Lecture 32 –

Neural Basis of Language Comprehension

Hello and welcome to the course introduction to psychology of language. I am Dr. Ark Verma from IIT Kanpur; we are in week seven of the course, in this week we are talking about the neural basis of different aspects of language. Let us talk, in this lecture about neural basis of comprehension, we've talked about, meaning per say but, we're going to talk about, how words are processed, whether they are coming from the written modality or they're coming from the auditory modality. So, this is what we are going to talk about in today's lecture. Now, as I was also discussing in the last class, while we receive input from different linguistic modalities:

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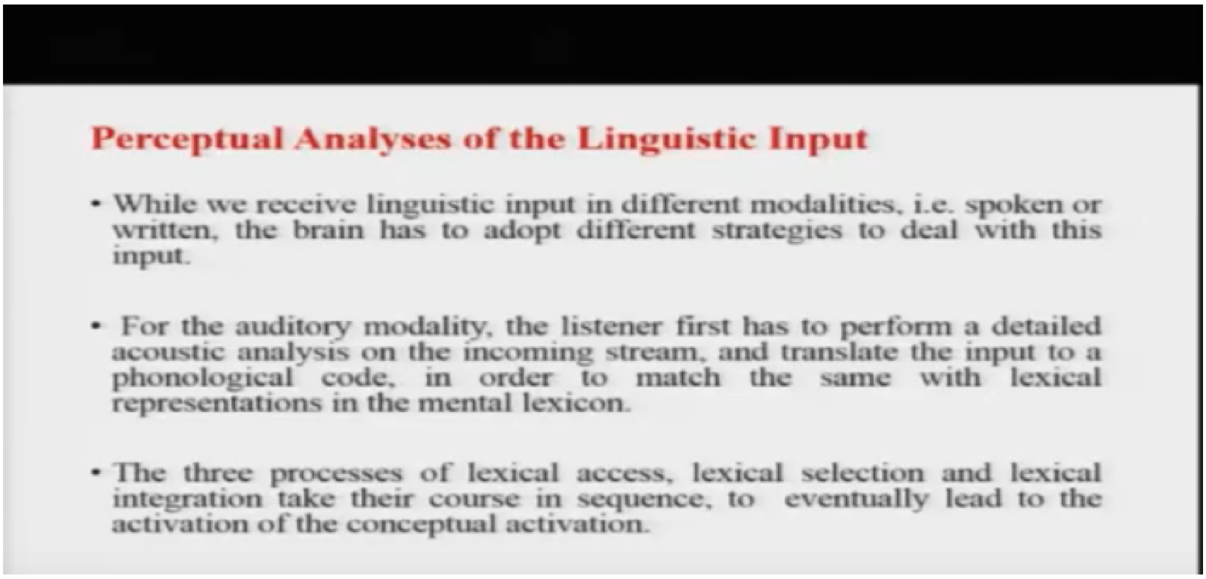

that is either spoken or written. The brain will have to adopt, a different strategy for different kind of input. So, the spoken input versus, the written input, there will be some difference, if you remember I think in another earlier classes I've talked about it, the written input needs to be converted, into a sound based representation and then goes to meaning, there's the auditory input is already in the sound waste form and probably will have a faster, access to meaning. So, in that sense how is the brain dealing with this? However, also say for having said that, the auditory input also, has to be sort of you know, it goes through that entire perceptual analysis process anyways, before you can you know, use that to comprehend or understand the meaning of the word. For the auditory modality, again let's just do a little bit more detail, for the auditory modality the listener first has to perform a detailed, acoustic analysis on the incoming input stream, speed stream or auditory stream and translate, the input to a phonological code. So, you know, what are the sounds made up of you analyze the sounds and then you kind of come to the phonological code, in order to match the same with the lexical you know, access the lexical representations in the mental lexicon. So, this matching is called, 'Lexical Access' you do activation, selection, integration all of those kinds of things. Now, there are these three kind of lexical processes: that we talked about lexical access selection and integration, they take their course, in sequence to eventually, leads to somebody understanding the meaning of whatever, the word is said.

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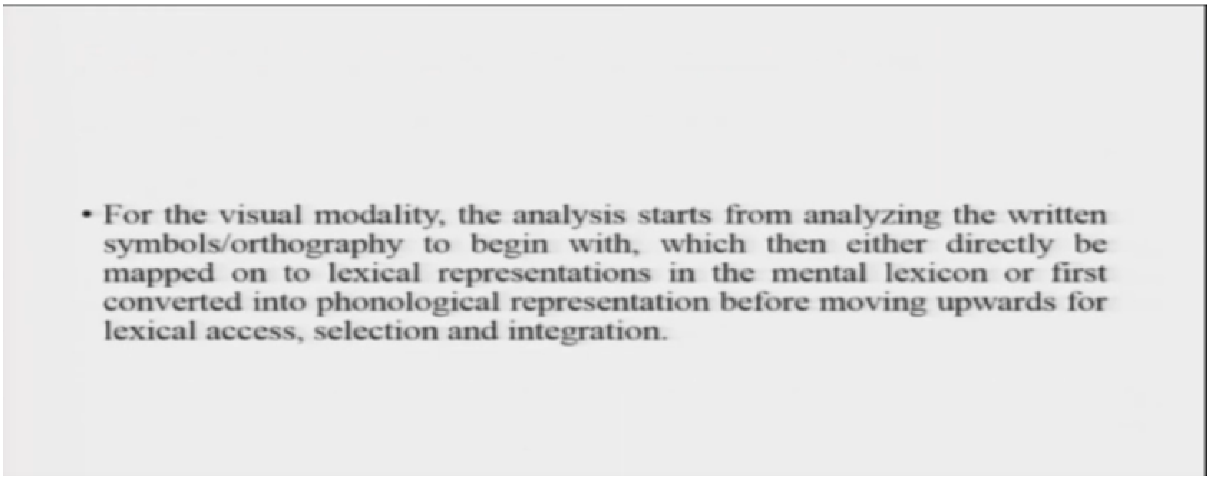

For the visual modality, the analysis starts from analysing, the written symbols or the orthography to begin with, we then either directly, which will then say for example, the visual symbols, which will then directly be mapped to the lexical representations, directly say for example, if you remember the dual route cascaded model, there were two routes, one was the grapheme phoneme conversion route and the other was the direct route. So, either once you've analysed and you've got the spelling, directly you read, say for example, irregular words like bouquet and genre and so on, are they directly, you know, match with the lexical representations or you do the grapheme the phoneme conversion, you convert written to the sound and then kind of magic. So, both, both of these things are done, once this is done once you have this output, you will perform lexical access selection and integration. Okay?

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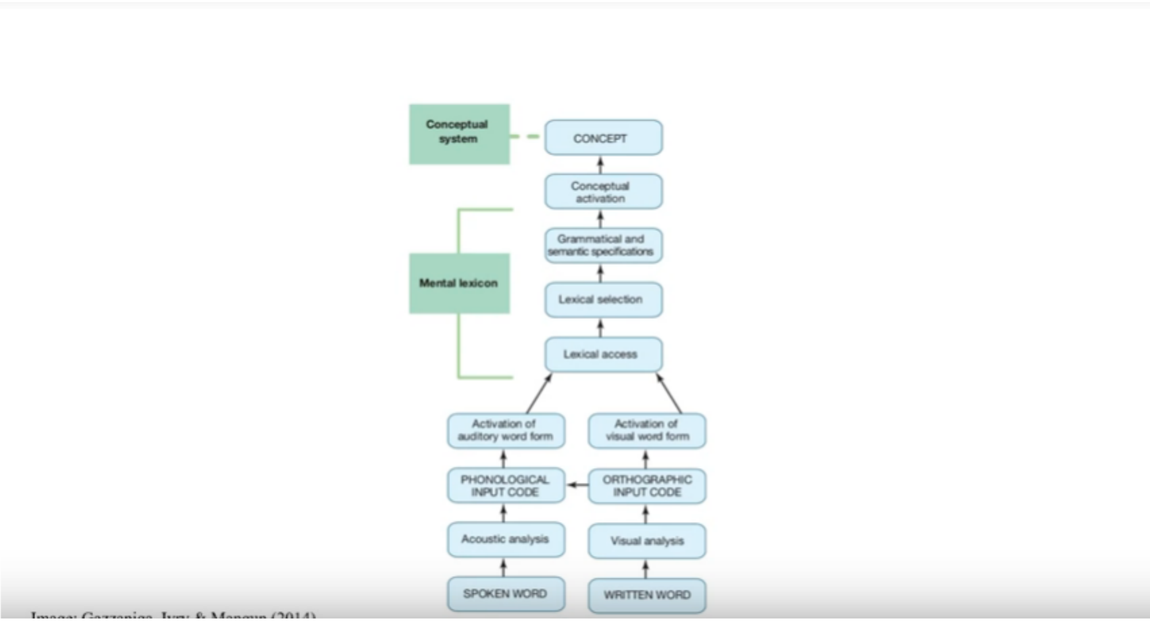

So that, happens, this is sort of a schematic of how the representation of concepts involved in spoken and written language you know, compression might be, you will see the conceptual system is one. However you will see the spoken and the written words are kind of going through, different routes, you will see, the spoken word goes to acoustic analysis, converts into phonological code, then odd ready, word form is activated and moves further. The written word goes through visual analysis, then it either, needs to get converted from the orthographic code, to phonological code and will move through or it can directly, the orthography code can activate the, the visual word form directly and then the processes are same, lexical access selection and integration, are all the same processes, which by the way, are in you know, negotiating with the mental lexical. So that, that is how basically, you will come across or negotiate words, whether you are listening to them or you're reading them.

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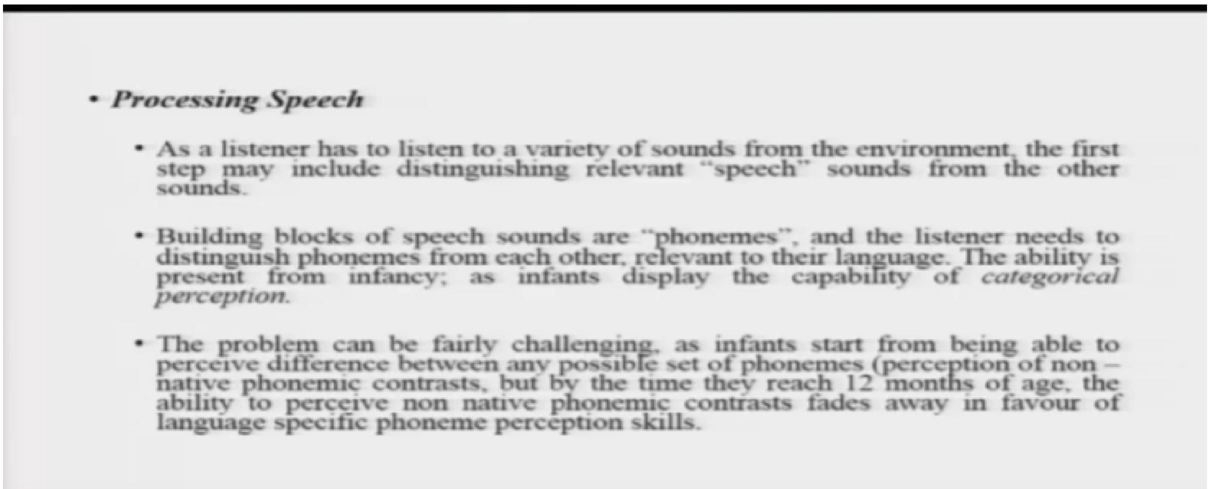

Now, going a little going into a little, bit more detail, let us talk about processing speech, as a listener: that you know, the listener basically as a listener you, probably have to do a variety of processes, say for example, as listener we listen to variety, of sounds from the environment, you have to distinguish, the speech sounds from the other kinds of sounds. Once you've distinguished that you have to further analyze, the speech sounds, therefore you know, the speech sounds are made of basic sounds called, 'Phonemes' and the listener needs to distinguish one phoneme from the other and also, the leader listener basically, needs to recognize the phonemes: that are relevant to their language. If you remember when you're talking about, this in the chapter on development we are talking about, now that initially, infants have this capability of perceiving, what are called non-native phonemic contrasts? So, they can distinguish between phonemes of an language, you know, Kikuyu children, could distinguish between phonemes of English, for that matter, which language which they, they would never expose to gradually, when they grow up, this person this generic phonemic, you know, distinguishing ability goes away, the generic perception of non-native phonemic contrasts goes away and the skills, with respect to the same language kind of sharpen up and get better and better. So, this is, this is what people are doing? This binary part of being able to distinguish, between particular phonemes, was as you know, referred to as categorical perception. Now, the problem actually, can be fairly challenging I mean we've talked about this in some detail as well, because infants, start from being able to perceive differences between any yes, so we've talked about this from any phonemes, from across languages to the specific phonemes that belong to this language.

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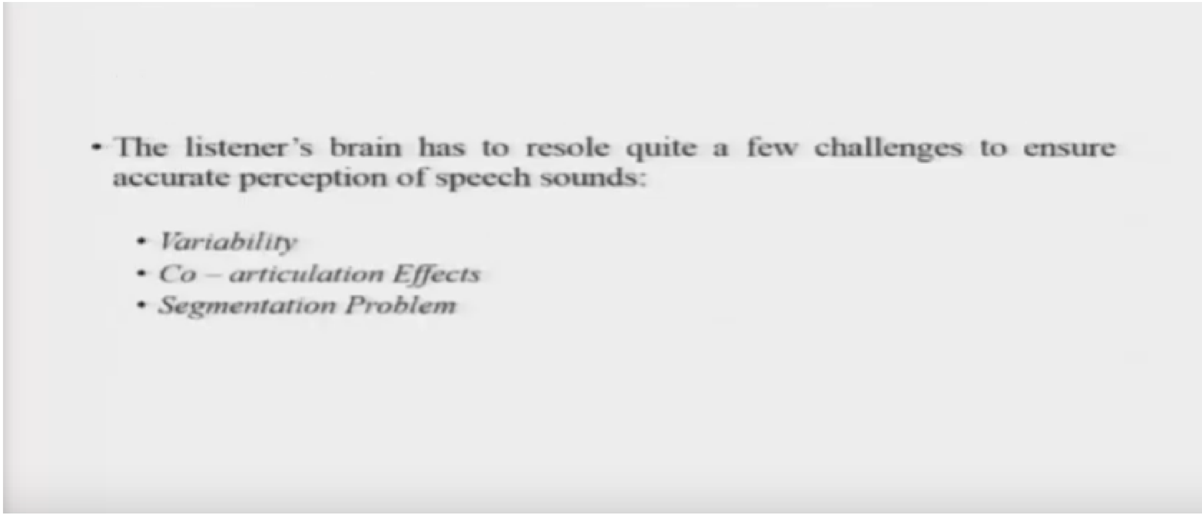

Then this kind of is a very specific skill, even once the inference of kind of forgotten how to perceive phonemes and what are the basic sounds of the language, they also still have to deal with some of the other factors, things like variability. Variability in terms of, the same speaker, in different situations might speak differently; the physical signature of the sound will be very different. Also, the same sound across different speakers might come out as very different and the infant's really have to figure that out, so there is a lot of variability, with which the infants have to deal with, in terms of listening to speech. There are also things like articulation effects, see for example, spin versus spoon, the you know, the sound of sha, of pha, kind of get oh sorry, the sounds will get slightly modified So, as you know, we don't really, speak in isolated phonemes, so you speak phonemes together, so do, d, those kind of things and the idea, is that say for example, based on what sounds a particular phoneme is being produced to it, based on what phonemes particular phoneme is being co-produced with, the physical signature changes. So, these therefore these are referred to as Co, articulation effects and you'll see that, a lot in a normal language and normal normally, when people talk to each other, they reduce some things, they extend some things, the extent is changed, all on the basis of what exactly, was being said, so you have to kind of look in to, look at the whole utterance as unit. Also, there's this whole problem of the segmentation problem, if you remember, we talked about metrical segmentation, prosody based segmentation: that is we talked about statistical segmentation. So, many of these things we've talked about, segmenting the continuous speech stream into meaningful units: that is, that is basically what I'm talking about. Now, I'm just revising,

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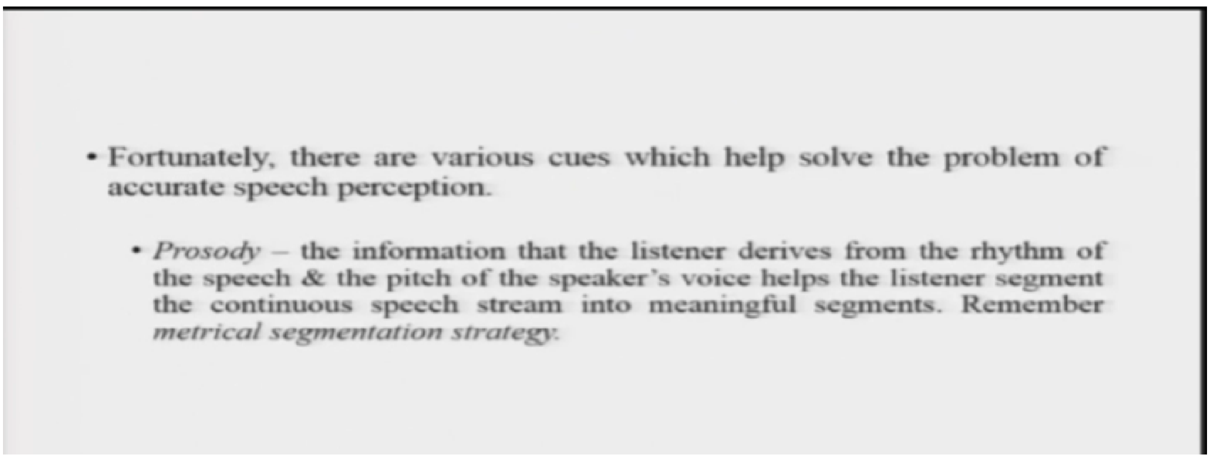

what listening to speech might be and we talked about, yeah! Prosody, so the information that the listener derives, from the rhythm, of the speech, the pitch of the speaker's voice, all of that, you know, remember me trigger segmentation. So, materical segmentation was what? Materical segmentation was, there are so many different words in the language, some of them, which can which have true shake, stress means pattern or ambach stress based pattern, TRO shake is bottle, baby, first syllable is stressed, the second syllable is unstressed or resistance you could have guitar, I am big, the first syllable is smaller and the second syllable is longer. In English more than 70%, of the words are true shake, whereas a few words, are ambach, this can be used to distinguish between the word pauses and the word boundaries. So, we did all of that already and in that sense we know that you know, this is a very fairly difficult task we have to see,

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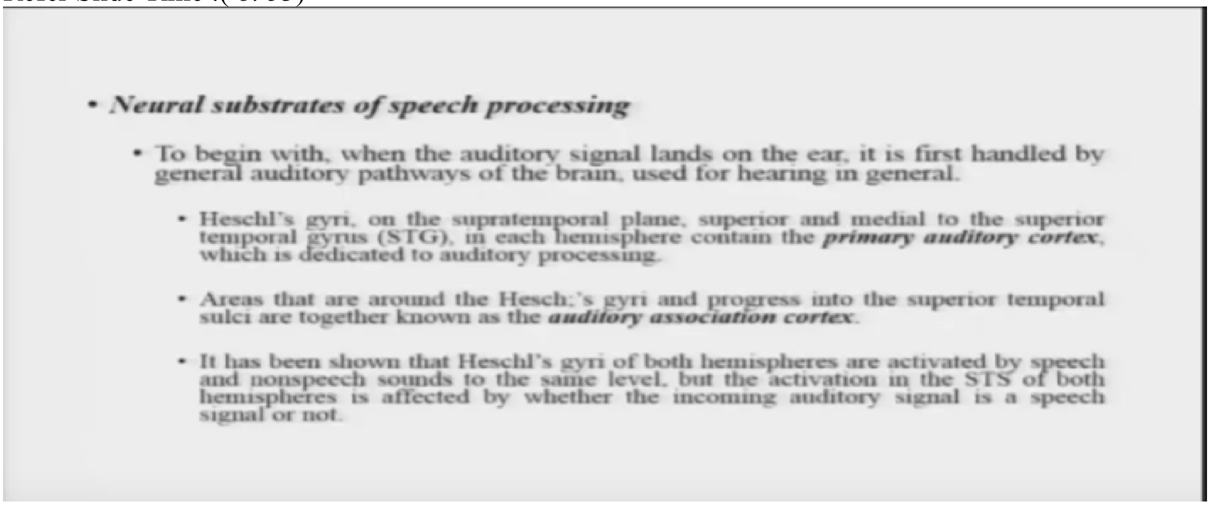

which areas of the brain doing it. So, let us now, look at which areas of the brain are helping us dupe, phonemes perception or which areas of the brain are helping us you know, figure out word boundaries and so on. Now, to begin with, what really happens is, when the auditory signal first lands on the year, it is handled by the general auditory pathways of the brain? Okay? So, there are particular pathways in the brain, which are basically tuned, to listen to whatever sounds are being created. These areas are basically the one of the most important areas are the Hesch;'s gyri. So, gyri as is that you know, is that bulge, in the brain we will look at the figures of the brain very shortly. So, we hold on for the moment. So, Hesch;'s gyri, on the supra temporal plane, on the temporal lobes, superior and medial to the superior temporal gyrius, in each hemisphere, so left-hemisphere, right-hemisphere this these are the regions, basically, which will, which contain the primary auditory cortex, are basically dedicated to this auditory processing, whatever you're hearing, speech sounds, non-speech sounds anything that you're hearing, first goes into this areas, I could kind of try and broadly and draw this,

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I don't know, whether really make a lot of sense. you know broadly, this is the area that I'm talking about. Okay? So, ideas that, are around the Hesch;'s gyri progress into the superior temporal sulcus, at the top and they are together known as the auditory Association choruses. So, they're in where all the auditory information is integrated with other kinds of information that are coming in. It has been shown that Hesch;'s gyri, of both hemispheres, the right hemisphere and the left hemisphere, are activated by speech sounds and non-speech sounds to the same level. But, the activation in the superior temporal sulcus, of both hemispheres, is affected by whether, the incoming auditory stimulus is a speech signal or not. So, at the superior temporal sulcus, is a sort of a difference being made, between speech sounds and non-speech sounds? So, this is the region of the brain, which is kind of telling you okay, now I know that, this is a speech sound, now I know this is the sound of a motor or the sound of a car going by or car horn on anything.

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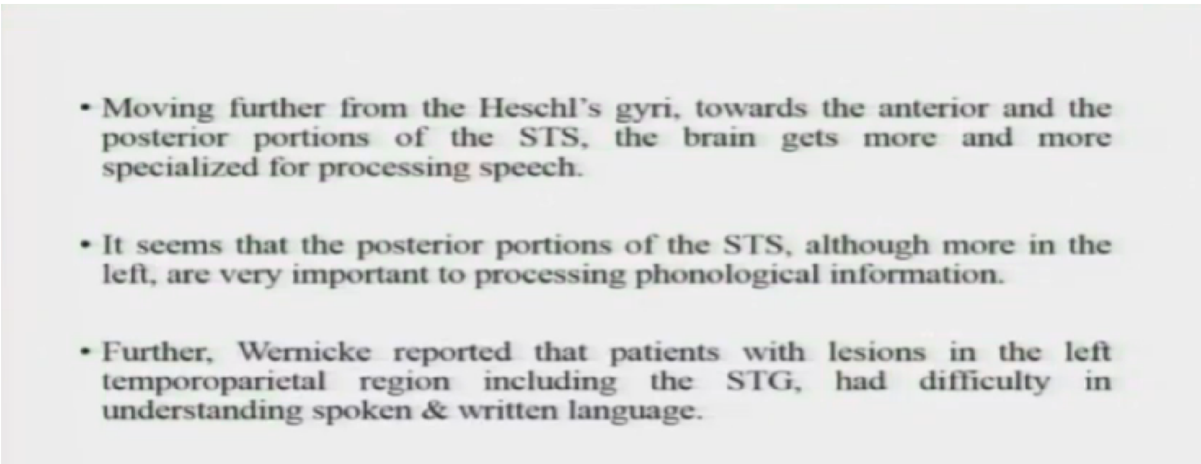

Further from the Heschi's gyri, I move slightly further, towards the anterior and the posterior Pole of the superior temporal sulcus, the brain gets more and more specialized for processing speech. This is where you're analysing, the incoming speech stimulus or incoming auditory stimulus, to get in more and more characteristics of speech our Theory chop, what is this? What are the basic phonemes? How are those phonemes link? What is the you know? What all of those kind of things are there. It seems that, the posterior portion of the superior temporal sulcus, although more towards the left side, are important for processing phonological information, as to what is this particular phoneme? You know, how are these particular four names linked. Also, some research done by a Carl Wernicke, he reported that patients with lesions in the left, temporal parietal region. So, temporal and parietal, left temporal parietal region, including superior temporal gyrius, usually had difficulty, in understanding, spoken and written language both. So that, part is where you probably are kind of doing some meaning related stuff.

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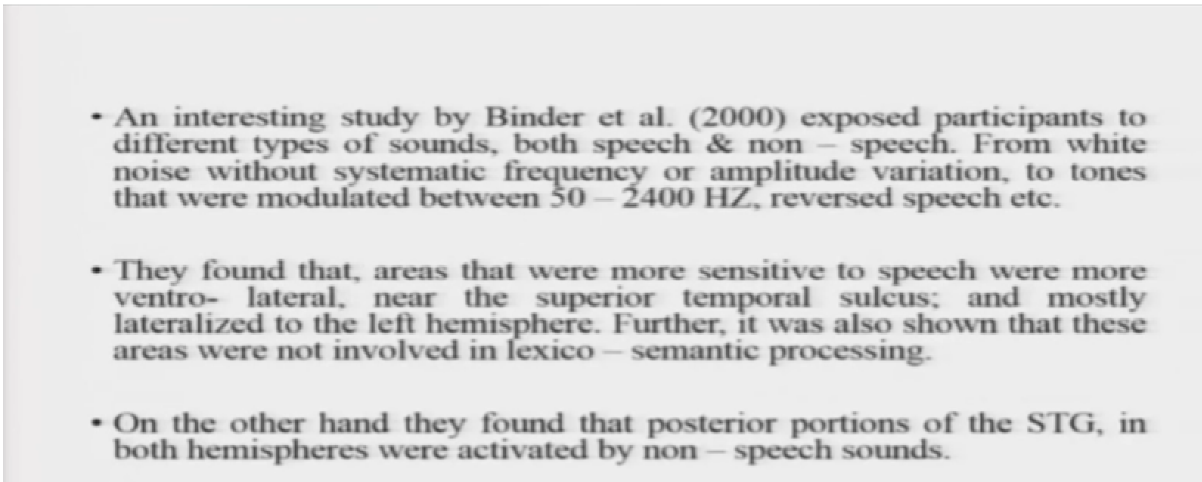

Now, this another very, interesting set of study is done by binder and colleagues and they did this in the year 2000, they wanted to kind of look at how the brain responds to speech sounds and non-speech sounds. So, they exposed participles with these different kinds of speech sounds, from the white noise, which had no systematic frequency violations, to sounds which had different kinds of frequencies. So for example, from 50 Hertz, to 2400 Hertz, even a reverse, speech is also different kinds of semantic and different kinds of auditory stimuli words there. Now, what did they find? Basically, is that areas that were more sensitive to speech, were near the ventrolateral, form or ventrolateral slightly, nears the bottom and there's a lateral part, near the superior temporal sulcus, I'll show you the figure, shortly and mostly little eyes to the left hemisphere. So, things that is, more sensitive speech, are more in the left hemisphere. Further, it was also shown that these areas are not really you know, so this area is not really, initially, involved in meaning or lexico semantic processing. They're not they are talking about word status and so on. On the other hand they, they found the posterior portions of the superior temporal gyrius, were activated by non-speech sounds as well. So that, is a generic area that is processing sound, but these areas, the ventral lateral area near the superior temporal sulcus, are probably doing some specialized processing, as far as speech is concerned.

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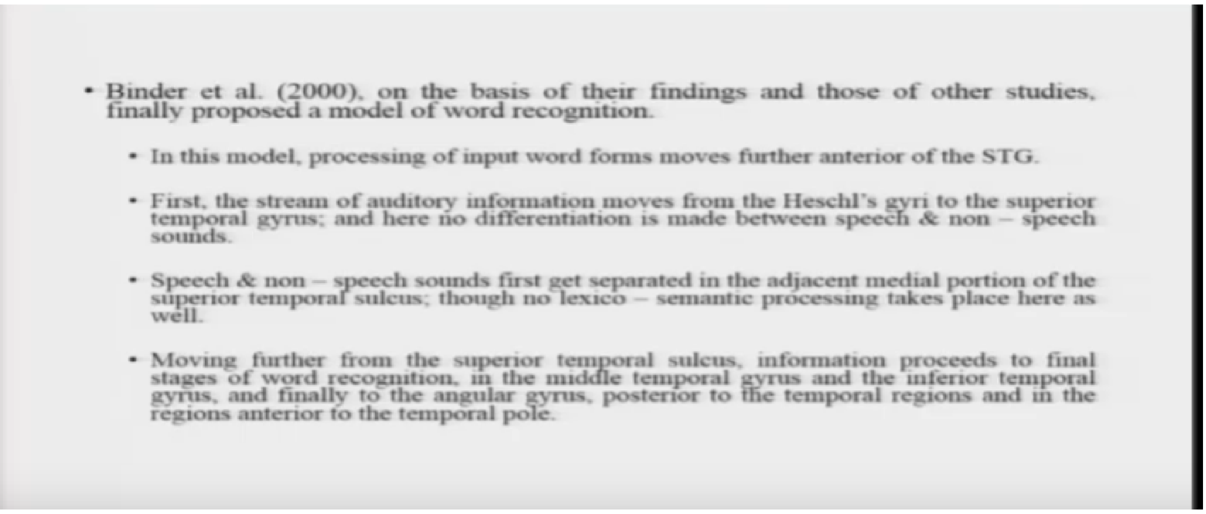

Binder further proposed on the basis of their finding: that there is this you know, a proposes sort of a model. And the model was like you know, that a processing of input word form, first you know, starts at the you know, anterior portion the superior temporal gyrius and moves on from there to more specialized processing. So, the first stream of auditory information, according to this model, put forward by binder in colleagues in 2000, is that moves from Hesch's gyri, to the superior temporal gyrius and here no differentiation is made between non-speech and speech sounds, first then get separated in the adjacent medial, portion of the superior temporal sulcus, though no lexical semantic processing or meaning related processing is happening. Moving further on, so at Hesch's gyri, the sound the auditory stimuli is first registered, no difference between speech and non-speech, going further around the superior temporal sulcus, difference is made between speech and on speech, moving further, from the superior temporal sulcus, information to the final stages of word recognition, is kind of happening in the middle temporal gyrius and the inferior temporal gyrius, finally moving towards the angular, gyrius and which is slightly towards the posterior of the temporal regions. Okay? So, what I am talking about? Temporal lobe, middle temporal gyrius and inferior temporal gyrius and basically, towards the back of the temporal regions, as well.

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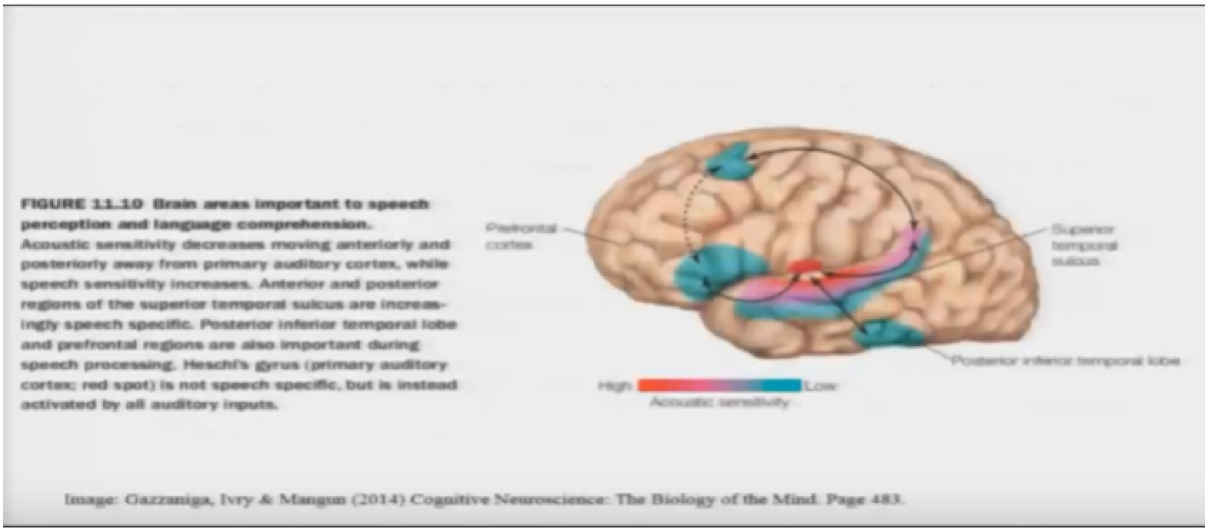

So let us look at this, this is the model, you can look at, this part is the frontal cortex, this one is the superior temporal circuits, the ridge, is the superior temporal sulcus as I said, this is the superior temporal gyrius. So, what are these areas are basically, this is where, things are actually happening. So, this is where, if you look at the arrows, this and this and this is where, the entire processing is happening. What, what does this model say? Acoustic density decreases, moving anteriorly and posteriorly, away from the primary, auditory cortex. So, this is your primary, auditory cortex, if you move further or if you move backwards, the sensitivity to speech sound is great decreasing, anterior and posterior regions, of the superior temporal sulcus. So, this is the superior temporal sulcus, the anterior regions and posterior regions of the superior temporal sulcus are increasingly speech specific. So, this is where speech specific analysis is happening. Okay? And then the Hesch's, Hesch's which is the primary auditory cortex the red spot, this one here, it's also not speech specific, but is instead activated by all auditory input. So, the input is first coming here and then from here it's going towards the back and also, from here it's going towards the front. Okay? And from here it's going to the frontal cortex as well and this is basically, the free prefrontal cortex this area here, so this is something that is, happening, so this is basically, what is happening with respect to speech processing, according to binder and colleagues.

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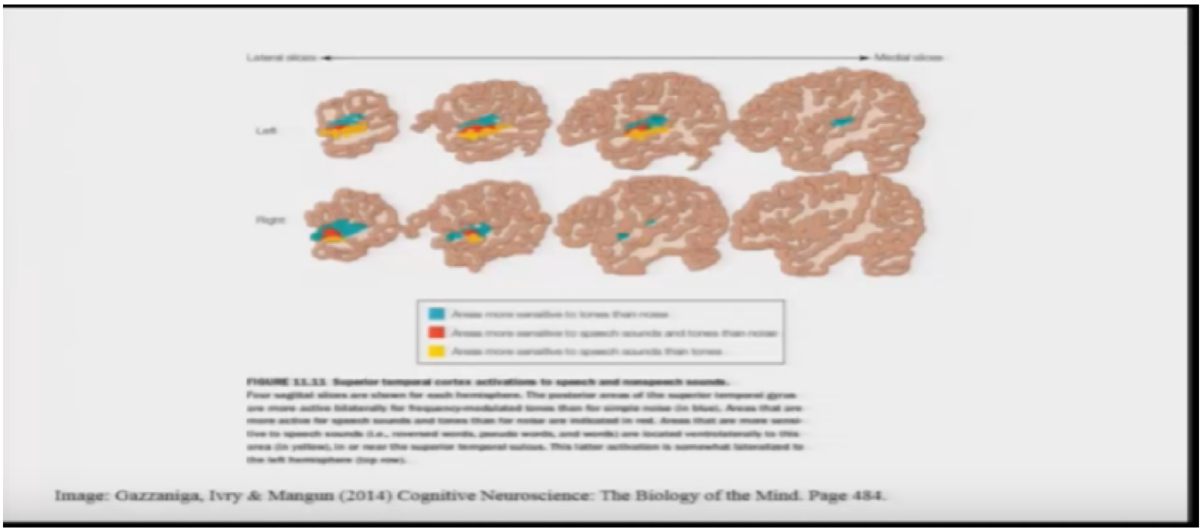

Now, they also kind of show, in in a figure slightly, differently: that how this difference is being made. So, if you in these figures, if you look at say for example, areas that are more sensitive to tones then noise you can see, the area's, the like this, this which are more specific, more sensitive to non-speech sound versus you know, other kinds of things and in yellow, you can see the areas that are more sensitive to speech, then tones and in the orange, these areas, you can see that these areas are more sensitive speech, sounds and tones then noise. So, three kinds of things were there. just white noise, tones which had different kinds of frequencies and then you have speech science. Here you can exactly see, in the left part, in the right part, exactly which are the areas, where you know, basic processing is happening. These slides that you see, are basically referred to as the societal sizes, the idea is you take debris and you cut it in this portion and then you kind of it's you can imagine as a cabbage and you've cut the entire cabbage, the in the middle part, is basically the societal slides. Lateral is slightly further, front and middle is slightly inside. Then here in this diagram, what you can see? Is you can see the regions that, are involved in the hierarchical processing, for speech. So, this is again basically, the Hesch's, you can see the Hesch's gyri you can see the primary auditory cortex, which is in purple, you can see the areas that are more sensitive, to tones slightly further in the temporal lobe, on the top, areas that are sensitive to words, then onwards the areas that are doing meaning, is more in this part the green areas. Okay? And then basically, what you're seeing also, is the areas in yellow that are most sensitive to speech, the nose is a speech, non-speech difference is being made here.

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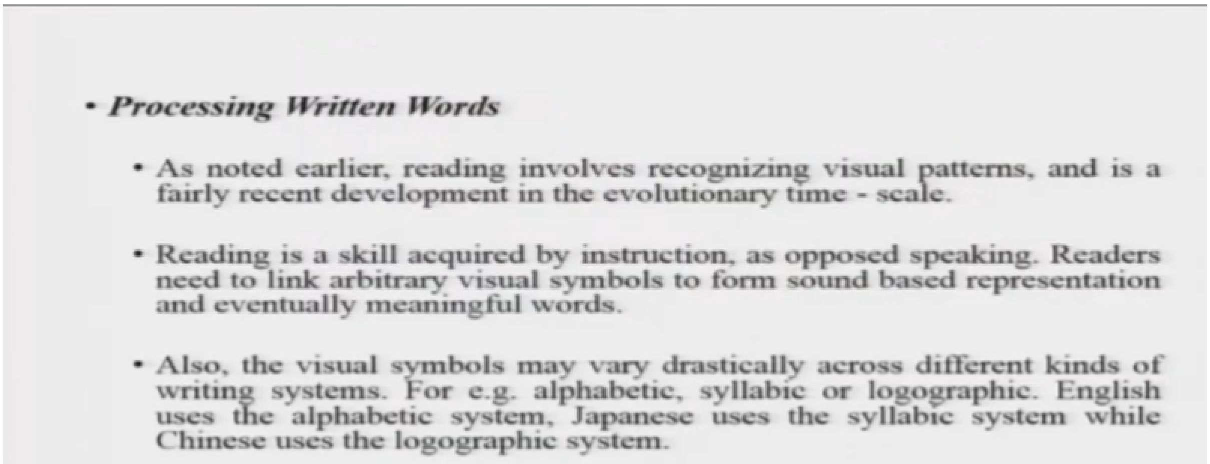

Now, this is typically, what is happening with respect to? You know, auditory speech. Let us look at, what happens with respect to? Written words, when you're reading, as noted earlier, the reading involves, recognizing visual patterns and is a fairly recent development, on the evolutionary timescale, you know ,we've is not something that we were designed to do, it's something that is, almost completely man-made, we started drawing particular symbols and we started attaching those symbols to particular sounds and then we kind of linked those sounds to specific meanings. So, this is something that we've kind of picked up, fairly recently or actually, it's probably the other way around, we have these words, the words are made of these sounds and the symbols, are ways to represent those sounds, they are another way of communicating. Now, reading therefore is also, a skill that, you don't, you're not born with, it is something that you acquire, by instruction you know, children need to go to school and to be and need to be taught, how to read and write. Okay? As opposed to speaking, which people if everything is normal, eventually do. Now, readers basically, have this extra task of linking these arbitrary, visual symbols the scripts, to form base representations or to form sound based representations. So, say for example, if I were to write C 80, typically, if I am an illiterate person, these figures will not really mean much. But, I have to kind of make a sound based obsession, on the basis of that, so C stands for ka/ and a/a stands for air and T cells would ta/ and I have to concatenate all of this link, this together and make a representations cat and then I in there is obviously a meaning attached to this particular representation. So, the visual so, this is basically, what a reader has to do, as opposed to a listener. Now, the visual symbols also, if you look at the nature of the stratum a drastically, different kinds of writing systems, we've talked about that, alphabetic syllabic logographic writing systems, English, typically is the alphabet, is a typical example of an alphabetic script, where Chinese uses the logographic kind of system. Okay?

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- Regardless of the writing system, readers first job is to be able to analyze the primitive features , i.e. the shapes of the symbols, that may for example, involve visual analysis of vertical lines, horizontal lines, curves, intersections etc., which would need to be combined to recognize constituent letters/alphabets and eventually linked together to form words.

Regardless however of the writing system, the readers first job is to be able to analyze, the primitive features, say for example, the shapes of the symbols: that may for example, involve visual analysis of vertical lines, horizont. So, the scripts are made up of you know, the symbols, are made up of so many different kinds of features. So, there are dots, there are vertical lines, there are horizontal lines, slanted lines, curved lines, a reader has to figure out all of this, connect this and see what it stands for.

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- Several proposals have been made to understand how visual word recognition takes place.
  - One of the earliest proposals cam from Oliver Selfridge (1959) who proposed a collection of small components (or demons) that working together could allow machines to recognize patterns.
  - These components would record events, as they occur, recognize patterns in those events and subsequently recognize the patterns as letters.
  - In Selfridge's ***pandemonium model***, the sensory input (R) is first stored as an iconic memory, by an ***image demon***; further 28 ***feature demons***, each sensitive to a particular feature, start to decode features in the iconic representation.

Several proposals obviously have been made as to how the brain might be doing this how, we might be doing this as people and one of the older or earlier models on the first models, on this was Oliver Selfridge, is the pandemonium model and in Selfridges, pandemonium model the idea, is that there is you know, the sensory input R and the sensory input basically, is very quickly, captured by iconic memory, the vision based memory, by something called an, 'Image Demon'. So, he basically says the, Selfridge is basically, looking at, components as demons, which give a particular task. So, there is an image demon, which kind of captures the image of the symbol, from the iconic memory and then goes on to analysing it further. The further analysis is basically done by that, feature demons and they came up with a list of, let us say 28 features that are possible. So, they are talking so, he proposed 28 feature demons and each feature demon, is actually sensitive to one kind of feature. So, one feature demon could be a horizontal line, one feature demon could ever could be of a vertical line, one feature demon could be of a curve and so on. So, each sensitive to a particular feature, they start to decode the features present, in the iconic you know, representation. So, the image demon tells. Okay. These are the features present in this particular iconic representation, I based or visual representation and basically, the a featured even cell. Okay. This which represent, this feature present, this feature present.

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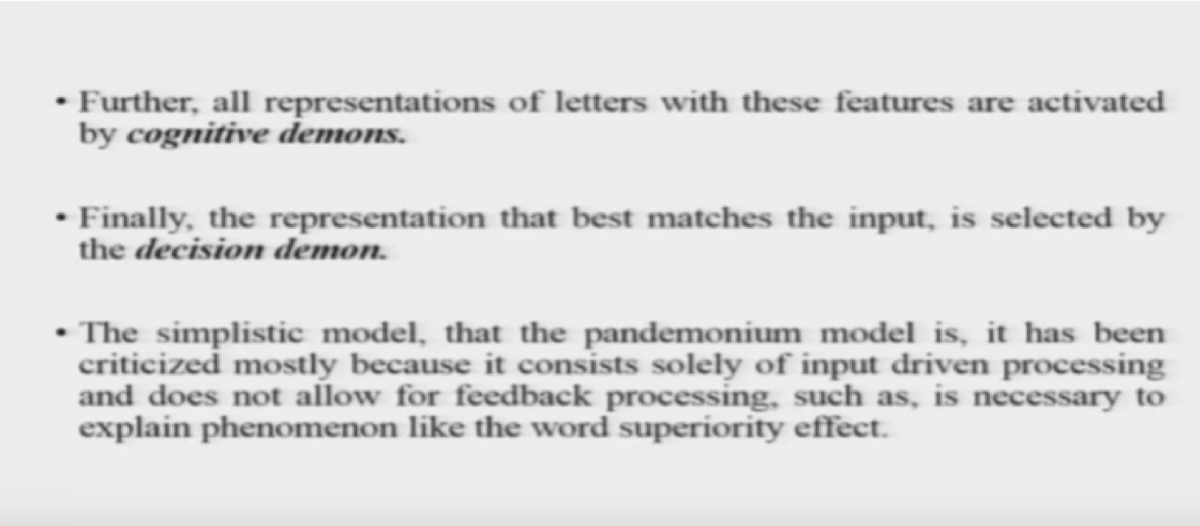

Once the future, L analysis is there, then you can kind of go to the you know, a letter, whole letter level and whatever the letter representation is, then finalized by the cognitive demon. So, it says. Okay? This is the letter that, might be represented in the input. There a and many similar you know, cognitive demons kind I know, cognitive even can come up with so many, different ideas that okay, all of this is letters contain these features. So, one of them has to be selected and that selection has to be done by their decision demon. So, it kind of is very familiar, I'm sure, now this simplistic model: that this you know, pandemonium model is, it has mostly been criticized, because it is a very, you know serial, no feedback, no interaction kind of model. Okay? And it cannot really explain a lot of effects, like the word superiority, effect and so on.

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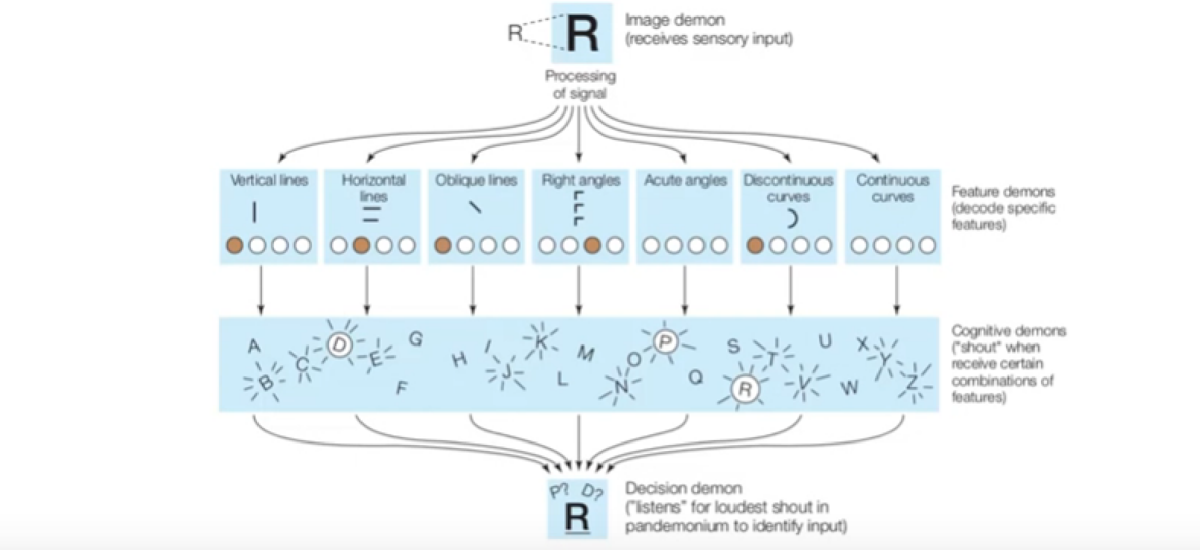

FIGURE 11.13 Selfridge's (1959) pandemonium model of letter recognition.

So, this is basically, what their diagram? What the you know, model looks like you can see R is the you know, the stimulus input, which is the image demon then you have these feature demons, which are kind of you know, coding for a chav, what are the features present in R. So, you can see say for example, for R there is the, the discontinuous curves, nothing has line right, angles have Ally have a line, horizontal lines, oblique lines, all of them have some feature. The only thing that is missing is the continuous curve, which probably if, it were an O would be present. Similarly so, in the cognitive demon stage you can see, all of those features, all of those letters are activated which have these features, so D is activated, because it has a discontinuous curve and a vertical line, P is activated and R is also activated. So, then there's a decision demon at the end, which is kind of deciding between, what is it? Is it a P or a D or an R, something like that. Okay?

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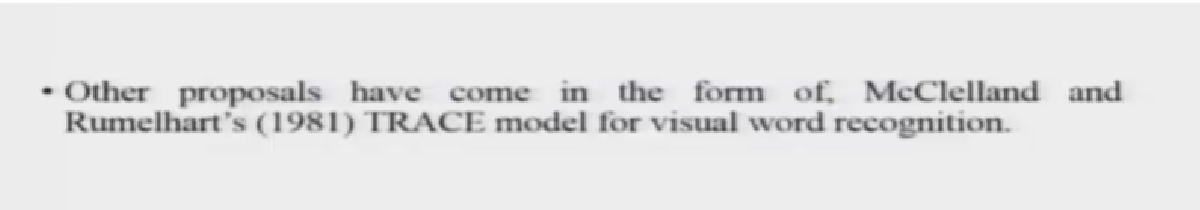

So, this is one kind of proposal, a very simplistic, early proposal in terms of how reading might be happening. Other proposal is the TRACE model, we've talked about the TRACE model in some detail, McClellan and Rumelhart's 1981.

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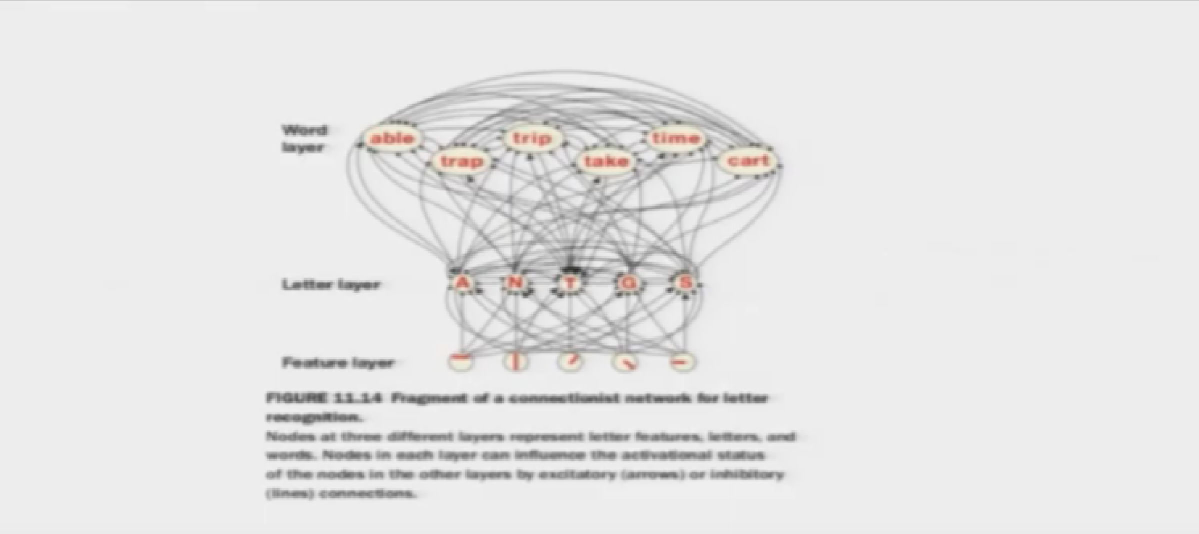

PDP based model, this is what the model looked like, it had feature level and has letter level and it has world level and there's also some feedback happening between the word level and the feature level, there's no feedback from the letter level and sorry, word level and the letter level, there's some feedback also going on, but there's no feedback between the letter layer and the feature layer. I've talked about the TRACE model, a lot in detail, in the chapter on word processing, so I'm not really going to go in a lot of detail. But, the idea is that say for example, the letters, activate, the features in which they are and they deactivate or they try and inhibit the letters, in which they are not and then the letters, activate the words in which they are a part of and they try and inhibit the verse they are not a part of also, at the same time trying to inhibit, the other letters. So, this kind of interaction is there, also from the word level, words try and you know, activate or strengthen, the activation of letters that, that they have, in their spelling. Say for example, Abel, will try and activate A, but, it will not try an activity, will try and inhibit, N or it will try an active inhibit you know, T and G and s. So, this is basically, what the model was, I'm not again going to talk about this in more detail.

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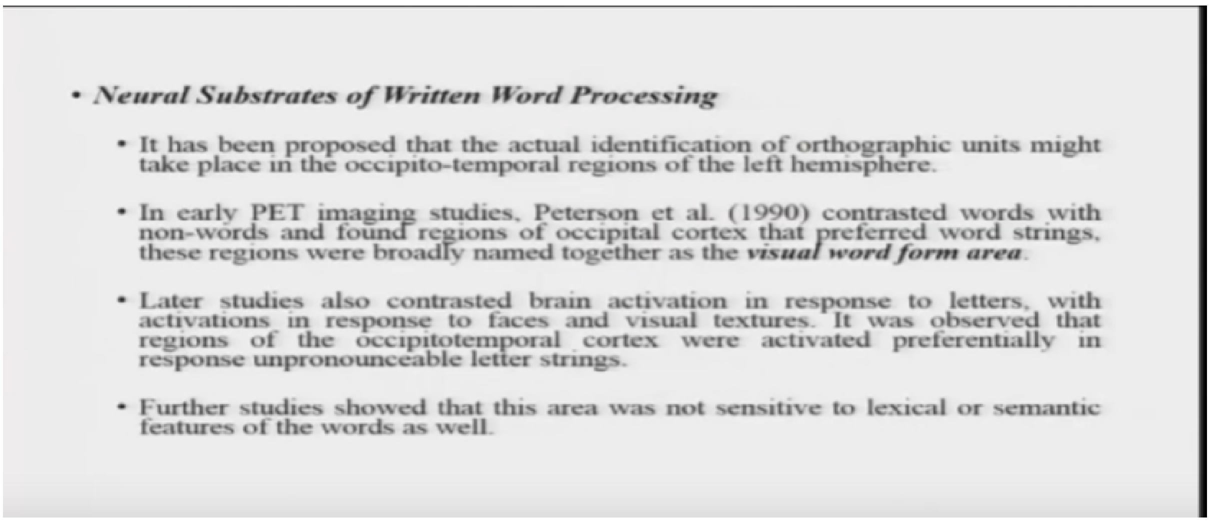

Let's talk about, the neural substrate. Okay. Let's talk about, where does the brain come in. Now, it has basically, been proposed that the actual identification, of orthography units, might actually, take place in the occipito, temporal regions of the left hemisphere, what are the occipital temporal regions? Okay? The occipital temporal regions basically, are these regions. Okay?

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This is the reason, so this is the occipital lobe, this is the temporal lobe, the occipital temporal regions are broadly these, these areas. Okay? And the juncture, of the occipital and the temporal lobe.

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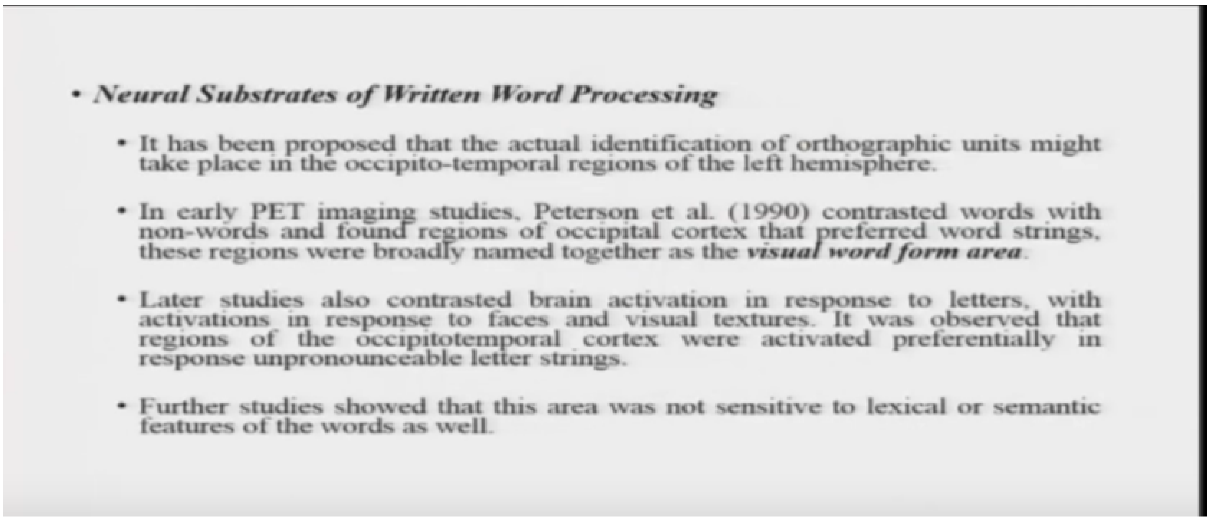

In early PT studies, Peterson and colleagues basically, have contrasted words, with non-words and they found that regions of the occipital cortex: that preferred word strings. And these regions were typically, you know, put together, lump together and you know, mentioned as the visual word, form area. So, this broad area, which has all of these regions, is referred to as the visual word form area. Latest study is also contrasted brain, activation in response to letters, with respect to you know, brain activity the response to faces and visual textures and so on and it was observed: that these regions of these occipital temporal cortex, which were activating, but, refrigeration preferentially towards, but, you're not getting activated by even you know, other faces, visual textures, houses and so on. So that is also, something that's strengthened this idea: that there is a you know, area of the brain or a region of the brain: that is you know, getting activated specific, to this particular word form. Okay? So, for this studies also, showed that this area is also, this is one thing, now but, the further studies also, showed that this area, was not really sensitive, to either lexical or semantic features of the words. So they basically, only the visual analysis, of word category, word status, is there okay, is this the word yes, this will get activated. Okay? The meaning and the other decision might happen later. So, in a combined ERP and fMRI study, on healthy persons and patients with callosal lesions, Cohen, Dehaene and colleagues.

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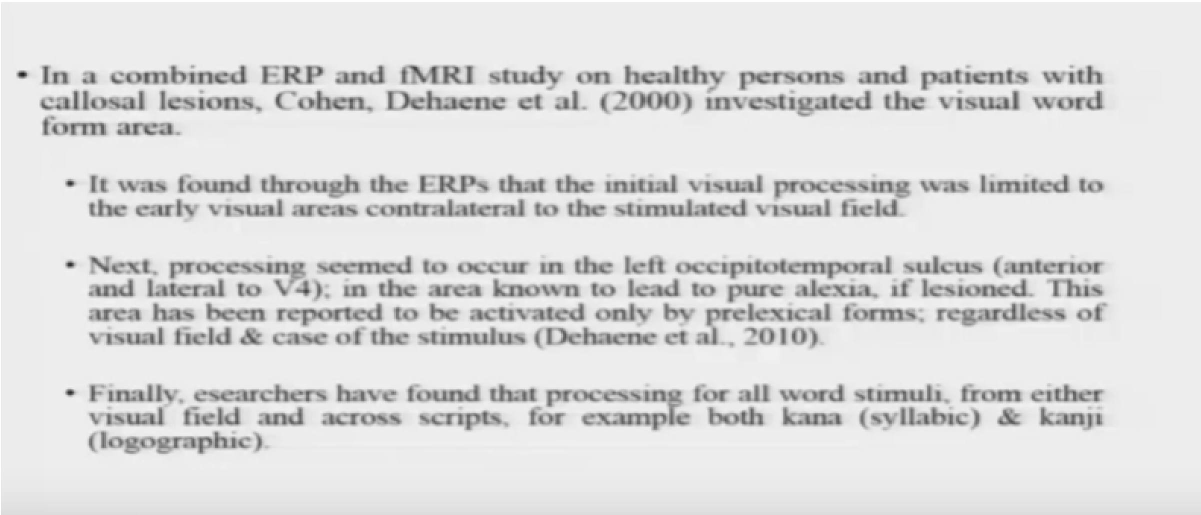

They were trying to investigate this visual word form area in some detail. And it was basically found: that through ERP, is that the initial visual processing was limited to the early, visual areas that contralateral to the visual field, so early visual areas are basically, areas at the back of the brain, in the occipital lobe. Next processing seemed to occur in the left occipital temporal sulcus. So, the sulcus that is at the you know, joining between the occipital and the temporal area, anterior and lateral to v4. So, this is basically again,

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so this is probably the region that I'm talking about. Okay?

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- In a combined ERP and fMRI study on healthy persons and patients with callosal lesions, Cohen, Dehaene et al. (2000) investigated the visual word form area.
  - It was found through the ERPs that the initial visual processing was limited to the early visual areas contralateral to the stimulated visual field.
  - Next, processing seemed to occur in the left occipitotemporal sulcus (anterior and lateral to V4); in the area known to lead to pure alexia, if lesioned. This area has been reported to be activated only by prelexical forms; regardless of visual field & case of the stimulus (Dehaene et al., 2010).
  - Finally, esearchers have found that processing for all word stimuli, from either visual field and across scripts, for example both kana (syllabic) & kanji (logographic).

Finally, researchers basically so this area by the way, the area in the left occipital temporal circus, if damage of this area leads to pure Alexia, people cannot read, at all if this area is damaged. Further, the area has also been reported to also, be activated only by pre lexical forms. So you know, regardless of the visual field, in case of the stimulus, so just word fonts. Finally researchers have also found that processing for all kinds of words seemingly from either, the visual field, you know, so these areas are also basically, processed all kinds of word stimuli, irrespective of where the input is coming, from if the input is coming from left or the right visual field, this this is the area that kind of processes the word stimuli. Okay? And also, a across script so, whether syllabic scripts are their alphabetic shifts, are there this area will get activated.

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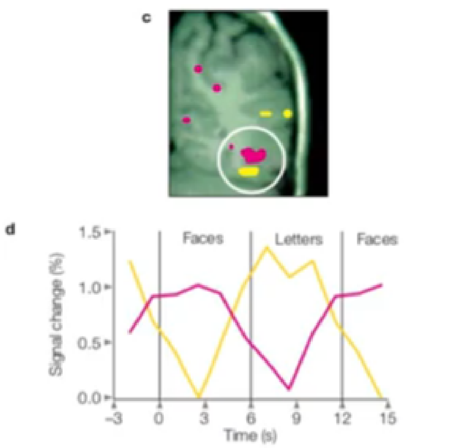

FIGURE 11.15 Regions in occipitotemporal cortex were preferentially activated in response to letter strings.
Stimuli were faces (a) or letter strings (b). (c) Left hemisphere coronal slice at the level of the anterior occipital cortex. Faces activated a region of the lateral fusiform gyrus (yellow); letter strings activated a region of the occipitotemporal sulcus (red). (d) Graph shows the corresponding time course of fMRI activations averaged over all alternation cycles for faces (yellow line) and letter strings (pink line).

This is the, this is a society view, of the brain, this is where the visual word form area is there. You can see say for example, the area in the yellow, there it is maximum activation for letters and a minimum activation for faces. Okay? So, this is broadly,

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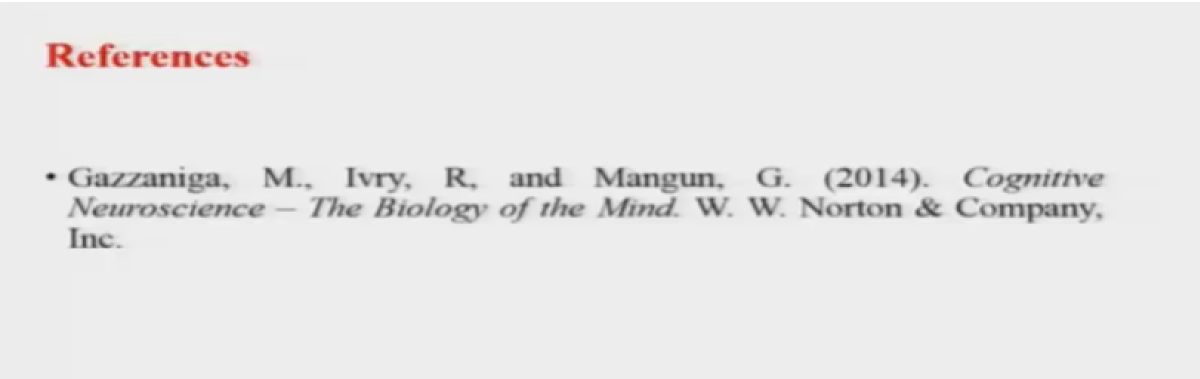

what I had to, talk to you about reading or encountering word forms, both in the spoken domain and in the visual order written domain.

Thank you.