Introduction to Brain & Behaviour
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Lecture 31
Cognitive Neuroscience of Language

Hello and welcome to the course, Introduction to Brain and Behaviour. I am Doctor Ark Verma from IIT, Kanpur. This is week 7 of the course and we will be talking about the Cognitive Neuroscience of Language.

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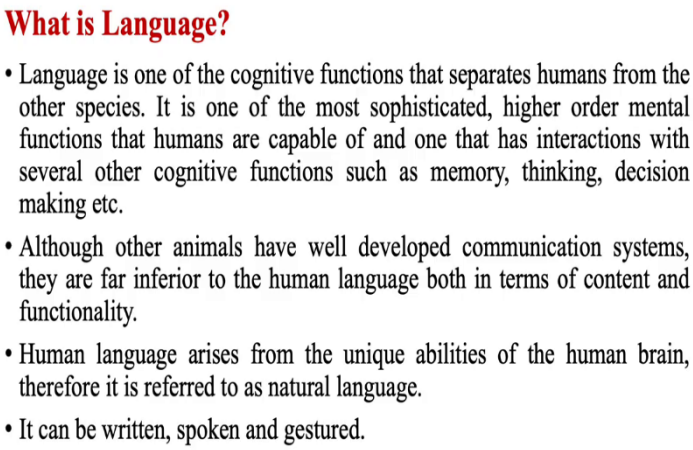

Now, before we get on with the neuroscientific aspects of language, it might be worthwhile to understand the importance of language as a cognitive function. Now, language is one of the cognitive functions that separates humans from the other species. It is one of the most sophisticated higher order mental functions that humans are capable of and one that has interactions with several other cognitive functions like memory, thinking, decision making etc.

Although other animals have well developed communication systems, they are far inferior to the human language, both in terms of content and functionality. Human language seems to arise from the unique abilities of the human brain, and therefore it is referred to as a natural language. Our language can be both spoken, written and even gestured.

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- Human language relies on symbolic coding of information to communicate abstract thoughts and concrete information about the world.
- Human language posses several unique characteristics, as described by C.F. Hockett (1960).
- Some of which are described below:
  - Semanticity
  - Arbitrariness
  - Discreteness
  - Spatial & Temporal Displacement
  - Duality of Patterning
  - Generativity

Now, human language basically relies on the symbolic coding of information to communicate abstract thoughts and concrete information about the world. This symbolic coding is usually in forms of sounds when we are talking about spoken language. It's in form of symbols, when we are talking about written language. And it is through manual gestures when we are talking about sign language. Now, C.F. Hockett in 1960 described several characteristic features of communication systems, few of which apply directly to human languages. So, let us discuss some of them.

The first very important feature is semanticity. Semanticity basically means that anything that you convey through language, any word etc. will have some meaning. We do not necessarily communicate gibberish in the language. So, if I am talking to you in a particular word such as apple, banana, mango, cat, dog, all of these words have some meaning attached to it. So, an essential feature of a human language is that it has meaning.

The other important feature is called arbitrariness. Arbitrariness basically means that there is, not necessary to have a correlation between the word form and the meaning that it is representing. For example, the word rabbit has nothing to do with how the actual concept of a rabbit looks like. Or the word ship does not have anything to do with the concept of the ship.

See, for example, you can say that ship is a small word but it represents a large object and hippopotamus is a large word but it represents a relatively smaller object as compared to a ship. So, arbitrariness basically means that there is not necessarily a relationship between the form of the code like the word or the written form. It does not have any correspondence mostly with the object that is represented.

Another thing that, another important feature of language that Hockett talks about is discreteness. Discreteness basically refers to the fact that the symbols in the language are discrete and they are separable from each other. Finally let us talk about Spatial and Temporal Displacement. Human languages have a very unique characteristic that they can communicate about things that are spatially removed from the current surroundings.

For example, I can talk about something that, that is here but I can also talk about something that is there and there maybe something, let us say, in another room or in another house or in another country or in another continent. So, human language has the luxury of being able to, you know, support communication of things that are spatially not in that current place.

Similarly, human languages also have the capability of being able to communicate about Temporal Displacement. The idea that we can talk about things that are not happening currently but have happened earlier or may happen later. These two are very, very important aspects of human languages.

Another characteristic that I would love to talk about is duality of patterning. Duality of patterning refers to the characteristic of the human language wherein basically what you are getting is that there are at least two levels of signals that are there. Say, for example, there is one broader level which has meaningful, which has meanings, say, for example, the words in the language have meaning. But there is another level that is that composes this higher level which is basically phonemes.

Human language is composed of these phonemes which are per se meaningless but when, we can combine to form meaningful structures like the words. So, there are two layers of signals that are embedded in the communication and we are capable of attending to and you know talking about both kinds of signals.

The final and the most important aspect of human languages is called generativity or recursivity. Generativity is the concept of the human language wherein basically we are saying that with a limited or a finite set of symbols we can communicate infinite messages. For example, there are around 40 phonemes in English language. But those 40 phonemes combined together in different fashions to form all the words and sentences, basically all the content that is available in English language and will be available in English language going further.

So, generativity is one of the most important aspects of the human languages. So, these were the 6, you know, very important features of human languages that were identified by C.F. Hockett. We have not given you the entire list which is of 16 design features. But these 6 directly apply to human language and I thought that they might be interesting to include.

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- Apart from these, human language fulfills the important function of allowing social communication, and transmission of knowledge through generations.
- In the current chapter we will focus at the neural basis of language.
- There are several theoretical perspectives which seek to understand language, for e.g.
  - ***Neuropsychology*** seeks to study patients with language deficits in order to understand the neural structures that enable different aspects of language, like production and comprehension.
  - ***Psycholinguistics*** seeks to understand the cognitive processes underlying language.
  - ***Cognitive Neuroscience*** basically seeks to combine both of the above approaches to investigate how humans comprehend and produce language, and which neural structures are responsible for facilitating these questions.

Now, apart from these features, the human languages fulfil the important function of allowing social communication and transmission of knowledge through generations. Basically, you know, we have seen that there are several stories that are passed on from generation to generation. Sometimes in some societies, the transmission is more oral. In other societies it is more written. But most of the time it is through language.

In the current chapter we will focus on understanding the neural basis of language. There are several theories several theoretical perspectives which have sought to understand language, and we will talk about a few of them. For example, neuropsychology seeks to study patients with language deficits in order to understand the neural structures that enable different aspects of language, like production and comprehension.

Psycholinguistics is basically a branch that combines insights from linguistics and psychology and seeks to understand the cognitive processes underlying language. Cognitive Neuroscience basically combine both of the above approaches, neuropsychology and psycholinguistics, and tries to investigate how humans comprehend and produce language, and also which neural structures are responsible for facilitating these abilities.

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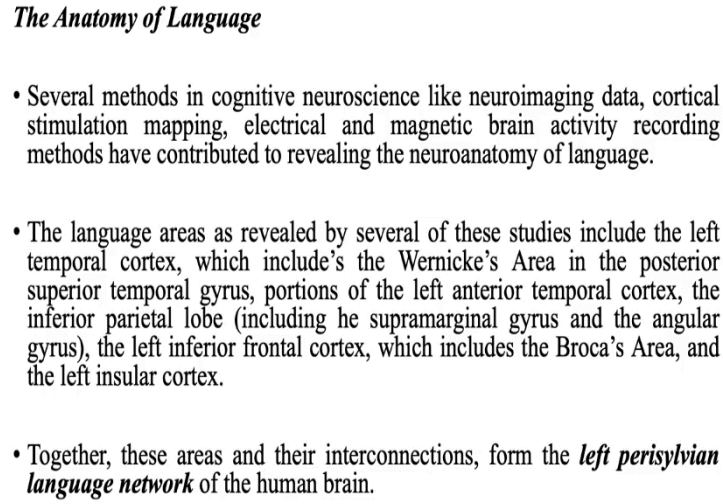

Let us talk a little bit about the anatomy of human language. Several methods in cognitive neuroscience like neuroimaging, like neuroimaging data, cortical stimulation mapping, electrical and magnetic brain activity recording, methods that record, method, these methods have contributed a lot to revealing the neuroanatomy of the language.

The language areas as revealed by several of these studies include the left temporal cortex, which includes the Wernicke's Area in the posterior superior temporal gyrus, portions of the left anterior temporal cortex, the inferior parietal lobe, including the supramarginal gyrus and the angular gyrus, and the left inferior frontal cortex, which includes the Broca's Area, and the left insular cortex. Together, these region, these areas and their interconnections, form what is called the left perisylvian language network of the human brain.

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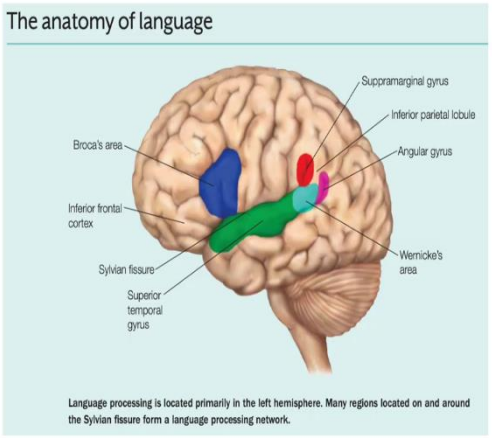

Image Source: Gazzaniga, Ivry & Mangun (2014). Cognitive Neuroscience-The Biology of the Mind. Pp 471, W W Norton & Company.

You can look at this figure and see that here all of these areas are mentioned that we have been talking about.

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- The left hemisphere is the dominant hemisphere for language processing, although the right hemisphere also contributes in various aspects of linguistic processing.
- The right superior temporal sulcus plays a role in processing the rhythm of language (prosody), and the right prefrontal cortex, middle temporal gyrus, and posterior cingulate activate when sentences have metaphorical meaning.
- Production, perception and comprehension language involve both motor movement and timing.
- So, all the cortical (premotor cortex, motor cortex, and supplementary motor area – SMA_ and subcortical (thalamus, basal ganglia, and cerebellum) structures involved with motor movement and timing contribute heavily to our ability to communicate.

The left hemisphere is the dominant hemisphere for language processing in most individuals, although the right hemisphere also contributes in several aspects of linguistic processing. The right superior temporal sulcus plays a role in processing the rhythm of the language like prosody, and the right prefrontal cortex, middle temporal gyrus, and posterior cingulate activate, activate when we hear sentences having metaphorical meaning.

Now, production, perception and comprehension of language involve both motor movement and timing. So, all the cortical areas like the supplementary motor area and the subcortical

motor areas like the thalamus, basal ganglia and the cerebellum, these structures are involved with motor movements and timing and therefore they contribute heavily to our ability to communicate.

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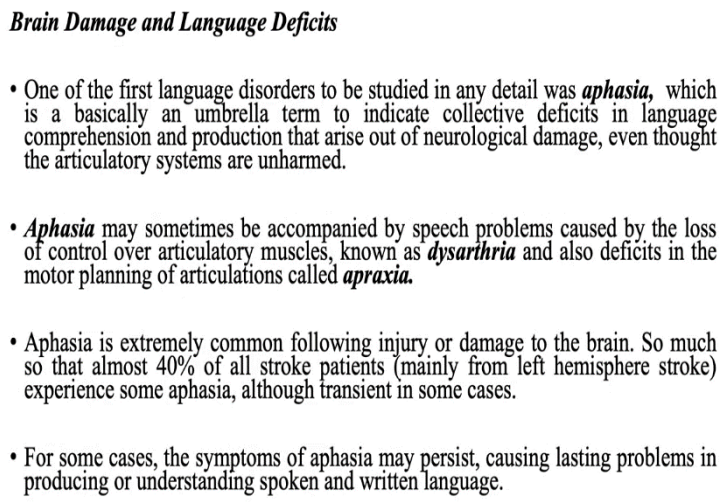

Let's talk about brain damage and language deficits. One of the first language disorders that has been studied in any detail was aphasia, which is basically an umbrella term for, to indicate the collective deficits in language comprehension and production that arise out of neurological damage, even thought the articulatory systems are unharmed. Aphasia may sometimes be accompanied by speech problems caused by the loss of control over articulatory muscles, which is known as dysarthria and also deficits in the motor planning of articulations that is referred to as apraxia.

Now, aphasia is extremely common following injury or damage to the brain. So much so that almost 40 percent of all stroke patients mainly from left hemisphere strokes experience some aphasia, although the aphasia might be transient in some cases. For some cases, the symptoms of aphasia may persist, causing lasting problems in production or understanding of spoken and written language.

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Broca's aphasia

- Broca's aphasia is one of the best studied forms of aphasia.
- First reported by Parisian physician Paul Broca in the 19th century, the disorder came to light when Broca came across M. Leborgne, a peculiar patient who could only say "tan", and hence came to be called as Tan.
- After Tan's death, Broca performed an autopsy on him to discover that the patient had a brain lesion in the posterior portion of the left inferior frontal gyrus, now referred to as Broca's Area.
- Several more patients after Tan, led to the conclusion that brain areas responsible for speech production are localized to the left hemisphere of the brain.

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After Tan's death, Broca performed an autopsy on him to discover that the patient had a brain lesion in the posterior portion of the left inferior frontal gyrus, now referred to as the Broca's Area. Several more patients after Tan, led to the conclusion that brain areas responsible for speech production are localized to the left hemisphere of the brain, more precisely in the left inferior frontal gyrus.

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- In severe forms of Broca's Aphasia, single-utterance patterns of speech are often observed. Although there is huge variability in symptoms, some of them may include unintelligible mutterings, single syllables or words, short-simple phrases, sentences that mostly are devoid of function words or grammatical markers.

- For some patients, the ability to sing normally is undisturbed, as might be he ability to recite phrases or prose or to count. The speech of Broca's aphasics is often telegraphic, coming in uneven burst and very effortful. Patients also report difficulty finding the appropriate word, or combination of words and then executing the pronouncing is compromised. They are often aware of their errors and usually frustrated.

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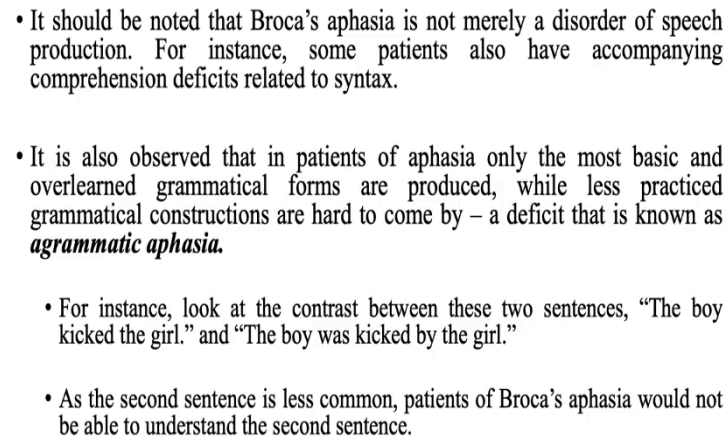

It should be noted that Broca's aphasia is not merely a disorder of speech production. For instance, some patients also have accompanying comprehension deficits related to syntax. It is also observed that in patients of aphasia only the most basic and overlearned grammatical forms are produced while less practiced grammatical constructions are hard to come by – a deficit that is known as agrammatic aphasia.

Now, for instance, look at the contrast between these two sentences, "The boy kicked the girl." and "The boy was kicked by the girl." Now, the boy kicked the girl is more practiced and it is easier to understand. The second sentence is less common and patients of Broca's aphasia will not be able to understand the second sentence also because the form is less frequent.

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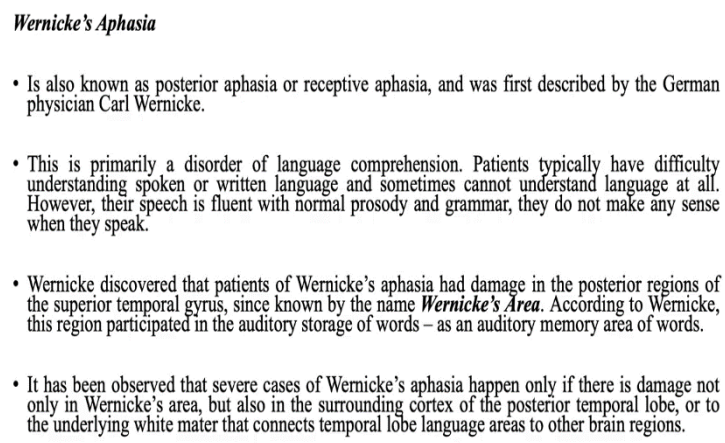

Now let us talk about Wernicke's Aphasia. Wernicke's Aphasia…

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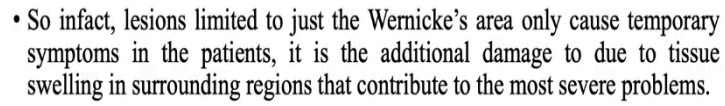

So infact, the lesions are limited to just Wernicke's area, only cause temporary symptoms in patients. It is the additional damage to the surrounding particle areas basically, that contributes to the most severe problems.

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Conduction Aphasia

- Ludwig Lichtheim in the 1880's proposed the idea of a third important region in the brain that stored conceptual information about words.
  - More specifically, he proposed that the once a word was retrieved from word storage it was sent to the conceptual area, which supplied all the information about the word.
  - Lichtheim described this model, termed the ***classical localizationist model*** wherein linguistic information, word storage (A = Wernicke's Area), speech planning (M = Broca's Area) and conceptual information store (B) are located in separate brain regions which are interconnected by white matter tracts, that are called ***arcurate fasciculus***.
- Wernicke had postulated that a different type of aphasia should result from damage to these fibers.

Now let's talk about Conduction Aphasia. Now, Ludwig Lichtheim in the 1880's proposed the idea of a third important region in the brain that stored conceptual information about the words. More specifically, he proposed that once a word was, once a word was retrieved from storage, it was sent to the conceptual area, which supplied the information about the word.

Lichtheim described this model, termed the classical localizationist model wherein linguistic information, that is word storage, A, Wernicke's Area, speech planning, M equals to Broca's Area and conceptual information, B, are located in separate regions and are interconnected by white matter tracts, that are called arcuate fasciculus. Wernicke had postulated that a different type of aphasia should result from damage to these fibres.

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- In around the 1950s, neurologist Norman Geschwind started to investigate more deeply into this specific type of aphasia, and its was termed as ***Conduction Aphasia***.
- Conduction aphasics are capable of comprehending words that they can hear or see and can also hear their own speech errors; but cannot correct them. Patients have problems in producing spontaneous speech as well as in repeating heard speech, and sometimes they use words incorrectly.
- Similar symptoms are also observed in patients with lesions to the insula and other portions of the auditory cortex.
- It seems that more than just the Broca's or Wernicke's Areas connections need to be studied in detail.
- Let's have a look at the Lichtheim Model of language processing.

In around the 1950s, Norman Geschwind started to investigate more deeply into this specific type of aphasia, and there it was termed Conduction Aphasia. Conduction aphasics are capable of comprehending words that they can hear or see and can also hear their own speech errors; but cannot correct them. Patients have problems in producing spontaneous speech as well as in repeating heard speech, and sometimes they use words incorrectly.

Similar symptoms are also observed in patients with lesions to the insula and other portions of the auditory cortex. It seems that more than just the Broca's Areas or Wernicke's Areas connections need to be studied in detail. Let us have a look at the Lichtheim's Model of language processing.

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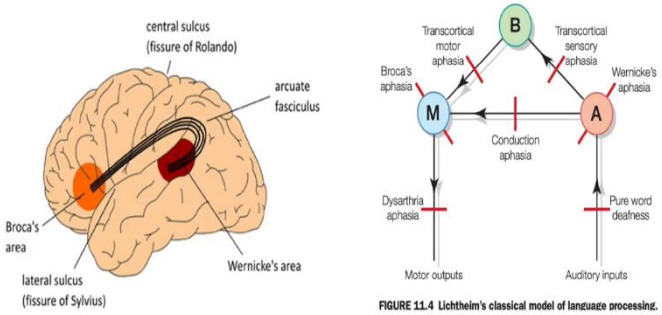

FIGURE 11.4 Lichtheim's classical model of language processing.

Ludwig Lichtheim's Classical Model of Language Processing. Image Source: (A: commons.Wikimedia; B; Gazzaniga, Ivry, & Mangun (2014): Cognitive Neurosicen-The Biology of the Mind. Pp 474, W W Norton & Company.

You can see here that the Broca's Area and the Wernicke's Area are connected by this bunch of white matter fibres called the arcuate fasciculus. You can see the depiction here that this is the Broca's Area depicted by M. This is the Wernicke's Area depicted by A and this is the conceptual store depicted by B.

There are several kinds of connection between B and M, and M and A and then A and B and there are other connections going towards the motor outputs and getting in the auditory inputs. Different sorts of damages to these connections can lead to different profiles of aphasia. Let us now talk about them in detail.

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- It can be predicted that damage to the connections between conceptual representation areas (B) and Wernicke's Area could lead to difficulty to comprehend spoken inputs but not the ability to repeat what was heard – ***transcortical sensory aphasia.***
- Such a profile of problems occurs when there are lesions in the supramarginal and angular gyri regions of the patients.
- Such patients display the unique ability to repeat whatever they are able to hear and to be able to correct grammatical errors when they repeat the utterances; but they are not able to understand the meaning of the utterances.
- It has been therefore concluded that this aphasia arises from losing access to the semantic information, without losing syntactic or phonological abilities.

It can be predicted that damage to the connections between conceptual representation areas B and Wernicke's Area A could actually lead to a difficulty in comprehending spoken inputs but not to, not the ability to repeat that was heard. This is referred to as transcortical sensory aphasia. Such a profile of problems occurs in patients when there are lesions in the supramarginal and angular gyri of the patients.

Such patients display the unique ability to being able to repeat whatever they are able to hear and to be able to repeat correct and to be able to correct the grammatical errors when they repeat the utterances. But these patients are not able to understand the meaning of the utterances. It has been therefore concluded that this aphasia arises from losing access to the semantic information, without losing syntactic or phonological abilities.

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- Another syndrome that arises out of similar disconnections is referred to as the ***transcortical motor aphasia***, which results from a disconnection between he concept centers (B) and Broca's Area (M), whereas the pathway between Wernicke's Area (A) and Broca's Area (M) remains unharmed.
- This condition leads to symptoms similar to Broca's aphasia although the ability to repeat heard phrases remains intact - a condition that is referred to as ***echolalia.***
- Finally, another disease is referred to as ***global aphasia*** which is a devastating syndrome that results in the deficits in the inability to produce and comprehend language.
- This profile of aphasia is associated with extensive damage to the left hemisphere including the Broca's Area, the Wernicke's Area and the intervening regions.

Another syndrome that arises out of similar disconnections is referred to as transcortical motor aphasia, which results from the disconnection between the concept centre B and Broca's Area M, whereas the pathway between Wernicke's area A and Broca's Area M remains unharmed. Disconnection leads to symptoms similar to Broca's aphasia although the ability to repeat heard phrases remains intact, a condition that is referred to as echolalia.

Finally, another disease is referred to as global aphasia which is a devastating syndrome that results in the deficits in the inability to produce and comprehend language. This profile of aphasia is associated with extensive damage to the left hemisphere including the Broca's Area, the Wernicke's Area and the intervening regions.

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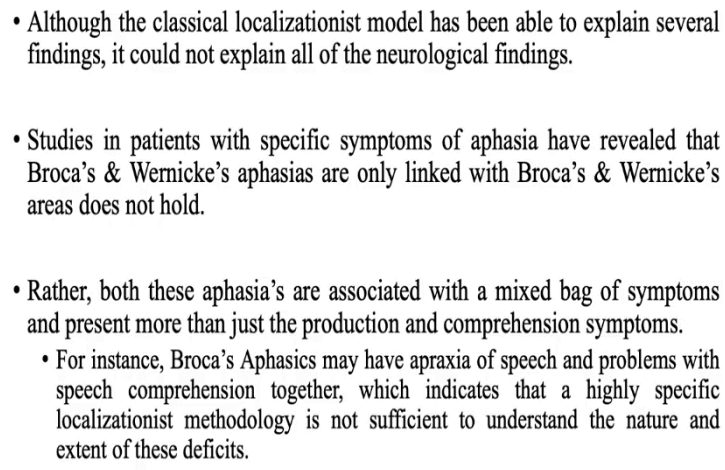

Although the classical localizationist model has been able to explain several findings, it could not explain all of the neurological findings. Studies in patients with specific symptoms of aphasia have revealed that both Broca's and Wernicke's aphasia patients are only linked with Broca's & Wernicke's areas does not hold. So, only in lesions of Broca's & Wernicke's areas does not cause the entire gamut of symptoms that you can see in Broca's aphasia and Wernicke's aphasia.

It is typically the damage is, it is typically observed that the damage is much more than that. Rather than, rather, both these aphasias are also associated with a mixed bag of symptoms and they present more than just the production and comprehension symptoms. For instance, Broca's aphasia patients may have apraxia of speech and problems with speech comprehension together, which indicates that a highly specific localizationist methodology is not really sufficient to understand the nature and extent of these deficits.

So, this is all I wanted to talk to you about in the introductory lecture. Thank you for listening.