Introduction to Brain & Behaviour
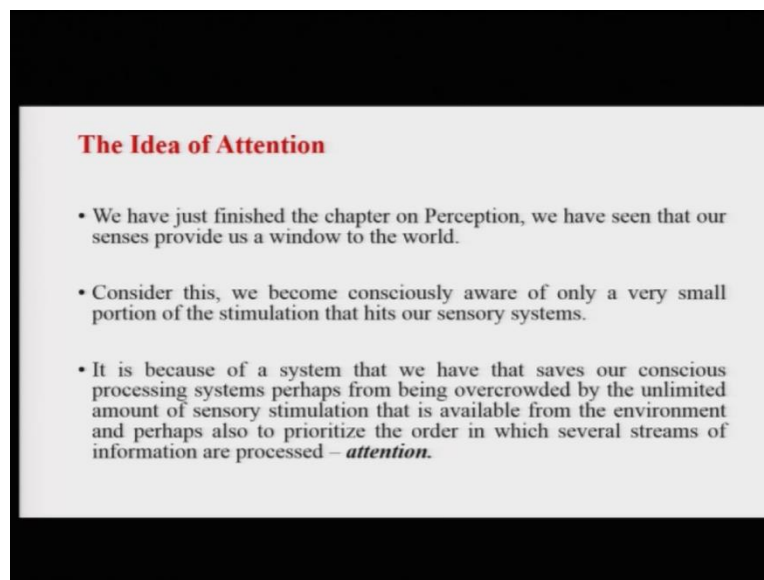**Professor Ark Verma**
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Lecture 16 – Attention

Hello, and welcome to the course, Introduction to Brain and Behavior. I am Dr. Ark Verma from IIT, Kanpur. As you know, I work with the Department of Humanities and Social Sciences and also the Program of Cognitive Sciences at the institute.

We are beginning the fourth week of lectures. In this week, we start talking about attention. Now, attention is a very interesting topic. And we, because we have just finished the chapter on perception, I might want to make you recall what were the basic things that we were kind of talking about in that chapter.

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So we talked about the flow of information from the sensory system onwards towards the brain and then for the processing of the stimuli. Where does this information come from the sensory system? We can ask questions like, is all the information that is received by the sensory systems processed by the brain eventually, or just a subset of that information actually goes through the entire processing cycle that we talked about in the chapter on perception and only a very small portion of whatever was received at the senses is eventually processed in a manner that we become consciously aware of that.

And we are basically let us say, you know, asked to take decisions about, okay, whether, do I have to take this decision or that with respect to the stimuli? Suppose, say, for example, there

are a couple of fruits kept on the table, and you have to sort of decide, okay, which of the two fruits you are going to eat for your breakfast, something like that.

Now, just taking this a little bit further, just to try and answer this question that I just raised. It is actually a fact that we become consciously aware of only a very, very small portion of stimulation that is received on the sensory systems. It is because of a system that we have that saves our processing or information processing machinery from being overcrowded by the unlimited amount of stimulation that is available from the environment. Let us take this example.

While you are sitting at, let us say, in your room and watching this video lecture, you are surrounded by not one but many sources of stimulation. Maybe there is some noise coming out of your air conditioner or your fan. You are sitting on a surface which might be having a very soft texture or a slightly hard texture depending upon say for example, if you are sitting on a cushioned seat or you are sitting on maybe a hard material.
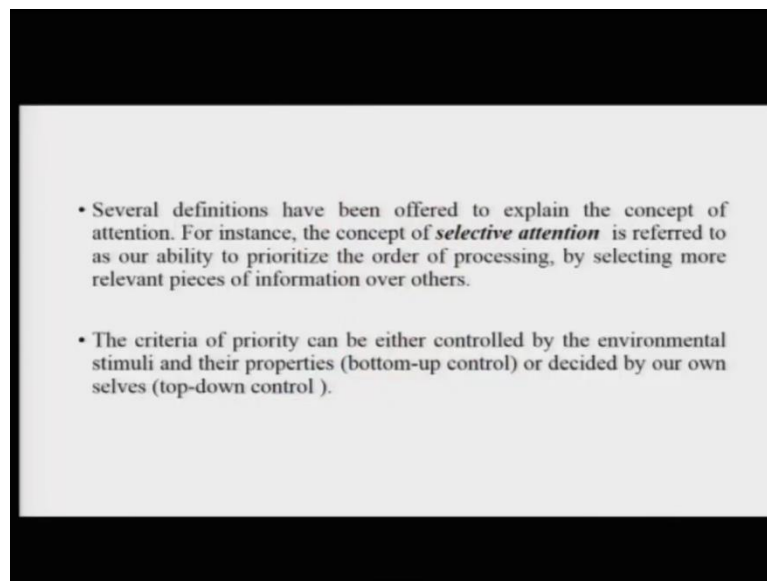
There might be some noise coming outside the room from where you are. There might be some other tabs open on the window, open on the system, which might be blinking due to various reasons.

Now, all of these sources of information are say, for example, in some sense received by our sensory systems. But if all of them were to be processed at the same time, and if an output were to be expected to each of these different streams of information at the same time, the system would simply get overcrowded and might collapse.

For this, we needed a system or let us say for negotiating this almost unending supply of stimulation, we need a system that sort of helps us prioritize as to what information needs to be processed first, and then what information will come later. What will be the criteria of this prioritization? What kind of, or what decides what, what piece of information gets selected and what piece of information gets left out? These are some of the questions that we will try and answer in this chapter.

To begin with, let me just give you a very brief definition of what attention is. Attention in some sense basically means or basically refers to our ability to prioritize the order in which several streams of information may be processed. We will qualify and we will sort of elaborate on this definition as we go ahead.

- Several definitions have been offered to explain the concept of attention. For instance, the concept of *selective attention* is referred to as our ability to prioritize the order of processing, by selecting more relevant pieces of information over others.

- The criteria of priority can be either controlled by the environmental stimuli and their properties (bottom-up control) or decided by our own selves (top-down control).
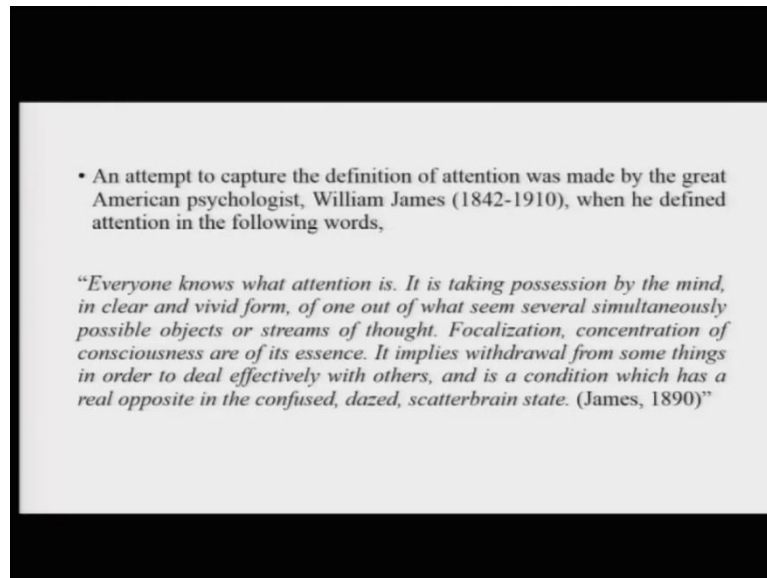
Now, several definitions have actually been offered to explain the concept of attention. For instance, we talk about selective attention. Selective attention refers to our ability to prioritize this order of processing by selecting more relevant pieces of information over others.

Now, the criteria of priority can either be controlled by environmental stimuli and their properties. Say for example, if there is a very bright colored stimuli or a low loud noise in the vicinity, that will automatically grab your attention and you will sort of look towards that, that is stimulus driven or bottom of control of attention.

Similarly, it could just be, say, for example, decided by your own self. Say, for example, if you are looking for something, if you are looking for a particular stimulus, amongst a bunch of stimuli, say, for example, if I ask you to do detect a red ball from a tub, which contains balls of three different colors let us say, green, orange, yellow, and there is just one red ball there you have to look for.

So, depending upon how our attention is sort of oriented, the definition might differ as to whether it is bottom up control, or top down control. More on that, as we move ahead.

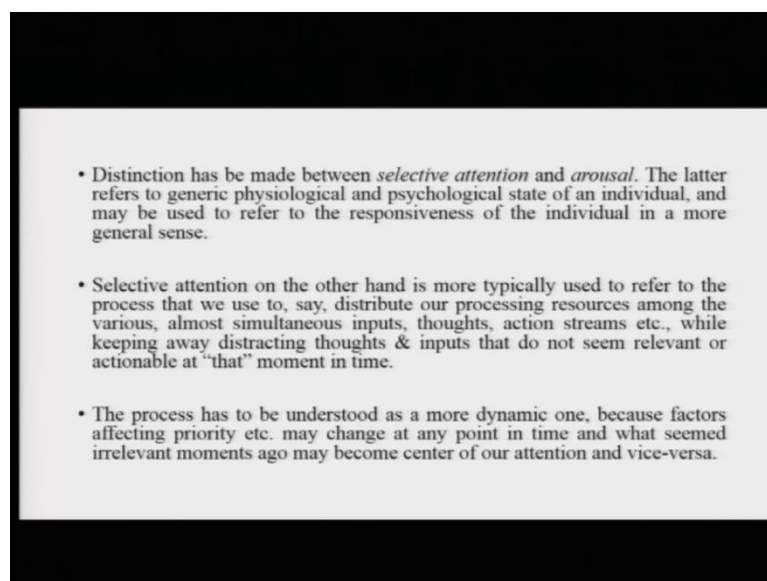A significant attempt to capture the definition of attention was made by the great American psychologist, William James, who is also referred to as the father of psychology, as you might already know. Now, let us look at his definition of what attention is or should be about. He says, everyone knows what attention is. It is taking position by the mind in clear and vivid form, one out of what seems several simultaneously, possible objects or streams of thought.

Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others and is a condition which has a real opposite in a confused, daze, scatterbrain state.

Now just take a gap, pause the video maybe 30 seconds, read the definition again. This definition is something that sort of captures whatever about attention has, you know already been said or say for example, might come later. Let us try and understand this definition in some more detail. Everyone knows what attention is. It is taking possession by the mind in clear and vivid form.

So, attention is basically when the mind sort of grabs hold of some stimuli, in clear and vivid form. And when the mind is sort of attending to that stimuli, it should, it is in all its clarity and its vividness of one of the possible several simultaneous objects or events. So this is of prime focus that we are talking about selecting one out of several possible streams of thought, several possible objects.

Let us say, if I am sitting in this room and while I am doing the recording, there are several objects inside this room. All of which may be interesting to me or may grab my attention, if I were so inclined. So, selecting one out of these several objects is a very, very important factor or is a very, very important aspect of attention.

And the other thing is focalization, concentration of consciousness. So we have to sort of give something our undivided attention. It will be a circle, if I use the word. But, say for example, we have to focus on that. We have to concentrate on that object or stream of thought, and try and analyze it in its details and try and understand or get the most out of, or get the most information out of this object or even that there as to get, okay.

It implies withdrawal from some things in order to deal effectively with others. Now this is, this is very interesting because when you are selecting something out of a pool of let us say, if you are selecting one out of a pool of four, you are effectively ignoring the other three. If you are selecting two out of pool of eight, you are effectively ignoring the other six. So this is something which is very, very important, which also sort of, as we just talked about, is a key characteristic of selective attention. You need to select one subset or one small, most relevant piece of information. And obviously, you can decide what most relevant might mean and we will discuss about that in going further.

But you have to select one particular relevant piece of information over the others, which let us say, are ignored for the time being. So basically what you are doing is you are selecting one and sort of deselecting the others, okay. So this is basically what is the essence of attention and it is a condition which is the stark opposite of a confused, dazed or scatterbrained state.

What could be a confused, dazed or a scatterbrain state, wherein you are trying to deal with multiple streams of information all at once. You are not going to be able to sort of deal with any of those bunches of information that you are dealing with, because none of them will get your full analysis. None of them will get your full processing capacity. And in that sense, you will be confused and let us say scatterbrained.

So, this is just a definition that was put forward by William James and I believe it has guided researchers in the field of attention ever since. Now distinction has been made between two concepts of selective attention and arousal. Now, we have talked a little bit already about what selective attention is. The latter here, which is arousal refers to the generic physiological and psychological state of the mind of an individual. And it may be used to refer to the responsiveness of the individual in a slightly more general sense.

Say, for example, whether I am awake, whether I am responding to stimuli in general, whether I am sort of conscious of what all is going on around me, in a very, very generic sort of loose sense can be termed as arousal. Selective attention as we already said, on the other hand, is more typically used to refer to a process that, say for example, we used to distribute our processing resources among various simultaneous inputs.

Suppose four people are talking at me at the same time, I have to decide which of the four people I have to actually listen to. When you go for shopping, when you go to a busy marketplace and five vendors are showing or thrusting products at you, you know, each telling the rates of the respective products, you have to sort of choose okay, which product do I want or which rate seems nicer so that I could direct my attention to that particular vendor. So, selective attention is more like this where you basically decide okay, how do I distribute my processing resources?

This, remember this comes with an understanding that the processing resources are limited and they are sort of, not say for example, they cannot be extended to support unlimited amount of information processing. So, it probably comes with that understanding. So, selective attention is basically a process by which you distribute our resources among the various almost simultaneous inputs, thoughts, actions, streams, etc, while keeping away distracting thoughts and inputs that do not seem relevant or actionable at that moment in time.

Say, for example, at this moment I am hungry and I want to pay attention to a food product rather than say, for example, a clothing item. But 10 minutes later, once I am satiated, once there is no more hunger, then maybe I will probably pay more attention to say, for example,

the product which has clothes or some kind of other accessories. So this process has to be understood as a more dynamic one, because factors affecting priority etc, will change and will and can change at any point in time. And say for example, as a result, what seemed irrelevant moments ago may suddenly become the center of our attention and vice versa. So, this is something again, which I sort of thought that, you know, it will be interesting to discuss.

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- Attention can have several modes of influence the chronology of the information processing cycle. For instance, it can affect the way people encode incoming sensory information, store that information in memory, process the significance of the information semantically and consequently decide upon a course of action.

- Systems that would determine the focus of our attention and its dynamics are referred to as *attentional control mechanisms*.

- These systems govern how exactly the process of attention modulates the incoming flow of information so as to decide the level and extent to which information is processed and also decide which streams of information require immediate or delayed action.

Now, attention can have several modes, or several ways to influence the chronology of this information processing cycle that we have started discussing since the last chapter. For instance, say for example, it can affect the way people encode incoming sensory information. How do you sort of encode or say for example, transduce the sensory information etcetera, it sort of, can be modulated by whether you are paying attention to certain information or not.

How we store that information in the memory, how do we process the significance of the information let us say at a semantic level, and consequently, how do we decide upon a course of action? Suppose there is something that we are not really paying attention at, it might never reach our conscious awareness, it might never reach a stage where we have to decide whether we want to act on that bit of information or not.
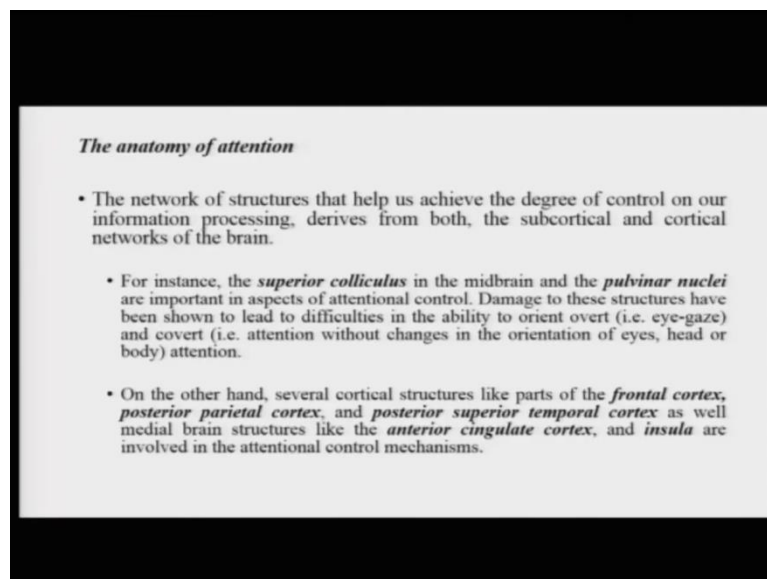
Systems that would determine the focus of attention or would determine what the focus our attention is going to be and its dynamics are referred to as attentional control mechanisms. These systems govern how the exactly the process of attention modulates the incoming flow of information so as to decide the level and the extent to which certain information is going to

be processed. And also decide which streams of information require immediate or delayed action.

Say for example, while you are busy enjoying a sandwich somewhere in the greens and there is an insect which is nearby, so while your entire let us say interest was in consuming the delicious sandwich that you were having. But if you see that the insect is very near and it might be a dangerous one or a poisonous one, your attention will immediately shift to that insect and you will sort of either try and push it away or maybe get up and change your place of sitting.

Did you suddenly become conscious of the insect or force it that you were attending to the insect, but while it was at a safe distance you did not really care. So, this is basically the dynamics of attention that we will time and again come and discuss during the course of this chapter.

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The anatomy of attention

- The network of structures that help us achieve the degree of control on our information processing, derives from both, the subcortical and cortical networks of the brain.

  - For instance, the *superior colliculus* in the midbrain and the *pulvinar nuclei* are important in aspects of attentional control. Damage to these structures have been shown to lead to difficulties in the ability to orient overt (i.e. eye-gaze) and covert (i.e. attention without changes in the orientation of eyes, head or body) attention.

  - On the other hand, several cortical structures like parts of the *frontal cortex, posterior parietal cortex,* and *posterior superior temporal cortex* as well medial brain structures like the *anterior cingulate cortex,* and *insula* are involved in the attentional control mechanisms.

Now, let us shift our attention to the brain areas that might slightly in a more generic sense support the processes of attention. Now, there is a network of structures that help us achieve the degree of control on our information processing systems. These structures derived from both the subcortical and the cortical networks of the brain. For instance, the superior colliculus in the midbrain and the pulvinar and the pulvinar nuclei are important aspects of attentional control. They are important structures that support attention control.

Damage to these structures have been shown to lead to difficulties in the ability to orient overt when you move your eyes towards a particular object and covert say for example,

without changing the orientation of eyes, if you are still let us say attending to something which is on your left or on your right. So, damage to these structures has been shown to be causing deficiency in the ability to orient overt attention or covert attention both.

On the other hand, several structures from the cortex, the frontal cortex, the posterior parietal cortex, the posterior superior temporal cortex as well as some midbrain structures, middle brain structures like the anterior cingulate cortex and insula are supposed to be involved in the process of attentional control.
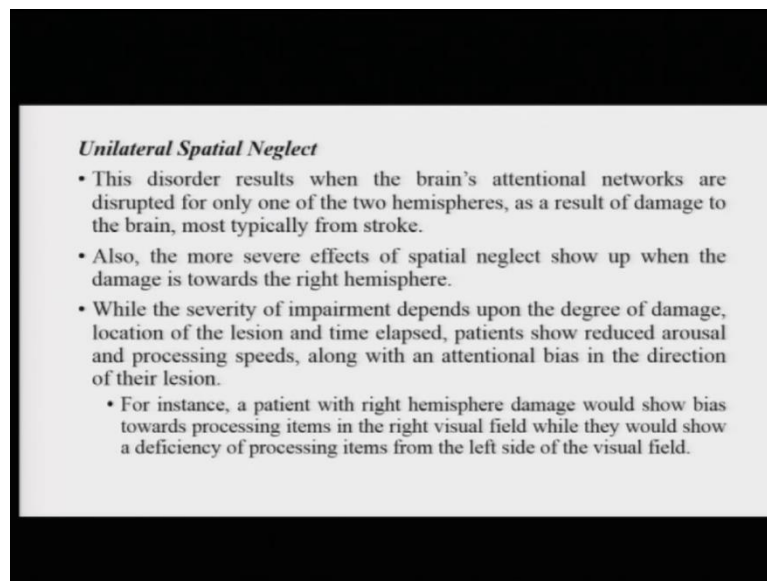
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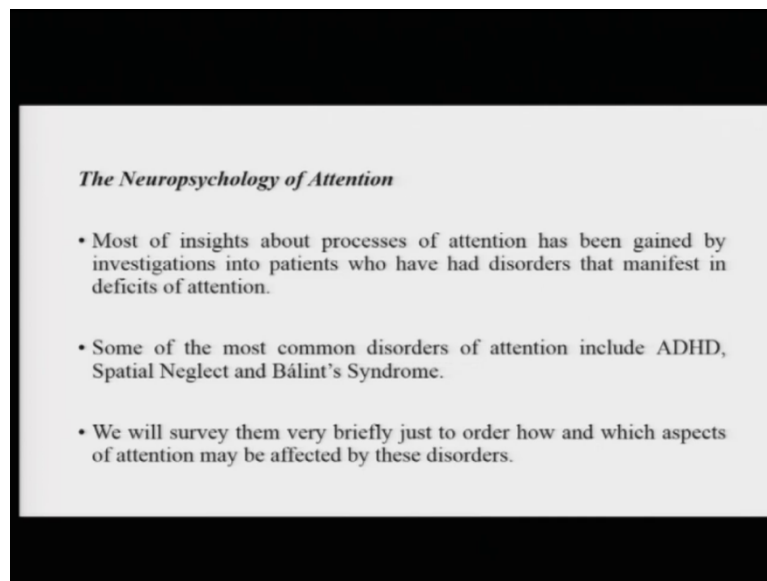
Now let us look at some cases from the neuropsychology side. If you remember I have told probably in an earlier lecture, neuropsychology typically deals with instances or cases where there is some sort of atypicality or abnormality in the brain and that atypicality or abnormality might be arising out of injury, congenital defect, some kind of a mishap with the brain.

Now, most of the insights about the process of attention have actually been gained by investigations into patients who have had disorders that manifested in deficits of attention. So that is one of the reasons we will have a look at some of these disorders now. Now, most common disorders are like ADHD, which is attention deficit hyperactivity disorder, spatial neglect, and Balint's syndrome.

Now, let us survey them very briefly in just to say, for example, understand how and which aspects of attention may be affected by these disorders.
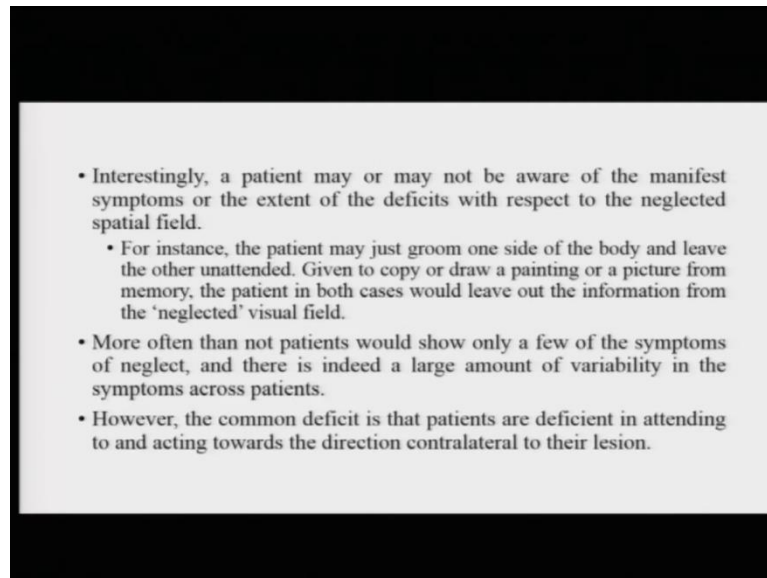
Now, let us first talk about unilateral spatial neglect. Now, this disorder typically results when the brain's attentional networks are disrupted for only one of the two hemispheres of the brain. Typically, this would happen as a result of damage by a stroke or some kind of injury. Also, the most severe effects of spatial neglect show up when the damage is more focused in the right hemisphere of the brain, as opposed to the left hemisphere of the brain.

While the severity of the impairment so the kind of symptoms that the patient would show will depend majorly on the degree of damage, how much injury is there, the location of the injury, the location of the lesion, and the time that has elapsed between the lesion and the testing. Patients typically show reduced arousal and reduced processing speeds, along with an attentional bias in the direction of the lesion.

Say, for example, if the lesion is on the left hemisphere, patients will be more attentive towards stimuli in the left hemisphere. If the lesion is in the right hemisphere, patients will be more attentive and will process more, process in a more better sense stimuli presented in the right hemisphere. I will tell you the reason behind that in a bit.

- Interestingly, a patient may or may not be aware of the manifest symptoms or the extent of the deficits with respect to the neglected spatial field.
  - For instance, the patient may just groom one side of the body and leave the other unattended. Given to copy or draw a painting or a picture from memory, the patient in both cases would leave out the information from the 'neglected' visual field.
- More often than not patients would show only a few of the symptoms of neglect, and there is indeed a large amount of variability in the symptoms across patients.
- However, the common deficit is that patients are deficient in attending to and acting towards the direction contralateral to their lesion.

Now, say, for example, why would this be? This would typically be because if you remember, the description of the visual system, while we are discussing visual perception is that information sort of crosses from one side of the visual field to the contralateral hemisphere at this place called optic chiasm just around the lateral geniculate nucleus. This is one of the reasons that when patients suffer damage to the right hemisphere, they typically lose the processing capacity of stimuli that are occurring in the left visual field. And when patients suffer injury to the left hemisphere, we typically face difficulties processing information in the right visual field. We will come back to this in a bit.
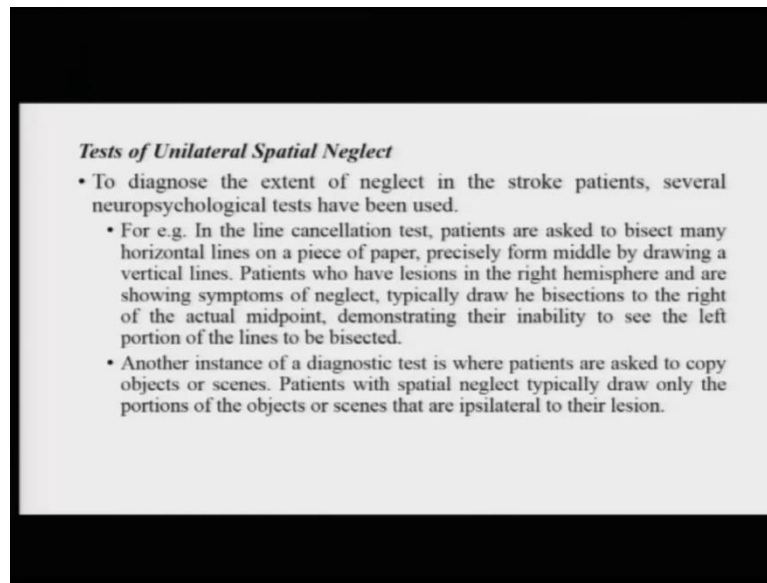
Now, a patient may or may not be aware of the manifest symptoms or the extent of the deficits with respect to the neglected spatial field. For instance, patients may just groom one side of their body, and leave the other unattained. Say for example, it has been shown in patients of unilateral spatial neglect that if they are asked to shave their face, sometimes they will just on one side of the face and leave the other side of the face completely unattended.

Similarly, if they are asked to copy or draw a painting, or say for example, even sometimes a picture from their memory. In both of these cases, patients typically leave out the information from the neglected visual field, say for example, right hemisphere lesion patients will leave out the information from the left part of these objects or memories.

More often than not patients would show only a few of the symptoms of neglect. Not everybody shows all the patients, not all patients show all the symptoms. And there is indeed a large amount of variability in the symptoms across patients.

The symptoms of patients 1 may not be identical to that of patient 2 and so on. However, the most common deficit is that patients are sort of face difficulty in attending to and acting towards the direction which is contralateral to their lesion. As I said, right hemispheric lesions will have, right hemispheric lesion patients will have problems in the left visual field, left hemispheric lesion patients will have problems in the right visual field, that is the idea.

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Tests of Unilateral Spatial Neglect
- To diagnose the extent of neglect in the stroke patients, several neuropsychological tests have been used.
  - For e.g. In the line cancellation test, patients are asked to bisect many horizontal lines on a piece of paper, precisely form middle by drawing a vertical lines. Patients who have lesions in the right hemisphere and are showing symptoms of neglect, typically draw he bisections to the right of the actual midpoint, demonstrating their inability to see the left portion of the lines to be bisected.
  - Another instance of a diagnostic test is where patients are asked to copy objects or scenes. Patients with spatial neglect typically draw only the portions of the objects or scenes that are ipsilateral to their lesion.

What can be some of the tests to diagnose that if a patient is suffering from unilateral spatial neglect? To diagnose the extent of neglect or the degree of difficulty that these stroke patients typically experience, several neuropsychological tests have been assigned. Say, for example, one of the very important tests that is used is the line cancellation test. And what happens here is that patients are asked to bisect, horizontal bisect many horizontal lines on a piece of paper, so they are given a piece of paper. There are many of these horizontal lines sort of drawn all across the sheet of paper. And what participants are asked is that you have to bisect these horizontal lines by drawing a vertical line in the exact mid portion of these horizontal lines.

Now typically what is expected is that, right hemisphere lesion patients would draw this vertical line to bisect these horizontal lines slightly towards the right of the actual midpoint. And now they actually draw it slightly towards the right of the actual midpoint because they are not able to get the picture of the whole line in the first place. Or they are actually getting is typically the viewpoint of the line, which is mainly the right part, but not really the left part, so their midpoint also shifts by that amount.

Another reason of a diagnostic test is where patients are asked to copy objects or scenes. Patients with spatial neglect typically would draw only portions of the objects or scenes that are ipsilateral to their lesion.

So, for example, you can see, you can just go on Google and see some of drawings of unilateral spatial neglect patients, you will see that if a patient is drawing a flower and say for example, you draw this circular part and then you have to draw the petals on the right and the left side, patients with right hemisphere lesions would only draw petals at the right side, but not on the left side of a flower because they are not that, they are not even visualizing that, they are not being able to visualize that.

If you ask them to draw a clock, then you will see that they will make around clock but they will all paste all the 12 digits on one side of the clock that is let us say if right hemisphere lesion patients are there, on the right side of clock, all 1 to 12 will all occur on the right side of the clock itself. So these are some of the actual deficits that these patients sort of show.

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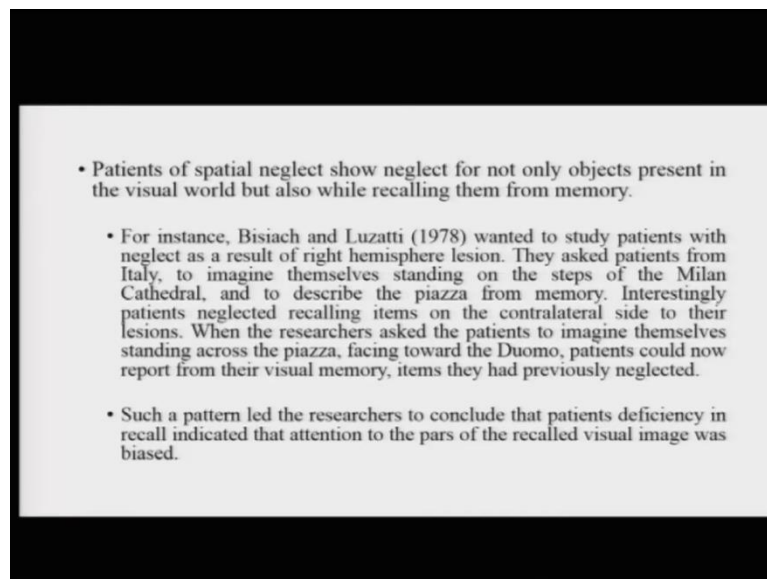
Now also patients of spatial neglect show neglect for not only objects present in the visual world, but even from when they are sort of recalling from memory. So, some of you might say that, okay if the stimulus is right there, and I am being able to process only the right part of the stimulus and not the left part of the stimulus, maybe that is where my drawing is suffering, but my memory typically should be a complete, my memory should be undamaged from this particular thing. And so, I should be, from the memory, I should be able to draw the whole flower or the whole clock.
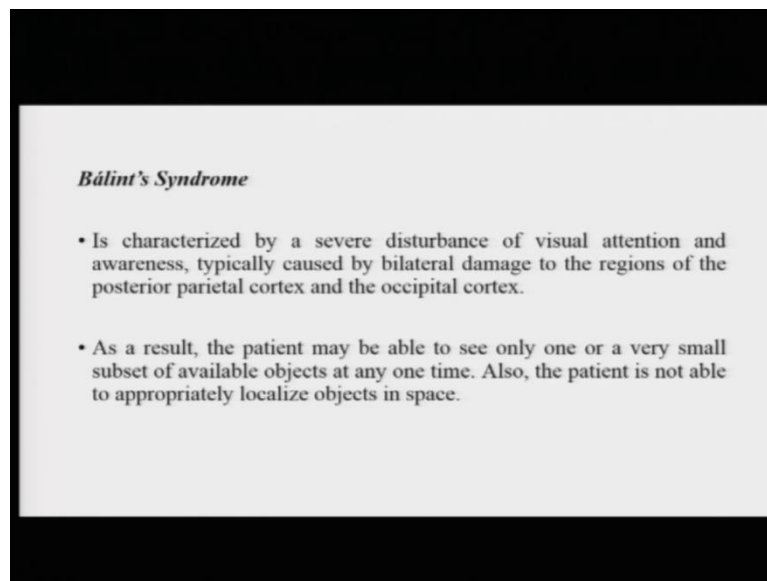
Bisiach and Luzatti in 1978 wanted to study patients with neglect as a result of right hemisphere lesions. And what they did was they asked patients, most of them were from Italy, asked these Italian patients to imagine themselves standing on the steps of the Milan Cathedral, and to describe the piazza from memory. So piazzas are these places around the cathedrals where there is a lot of activity. People sit there, they can have, say, for example walk there, this is mostly cemented surface. So the idea is that the patients were supposed to describe the piazza from memory and maybe draw it in some sense.

Now when the researchers asked the patients to imagine them, so typically what happened was while they were recalling patients neglected recalling items on the contralateral side to the lesion. So these were right hemisphere patients, so they neglected the entire information from the left side of let us say where they were standing.

Interestingly, when the researchers asked the patients to imagine themselves standing across the piazza now facing towards the Duomo, the patients could now report from their visual memory information that they had initially neglected and not been able to report or draw. So it seems that the memory is indeed complete, but because their attention is not attention to that side of the representation is not intact, they were not being able to reproduce that information. There is a very fascinating pattern of deficits there to observe.

So such a pattern led the researchers to conclude that patients' deficiency in recall, indicated that attention to that indicated, the lack of attention to the parts of the recalled, the recalled visual image was there, so they could not really pay attention to those parts of the visual image. Because say, for example, they were not able to process it.

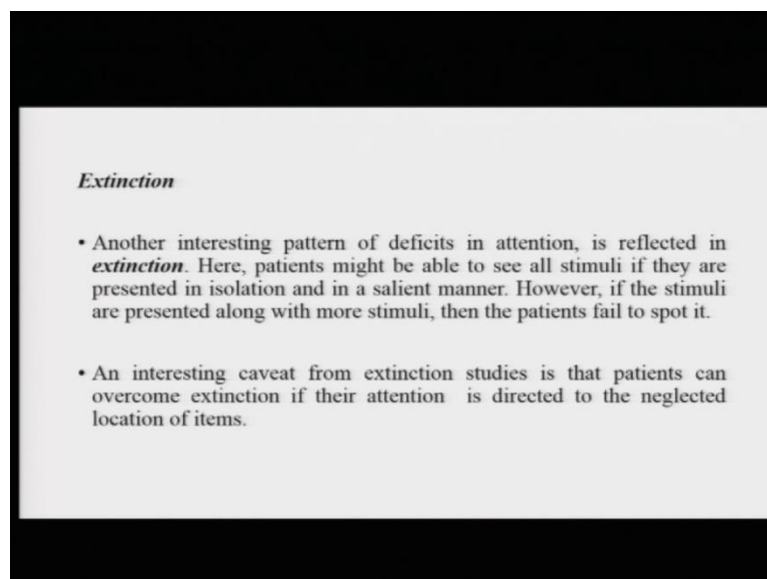Let us move further to the disorder called the Balint syndrome. Balint syndrome is typically characterized by a severe disturbance of visual attention and awareness, typically caused by bilateral damage to the regions of posterior parietal cortex and the occipital cortex. So this is typically only happening when bilaterally in both the hemispheres damage is there, the posterior parietal cortex and the occipital cortex.

As a result, what happens is that the patient is not able to see or is able to see only a very one, or a very small subset of objects available at any point in time. Also, the patient is not able to appropriately localize objects in space where each of these objects are located, so, this is also very interesting thing.

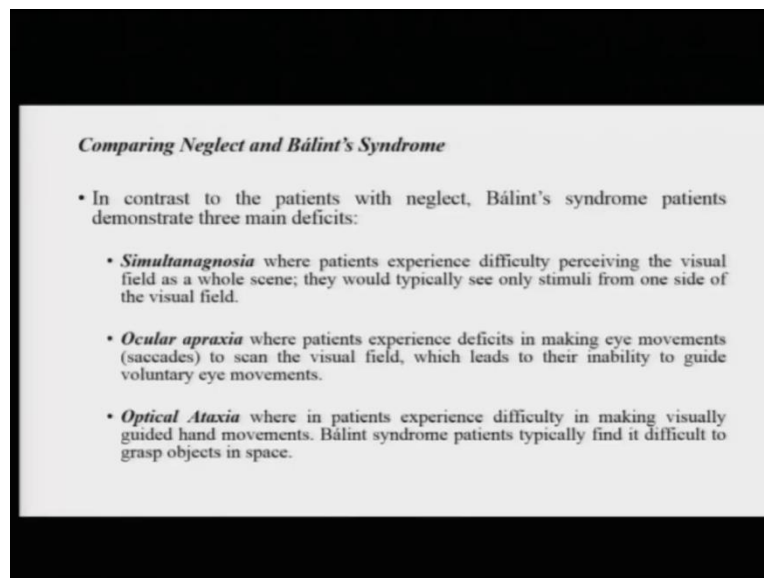Now, this phenomenon of using out this information is actually referred to as extinction. Typically, what happens in extinction is that patients might be able to see all stimuli if they are presented in isolation and in a salient manner. But if the stimuli is presented along with more stimuli, then the patients would fail to spot it, they will not be able to pick that up from the visual field.

Now, an interesting caveat from extinction studies is that patients can overcome extinction, if their attention is directed towards the neglected location of items. If you point towards them, okay, see you have not drawn the left part of this. But then when they kind of get to drawing again, sort of, for the most part, they are not able to draw that.

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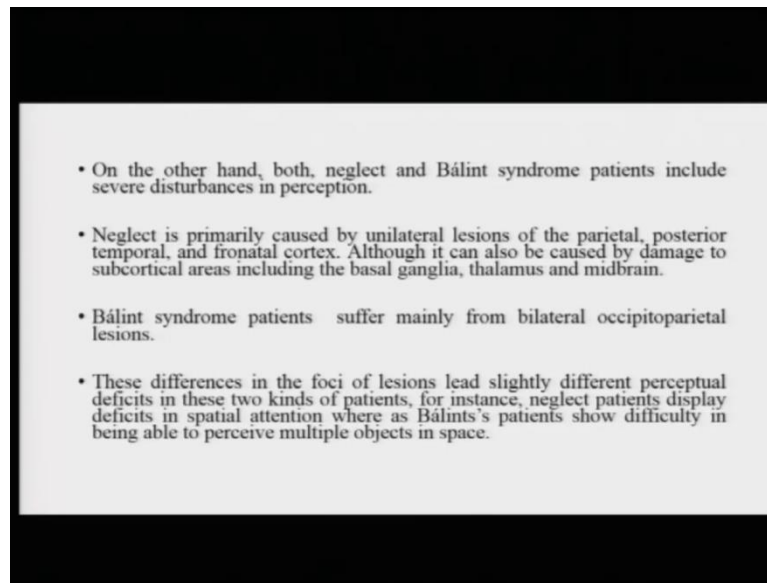

Comparing Neglect and Bálint's Syndrome

- In contrast to the patients with neglect, Bálint's syndrome patients demonstrate three main deficits:

  - *Simultanagnosia* where patients experience difficulty perceiving the visual field as a whole scene; they would typically see only stimuli from one side of the visual field.

  - *Ocular apraxia* where patients experience deficits in making eye movements (saccades) to scan the visual field, which leads to their inability to guide voluntary eye movements.

  - *Optical Ataxia* where in patients experience difficulty in making visually guided hand movements. Bálint syndrome patients typically find it difficult to grasp objects in space.

Now, let us compare the differences between the patients of spatial neglect and Balint's syndrome. In contrast to the patients with neglect, Balint's syndrome patients demonstrate three main kinds of deficits. One is simultanagnosia, where patients experience difficulty in perceiving the visual field as a whole scene. So, they would typically see only stimuli from one side of the visual field and the visual field will be sort of, in some sense fractured.

The whole visual field as, is available to you and me is not really available to the Balint's syndrome patient. Another difficulty is that they face ocular apraxia, that is they experience deficits or difficulty in making eye movements to scan the visual field. They cannot smoothly scan the visual field by moving their eyes across the visual field as you and me would be able to do.

Finally, they also have difficulties which are referred to as optical ataxia. That is, they cannot also make visually guided hand movements to grab objects from the visual space. Balint's syndrome patients typically find it very difficult to actually grab objects from the space and these three form a very integral part of the symptomatology that is there with Balint's syndrome patients.

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- On the other hand, both, neglect and Bálint syndrome patients include severe disturbances in perception.
- Neglect is primarily caused by unilateral lesions of the parietal, posterior temporal, and fronatal cortex. Although it can also be caused by damage to subcortical areas including the basal ganglia, thalamus and midbrain.
- Bálint syndrome patients suffer mainly from bilateral occipitoparietal lesions.
- These differences in the foci of lesions lead slightly different perceptual deficits in these two kinds of patients, for instance, neglect patients display deficits in spatial attention where as Bálints's patients show difficulty in being able to perceive multiple objects in space.

On the other hand, both Balint's syndrome and neglect patients include or demonstrate severe disturbances in perception. Neglect is primarily caused by unilateral lesions of the parietal posterior and the frontal cortices, although it can also be caused by damage to subcortical areas like the basal ganglia thalamus and the midbrain. Balint's syndrome is typically caused by bilateral occipitoparietal lesions. Now, these differences in the foci of these lesions lead us to slightly different perceptual deficits in the two kinds of patients.

For instance, neglect patients display deficits in spatial attention whereas Balint's syndrome patients show more difficulty in being able to perceive multiple objects at the same time. So, this is basically is that because the location of the lesions that are experienced in these two different kinds of patients, the kind of deficits they experience or they demonstrate is also and intuitively different.

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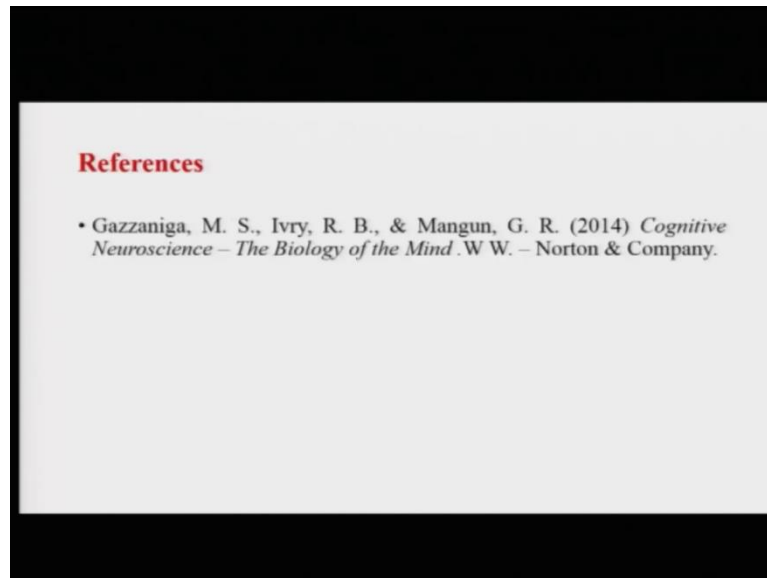
This is all with which I wanted to start this topic of attention, start the chapter on attention. In the next lecture, we will talk about some more details. Thank you.