Language, Culture and Cognition: An Introduction

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Module - 06
Part - 01
Lecture - 13
Language in the brain

Welcome to the 6th module of the course, this is the part 1 that we will start today. The 6th module will focus on the cognitive neuroscience of language. So, till now, we have looked at the language structure and the various aspects of language structure and how it connects both the cognitive apparatus as well as the social cognition and so on and so forth, with respect to language learning as well.

So, now, we will move on to the brain. So, the neuroscience of language, as far as it is concerned, there have been, there has been a lot of contribution from neuroscience towards understanding the functions and representation of language in the brain. So, initially, it was not, it was primarily the contribution of neuroscientists that we come to know about the various language centres, so called language centres, in the brain and gradually, things changed and now, it is an interdisciplinary research domain.

So, let us go a bit to the historical aspect of how the brain has been seen over a period of time. Historically, if we go back in time, brain was not really considered very important. One of the ancient texts that go back to the 1700 BCE that talks about the Egyptians' practice of mummifying the body and it mentions that the brain used to be scooped out and discarded while mummifying, whereas, the heart was preserved for after life meaning that the brain was not considered important enough.

Fast forward a bit, during the Greek times, even Aristotle did not give as much of importance to brain as he gave to the heart. He placed heart at the top of the hierarchy of all the bodily organs and but placed brain at a lower level and in a position to cool the blood as a kind of a radiator.

So, the oldest mention of the position of brain is concerned as far as it is concerned in the we go back to the; go back to Greek fellow Greek physician Hippocrates, who is also considered the father of modern medicine in the western world, so, he is the first person who is credited with giving the brain its due position within the hierarchy of the bodily organs.

And interestingly also, it is Hippocrates who placed who said who for the first time, dissociated diseases from religion. Earlier, it was considered that diseases are caused by some kind of a curse, by the Gods and so on. However, Hippocrates was the person who said that diseases are caused by certain elements in the lifestyle, food and so on. So, that is with so, he is credited with all these contributions to understanding the human body and its afflictions, including the brain.

In the modern times, in the European tradition, it was in the 1600s that William Willi Thomas Willis a pioneering physician in Oxford, who through a series of experiments found out that there are there is a series of you know a series of forces that constant force that courses through our nervous system, which is responsible for our perception, thought, feeling, memories and so on.

So, there is something that is happening through, the something that is running through the nervous system which is related to all these mental functions. So, this is one of the oldest findings that relates the nervous system with the mental functions. By the end of 1700s, this had a name; the force that goes through the nervous system was given a name by Galvani. So, Galvani call said that this is actually a kind of an electric impulse.

And then fast forward a little bit more, we have Franz Joseph Gall, who is the father of phrenology. So, what is phrenology? Phrenology is a school of thought we have we did talk about it in the very beginning while we talked about the background of cognitive science from neuroscientific perspective.

So, phrenology was basically a kind of a school of thought that said that the brain has localized functions. So, for there is a local area, there is an area, a particular area responsible for various kinds of mental functions. So, this is a very strong localization hypothesis that says that the various functions in the brain are localized in certain areas.

Now, this was 1796 and at that time, there was the brain scans were not yet in place, so, what Joseph Gall set out to do is he ascribed the size of the skull depending on the area in the on the skull that represents the area beneath it was considered to be an indicator of the functions. So, shape of the skull deciding the nature of a person.

So, elements of personality and mental ability were mapped onto the brain by Gall in this particular method. So, this is one of the representative pictures that shows how phrenology really works. So, you can see that there are various areas in the brain basically, mapped on the skull so, which represents various kinds of mental functions.

Phrenology went out of fashion after some time because it was not quite scientifically tenable because it was already found out that it is not strong localization pattern probably is not a good idea to talk about mental functions, because there is a lot of connectivity that happens, lot of connectivity that is required for any simple mental function. So, that was the time of a lot of activities in the in neuro anatomy, neurosurgery and so on.

And then, we go on to the next the biggest, the this is the biggest possible name in neuroscience, the father of modern neuroscience Santiago Ramon Cajal. So, his drawings are the first ones that show how the brain actually works, how the neuronal structure really is. At that time, there was no fine machinery available to him.

So, what he did was he was all he was not only a neuroscientist, he was also a very good a painter, he was also a very good artist. So, this is one of his most famous drawings, all his drawings are of course, preserved in Cajal institute. So, this drawing shows that the neurons are the there are groups of neurons, and the neurons are not connected to each other, they are discrete; they are discrete units of function and they are not connected to each other. There is a slight gap between two neurons and the impulses, the electric impulses that that is a signal that pass from one neuron to another.

And he also proposed that the signal is the starts at the dendrites and exits, it enters through the dendrites and exits through the axons. This is how he postulated, and this is a later called; this was later called ‘neuron doctrine’ that there is a gap between the neurons which later was called synapses and that they are not connected.

So, at that time, because it was very difficult to really objectively through a machine to look at it and there was a lot of scepticism. However, it was proved to be true, all his predictions, all his studies, all his calculations were found out to be absolutely true when electron microscope were was came to place. But in any case, the most important contribution of Cajal is the study of brain at the neuronal level and their structure and to show that there is a connection that happens.

So, he departed from the earlier held view. Around that time, the fashion the most commonly held view was that the brain works like a connected network of a sort of a net sort of a thing which is fused together, but however, this was Cajal's contribution was that they are not fused together, they of course, work together, but they are not connected together, they have there is a gap between them.

So, and then in the 20th century of course, this was 1889 and by the time, we come to 20th century, we see a lot of progress in this domain. A lot of progress in terms of two things, first and foremost was that interdisciplinary research begins to take place in a very very strong way.

We have already seen that 1940s, 1950s saw a lot of activities in neurosciences, in artificial intelligence, in cognitive sciences and so on and that is when the scientists from all these fields came together and thereby the field got immensely enriched. So, now, linguistics and neuroscience and cognitive science and artificial intelligence joined hand together. So, this led to a significant development in the understanding of human brain with respect to the various language functions and so on.

Another important development that happened around this time was the new techniques that came into being, there was a lot of development in devising newer and newer methods to look at the brain not only in terms of structure, but also in terms of function. So, not only earlier methods were the time at the time of Cajal and others, they were looking at the brain of other animals most of the time.

And sometimes, they would also dissect the you know the dead persons' brain in their own laboratory and in a very from today's perspective, it looks rather rudimentary way. But now, we have state of the art machinery that looks at the brain as it is functioning right you know online in a in its dynamic fashion as it is processing some information and so on. So, we do not really have to depend on those techniques anymore.

So, these are the two things that happened in 20th century, part of which we have already discussed in the introduction, a lot of active a lot of scientific developments took place at this time and that is how; that is how the latest knowledge system and latest knowledge about this field actually generated.

So, there will be this module, we will be looking at the structure of the brain, the various you know ways of categorizing the various domains of the brain and then, we will look at the various kinds of language disorders that have, that were the precursor of language studies in the brain with respect to the brain and so on.

So, we will start with the structure of the brain. Now, the brain there are certain fundamental things about human brain. One is that, like all vertebrates human brain is arranged contra laterally. What with what that means, is that the brain has two hemispheres, however, the left side of the brain controls the right side of the body and the right side of the brain controls the left side of the body, which is not the way in invertebrates.

Invertebrates it is lateral like right side right brain controls the right side of the body, left brain controls the left side of the body. So, contra laterality is a very significant aspect of human brain like all vertebrates. Another important, crucial feature about human brain physiology is that like other unlike other paired organs like you know the lungs and other paired organs, the two hemispheres have distinct functions which is not the case for other paired organs.

So, both the lungs function the same way, both the kidneys function the same way and so on. But the hemispheres of the human brain do have distinct functions. So, they have separate ways of working. So, that is why brain functions are hemispheric brain functions are called asymmetrical. These are the two important things that are important to remember as we go ahead.

So, the right hemisphere apart from controlling the left side of the body, it also controls the spatial acuity, the awareness of position in space. So, as you move in space, the brain does keep a map of the movement in space and position of yourself in at all times, in all directions simultaneously.

Similarly, the left hemisphere, in addition to controlling the right side of the body, also controls abstract reasoning, physical task which require step by step progression and so on and for us what is more important is that the left hemisphere also controls language.

So, these are the fundamental building blocks on which we will move on now, organization of the brain areas.

Now, brain organization of the brain areas has been as we have seen already that going back to the days of phrenology, the there have been various ways of you know approaching the same question as to which part of the brain does what, you know how is the brain organized in terms of structure as well as in terms of function. So, there have been various the various you know various ways of looking at it.

So, the most fundamental thing is one of the fundamental ways of organizing, understanding the organization of the brain is a gyral-sulcal organization. What does this mean is that the brain is not it is folded, it is convoluted, the structure of the brain is convoluted, it is like you just you know scrunch together a net sort of a thing and then, you know put it into a put it into a small box that is what the brain will be in some sense. So, there will be some raised part, there will be some parts like this.

So, this is basically how it is, when you folded it so, this is how it looks. So, the raised parts this is called gyrus, and this is the sulcus, this is how it goes. I mean the whole entire brain is like this so, the top-part is called gyrus, and this is a. So, gyral-sulcal organization is one of the basic organizational aspect of the brain.

So, why while we have this kind of a convoluted structure there is a very important aspect to it, because by having this kind of a structure, it helps mean it helps minimizing a lot of surface area. Imagine the if the brain was opened you know in a flat surface that that would you can imagine what would happen. So, this is basically be because of the because of the folded structure of the brain because of the convoluted structure of the brain, it has a very small three-dimensional volume.

So, as much as two-third of the cortex lies within the sulci, so, this is two-third of this is the part so, this parts these sulcus, sulcus is the singular and sulci is the plural. So, this two-third of the brain cortical area that is the surface area of the brain lies in the sulci. So, also this reduces the amount of axonal wiring needed in order to in order for the conduction of signals.

And although some major sulci and gyri are present in all humans, their shape and size differ. So, most even though there is a sort of an universality across human brains, but there are sometimes some differences in their shape and size which is genetically influenced. So, this is the size gyral-sulcal organization.

Another way of looking at the brain organization is what is called the cytoarchitectonic organization. This organization depends on the presence or absence of and packing density and layering of various cells, so, basically how the anatomical aspect of the brain.

So, in a tiny area of the brain, how much of brain cells are there, how are they packed, what is the density and which cells are present, which cells are absent and so on that is one aspect, another aspect is the functional layers also. So, cortex is almost so, basically the cortex is the top part of the brain.

So, this cortical region has 6 layers, it is like some something, this is how it actually looks if you take a. So, this is a tiny part of the brain that can be; that can if we have a if we dissect it, this is how it will look. So, there are this 6 layers and each layer as you can see there is, there are different kinds of structure as well as connections are also different for each layer.

So, each layer is characterized not only by the morphology, that is a structure of the cells within it, but also by their connectional properties, each layer has a different connectional structure, connectional property. So, layer I, II, III that is the top 3 layers communicate with other cortical areas that is you know other outside of that.

And the layer IV receives input from the thalamus, layer V sends output to sub cortical areas that is the areas under the cortical area and layer VI sends output to thalamus. So, you can see even within a tiny area like this, and it has 6 layers 6 vertical layers and then, each layer has it has a different function altogether. So, when you are looking at the brain in terms of this kind of a structure, this is called cytoarchitectonic structure.

So, perpendicular to these horizontal layers are vertical columns measuring 0.5 mm and consist of roughly 100 neurons and these columns are considered the basic functional units of the cortex. So, this is the functional in a way the more be the basic functional units of the brain.

So, then, we go on to another important way of structuring, way of organizing the brain that is we are now move on to Korbinian Brodmann. Brodmann's areas are still used. He used he published his findings in 1909 and they are still used much of his findings, much of his areas, Korbinian Brodmann areas are still in used after some divisions.

So, he was a German neurologist. He drew a map of the a drawing of the lateral and medial view of the brain and segregated it into 43 cortical areas. Initially, he had of course, it was not only human brain that he dissected, he had dissected a lot of other mammals' brains as well and then, he decided that there are all these areas in the brain which some of them do correspond to human brain as well some of them do not. So, ultimately, he came out with this 43 cortical areas, later on some divisions happened.

So, these area; his areas have been updated many times recently based on obviously, latest technology and so on, but many are still; many are still utilized, many are still understood to be valid.

So, this is a map from this is how the Korbinian Brodmann's map looks like, there are many of these areas so, it is. So, you can see area 22 is; area 22 is primary auditory cortex here, and then, this is the Broca's area and primary motor cortex so, these are the areas that we will be talking about when we talk about language functions.

So, auditory cortex, visual and then, this is motor cortex and of course, the visual cortex. So, and then there is Wernicke's areas, these are the most important areas as far as language is concerned. Also, there are many others that he has given.

So, this is a kind of a list that Brodmann's areas which area refers to what. So, 1, 2, 3 will be primary somatosensory cortex and so on. So, basically, Brodmann's areas are referring to various a local areas within the brain on the surface of the brain that is responsible for certain functions. So, this is again a functional organization of the human brain.

And then, there is of course, connectional organization. Brain though, there are areas, localized localization of certain functions in the brain, but as we know today already and as we have also talked about in the introduction that of course, there are areas that are responsible primarily for certain functions, if not exclusively and, but the functioning of the human brain depends on connections and networking across domains.

So, the structural areas do not operate in isolation, they depend on a massively interconnected network giving rise to complex neural functions. So, dynamic cooperative interplay of signals carried by bundles of axons coursing through pathways along the white matter is basically what it depends on, what this connection depends on.

So, this is kind of a highway in the human brain and of course, the biggest the and the busiest, the most well-known pathway fibre tract so to say in the human brain is the corpus callosum that connects the hemispheres.

In the 1940s, as we have already talked about, there have been lot of you know new developments, lot of new studies, now lot of new discoveries that have happened, one of them were the radical brain surgeries. What happened? Many of the brain surgeries that were required at that time in the earlier times were due to epilepsy, most of these surgeries took place on epileptic patients.

So, one of the; one of the surgical interventions was to cutting the corpus callosum. Now, what happens if you cut the corpus callosum which connects the both hemispheres? Automatically what will happen is that the brain, the hemispheres will not be able to communicate with each other, they will be as if they are separate entities.

So, as a result of which what we have, what we call technically is split brain patients. So, that is when this due to this kind of surgical interventions, due to this kind of machinations that helped researchers gain a lot of a lot of understanding and insight into the individual properties of the hemispheres in isolation.

Remember that was a time when technical sophistication was still making its way and we still so, we still could not really technically today, we can put to sleep so to say, a particular part of the brain and check the working of the other side of the brain, but at that time, how it actually started was due to epileptic, surgeries on epileptic brain patients. So, how the individual hemisphere works in absence of the connection to the other hemisphere, that data comes from cutting of corpus callosum in epileptic patients.

So, now, let us after this brief introduction, let us move on to what is our concern, which is the areas related to language functions in the brain. So, these are called language centres. So, there are parts of the; there are parts of the brain, the cortical regions that are responsible for language production and language understanding and so on, they are called the language areas.

But apart from that, there are also other areas as we have seen language is not a function in isolation, language whether it is within the brain or outside, the brain it is always a connection of various things. So, even with inside the brain, when language function does take place, there is a language area that also connects to other cortical regions. Primarily, those cortical regions are the auditory cortex, visual cortex, and the motor cortex.

Obviously, this is quite are easy to understand; visual cortex because our most more often than not our language learning and a serious amount of language learning, a serious amount of language processing, the way we use language depends on the written aspect of it, written and through reading and writing. Through reading and writing constitute a large amount of language use for us.

So, that is why visual cortex automatically gets involved, so, visual cortex plays a very important role in terms of language functions, language processing. Similarly, the auditory cortex, because our spoken language is dependent on the auditory spoken loop and because motor cortex is again very very crucial, this is upper middle of each hemisphere, responsible for sending signals to muscles including jaw, face and other places.

So, the tongue to produce language to be able to speak. So, motor cortex controls the motor activity of the body which includes production of language. Similarly, visual cortex is in the lower back of each hemisphere. So, this is where the visual occipital area is and so, and this part particular part of the cortical region, it receives and interprets visual stimuli and is thought to be storing images.

So, as we I have just talked about, language is often dependent on reading and writing so, this is where the part of the visual cortex, the participatory action of visual cortex is important for language functions.

Apart from these three cortical regions, there are two more areas that are considered primarily language areas so, one of them is Broca's area, the other is called Wernicke's area. Broca's area is located at the, this is where Broca's area is and Warnicke's area should be mentioned here 22, 39, this is Warnicke's area.

And so, these are the two most important areas which respect with respect to which are called primary language areas. So, Broca's area is at the base of the motor cortex which is why we my Broca's area has certain typical types, certain typical problems associated with it. So, this is responsible for organizing the articulatory patterns of language and directing the motor cortex when we want to talk.

This area also controls use of inflections like tense marking, number marking, gender marking and so on. Function morphemes like determiners and prepositions and so on. Recent research has also found evidence of involvement of this area in comprehension as well not only in production of language, but also in comprehension. And Warnicke's area is located near the back section of the auditory cortex. This part is involved primarily in comprehension of words and selection of words when producing sentences.

So, these are the primary regions in the brain which are considered responsible for language representation as well as language processing. Though it is not without much without controversy nowadays, there is a lot of disagreement, and the latest findings suggest some more additions and some changes in the earlier held view, but this is still roughly the; this is still where we are, these are the primary areas which are considered responsible. Of course, now we also include the executive function network and so on.

So, before we move on to the aphasia and other studies, let us just talk about the methods a bit, because this is how we have got the data, this is what we will be talking about. So, let us talk about the tool through which you got the data.

As we have been mentioning from the in the introduction as well as today, we have talked about there are lot of data in brain studies with respect to language as to where the language is located, how language functions are carried out, which part of the brain does what and so on, all these data primarily were derived from the patients of various types.

So, because either they are you know there some kind of a brain damage has taken place due to certain kinds of accidents or disease or so on and sometimes some kind of a also neurodegeneration so, basically some amount of there was a this was a clinical intervention as opposed to a research intervention. So, basically, primarily in the initial stages, all the data came from patients.

As we have seen that machinery the fine-tuned sophisticated machinery has come into has been available to researchers only recently and even today, it is not so easy to get a healthy person to go through all kinds of brain mapping mechanisms voluntarily and it has to be voluntary obviously, so, it is still at a nascent stage.

So, large amount of data that we have, come from brain damaged patients. So, here is that is why there is a word of caution here that brain damage is always bad for you, but if you are lucky, it will be bad for you in a theoretically interesting way. So, this basically captures the essence of the field.

So, let us go back a little bit again history. So, Dr. John Fulton worked for two years with a patient named Walter K, who suffered from severe headaches and visual disturbances at the same time. And why this happened? Because he is this person had a large collection of abnormal blood vessels carrying overlying his occipital cortex that is where the visual cortex is.

So, occipital cortex, the this person had an a large amount of brain large amount of blood vessels on the occipital cortex of this brain as a result of which he had not only headache, but he also had visual disturbances. Now, when blood courses through these vessels intensely, it created a pulsating sound that he could even hear, he could hear as if some kind of a humming sound is there and the patient could hear the sound, even the doctor could hear it with the with his stethoscope.

So, that was the kind that was heavy blood flow that happened during those through those areas.

Now, through a series of carefully designed experiments, the doctor discovered that the blood flow and the resultant sound were correlated not just with his heartbeat, but also with his visual experiences. Today, it seems commonsensical because we already know certain things as basic, but at that time, this was a remarkable finding that the more the blood flow of course, there was a sound effect to it because he could hear the resultant sound through his telescope.

Even the person could the patient himself could hear a humming sound, but he also experienced visual disturbances. So, the amount of blood flow that kept fluctuating also kept disturbing his visual sensation to a large extent. So, these were the first compelling evidence that regionally specific blood flow can have, can alter our neural activity in that particular area. So, regionally specific changes in blood flow reflects regionally specific neural activity.

So, there is a correlation that blood flow can is correlated with activity at the neuronal level, these are one of the first pointers to that aspect. In fact, this is why this is the fundamental premise on which a lot of methods are based today.

So, what we the what are the primary goals, primary aims of the neuropsychology research with respect to language is that there are this is there is a two way approach to it. One is that it tries to determine which components of the language faculty can be selectively disrupted as to where the language faculties are you know positioned and that can be disrupted separately distinctly.

This relates mainly to understand the cognitive architecture of language as to how it is really represented and how it really works. And secondly to identify the reliable link between language deficit and brain lesion specific deficit. So, if there is a brain an anatomical problem with the brain and there is a correlation with language deficit.

So, is the what kind of a language disorder is connected to which kind of lesion, brain lesion, so, that is the second thing and both of these are of course, connected. So, both these type of research as I said are connected, they go hand in hand because once the there is a brain damage, there will be a say resultant language disability and then depending on which area that is, you can know how the cognitive architecture of language really works.

So, the implication of these studies not only have theoretical outputs towards understanding of language- mind-brain, but also it helps us clinically, in clinical research as to how to diagnose and probably treat language impairment. In fact, this is a big area of research now as to both in terms of atypical children, a typical population as well as brain damaged patients, to restore their linguistic capacity or to at least improve the linguistic capacity.

So, these are very important first steps towards that goal not only in a theoretical way, but also in a practical way in an that the application aspect of it is also very very significant.

So, the two there are two kinds of data the that are typically with that are that researchers typically work with, they are called dissociation work and dissociation data say neuropsychological data of dissociations, there are two kinds of dissociation: single and double.

The single dissociation basically refers to a scenario when a patient is administered two different tasks ok, and he performs worse in one compared to the other. So, let us say a patient who suffers from a brain damage in a particular area of the brain, and he cannot name objects, but he can easily identify actions.

So, basically the nouns are impaired, but the verbs are perfect. So, this will be a single dissociation, only one person having one problem in the in one physiological problem and then, one kind of a language disorder. So, what will be the inference? The patient's lesion has selectively disrupted that particular activity, that particular linguistic activity which he has not been able to do properly. So, and then not by the better performed one.

So, the this particular so, you map the lesion site and the disability in language task and say that because of this particular damage, the damage in this particular region, he has this particular problem. So, this is the this is what is called single dissociation.

Now, the problem with this is that though it sounds simply simple enough, the problem there is a problem, what if the tasks are not you know generalized, how what if the tasks are not similarly designed. So, what if you know there is a patients patient mind has abnormal sensitivity towards one aspect of language as opposed to another?

For example, many of us might be good in you know creating a metaphorical understanding metaphors, but not so good in understanding other figurative speech parts of speech or so on and so forth, even at the simple level. So, we might be doing well in better; better with nouns as opposed to verbs and so on. So, what if the patient himself has some pre-decided such kind of an abnormality in language functions, that is one problem and second could be the task may not be balanced.

So, for example, what do we mean by a task may not be balanced? Suppose you give a picture naming task to a patient where he has to name objects versus actions so, thus noun versus verbs and he performs better in one and compared to the other, this would be a single dissociation, but what if the nouns were longer like orangutan and the verbs were shorter like walk and so on. So, this is there are these are some of the problems, but there are many other also that has been that have been pointed out.

On the other hand, you have double dissociation. Double dissociation happens when there are two patients instead of one and they have two diametrically opposed patterns of performance on two different tasks. So, there are person one and person two A and B and one person does well in noun, another person does well in verb-based tasks and they have two different kinds of brain lesion.

Now, you superimpose one on the other and you see that because they have different patterns of brain lesion and different patterns of language difficulties, so, this could be a better way of looking at the connection between lesion sites and the resultant language function. So, this is what is called a double dissociation.

So, this is what we have already discuss.

So, and, but how do we; how do we have language deficit, what are the reasons for having language deficit? One of the reasons we have been talking about is epilepsy that is that has been one of the reasons that epileptic patients have sometimes exhibited problems with language, but otherwise, why do we have problems.

So, these are the most common reasons for having language deficits, stroke, it is very common when after a stroke, the patients sometimes permanently, sometimes for a short period of time, they will lose the ability, certain linguistic ability if not entirely so, stroke is one.

Then, either open head or closed head traumatic brain injury, neurodegenerative and infectious diseases and of course, tumours. Neurodegenerative diseases happens when at an advance stage, but others can happen any time. So, these are typically the reasons why we that are connected to language deficit.

These are some technicalities of analyzing lesion deficit correlation as to as we have already seen that there is a deformity in terms of language function and there is a problem with the brain structure in terms of some injury or something and then, there is a overlap and as a result of a subtraction analysis. So, superimposed lesion sites of patients with a particular deficit, it contrasted with the superimposed lesion sites of patients without that specific problem.

So, you match with the patient, one patient who has the problem, one patient who has not who does not have the problem and then, you from there you can decide as to which particular kind of lesion has resulted in this kind of a language problem.

Similarly, there is a voxel-based lesion symptom map mapping. For each voxel, the behavioural performance of the patients with damage at that particular locus is statistically compared with those without the damage at that locus. So, there is that in fact, gives us a lot more precision with respect to the results. So, it indicates the degree to which the damage in so, the degree is very crucial and the damage in particular region disrupts specific ability. So, at the level of at the voxel level that understanding goes.

So, and then, this depending on this kind of techniques, there are various kinds of tools that are used today, these were not available to researchers some 50, 60 years back. So, today, we have all these various kinds of brain mapping techniques that are also used for research purposes along with of course, clinical purposes. So, they are of different types. One is called the functional neuro-imaging, the other is electrophysiology and then of course, transcranial magnetic stimulation.

So, functional neuro imaging all of us are aware of MRI’s and then, there is MRI and then of course, we have PET and electrophysiology is a different type of machinery altogether.

But before we go on to the nice colourful pictures of what these machines give us, there is a word of caution of course, that there is also a scope of human error and you know there is that is a lot of this thing, this should be taken with a spoon of salt let us say. So, as it is said that it is dangerously seductive, this kind of functional neuro imaging data is dangerously seductive because it combines the prestige of serious science with broad appeal of images.

So, what we see ultimately the results of these machines are images that are that seems to be the final word. However, it is important to remember that these images are results of processing, multiple layers of processing in fact, and statistical analysis and as a result of which we see what we see.

And so, there are and as a result of which these are dependent on lot of assumptions. So, that is the statistics that is coming into here and that is also the image processing part of it and the assumptions on which those calculations are carried out are not always uncontroversial, they are there are some debates there. So, there is so, this cannot be this there is a little risk there that we must keep in mind.

So, anyway functional neuroimaging has two different kinds of techniques, one is called positron emission tomography, which is PET. What it basically does is that it tracks the distribution of a radioactive isotope through the blood vessel. So, the blood vessel as it go, blood as it courses through the brain, the machine tracks the radioactive isotope as it moves around in the brain, so, where in the brain it goes and how is the activity happening and so on, that is what it picks up.

On the other hand, fMRI picks up the ‘bold’ signal, which is blood oxygen level dependent signal. Basically, it talks about that area of the brain where you have larger amount of blood flow which will also have larger amount of oxygen level. So, that is what the fMRI machine picks up and this function typically this in both cases, the function will typically last for only a few seconds because the patients cannot be put through that thing for a long period of time So, the data that comes from is for 10 to 12 seconds.

So, this is how the machine looks in both cases. fMRI and PET machines look similar, and these are the output that we see. So, in the first picture is that of this is a PET output, this is an fMRI output so that you can see that when that is the when the person speaks, these are the areas that are getting you know more oxygen. Getting more oxygen means getting more blood flow and we have already seen that higher blood flow is connected to higher neural activity.

So, this if you have more blood flow in these regions that means, these are the areas of the brain that are active when a person is speaking. Now, depending on what kind of speech, what kind of which aspect of the language is being looked at, that will give us the, that will take us to the particular specific problem of that study.

However, this basically shows that this area is more active and not only one area, as you can see so many areas are simultaneously active, whereas, finger tap only activates this particular region. So, this is basic and listening this. So, what do we what do we mean by all this is that these are the areas.

So, whether it is the isotope or it is the oxygen level, these are the regions where more blood flow was noticed while the person did something, when the person was processing some amount of information or just given a simple thing like a finger tapping or listening to something and so on and so forth.

So, this is an indirect way of understanding the brain's activity, brains mechanism; indirect, why indirect? Because we are dependent on the level of blood flow to that particular region, this is an indirect method because we do not know what the brain is actually doing, all we know that it is active. It is active because it has gotten more blood flow and as a result of which we get this kind of signals.

So, the basic principle underlying these machines is the amount of blood flow as we have just seen to a certain brain region and that is the marker of activity. So, higher blood flow marks higher activity in that particular region and in fact, this has also been dramatically called as a 'vampire theory' because it is dependent on blood more blood to support the higher metabolism, increased metabolism.

So, thus, blood flow is associated with neural activity and that is what these methods are dependent on and because it is dependent on blood flow, it is called hemodynamic method.

Now, next method is electrophysiology. Now, neither PET or fMRI scan measures brain activity directly. As we have seen that we only have the understanding of the metabolic functions, consequences of the brain activity. In contrast, we have electrophysiological techniques that bring us much closer to neuronal firing. This is a word that is constantly used in neurosciences 'firing' that is the activation level of the neuronal network that is called firing.

So, these electrophysiological techniques are take us closer to that activity because it picks up the signal directly. So, sometimes this techniques involves stimulating certain brain parts of the; certain parts of the exposed brain and observing the effect on cognition and behaviour directly as we will just see.

The other technique is recording electrical signals of neuron as they unfold. So, there are two kinds of electrophysiological technique. One is picking up the signals from outside the scalp and as it is as the brain is busy doing some work, it picks up the electrical signal. The other kind is that the specific brain area, specific areas within the of the cortex can be electrically stimulated and then, we can check the check whatever happens in terms of if cognition and behaviour.

So, this is one such case were direct electrical stimulation. So, this was first performed in long back in the 19th century by Penfield. He mapped functional organization of exposed cortex as we have already seen that it that this was a common practice, it still is a common practice for epileptic surgeries.

So, in the exposed part of the cortex for epileptic patients, he tried and he applied electrical stimulations to certain areas where he has to do the operation to see if language function gets disrupted, so that that area can be protected and while doing the surgery the because the idea was as a result of epilepsy surgery, the person should not lose his capacity to speak also. So, language ability must not be lost as a result of the surgery.

So, on one instance, when an electrode was introduced into the cortex of the superior surface a particular region of the temporal lobe and a gentle current, this current is extremely of a very low a very low intensity and the current was switched on, the patient exclaimed, ‘oh, a familiar memory in an office somewhere’ and so on and it goes on like this.

So, a particular brain region which is activated which is stimulated by an external agent through current, the person says that he is you know he suddenly he activates some memory of a thing of a particular event that happened.

Similarly, for so, this kind of research was going on for during that time. So, following him, another study that took place on this kind of similar kind of patients was carried out by John George Ojemann and he found or he actually this research actually gave rise to some landmark studies using on language.

So, what the protocol was: there will be line drawings basically, pictures, pictures not in detail, but only in outline. So, the drawings of familiar objects were projected on the screen, and they had to just say this kind of a sentence this is a …and then, whatever was there. So, this is they are given a matrix sentence, “this is a” and whatever appear they have to name it.

There were the number of data, number of participants was very high, 117 patients and on the onset of the some of the slides, the experimenter stimulated some points in the cortex before they would speak, certain areas of the cortex was it stimulated electrically and then, this is how it was and this was repeated thrice and the response was recorded.

So, what the finding shows that, what they were trying to see is which are the brain areas that are responsible for production of speech to name, naming how which area is responsible for naming. So, what they found out was that in a vast majority of cases, stimulation disrupted naming only in few discrete. So, as they were beginning to speak, and the certain areas were stimulated electrically and that disrupted the speech.

But in 67 percent of patients two or more such sites were detected, right, there were two or more sites not only one site for naming, there were two or more sites and one in the frontal cortex and one in the temporal or parietal cortex. Basically, what they found was that there is not one area, there are more than one areas in the brain for responsible for naming and also that there were inter-subject differences.

So, there was a lot of variability across subjects, not every person had the exact same location for the exact same function. So, this was one of the earliest findings of direct cortical stimulation.

Then, there is intracranial recording. This is used to measure neural activity at the level of single cell, which is even more precise, but more often, they are used at the level of cell assemblies. One method is called the electrocorticography. This involves placing high density multi-electrode grid.

This is how it looks. Now, in the exposed cortex, in a very tiny area, this is a representative picture, not a real human. So, the in the exposed cortex in a very very tiny area, there will be a grid of electrodes that is placed and that picks up the signals.

And so, the it measures the local field potential of cell assemblies that can be measured at sub-centimetre partial resolution and millisecond temporal resolution. So, as it is within a sub-centimetre region and the temporal resolution is at the level of milliseconds so, as something as any activity goes on, the signal the signals are picked up.

So, while the patient performs various linguistic tasks, the grid picks up very very precise signals from that particular location. So, this is electrocorticography, this is yet another this is an invasive technique, this is yet another machine that is targeting the exposed cortex so, inside intracranial inside the cranium.

Now, we move on to extracranial recording. Extra cranial recording refers to the recording that happens from outside the cranium. So, the skull is not opened, it is still closed, and we are picking up the signals from outside the skull. So, this is again a representative picture of how it looks. So, this one of the machines is called electroencephalography; EEG.

EEG is these days very is used a lot for language related research, this picks up the signals as the event unfolds, as the person as the subject is carrying out some kind of an activity, linguistic activity, whether it is comprehension or production or any other task sometimes even non-linguistic task, the cap which has a lot of electrodes attached to it, this basically picks up the signal as it is happening, as it is unfolding in real time.

So, this picks up event related potentials event related potentials as in as a result of some amount of stimulus, something that has that the person is doing and that is picked up and then, it is in various dimensions of latency, amplitude and so on and so forth so, basically the signal is picked up by the tiny electrical signals are picked up by this machine and amplified and projected on a screen and the output data is like a sine wave and that is what the data is and which is then analysed.

Yet another technique that a tool that we have today is transcranial magnetic stimulation. This is also an extracranial method, this does not have to open the skull. This alters the organization of neural activity in a target cortical area by projecting a magnetic field through the overlying skull. So, there is a magnetic field that is created on top of the skull and by thereby, it changes the neural activity in that particular region.

So, the temporal resolution is again in terms of milliseconds, spatial is in millimetres also very very accurate and very very precise. So, it mainly depends on the frequency of pulses and so on. So, these are some of the technical sophistication that we have today on the basis of which we get our data which in the region of brain and language relationship.

Now, we can move on to the actual research that took place with respect to locating brain language in the brain. The first study on language disorder in terms of aphasia goes back a lot of a long time. So, the first writings on this link actually goes back to 5th century BC, but scientific research in terms of aphasia started only recently.

Even though, we have some reference to language loss and brain damage being connected in the 5th century BC, but more precise and more scientific way of looking at the research started only in 19th century. So, in 1836, Marc Dax described an association between aphasia, aphasia as in language disorder and disease of the left hemisphere, this is where he wrote it, but he never published and nor he did he present his study.

He titled the paper 'Lesions of the left hemisphere coinciding with forgetfulness of signs of thought'. He never published, as a result of which we now associate the language aphasia research starting with Carl with Broca. His son however, Gustav brought out this paper to light after Broca published a lot of series of studies on this.

So, it is because Broca was the first person, Paul Broca was the first person to report evidence in print, he is credited with the discovery that we speak with our left hemisphere. Paul Broca's contribution towards aphasia studies is enormous, where he looked at a particular patient who could speak, who could utter only a few sounds and later on after his death, eventual death, he did he studied the brain of the person.

And then, found out that person had a lesion in the left hemisphere in a particular region which later on came to be known as Broca's area, which is responsible for language production. So, this is how he correlated them that this because of a lesion in this particular area, this person had a speech difficulty, he could not utter words which later on was called Broca's area and because of his contribution, we know this as Broca's aphasia even though he was not the first person to talk about to find this out.

So, soon other scientists followed in his footstep and in the late 1800, 1800s, Carl Warnicke systematically explored other forms of aphasia as well. So, Broca started actually he opened the floodgate of studies in aphasia, so, there is Broca's aphasia and then, Carl Warnicke talks about Warnicke's aphasia, he published a monograph documenting a new type of aphasia and he also predicted the existence of many others.

So, Broca's aphasia and Warnicke's aphasia and little gradually, we come to know that there are many others kind other kinds of aphasia. Aphasia basically refers to a problem with either production or understanding of speech.

So, Broca's aphasia for example, is like this. So, this is you know today, we have a lot of taste batteries that pinpoints the exact problem with the language. So, there are various diagnostic tools, one of them is called 'Boston diagnostic aphasia examination' which basically has a picture, a scene basically and that the that is given to the patients and asked to describe.

So, in this particular cookie theft, this is actually the 'cookie theft' picture, the cookie theft story picture where and one can see how difficult it is for the patient to actually say what is happening in the picture. So, there is a child who is trying to steal cookies while his mother is busy washing dishes and the sink overflows with water and so on.

So, this these dots refer to the pauses in the speech the person has extreme difficulty, the person suffering from Broca's aphasia has extreme difficulty producing word. So, it is laboured, it is lengthy, and he takes a lot of time that is a lot of pauses and so on, verbal output, average verbal output in a Broca's aphasic patient is very less.

So, it is slow, laboured and hesitant manner in which he speaks and also, the rhythm and melody will be abnormal. Average number of words generated per minute is also greatly reduced because of the same difficulty in producing words and or sometimes, they might also have a apraxia of speech which is resulted from disturbances to the high-level of articulatory coordination and so on.

So, basically, Broca's aphasia affects the articulation, the because this is affecting the motor cortex, part of the motor cortex. So, the there is a difficulty in producing speech. However, even though Broca's aphasia is associated with difficulty in speaking, there have been findings that even comprehension to some extent gets affected. So, the and similarly, on the other hand, Warnicke's aphasia will have will be will affect the comprehension aspect primarily, however, there might be some other difficulties as well.

So, because Broca's aphasics can find it difficult to produce speech, their fluency is affected, it is called non-fluent aphasia and because as we can see that there is a lot of difficulty, there is a lot of time taken to speak the same a simple sentence and so on so, it is non-fluent aphasia. On the other hand, Warnicke's aphasia is called fluent aphasia.

The reason being in case of Warnicke's aphasia, the area that gets affected has nothing to do with the articulatory aspect of language. So, the person goes on speaking most of the time without any meaning to it.

So, let us see this is an example of Warnicke's aphasia, the this is called fluent aphasia because there is no dearth of; no dearth of output in case of in Warnicke's aphasia patient, but as if you can if you just notice this, there is hardly any meaning in it. So, in case of Warnicke's aphasics, the comprehension aspect of language is severely affected and then, but however, the fluency is not affected, as a result of which we call this fluent aphasia or Warnicke's aphasia.

Similarly, there are different other kinds of aphasias as well which we will see in the next lecture.

Thank you.