimulus. Now, the cue was followed by either a short interval of 100 to 150 milliseconds, or a long interval of 1500 milliseconds before this stimulus was presented. So the cue 150 milliseconds and the stimulus, the cue 1500 milliseconds and the stimulus. So this is the experimental setup.

The stimulus was actually vertical gratings that could move to the right or the left. And when superimposed of an image superimposed on an image of a male or a female face, so for the gratings, you have to tell whether it moves left or right, for the face, you have to tell whether there is male or female.

For half of the trials, 134 milliseconds after the cue, the FEF was stimulated using TMS. So, you know, that in the TMS method, so you know that in the TMS methodology, V currents can either excite or inhibit activation in targeted areas of the brain. So, basically 134 milliseconds after the presentation of the cue, the frontal eye fields were stimulated.

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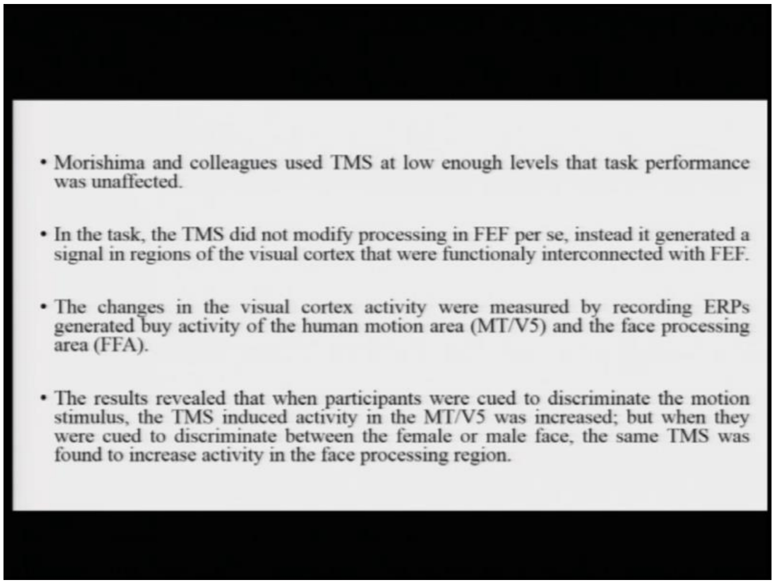

Now, Morishima and colleagues used TMS at a low enough level so that TMS does not really impede their performance during the task. So, basically what the TMS did was it did not really modify the processing in the FEF per say. Instead, it generated a signal in the regions of the visual cortex that were functionally interconnected with the FEF. So, basically some regions which are connected with FEF were actually observed to show some kind of response.

Now, the changes in the visual cortex activity that were measured by recording the ERPs generated by the activity of the human motion area and the face processing area. So, basically these two areas showed some activity depending upon the kind of stimulus that was presented or whether you're attending to motion or gender of the face.

These results reveal that when the participants were cue to discriminate the motion stimulus, TMS activity in the MT V5 area was increased. Whereas when the participants were cued to discriminate between the gender of the face, the same TMS wave was found to increase the activity in the face processing region.

So, this TMS based stimulation of frontal eye field is actually not really you know, changing something in the frontal eye field activation per say. But what it is doing is, it is in a task specific manner, enhancing the activity of areas, which are in some way tuned to, you know, process the upcoming stimulus. It is again sort of a preparatory response that you can see.

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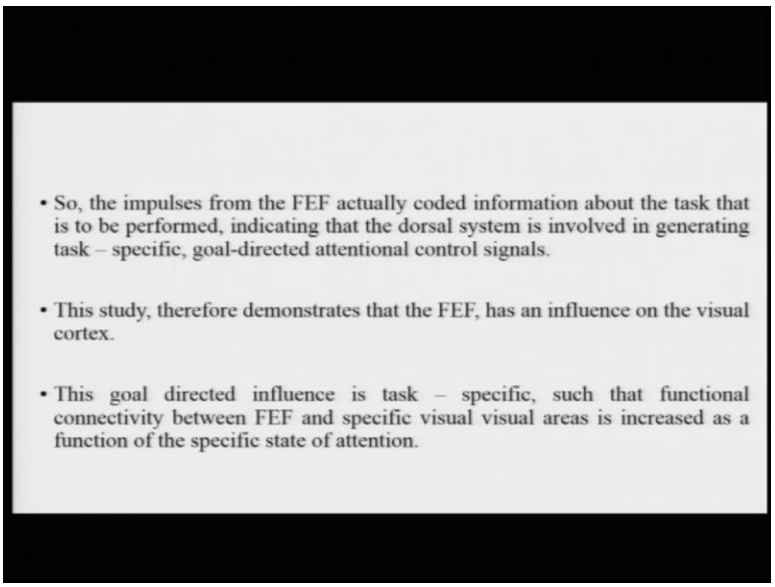

So, the impulses from the FEF actually code information about what is the task that is to be performed, indicating to the dorsal system indicating that the dorsal system is involved in generating task specific, goal directed, attentional control signals, alright. So, this study therefore demonstrates that FEF has actually an influence on visual cortex. So, in some sense that, this is a member of the attentional control system or the dorsal attentional control system, which modulates activity in the visual processing areas.

In this goal directed influence is a specific, basically meaning that functional connectivity between the FEF and the specific visua areas is increased, as per the function of the specific state of attention, what is it that you are going to process that is basically going to get enhanced.

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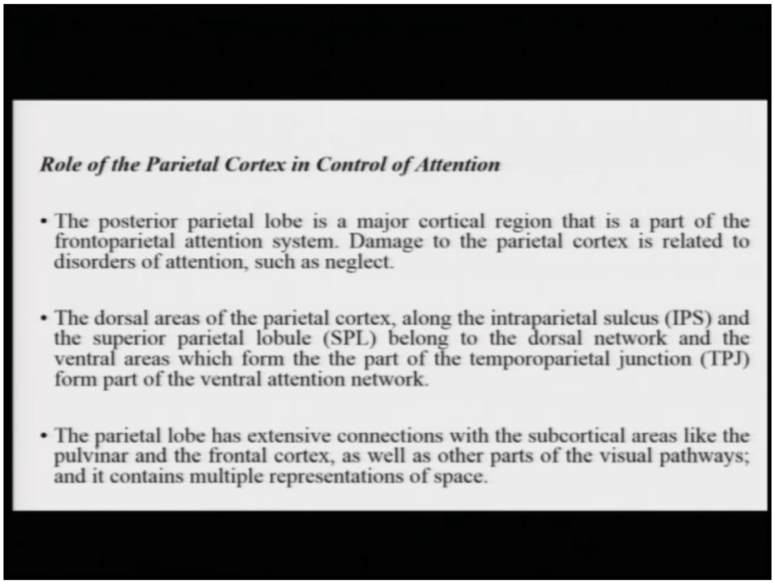

Now, lets talk about the role of the parietal cortex in control of attention. You know, as you know, the posterior parietal lobe is a major cortical region that is supposed to be a very, very important part of the fronto parietal attentional system. We have seen the damage to the parietal cortex is related to several disorders of attention, such as neglect. We also seen that the dorsal areas of the parietal cortex along the intra parietal sulcus and the superior parietal lobule belong to the dorsal network and the ventral areas, the bottom areas, which are on the part of the temporoparietal junction form part of the ventral attention network.

Now, the parietal lobe has extensive connections with their subcortical areas like the pulvinar of the thalamus, the frontal cortex, as well as some of the other parts of the visual pathways, and it also contains multiple representations of space.

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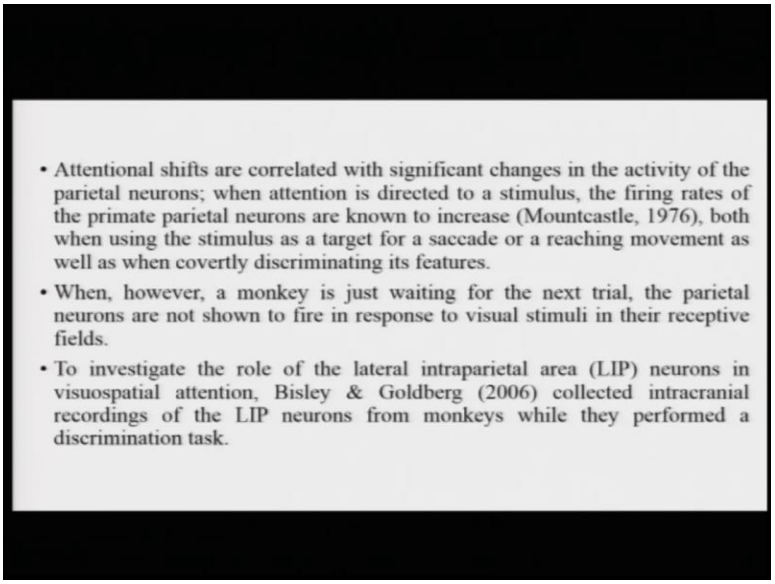

Now, let us talk about attentional shifts. Attentional shifts are correlated with significant changes in the activity of the parietal neurons. When attention is directed towards the stimulus, the firing rates of the pyramidal neurons are known to increase both in the stimulus, you know is a particular target. Also, for example, you are just covertly analyzing the features of the of the, you know, particular target.

Now, when the monkey is just waiting for the next trial, the parietal neurons are not shown to fire in response to the visual stimuli in the receptive fields. So, it is basically when you are actually attending to something or looking for something is when the parietal neurons will show activity.

Now, to investigate the role of the lateral interparietal area, or the LIP neurons in visual spatial attention, Bisley and Goldberg in 2006, they collected intracranial recordings of the LIP neurons specifically from the monkeys while the monkeys performed a discrimination task.

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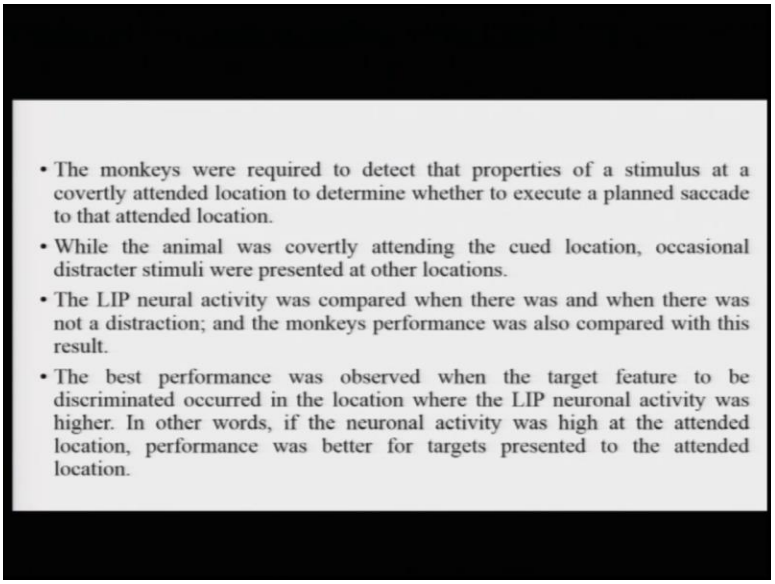

Now, the monkeys were asked to detect the properties of a stimulus at a covertly attended location to determine whether to execute a planned saccade to that location. While the animal was covertly attending that cued location, occasionally, distracter stimuli could be presented at other locations. So, this is the cued location. This is where you are attendant has to be directed sometimes on some trials, some services being presented or distracter services being presented at these uncued locations as well.

Now, the LIP neural activity was compared with when there was a distraction versus when there was not a distraction and this overall pattern of performance was also compared. So, when is the monkey performing say, for example, how good or how bad is the performance when there is distraction versus when there is not a distraction?

Now, what did they find? The best performance was observed when the target feature to be discriminated occurred in the location where the LIP neuronal activity was actually higher. So, if the neuronal activity was high at the attended location, the performance was better for targets presented to the attended location. So, in the area where the LIP activity is higher, and as the target comes there, it is processed better, that is one.

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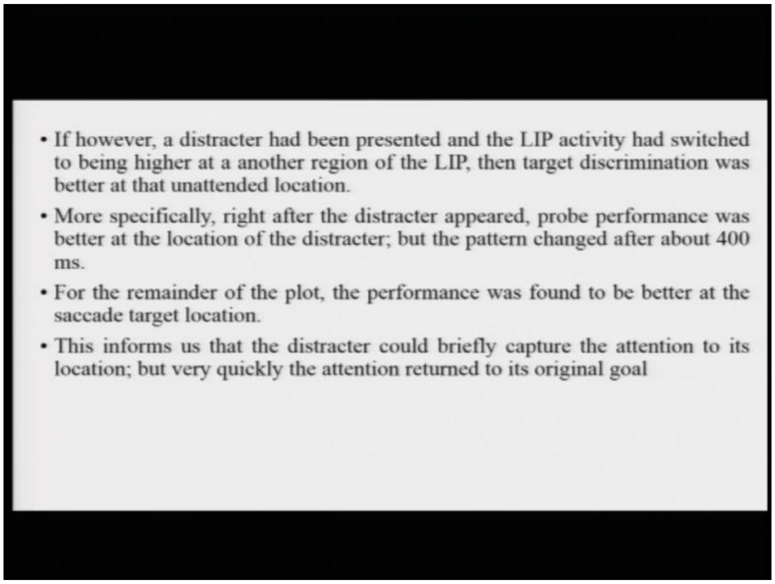

Now, if say, for example a distracter had been presented and the LIP activity had switched to being higher at another region of the LIP, then target discrimination was found to be better at that unattended location. So, wherever the distracter is being presented, let us say that is capturing the attention in the initial few seconds.

Now, more specifically, that is basically what is, what I am coming to, more specifically after the distracter appeared, the pro-performance was better at the location of the distracter. So, it is indeed grabbing some attention as an extra cue. But this pattern changes about after 400 milliseconds. So, for the remainder of the plot, what happens is, the performance is found better at the cued location, at the saccade target location as opposed to the un cued or in valid trial locations.

Now, this sort of informs us that the distracter has actually been able to capture attention for the initial bit for up to lets say, around 400 milliseconds and the attention is being directed at this point. But as soon as 400 milliseconds have passed, the advantages to the cued location are restored.

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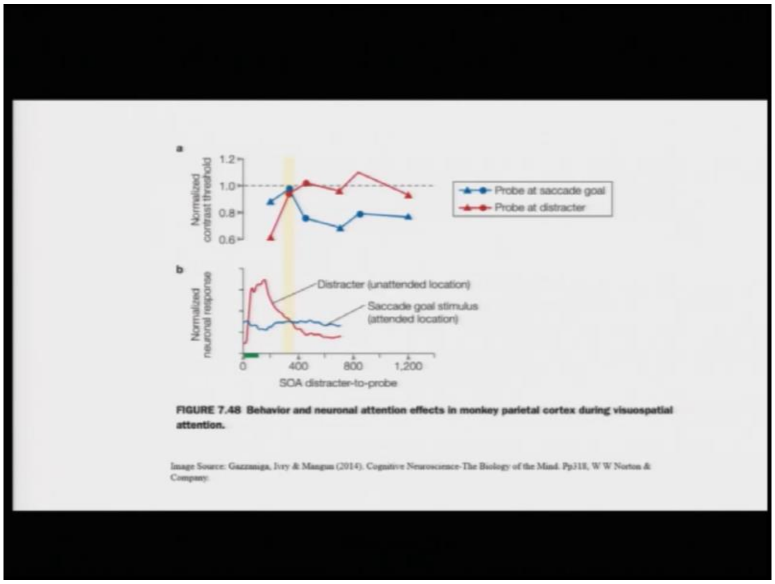

This is where you can see that the up till 400 milliseconds, the distracter has sort of grabbed attention, this larger response. But post 400 milliseconds, you can see that the saccade location or the attended location is basically getting you better responses.

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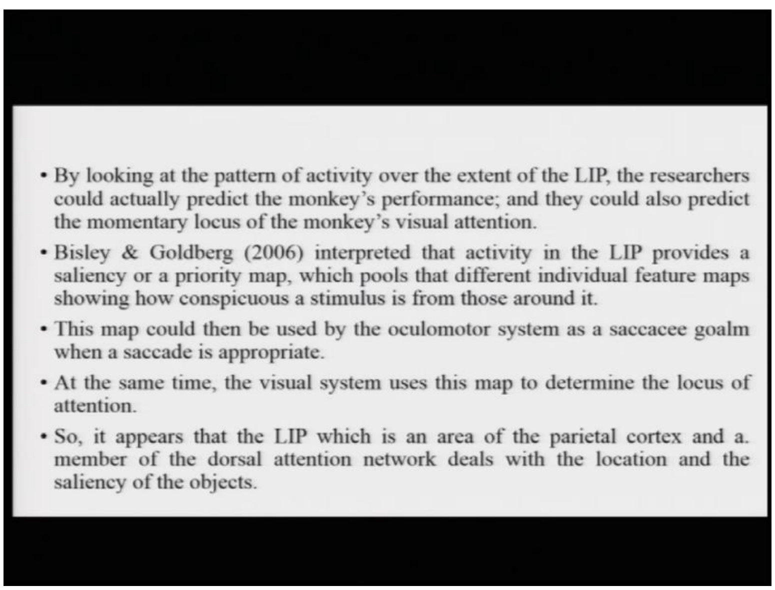

Now, by looking at the pattern of activity over the extent of the entire lateral intraparietal area, the researchers could actually predict the monkey's performance. So, they could actually predict that, okay, this is the region where the attention is there, this is where the performance will be better. By corollary, they could also predict where the attention is there. So, for example, if the performance is better than this, then this is probably where the attention of the monkey's momentarily captured.

Now, Bisley and Goldberg interpreted that the activity in the LIP provides the monkey with a sort of saliency or a priority map. And this priority map, what it does is it pulls the different individual feature maps, so Color Map, location map, shape map, etc. And it sort of combines all together and comes up with a saliency map.

This saliency map can then be actually used by the oculo motor system, the system that controls the movement of eyes as a saccade goal rather, when the psychiatrist's made to the appropriate location, so basically, depending upon where the stimulus is going to be salient, that will probably automatically become the goal of the next saccade and that is where your attention will be oriented.

So, at the same time the visual system will also use this map to determine the locus of attention, where do I have to pay attention? I look at this saliency map and I find that this is the region which is standing out. So, my attention sort of automatically gets directed over there. So, it appears if you look at this results that the LIP is actually an area of the parietal cortex and a member of the dorsal attentional network which deals with the location and the saliency of objects at what location in space is what objects are very salient and that is what will grab your attention.

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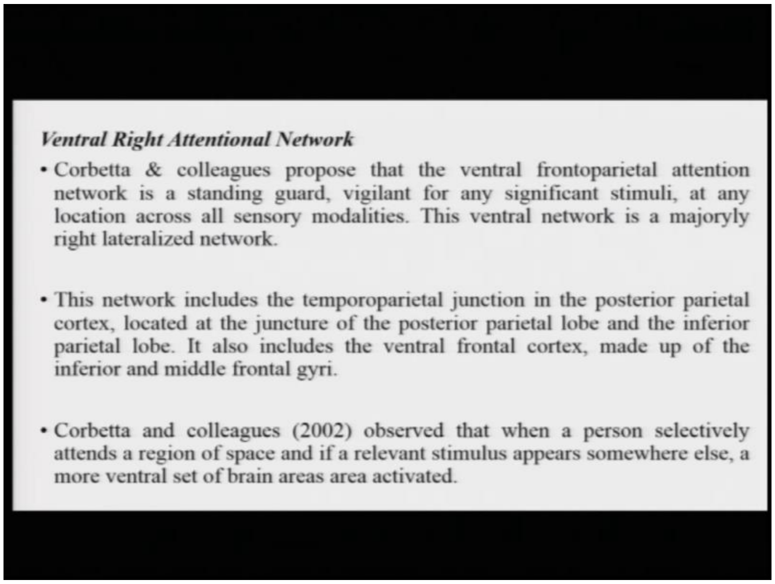

Now, we've talked mainly about the dorsal attentional network. Let us talk a little bit about the ventral right hemispheric attentional network. Now, Corbetta and colleagues have proposed that this ventral front right attentional network is actually you know, is almost like a standing guard and is vigilant for any significant stimuli at any of the locations across all sensory modalities.

If something grabs my attention, or if there is a salient stimulus in the entire visual field is a visual stimulus or auditory stimulus or a tactile stimulus. Anyways, my attention will be grabbed by that stimulus. And the areas that will engage will be these will be the areas that we call the ventral right attentional network. So this network, as the name suggests, is highly lateralized towards the right hemisphere.

There is higher activity in the ventral regions on the right hemisphere. Also, this network includes mainly the temporoparietal junction in the posterior parietal cortex, which is located at the juncture of the posterior parietal lobe and the inferior parietal lobe. So, we just probably see it in a bit. Now, also includes the ventral frontal cortex, which is made up the inferior and middle frontal gyrus.

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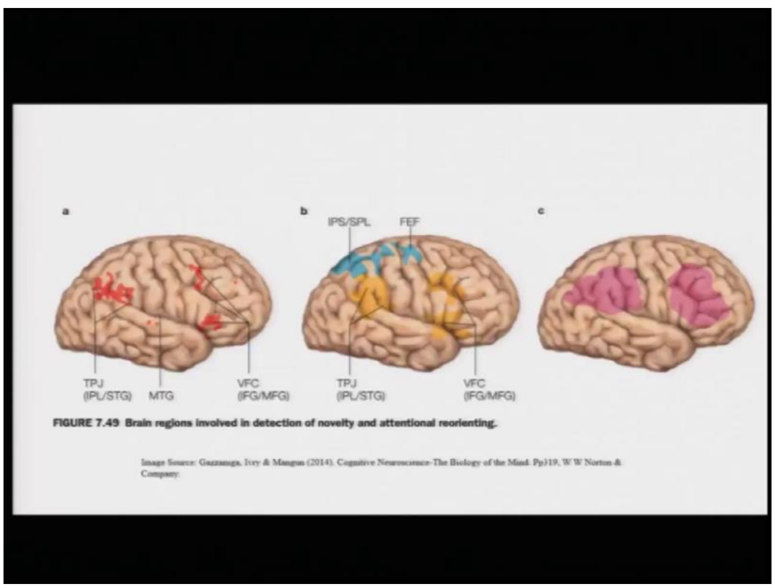

So, here is where you basically can see the temporal parietal junction. Here you can see the middle temporal gyrus. Here you can see the ventral frontal cortex and so on. So, Corbetta and colleagues observed that when a person selectively attends a region of space, and if a relevant stimulus appears somewhere else, more ventral areas of the brain are engaged in detecting or responding to that stimulus.

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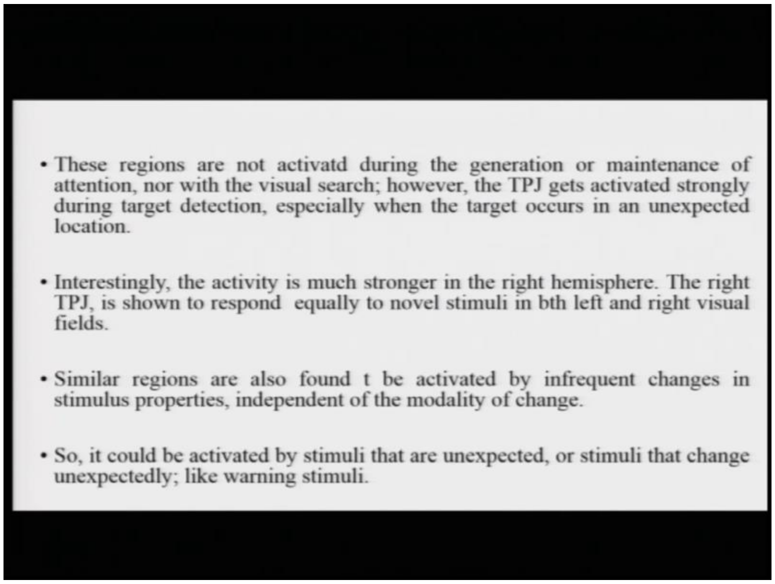

These ventral areas are not activated during the generation or maintenance of attention, nor with visual search. However, the temporoparietal junction gets actually strongly activated during target detection, when a target is detected, especially when the target is appearing at an unexpected location. Interestingly, this activity at the temporoparietal junction is much stronger at the right hemisphere as compared to the left hemisphere. So, the right TPJ is shown to respond equally strongly to novel stimuli both in the right and the left visual fields.

Similar regions are also found to be activated by infrequent changes in stimulus properties independently of the modality of change. So, for example if the stimulus changes its color, its sound, its shape, any unexpected change happens in the stimulus. This is the you know area the temporoparietal junction which will get engaged or the ventral attentional network will get engaged. So, this ventral attentional network can be activated by stimuli that are unexpected, or stimuli that change in expected manners, say for example, like warning stimuli.

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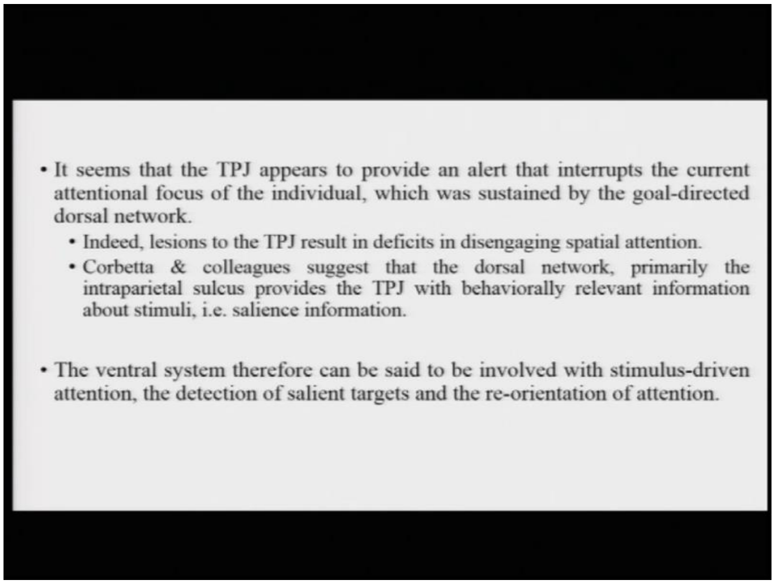

It seems that this temporoparietal junction appears to act as an alerting signal that interrupts the current attentional focus of the individual. So, for example, let's imagine that you are a pilot and you are riding in the plane and you are actually sitting in the cockpit of the plane and you are, you know, the flight is going on as per schedule, everything is nice and you are supposed to be relaxed and everything is going as per plan.

Now, suddenly one of the buttons or one of the you know lights starts blinking rapidly, maybe it a red colored light, maybe there's a sound that starts you know coming beep, beep, beep something like that. So, that is basically what is a warning signal. To detect that kind of warning signal immediately to counter or to understand that unexpected change in either the you know, feature of the stimulus or you know, the location of the stimulus basically is going to be done by this temporoparietal junction and the entire ventral attentional network.

Indeed, lesions to this temporoparietal junction has actually resulted in deficits in disengaging spatial attention. So, if this region is damaged, you will not be able to orient or disengage from the region that you are working at and orient to the new location where the warning signal is being presented.

Further, Corbetta and colleagues actually suggest that the dorsal network primarily the intraparietal sulcus is the one that actually provides the temporal parietal junction with behaviorally relevant information about stimulus that is the salience information that, you know, this is where the salience stimuli aligned and you need to get oriented over there.

This ventral system that we are talking about, therefore can be set to be involved with stimulus driven attention, the detection of salient targets and the reorientation of attention, so while you are doing this task, you are actually you know, involved in flying the plane, everything is going as per planned, in a goal directed manner, you are monitoring, you know, some of the things that are supposed to be monitored. And then there is suddenly this warning signal, the reorientation of attention to this warning signal is what is being accomplished by this, you know, ventral attentional network.

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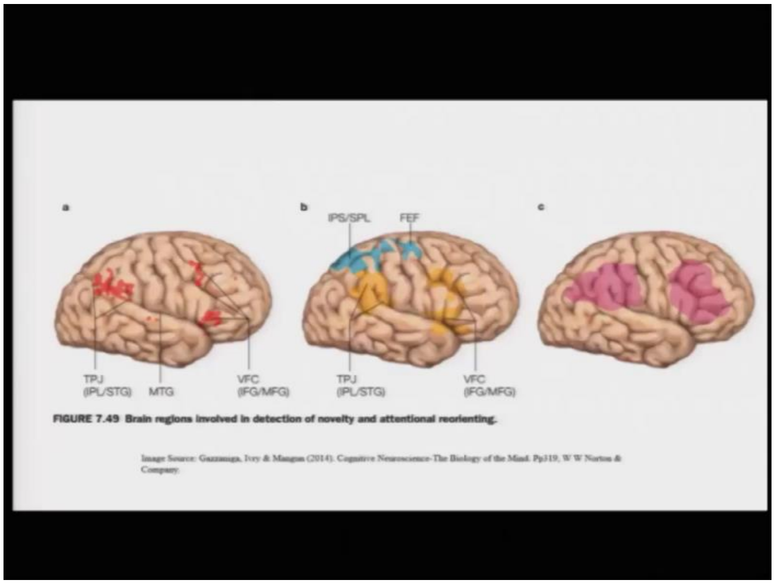

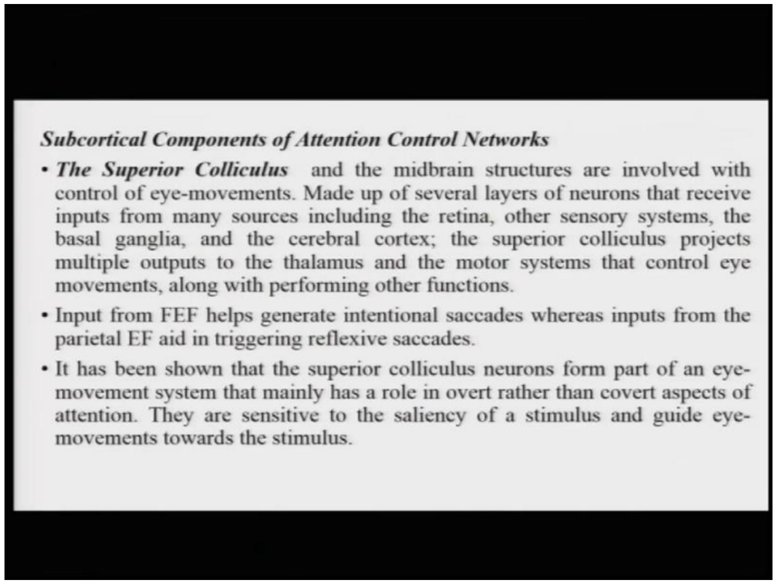

So, this is as I showed you the regions that formed the ventral attentional network. Now, other than the regions in the cortex, there are subcortical components also that play a very important role in the attention control networks. One of the most important region is the superior colliculus. We have been talking about that a lot. The superior colliculus and the midbrain structures are typically involved with the control of eye movements.

Now, these regions are made up of several layers of neurons that receive input from many sources, including the retina, other sensory systems, basal ganglia and the cerebral cortex. Now, the superior colliculus actually projects multiple outputs to the thalamus and the motor systems that control eye movements along with warning some other functions.

Now, for instance inputs from the frontal eye fields help generate intentional saccades, where inputs from the parietal eye fields aid in triggering reflexive saccades. So, the frontal eye field is basically helped the eye movement system to generate intentional saccades, whereas the inputs from the parietal eye fields helped in generating reflexive saccades which are in response to peripheral stimulus, or in a manner, when the stimulus is grabbing our attention.

Now, it has been shown that the superior colliculus neurons form part of an eye movement system or eye movement control system rather, that mainly has a role in overt over covert aspects of attention. So, when you have to actually move your eyes to particular target locations, this is where the neurons and the superior colliculus are actually going to play a part. And these neurons are found to be sensitive to the saliency of stimulus and therefore, we are able to guide the movement of the eyes to regions in space that contain the salient stimulus.

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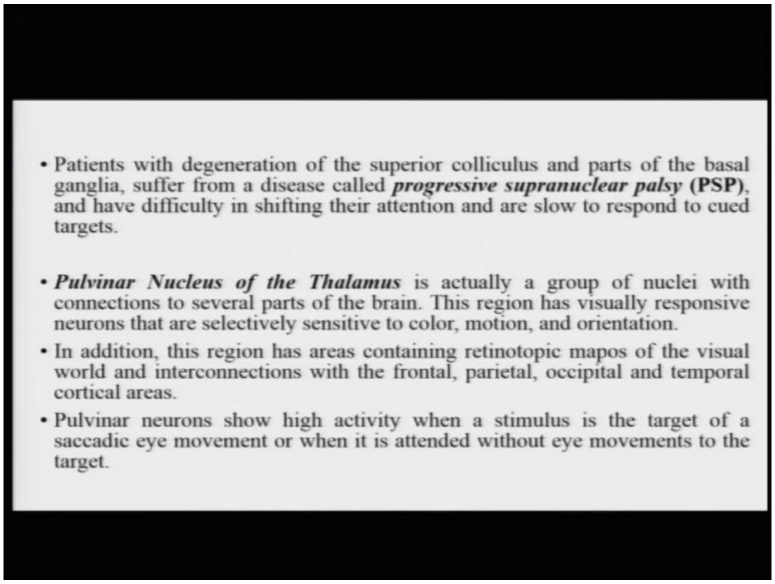

Patients which have degeneration of the superior colliculus and parts of basal ganglia suffer from a disease called progressive supranu clear Palsy. And this disease is characterized by people having difficulty in shifting their attention and being slow to respond to cuef targets. So, if there is a cued target, you will not be able to orient your attention by moving your eyes towards that location. And that is basically because the superior colliculus neurons are not functioning properly.

The other region in the subcortical area, there is a part of the attentional control network is the pulvinar nucleus of the thalamus. Now, the pulvinar nuclei is actually a group of nuclei that have connections with several parts of the brain. This region has visually responsive neurons that are selective to color, motion or orientation. In addition, this region also has it contains retinotopic maps of the visual world and it has interconnections with the frontal, parietal, occipital and temporal cortical areas. So, this is a well-connected region, which sort of also has the retinotopic map of the visual field.

Now, typically pulvinar neurons show high activity when a stimulus is the target of the saccadic eye movement or when it is being attended even without eye movements to the target. So, if there is this target here which I want to attend, the pulvinar nuclei will show more attention or they will show more activity.

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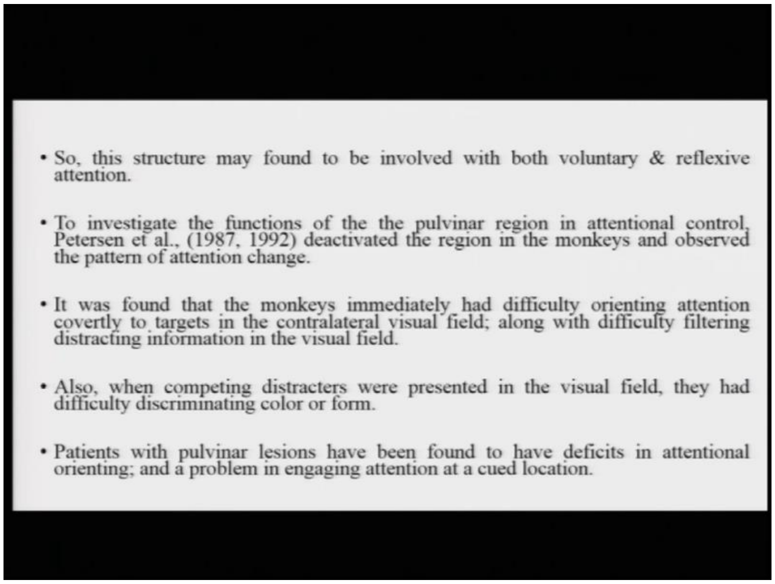

So, this structure has been found to be or maybe found to be involved with both voluntary and reflexive orientation of attention. To test this or to investigate the functions of the pulvinar region in the attentional control, Petersen and colleagues basically deactivated this region in the monkeys and they observed the pattern of attention change. What did they find? It was found that monkeys immediately started having difficulties in orienting attention covertly to targets in the counter lateral visual field, so they could not attend to targets in the contralateral visual field.

Also, the monkeys face difficulty in filtering out distracting information from the visual field so they could not control the orientation of attention. Also, it was found that when competing distractors were present in the visual field, they had difficulty discriminating the color or form of these objects.

So, basically all kinds of orientation to targets basically is suffering when the alumina nuclei of the thalamus are damaged. Finally, patients with pulvinar lesions have been found to have deficits in attentional orienting. And they also have been found to have problems in engaging attention at a cued location. So, when you are cued, let us say there is an arrow towards the left side or the right side, if the pulvinar nuclei are damaged, it will be difficult to orient your attention to this feature.

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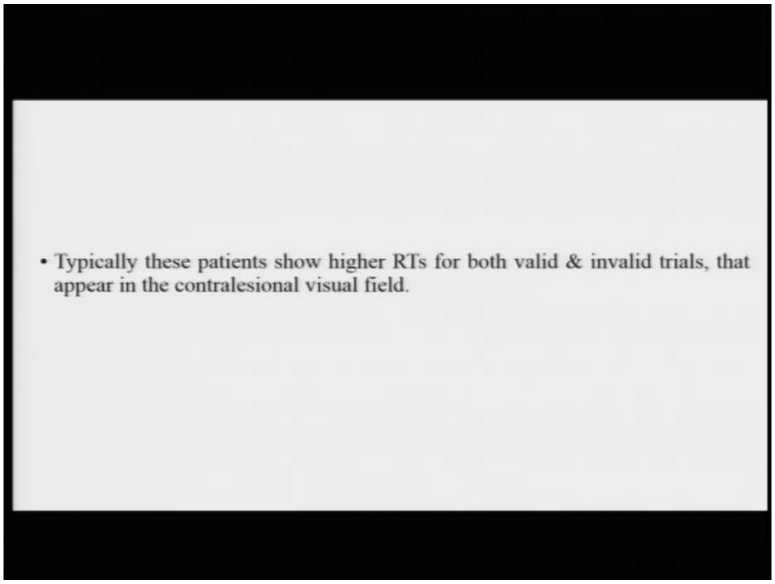

Typically what happens is these patients with you know pulvinar nuclei damage showed high reaction times on both valid trials because they are not being able to orient their attention to the cued location and also invalid trials because they are not being able to discriminate the cued from the uncued location, if these stimuli are appearing in the contralesional visual field.

Now, just something that you will need to remember is when we are talking about deficits resulting from damage to particular areas of the cortex or particular areas of the brain, we are not really saying that, say for example, no other areas involved. Say, for example, when I am saying that people who experienced difficulty in orienting attention as a result of damage to the pulvinar nuclei, it does not mean that say, for example, other areas are not involved in orienting the orientation of attention.

And understand that, if this area is damaged, this is the aspect of deficit that is most typically observed. So, with that, I would like to conclude this, you know, week, conclude the chapter of attention. We have talked about various things. We have talked about disorders of attention. We have talked about specific kinds of attention, space based, object based, feature based. We have talked about attentional networks today.

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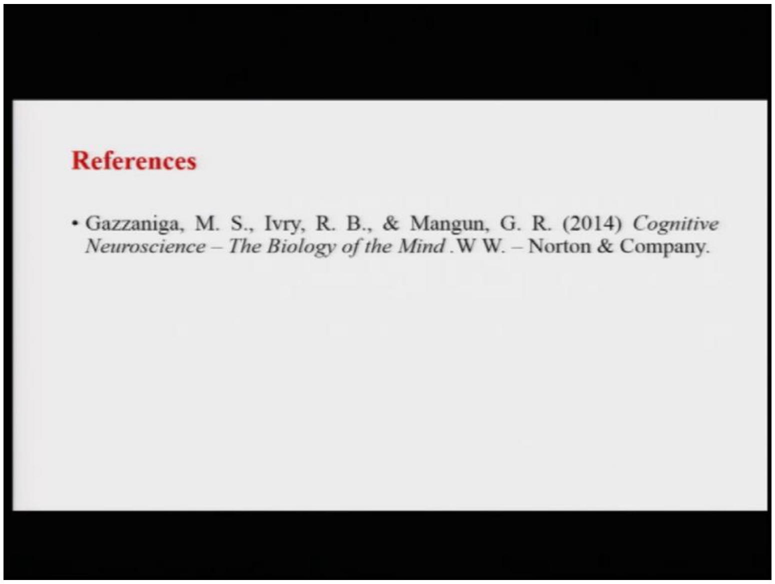

And this sort of completes a total idea of how is attention manifested in the brain and how is attention basically manifested also acts as a very, very important aspect of processing information in the visual area. Thank you.