Language, Culture and Cognition: An Introduction
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Lecture - 14
Language in the Brain (Contd.)

Welcome back. We are at module 6. And we are looking at the neural substrates of various linguistic functions. We started with the brain structure and the various functional domains of the brain with respect to language and then we went on to talk about the various kinds of aphasia. Aphasias are language disorders which typically result out of some kind of a injury or stroke to the brain.

Typically they will have a lesion in some of the one of the linguistic one of the areas that are responsible for linguistic functions. So, we looked at how Broca’s aphasia is.

So, Broca’s aphasia has certain features like this is a labored speech and typically it will be a non fluent this is called non fluent aphasia it is marked by this kind of a labored utterance.

So, this is one of the most commonly utilized test battery. This is the Boston Diagnostic Aphasia Examination picture. So, this is the cookie theft story that is the that the person that the aphasic patient was describing in this case and then we now go on to the Warnicke’s aphasia. This is yet another very most studied type of aphasia Warnicke’s aphasia and this is one example that we have already seen.

So, Warnicke’s aphasia, as opposed to Broca’s aphasia, is a fluent aphasia which means that the production of language is not affected rather it is often marked as a very hyper fluent aphasia.

Patients are hyper fluent very often of course, fluent, but sometimes hyper fluent because they have a speech rate ah which is higher than the normal. However, the major problem with Warnicke’s aphasia is comprehension because comprehension is severely affected severely impaired in this kind of aphasia.

And in some severe cases patients understand almost nothing that is spoken to them. As far as repetition is concerned it is also abnormal. So, we will look at the clinical features of various aphasias through production, comprehension, repetition of words and sentences and of course, the lesion site.

And then as far as the lesion correlate is concerned, in this case in case of Warnicke's aphasia posterior third of left superior temporal gyrus is the one that is found to be most affected, along with the left middle temporal gyrus.

However, this is not universal; some many patients have shown a variety of different slightly different domains. Sometimes some patients have also exhibited lesion extending up to the left inferior parietal lobule as well. So, there are some areas which are typically found to be affected, the brain typically the lesion sides will typically occur in the in most cases in left superior temporal gyrus, but this is not universal some patients do show some extended damage as well.

Then we have conduction aphasia. This is somewhere in between Broca's and Warnicke's aphasia in terms of fluency. So, this the patience of conduction aphasia will be more fluent than Broca's aphasics, but less fluent than the Warnicke's aphasics. In terms of comprehension it is generally well preserved, except when the patient is faced with grammatically complex structures.

Simple structures they are able to comprehend perfectly; repetition is also impaired in in these patients. In most severe cases it is found in case of sentences, but visible at word level also. So, sentence level, complex sentences are difficult to repeat, but at word level they are they have less trouble; however, it can be seen at word level as well.

In terms of lesion, this type of aphasia is traditionally thought to arise due to a disconnection between the Broca's and the Warnicke's area. So, basically this the connection is disrupted; however, many aphasics also show some damage. So, some more damage than the subcortical white many aphasics also show more damage than the subcortical white matter area which is the which is the pathway sometimes extending to the sylvian fissure as well.

So, this is not only affecting the subcortical white matter that connects the Broca's and Warnicke's area. But also extends to other regions.

The fourth type of aphasia that we will be looking at now is global aphasia. This is, as the name suggests, this is the most severe kind of aphasia, most devastating type of aphasia and it is also the most easy to describe because this is an aphasia where almost all language functions are disrupted, all kinds of communication is compromised. So, spoken language production is extremely limited, often restricted to some typical utterances like yes, no, da and so on.

So, basically what they do is because the production repertoire is so restricted they kind of make some prosodic changes to the same to the same words and try to use it for various purposes. Comprehension is also severely damaged and lesion correlate typically generally will show entire left perisylvian cortex and the underlying white matter.

So, it is a rather broad area that gets affected and as a result of which, we see that the global aphasics have severe difficulty in comprehension, repetition and every production etcetera.

So, this is a sort of a comparison across the top four types and you can see them on various kinds of tasks like fluency, comprehension repetition and their neural correlates.

There is also yet another kind of syndrome that is related to language that also affects language function in people which is called tourettes syndrome. Tourettes syndrome is a syndrome that this is a nervous system disorder which also affects language. So, this produces this syndrome produces random and involuntary reflexes, which are called tics.

So, those tics sometimes may also involve you know uttering involuntarily uttering some sounds, some kind of a you know verbal utterance which has and it is uncontrollable, it goes on for some time it is like a it is like an impulse it is a random reflex sort of an outcome. So, in this type of disorder which also affects language use quite often is caused by a dysfunction of the sub cortex. So, that is the neural correlate of tourette syndrome.

Now aphasia research though it has largely been dependent upon data from monolinguals; however, there have also been some investigations on in of the same problem in case of bilinguals and polyglots as well. So, for over hundred years researchers have tried to look at how aphasia may affect bilinguals; does aphasia whatever kind of aphasia, does it affect a bilingual’s two languages differently that is the question that has been asked.

And there have been different kinds of publications, different kinds of findings that have been that have been put forward, that we have data for. For a long time there was a belief. In fact, the data suggested that the languages will be affected similarly. On the one hand that was that was the finding that languages will be both languages of a bilingual will be affected more or less similarly, but on the other hand there is also a large amount of data that suggests that bilingual's two languages are affected differently.

So, the there is you know there is the picture is not very clear; however, we know that there is a lot of cases, there are lot of findings that show that there is a degree of comparable degree of impairment in both languages. However, since there are also cases that have been reported, where two languages are not affected similarly.

we will that we will look at the kind of aphasia kind of different patterns that emerge from that kind of an empirical evidence. So, these patterns these different patterns when the bilinguals two languages are not affected similarly were studied and listed by Michael Paradis in these two publications and many other subsequent publications.

So, there are about six types of differences different patterns of bilingual aphasia that he lists, one of them is, the 1st is called selective aphasia. 'Selective aphasia', as the name suggests that patient's only one language is impaired the other language is spared. Then we have 'differential aphasia' where the languages bilinguals two languages show different patterns of impairment.

So, in one language maybe it is comprehension in another it can be production or reputation or so on. So, there are there is a differential status of the two languages in terms of how it gets affected.

Then we have successive aphasia; this is the 3rd type where one language shows signs of impairment following another. So, one language gets affected first, then the other language.

Then the 4th type is called antagonistic; antagonistic is when the recovery of one language means you know as it progresses, it is inversely proportionate to the recovery of the other language. So, as one language progresses the other language regresses, the recovery of the languages.

Alternating antagonism is availability that shifts between language sometimes one language sometimes another language.

And then there is the 6th type that he also lists is blending or mixing; this is a this is a strange case where properties of multiple languages are mixed. So, one thing from one language gets attached to another property of another language. So, one language spoken with the accent of another, let us say English spoken with French accent or inflection of one language getting merged with the root of another language and so on. So, these are the six types.

So, when there are these differences how do you how do we explain the differences in terms of the languages being either affected or there is a difference in the way they are recovered. There have been a few theories; the first one of the most cited reasons, is called the Rule of Ribot.

This is actually dependent on the theory of retrograde amnesia, which was which is suggested in 1881. It says that the memories when you when amnesia is affecting a person a patient of amnesia will show a particular pattern. So, what is the pattern? The earlier memories or skills that are learnt earlier in life are more likely to remain intact. And the memories that are collected later will be affected more when a person suffers from amnesia.

So, dependent on this theory, incorporating this theory in bilingual aphasia says that the language that is learned first will remain intact, the language that is learned second will be more affected by aphasia meaning that the second language is more likely to be affected.

Then we have Pitre's rule which says that it is not when the language was learned, but how well it was used, focusing on the use and usage pattern of the language rather than the chronological factor. Third standpoint in this is that the more importance a language has in terms of the emotional significance.

So, what is the language that you know you have which has more emotional significance for people. There was nowadays it is no more, we do not anymore use the word mother tongue and other tongue and so on and so forth; we use a very objective terminology 'first language', 'second language'. But earlier the word mother tongue was commonly utilized.

And one of the aspects of one of the important aspects of mother tongue was that it is the language of emotion.

This is the language in which you express your emotions best, this is the language in which you dream and so on. So, this is kind of a similar standpoint that is taken here that the language that has higher emotional significance will be more intact and of course, and then comes the standpoint given by Luria, which says who says that it is impairment will depend entirely upon the area of the brain that has been affected.

And whether the language has been learnt you know the mode of learning the language mode of acquiring the language. So, has it been you know whether the language was primarily spoken or primarily written. So, basically if you have learnt the language in the social scenario; that means, the it has been picked up by mostly in the by the auditory loop.

But if you have been formally taught the language, it is most more often than not it will be primarily written form that you have been that the person,, patient has been exposed to. So, as a result if the visual cortex gets affected you know that language will be. So, whichever language is dependent on whichever mode of acquisition it will have similar. It will show a pattern of impairment in that way depending on the brain area which was utilized for acquiring that language.

These are the four stand points in terms and which tries to which try to explain the differential pattern of bilingual aphasia and the way it affects bilinguals two different languages. However, the problem is that there is since the data is so varied and each patient is different.

Each patient has its has his own unique language record as well as own unique disorder with respect to that lesion side and so on and so forth. So, it is very difficult to come to a conclusion and consensus as to that that is only one pattern, there are actually many patterns to it.

So, and that is why the problem that is the problem and we have to kind of leave it at that that we do not have the final answer. Another problem with respect to this the findings is that often for a long time often the patient’s two languages were not assessed properly. The tools, the diagnostic tools were not developed until very recently a diagnostic tools that objectively assess the bilingual's proficiency in both the languages, proficiency at various levels.

So, which these test batteries became available only recently as you can see bilingual aphasia test by Paradis 1987, which is quite recent. So, and now of course, using these tools we have a better see we have a better scenario to collect objective data and the field is still developing.

However we know that there are every kind of aphasia has a neural substrate.

There is yet another kind of aphasia which is not caused by an injury to the brain, but by neurodegenerative diseases. Neurodegenerative diseases most more often occurs in the old age, we all know that Alzheimer's and Parkinson's and so on affect people of an advanced age.

And this is when neuro-gene- degeneration takes place and this is where a different kind of aphasia also is visible which is called primary progressive aphasia. Because it gradually progresses starting from depending on how the neural degeneration is taking place, gradually language will get affected more and more.

So, in a host of related neurodegenerative diseases, the degenerating language ability is the most salient feature and the principal cause of restrictions in daily life which is what we often see in patients for in advanced age.

So, this the study of primary progressive aphasia goes back in time, when the neurologists discovered that some patients had linguistic disabilities, language disorders which co occurred with various other problems other kinds of gradually advancing cognitive disorders. Sometimes social cognition is missing.

So, there was a particular case where a person was having serious social conduct problem along with language getting affected. So, at one time he actually threatened his wife with a knife, but one this kind of one of incidents that co occurred then there are many other cases as well. In another case a woman with slow deterioration of word comprehension was also found. So, gradually this kind of findings built up.

And then we come to better understanding of various kinds of aphasia that are part of neurodegenerative diseases. So, these are there are typically there are three types;

progressive non fluent, semantic dementia and logopenic progressive aphasia. Each of these is defined in terms of characteristic cluster of linguistic deficits and a distinctive distribution of cortical atrophy. Atrophy refers to the thinning of cortical areas.

Basically brain cells die off and those cells are degenerated and as a result of which those cortical areas become thinner and the functions associated with that particular cortical domain gets affected, which also includes language.

So, progressive non fluent aphasia; this is a case where typically the patients will show degradation of morphology and syntax. In the early stages of this disease, other cognitive functions like core cognitive functions remain intact, but with gradually with time, deficits involving working memory and executive functions as well as complex visual tasks are found to be affected.

So, what is the neural correlate of this? What is the neural substrate that is responsible for this? left posterior inferior frontal gyrus, roughly which translates to Broca's area in fact. Because this is Broca's area is affected that is why we see non fluent aphasia remember non fluent aphasia is also called Broca's aphasia.

So, when Broca's area gets affected when neurodegeneration affects Broca's area. We not only have various kinds of core cognitive functions getting affected, but also a kind of aphasia that is called primary and that is called progressive non fluent aphasia.

Then you have semantic dementia. This is a degradation of as the name suggests semantic and conceptual knowledge grammatical and phonological knowledge is largely spared. So, what is affected is the semantics the comprehension part the conceptual part of it. Also it has poor object recognition, abnormal social cognition and emotion regulation. Emotion regulation as in the patient will have inappropriate emotional reactions to in various situations.

This again the neural substrate will be anterior temporal lobes. Typically bilaterally, meaning both the hemispheres get affected, but of course, the severity is higher in the left hemisphere.

Then we have logopenic progressive aphasia. This is a degradation of word retrieval and auditory verbal short term memory. Then they also have they also co occur often with Alzheimer's disease and then there are calculation difficulties also.

This is again the found in the and with the with co-occurring with the degradation of the Warnicke's area.

Now, let us go on to see the what about the other normal language processing, normal language processing, speech processing, how we find the neural substrates of this. As we have said before that aphasia the data from aphasia research has been the earliest source of information, source of all the neuroscience scientific results, neuroscientific data for understanding the neural substrate of language functions.

However, the we also have adequate data today to talk about language functions in normal human beings, human brains. So, starting with speech perception, we see how speech perception actually goes through various stages starting with the inner ear and then going to the auditory cortex. There are it is a complex process and it is a multi layered process.

But we will look at the major points that are part of that processing here. So, it goes from undergoes many transformation before it reaches the cerebral cortex. So, basically the physical aspects of sound are given are received or are you know given input through the auditory system and then they are basically encoded as electrical signals in the spinal ganglion. So, this is the first important location where the input is taken and as electrical signals which is which resides in the cochlea in the inner ear.

Now, this wave of sounds that have been now give taken in through the ears. They this in the form of electrical signals they will move through thousands, in fact, 16000 sensory receptors which are called the hair cells, this the wave travels through the hair cells and then it goes via it goes through a long winding way. So, these cells are topographically arrayed along the length of the spinal ganglion.

Now, there is a very fine and very nuanced arrangement of those cells as they carry the information to the to the cortical regions. So, the cells towards the base are sensitive to low frequency and the cells at the apex level, top level are sensitive to high frequency sounds. So, that is how the cells the hair cells are organized in the spinal ganglion.

And neural signals are then propagated along the nerve to brainstem, through three levels of nuclei and then from there of course, there are three levels and then it goes to the auditory cortex to be processed for to be further process.

So, this is a roughly the map showing how it actually happens. Now the most important thing about one of the most important things about speech perception is that it is the early stages at least are have two important features; one is that it is bilaterally organized; another feature is that it is hierarchical. We are talking about the early stages, that is when the speech signal is received and its it travels from the inner ear to the auditory cortex.

So, two features of bilaterality and hierarchical arrangement are this is what we will talk about. So, 'bilaterally organized' means that it is found in both the hemispheres. It is not only one only left hemisphere that works, we receive signals from both the ears. So, it is bilaterally organized and then this the signals travels through the hair cells to the cortical region that is responsible for processing.

So, it happens on both sides though left hemisphere has slightly slight high slightly higher advantage. This is why we also we see that there is a right visual field and right auditory field advantage in case of bilaterality laterality in brain functions. And then there is higher and the process is also hierarchical. Hierarchical there are stages. In the 1st stage the dorsal STG that is superior temporal gyrus processes the elementary properties of speech sounds.

And then in the later stage lateral superior temporal gyrus and middle superior temporal sulcus will be processing the complex, language specific phonological properties. So, there is a hierarchy of function, depending on what the process is and where it is processed. So, there are different areas responsible for different functions and different processes in that pathway.

So, it has electro physiological studies have shown that this the this ascending pathway preserves with exquisite fidelity the elementary acoustic features of human soundscapes. Human ears can do what till now most AI systems have not been able to do. We are capable of may understanding very fine nuances within the soundscape and that is because the pathway maintains with utmost fidelity all the signatures that are responsible for those subtle differences, subtle nuances.

The ascending pathway is parallel by also a descending pathway all the way to the spinal ganglion, thereby allowing cognitive states like selective attention. So, processes most of the processes so, that is visual or it is auditory process there is a two way traffic; one is the bottom up processing which is dependent on the stimulus.

So, as we hear the sounds the ear picks up and then takes it you know the signals that are received are they travel to the cortical region and gets processed. At the same time, there is also a top down process that happens, top down process from the brain to the receptive organ sensory organs and these are motivated by the attentional mechanism and so on.

So, this is the descending pathway that we are talking about and they allow things like selective attention and to modulate early auditory perception, because a person who is listening is also attending to the source of the sound and so on. So, there is an ascending pathway and there is a descending pathway. Ascending pathway takes the signal to the brain and the descending pathway takes our is responsible for modulating cognitive other cognitive functions like attention.

In terms of speech perception, there is also one interesting finding that needs to be mentioned here, which is the McGurk effect. This is an interesting illusion that the that demonstrates that during face to face speech perception the brain automatically fuses simultaneous signals at the same time.

So, we do not when we when listening to somebody face to face, we not only pick up the signal from the auditory loop within the auditory loop, but also the visual loop as well. So, we get signals from both the properties and what the brain does? Brain does something very interesting, it fuses those two signals together and kind of takes a middle path. How do we what is the finding in this regard? The typical experimental setup is like this.

The participants will be presented with an auditory recording of a syllable /ba/, simultaneously they will also look at a video recording of a face that is producing the sound the syllable /ga/ and ultimately the subject will end up, when you ask the subject what they do hear, he will say he or she will say he heard /da/.

So, in the channel in the airway in the pathway where the articulation takes place, /ba/ is at the end at the opening of the mouth that is where it is produced and /ga/ is towards the end in the back of the channel. So, what the brain does is it fuses. So, this is if this is how our vocal channel is then /ba/ is produced here /ga/ is produced here.

And what the brain ultimately thinks it heard is something like here /da/. So, some it fuses both the signals together and so, the brain integrates the two competing sensory inputs and adoption intermediate position.

The brain is a fascinating organ the most fascinating of all organs probably. Now, let us move on to speech production; speech production is of course, a an enormous domain of study; it has generated lot of empirical data that typically with respect to three kinds of functions, three main domains.

It is a very complicated, cognitive motor skill that includes incorporating that incorporates information from various domains, but largely we can we can divide we can categorize all the research domains into three typical typically three area sub areas that is lexical representation and processing, lexical representation in the brain and its processing, articulation that is the speaking part and then peripheral motor system.

So, one of the most widely accepted and the one of the most famous models for this lexical representation in the human brain was given by William Levelt 1989 it is called the Lemma Model and he proposes a six stage system through which we actually speech production takes place.

So, its starts with the conceptual preparation, goes on to grammatical encoding and then it goes on to morphophonological encoding, followed by phonetic encoding, then comes articulation. And once articulation happens, the speaker is also a hearer the person who is speaking also hears his own articulation. So, the self perception and monitoring and repair happens after that.

So, once you have articulated, all of us are aware that when we have said something wrong we will immediately correct it. So, that is also part of the loop. So, the moment articulation happens then self perception, monitoring and then repair and the same process goes again. This is a simplified version of a rather complex model, but that takes care of the primary aspects of it.

These findings the model has been tested through various neuro imaging studies that take that utilized various kinds of methods like linguistic methods. So, there are neurogen neuroimaging studies that make the subjects do any of these or many of these very many of these experimental studies they can be verb generation, noun generation, picture naming word naming and so on and so forth.

So, there is a huge amount of data that is available in the in this research domain that has looked at various kinds of language producing structures. So, if one can be you know one they have utilized verb naming versus object naming versus picture naming versus various things and then there is also generating words starting with a particular sound and so on; this particular sound and so on.

So, it can be the sound /ba/ or /ga/ and then go on. So, that is how and simultaneously there will be a neuro imaging study that will be part of this paradigm. So, as a result of which, as the person produces various kinds of gives a various kinds of linguistic output, the brain can be imaged.

And that is how we have come to the understanding as to how what are the brain what are the neural networks that are responsible for each of these or a combination of these various types of articulation. And largely they satisfy the lemma model of William Levelt and that is why it is widely accepted. There are of course, controversies, but we are not going there it is largely accepted. So, the results point to.

So, all these various types of studies have pointed to a huge vast network of neural areas in the left lateralized perisylvian network. Also there are functional specialization for various processing stages of production ,within this network. So, there is a huge network of neural domains, cortical regions that are responsible for this. However, there are certain domains that are specialized for any of those or many of those functions that we have seen.

So, conceptual preparation will be processed in one name domain versus phonetic encoding takes place in another domain and so on and so forth. So, these are the two primary findings that there is a huge network vast network of neural areas and also there are functional specializations for various any many of these processes.

Yet another domain of language where which takes us to the neural substrates of language use is the case of ‘specific language impairment’. Specific language impairment is the case where deficits in language in happens even though the child is otherwise developing normally.

So, basically on the on the surface it is a typical child which has no cognitive other cognitive disorder or any other developmental disorder, still the child shows some difficulty in language. So, the difficulties in producing and understanding basically happens as if there is no obvious reason. So, because the child is typically growing, this kind of disorder cannot be related to general cognitive impairment, physical abnormality of the speech apparatus like cleft palate and so on. Or the developmental disorders like autism spectrum disorder or acquired brain damage or hearing loss, nothing.

None of these problems are there associated with specific language impairment it that is why it is called specific language impairment. It is a problem an impairment specific to language. This also has a neural underpinning. It is found it is found that the grey matter in Broca's area which is involved in speech production it was found increased in case of SLI, speech specific language the impairment, but the same time even though there is an increased amount of grey matter it showed decreased amount of activity.

So, did not show as much activity during the task. So, though the white though the grey matter is increased that activity level was not. In the temporal lobe which are important for comprehension of speech and language, the grey matter is both reduced and activity is also reduced. So, in case of Broca's area the production area heightened grey matter, but lower activity and in case of in the temporal lobe that is the roughly there Warnicke's area the amount of grey matter is reduced as well as lesser activity level as well.

So, SLI also has a strong neural underpinning.

Now let us move on to yet another domain of language processing which is reading and writing. Reading is called the receptive language domain of receptive language processing. There is a very interesting travel blogger travel you Youtuber who records his travels across the world is called 'bald and bankrupt'. So, there is one in one of his videos he which is called 'lost in Burma adventures in squiggle town' that takes us to a very interesting thing that we take for granted in human in modern humans brain capacity, which is the capacity to read.

So, what does our brain does when we read. A reading brain basically changes mere marks or squiggles, as bald and beautiful videos talks about, into it processes is into words of a language. So, when he went to Burma, he went to Burma through India from Manipur or somewhere and then he goes and sees all those notice boards everything written in their language and of course, he does not read.

So, he just says squiggle, squiggle, squiggle and more squiggle. So, the languages that we do not read remain squiggles for us. The language that we read becomes words of a language for us. So, that is where the reading brain comes into a picture. So, how does it happen? The languages that we know the familiar languages are read and this reading happens like through an assembly line of multiple stages of neural representation.

It is not a simple process again there is an almost like an assembly line of various processes neural representation and their processes. So, this one of the most well known and well accepted model for this process is the LCD model, the Local Combination Detector model by Dehaene et al.

This is the representation from his famous paper. So, basically we are not going to the details of it, but roughly what happens is that reading happens through a lot of processes it goes like this. So, starting with the receptive field and then goes on to LGN; that is the lateral geniculate nucleus of the thalamus, where the first stage of processing does take place and then it goes through various parts of the cortical regions of V 1, V 2 1, 2 and 3 and then it goes on to this is V 8 and then it goes to the left OTS oxite occipital temporal sulcus.

So, this is the this is the pathway through which reading happens. And at every level there is a different process that takes place, different organization of various inputs and so on.

So, this is. So, the retina is the first step to the eyes that we get the signals from input letter strings and then within the brain, the first area in LG and the thalamus is where the first processing happens. And then it goes on to four stages here itself, in the primary visual cortex and then it goes to left OTS again there are two stages they are called minus 56 and minus 48; these are the names given and then the finally, the processing happens.

So, basically there are various brain regions, various neural domains through which the signal goes and gets processed at every level and ultimately we read. So, the recognition finally, recognition and understanding, the word meaning and everything happens through various stages. One very important discovery in this domain was that a visual word form area in 2000, it is a very recent comparatively very recent development in 2000 year 2000 by Cohen at al.

They found out that there is a particular domain in the brain which is responsible for what form for forming word. So, visual work from gets processed in this area. It has a lot of functions and many research is still going on as to how what are the other processes that take place there, but primarily we have listed some: here what does this area do? It responds to printed words, that you that we see, it regardless of position to left or right of visual fixation.

So, let us say, when we are reading something like this, there is, the moment I am looking at d this is the foveal fixation, foveal area that is the fixation area, where my eyes are looking right now. So, this is foveal region these are parafoveal. So, the side the peripheral area where the eyes also see. So, we do not when I am seeing d I can also simultaneously see a ‘n’ and ‘g’.

So, these are these are regions of parafoveal uh visual areas and this is the foveal. So, this is the visual fixation area. So, my VWFA processes this printed word irrespective of which side of the fixation area this is. It also detects identity of printed words regardless of the case. So, whether it is in upper case or in lower case it identifies both as the two different manifestation of the same letter, same sound or whatever the case may be.

So, the case is not a problem problematic case in this case or the font. Whichever font or the printed words are written in it understands perfectly. This area has also been found to be found to respond to more to printed words than to spoken word. So, this is basically that is why it is ‘visual word form area’.

Responds similarly, to various different types of familiar scripts whether it is alphabetic, it is syllabic or any other kinds of script. So, it is it also responds similarly to different types of scripts. It responds more to printed words than any other visually of presented objects and then so, these are some of the areas, but there are many other some of the functions there are many other functions also.

In fact, there is a lot of empirical evidence, a lot of work that has been that are still going on as to find out to find out what are the different functions of this area, but these are the primarily the most important ones. As a result of which if this particular area gets damaged, there will be a disorder which is called 'alexia'. Alexia basically is the disability to read printed words or letters there are different levels of alexia.

Of course there are various different types, but roughly the any damage to this 'visual word from area' will result in this. So, there is a correlation between this. So, we can see that reading happens actually there is a particular area in the brain that is dedicated to various aspects of reading. So, which again AI has not come anywhere closer to this till now.

Then let us go on to the writing. Writing research reading on the one hand when though we have a huge there is a wealth of data wealth of empirical evidence in case of reading research with respect to neurological findings, neurological underpinnings. Writing research is comparatively less investigated, it is a less studied area; however, we still do have a lot of information even here.

So, when asked to write real words the brain uses either a phoneme-grapheme pathway or a root that includes the phonological, orthographic, lexicon as well as semantic system. So, there are various models given for this as well. So, there are various pathways in the brain that have been found to be utilized while writing.

So, one can be a phoneme-grapheme pathway another is a more core route that is that includes the phonological, orthographic, lexicon and then the semantic because we need all the information in order to be able to write. So, which pathway it will take the writing process will take depends on whether it is regular versus irregular spelling patterns. So, regular spelling patterns are like something like 'shelf'.

So, you write as you speak that is regular and, but here we write this d e s p o t, but the t is silent and so on. So, there are these are called irregular spelling pattern. So, depending on the kind of spelling pattern, then the kind of length of the word complexity and various other aspects of writing has been found to be processed slightly differently within the network.

So, there is a different pathway for the slightly different pathway for different kinds of processing in terms of writing as well. Disturbance to any of these roots will result again in another kind of disorder which is called dysgraphia. Dysgraphia is inability to write properly. So, neural correlates are again referred to the VWFA.

In fact, VWFA is proving to be an extremely important brain region with respect to writing and reading as well as writing. And we asked we still do not know what all it is capable of doing more. So, it is the work is still going on. So, it is in case of writing also neural correlates to go and take us to the VWFA as well as some other regions like the left inferior frontal cortex.

So, we have seen that with this brief overview of the various kinds of language functions, that in terms of both the disorders of language as well as normal language functions in speaking, listening, that is speech production and speech perception and as well as reading and writing. All these aspects of language has their own neural underpinning neural substrates that are responsible.

So, that the puts it firmly in place, the idea that research that all kinds of language functions all types of language functions are, whether in the domain of learning or processing or disorder, they do take us back to the neural substrates. So, there is a very deep connection, very close connection between language and the human brain.

These are the references. Some of these are this is this is a book, but so is this. In the this is one of the most important, then again this is the paper on in which Paradis has referred to various types of bilingual aphasics, and of course, this is where the model Cohen has Cohen at al, have given the model about the visual word form area. So, very important papers. So, this takes us to the end of module 6.

Thank you.