INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

NPTEL

NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

COURSE TITLE
INTRODUCTION TO THE PSYCHOLOGY OF LANGUAGE

LECTURE-33
NEURAL BASIS OF LANGUAGE COMPREHENSION

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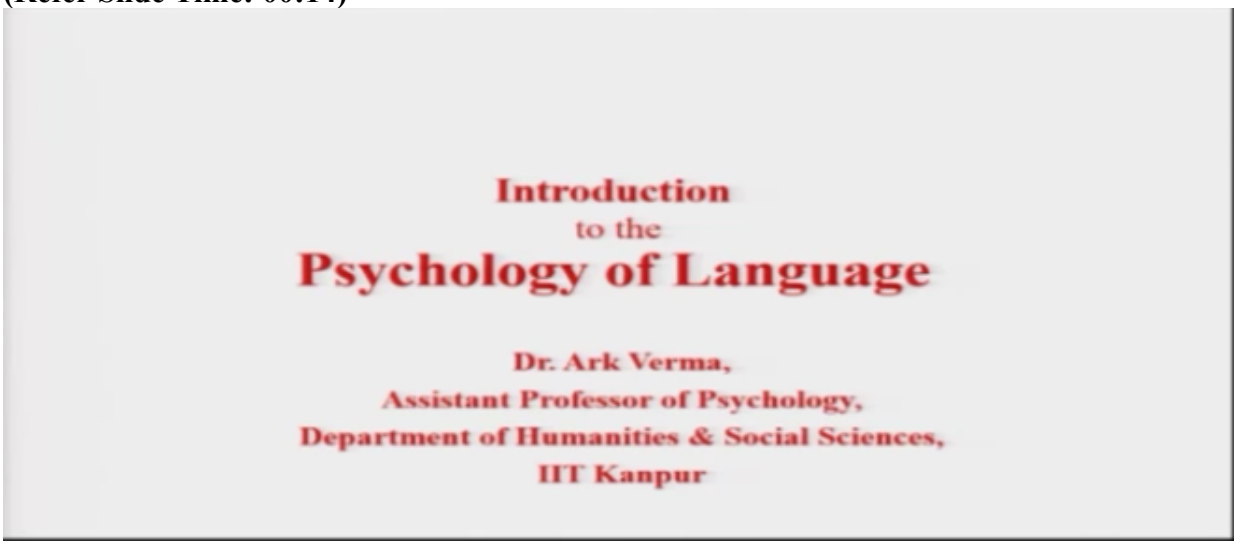

Hello and welcome to the course Introduction to the Psychology of Language, I'm Ark Verma from IIT Kanpur, and we are in week 7 of the course, we are talking about neural basis of different aspects of language.

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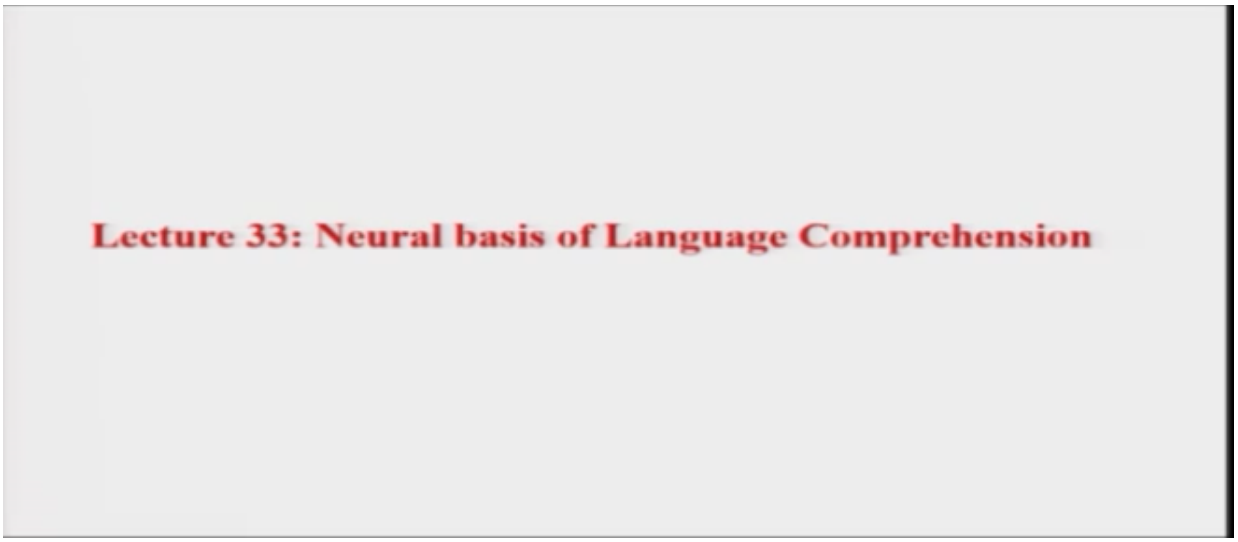

In the last two lectures I have talked to you about neural basis of understanding word meaning, concepts, and also in the last lecture I talked to you about neural basis of understanding word form or negotiating word form, spoken or written.

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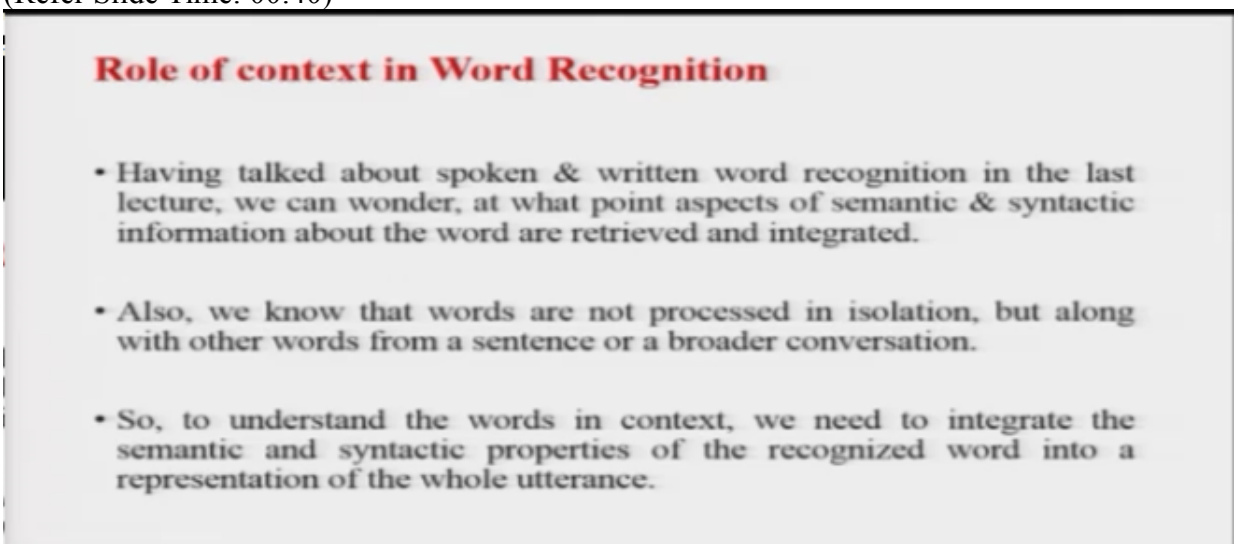

In today's lecture we'll move to slightly different aspect which is basically talking a little bit about syntax and some of the other kinds of information. So one of the things that is being said earlier as well is that it's not necessarily enough, it's not sufficient sometimes to just have negotiated the words form completely and understood the words meaning in some sense, because word meaning is not complete without also understanding the broader context in which the word has been uttered, so this kind of brings us to the question of whether and when context starts you know, affecting how you're understanding the meaning of a particular word.

So we have talked about you know in that sense, so the question is that you know when is it that the context starts to come in and interfere or influence the way we are understanding a particular word, okay, and this question is very natural to us, because we never really are reading words in isolation, so you know language is not list of words, languages words organize

in phrases and classes and sentences, organize in conversation and larger discourses, stories, so many things, okay, so because we are not only dealing with words and isolation, it is probably premature to say that if you've understood a particular word by its form and kind of gotten its meaning, you have completed language comprehension, there are other factors to it, other information also needs to be taken into account, so let us look at that.

To understand the words in context what we really need to do, is we need to integrate the semantic and the syntactic properties of the recognized word in to the larger you know representation of the entire utterance, what was I saying? Okay,
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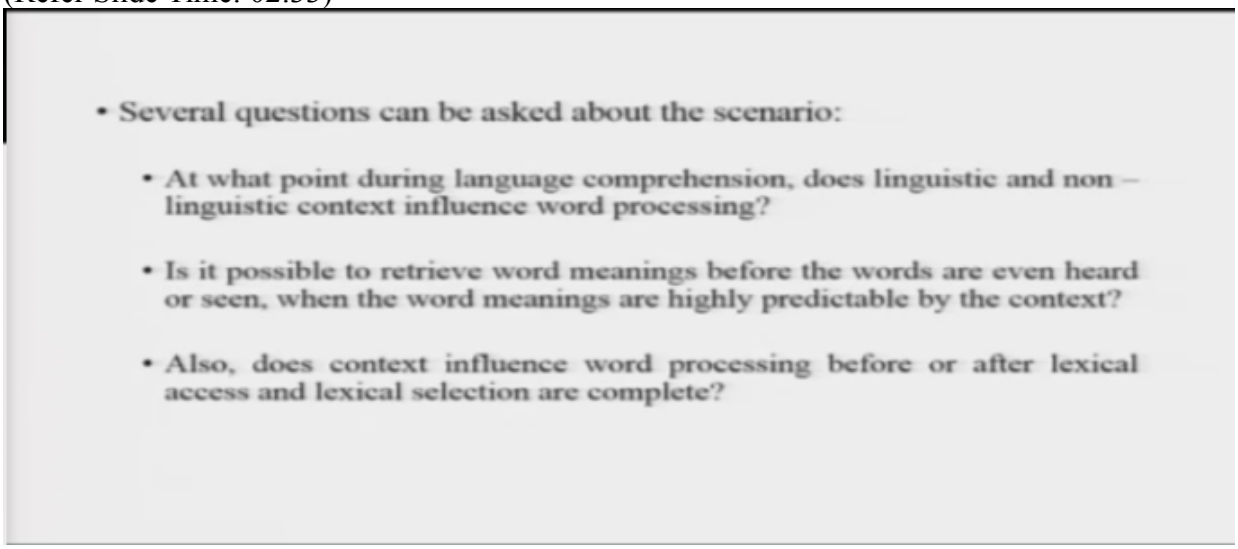

so some questions can actually have been, and some questions have been put up and can be asked about this particular scenario, and those questions are like for example at what point during language comprehension does linguistic and non-linguistic context influence word processing, what would be an example of non-linguistic concepts, suppose I have to you know say a particular word I can say that very happily, versus I can say that in a very sad way, you know, okay, in that sense, so is that is also part of the context, that's also part of how you will understand the meaning of the word, you know, we can say some very interesting complements in a very sarcastic way, so in order to understand that you have to understand the you know sarcasm which is non-linguistic property, okay, so that part.

Also a question can be that is it possible to retrieve word meanings before the words are even heard or seen, say for example when the words are highly predictable by the context, suppose there is a conversation going on, okay, and you know exactly what this person wants to say or what is going to say, so you kind of already made a judgment of that this is what he will say now, and even before the person is uttered at the word or moved his mouth in order to utter that word, you've not heard the word, but you've already predicted what is going to come in, so how is it that context almost helps you exactly know what is going to happen, okay.

Also say for example a third question and also very important question is that does context influence word processing before or after lexical access and lexical selection complete? Is contextual information taken into account during the lexical access process or during the lexical selection process or once everything is done you've come up with the meaning and then you are

trying to indicate with a context, you know, what is really going on here, with respect to how is context being used.

Now we've had some discussion about context earlier, you've talked about ambiguous words by you know, bias ambiguous words, balanced ambiguous words you know, you've talked about neutral context and biasing context so just keep that discussion in mind when we are moving further here.
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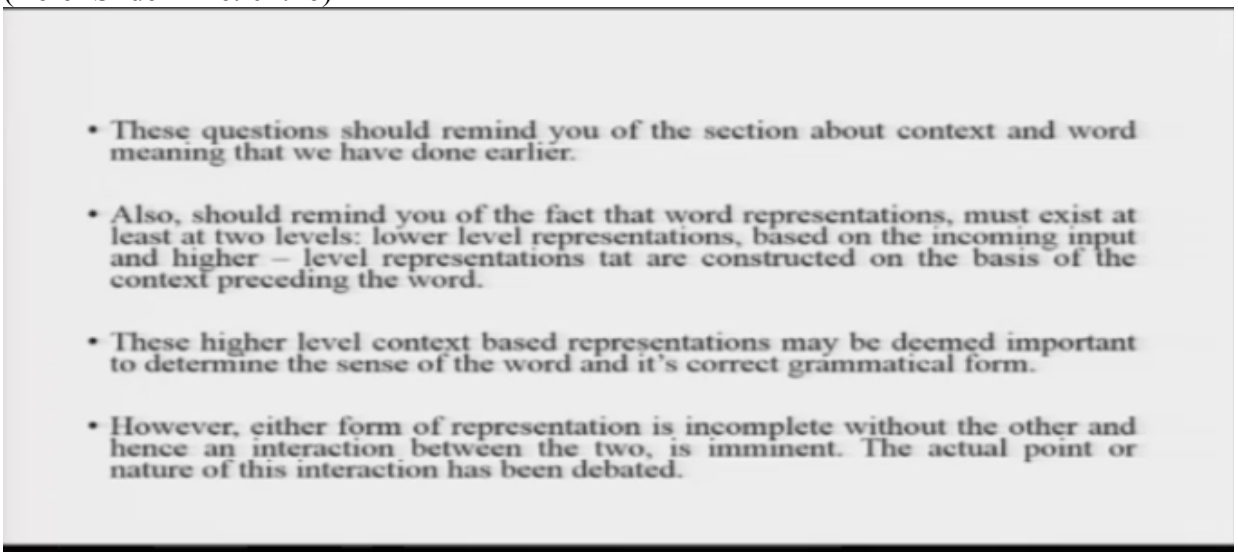

Now this questions, so that's what I was trying to saying, these is also sort of remind you that word representation, so one of the things that I will just add to that discussion is that word representations, and idea of what a word means, can we build up from 2 sources, one is the input level source, one is the lower level representations basically based on the form of the word you know how you're going to get to the meaning of that word, okay.

The other level is basically the higher level representation, broadly in terms of context, what is going to be said here, you know, or say for example you know I was giving you that example you know my friend planted a tree by the bank, financial institution or river, okay, so my friend planted a tree by the bank, now if you know me, if you know which friend I'm talking about or if you know say for example you know which city we are leaving in, if there are no rivers here versus if there are no banks here if you are leaving in a village, all of this will kind of you know, in some sense dictate how you understand the meaning of the word bank at the end of this utterance, or in order to really understand what bank meant, you have to take into account all of this context, all of this, the whole of this utterance, the knowledge about myself, my friend, the city we are leaving in, all of that, so this is the idea, so there will be, this will be the higher level representation, you know, B, A, N, K, and combining that and coming up to the lexical access part is the lower level representation.

Either form of representation is obviously incomplete without the other one, and the interaction between two is therefore very natural and is very eminent, that will happen at some point of time, information from both kinds of representation should converge, and help us to correctly understand a particular word, okay, so the actual point at what point this convergence or this interaction really happens is the one that is debated.

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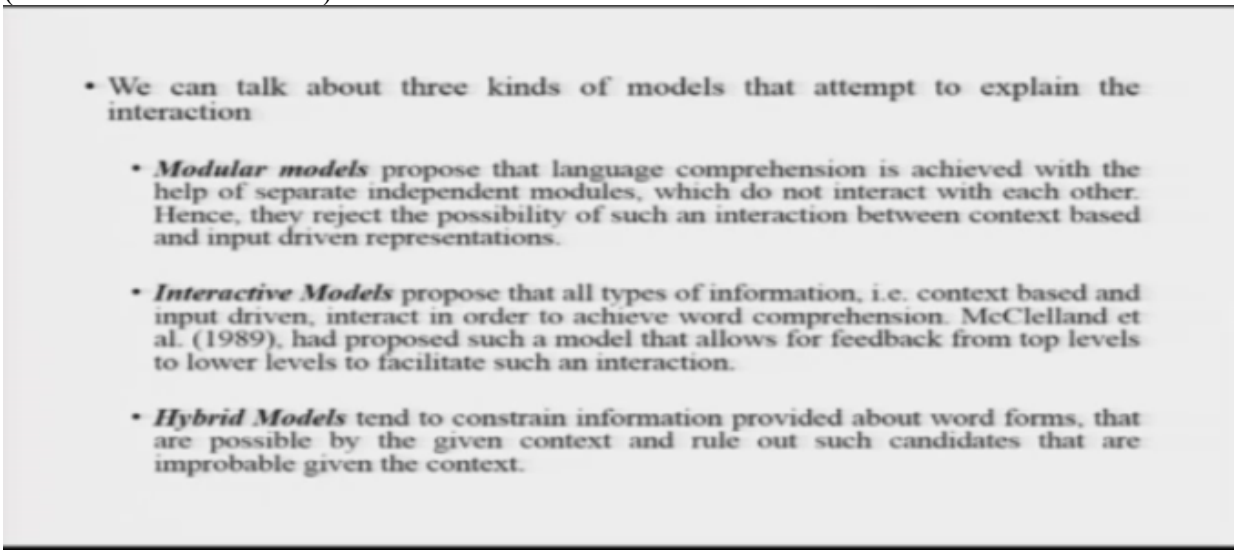

There are three kinds of models which talk about how this interaction might be happening, there are modular models, there are interactive models, and there is a hybrid model. The modular models basically you know borrowing from the modularity theory Jerry Fodor, basically proposes that language comprehension is basically achieved you know with the help of separate independent modules, and these modules do not interact with each other, so perception, comprehension, you know context or something else, so language comprehension does not, so language comprehension is achieved within the language module, and everything that is non-linguistic outside this particular module this will not be taken into account, so they reject the possibility of an interaction between context based, and input based representations, but we have talked about a fair number of studies where we see that this thing is taken into account, if you remember you know that particular sentence rumor had it that the government building had been plagued with problems, many you know the people found many roaches insects and bugs, other bugs in river, and when people representative words like ant and spine sky they really kind of, you know they took into account this information, so we know that this probably is not true.

The other kind of model that you can talk about is the interactive model, and the interactive model basically proposes that all types of information context based and input driven, interaction order to achieve the word comprehension, this is typically you know the trace model and those kind of things, so McClelland and colleagues had proposed such a model that allows for feedback between top levels from the word levels to the you know, letter levels at least and that interaction kind of you know is taking into account that thing.

And then you have the third kind of models, the hybrid models, the hybrid models typically tend to constraint information about word forms, so that are possible by the given context and we've rule out such candidates that are improbable given in the context, so hybrid was basically already narrow down on the possible candidates that will be activated, so they already said okay are we talking about cricket, we are in the cricket ground, we are all say for example in the kit, and then whenever the word bat is you know uttered you know exactly what is it that we are talking about, so these are the three kinds of models that have been there.

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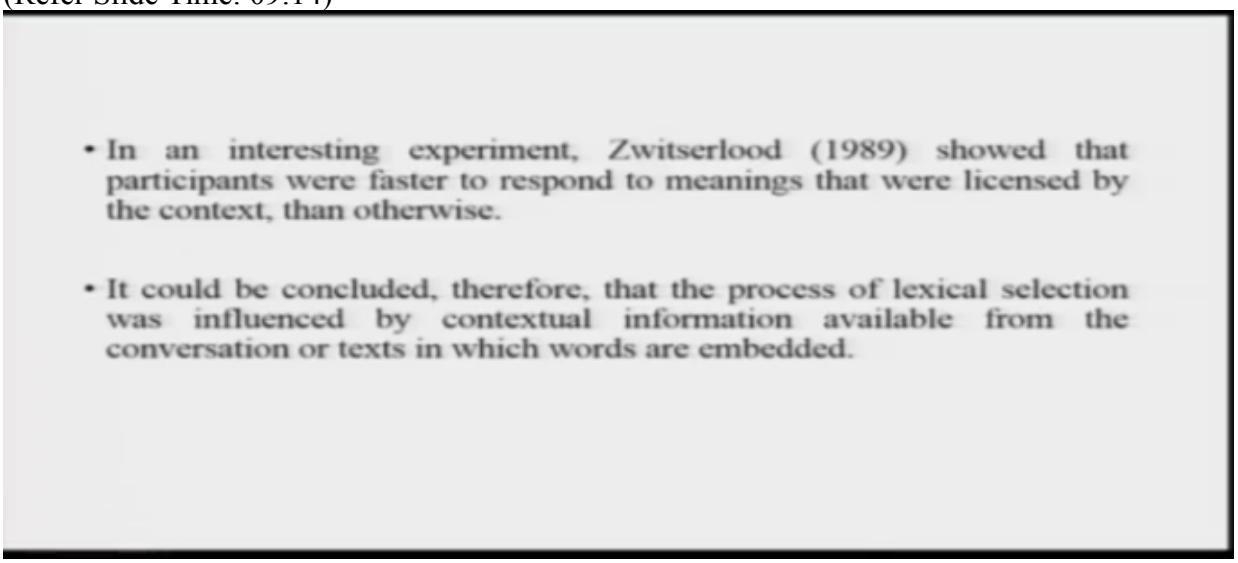

Now in a very interesting experiments this elude and colleagues we basically show that participants were actually faster to respond to meanings that were licensed by context, as opposed to meanings that are not licensed by context, so it kind of tells that okay in word meaning role of context is there, context is being considered, so the process of lexical selection therefore to be more specific is actually influenced by the contextual information available from the conversation or the text within which this particular word was embedded.

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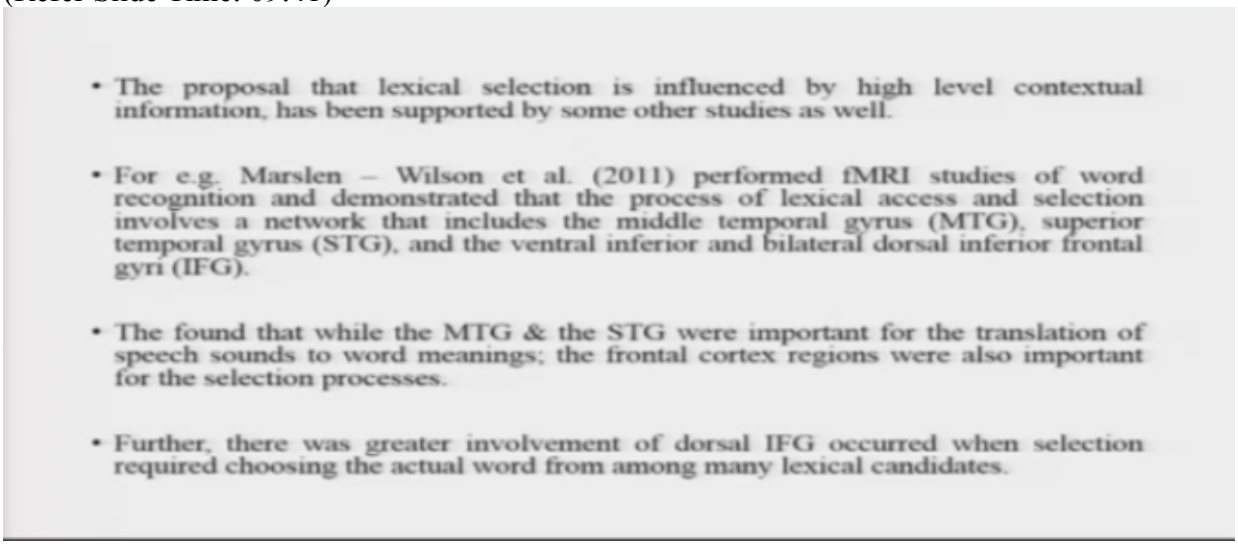

The proposal that lexical selection is influence by high level contextual information has also been supported by some of the other studies, for example Marslen Wilson and colleagues in 2011 performed FMRI studies of word recognition and they demonstrated the process of, demonstrated the fact the process of lexical access and selection actually involves a network that includes the middle temporal gyrus, superior temporal gyrus, and the ventral inferior and bilateral dorsal inferior frontal gyri, so these are the areas that were you know activated.

They found that the middle temporal gyrus and the superior temporal gyrus were actually important for the translation of speech sounds toward meanings, and the frontal cortex regions were also found important for this selection process, now you could remember the binders model, you can kind of go to the last lecture and see what areas I'm talking about.

Further they found that greater involvement of the dorsal inferior frontal gyrus basically occurred when selection required choosing the actual word from among many lexical candidates, so these could be the regions wherein context based information is kind of being factored in, we've respect to say for example selecting the exact word that is in question.

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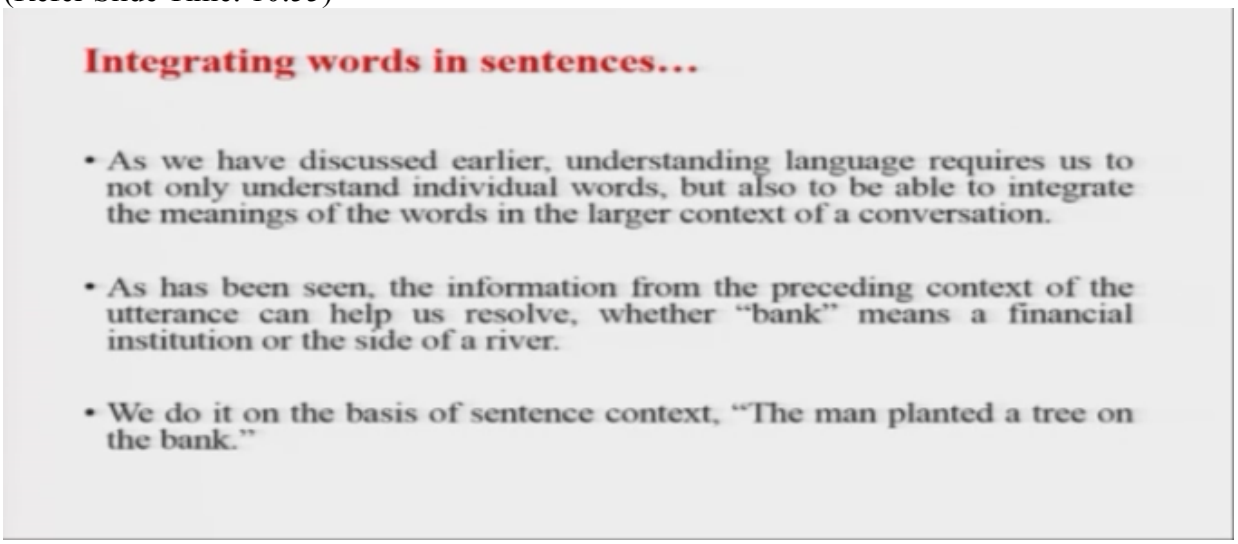

This was broadly about context in words, let us look at slightly more narrowed form which is basically, which has to basically do with integrating particular words in the sentence, where is the word uttered? It's uttered in the sentence, how you integrate the word with the sentence.

So as we have discussed earlier understanding language requires is not only to understand individual words, but also to be integrate the meanings of the words into a sentence, we've talked about this, we have talked about this example of you know bank being a financial institution of the side of the river, we talked about the sample as well, let's move further.

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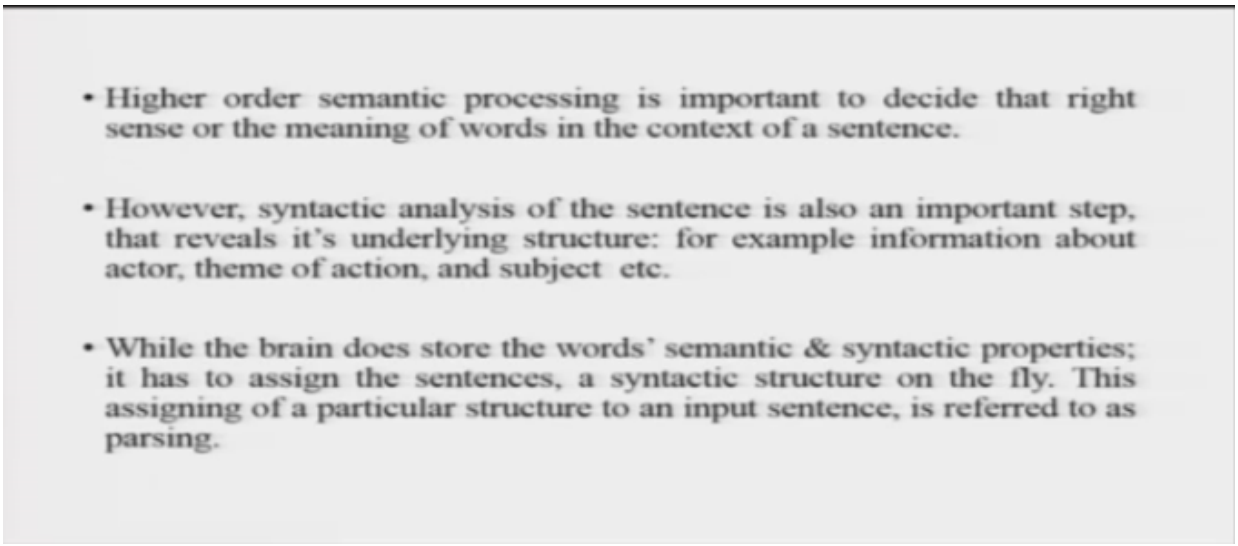

Now higher order semantic processing is basically important to decide the right sense or the meaning of the word is that you know, is in the context is there, syntactic analysis is also very important step, so not only at the level of semantics but whether the word is syntactically fitting there or not, is it syntactically structurally expected there or not, okay, this is also very important step and because syntax kind of gives you an idea of the underlying structure, it kind of gives you an idea about you know whether it is an actor or you know object or subject of the sentences or so on, so that part is there.

Now while the brain actually does store the words semantic and syntactic properties, let us say in the mental lexicon it has to assign the sentences the syntactic structure on the fly, you know how many sentences that we speak and hear every day, it's very difficult to store a structures specific to sentences, that's not what the brain does, it probably stores you know information relevant to the words, you've probably hardly know around 50,000 to 60,000, 70,000 words, so that maybe is easier to keep, but with sentences we know so many sentences, and the sentences even with the same words can be said in so many different ways, so what the brain would needs to do? It needs to compute those structures on the fly, on the go, okay, we've talked about the constraint based parsing models, we have talked about limb phrases, garden path theory, we've talked about good enough parsing, race-based parsing, contextual based parsing, we've talked about so many of these things, alright, so all of this is kind of you know somewhere being accomplished in the brain.

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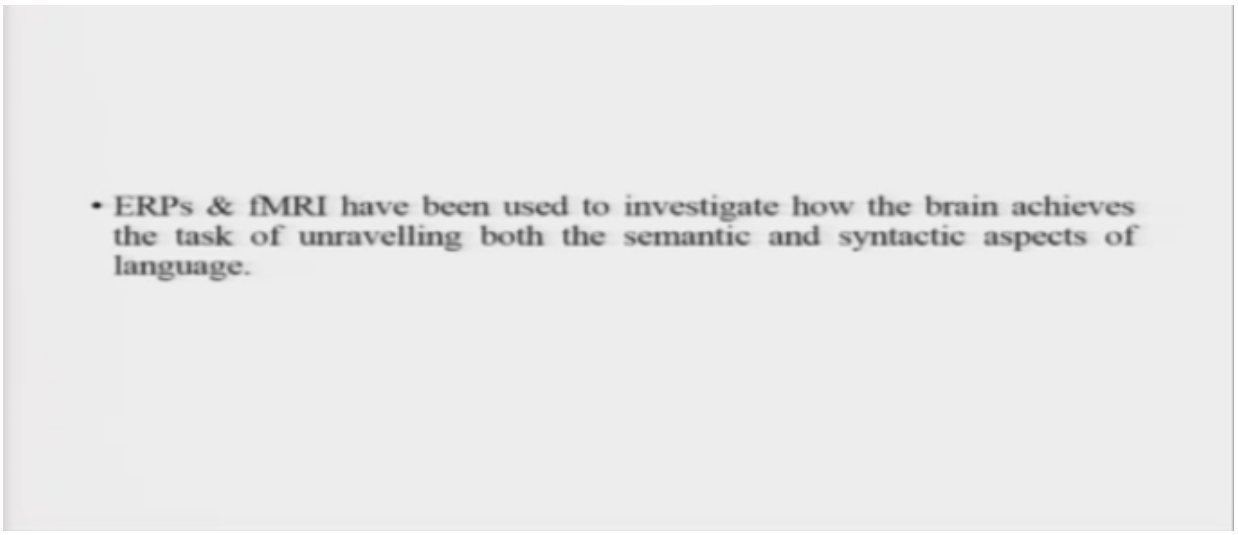

ERP's and fMRI's have been used, so ERP is the Event Related Potential, fMRI is Functional Magnetic Resonance Imaging, we know that these techniques have been looked, used to look in the brain while it's performing the task, and while it is unraveling both the syntactic and semantic aspects of sentences, so let us look at this a little bit more closely,

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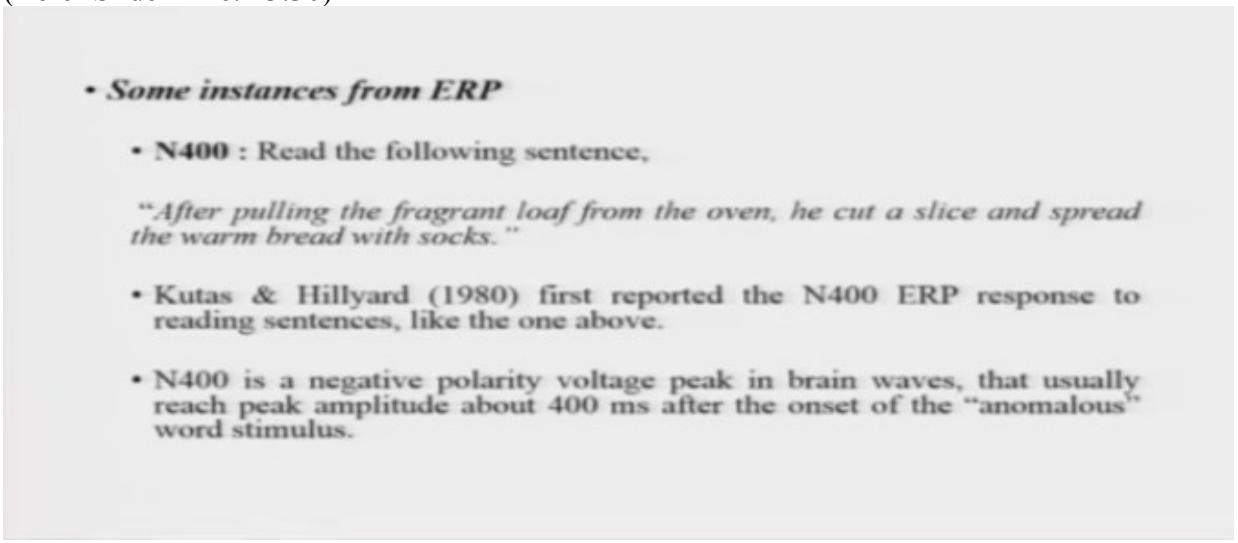

from ERP studies two particular components have come up which are very important in understanding how the brain is analyzing the structure, the first of those components is the N400 component, if you read the sentence after pulling the fragrant loaf from the oven, he cut a slice and spread the warm bread with socks, as soon as you read the word socks there is you know a negative potential forming in the brain at around 400 milliseconds which is the N400.

It was first reported by Kutas and Hillyard in 1980 who were the first to report this N400. N400 typically is a negative polarity, it's a voltage peak in the brain waves, usually reach peak amplitude about around 400 milliseconds after the, you know occurrence of the anomalous word, what is the anomalous word here? The word socks.

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- N400 has been reported to be sensitive to the semantic aspects of the linguistic input.
- It has been shown in various studies that N400 is specific to semantic anomalies, and does not get evoked in case of physical deviation or other nonsemantic deviations like musical or grammatical violations.
- Further, the N400 response has also been shown sensitive to comprehension of language that goes beyond single sentences; for instance, Berkum et al. (1999) showed that N400 could be elicited also in response to words that were inconsistent with the meaning of an entire story.

N400 has been reported to be sensitive to the semantic aspects of the linguistic, when the meaning anomaly is there then N400 figures up, it has been shown in various studies that N400 is specific to semantic anomalies and it does not get evoked, it's syntactic or physical deviation are there, or musical or grammatical deviation, it's only there for in case of semantic anomalies.

Also the N400 response has been shown sensitive to comprehension of language that even goes beyond single sentences, you know in broad structure whether the particular word is fitting in the broad structure, so this is you know in a sense of how this higher level representation is stabilizing or it's not stabilizing in that sense.

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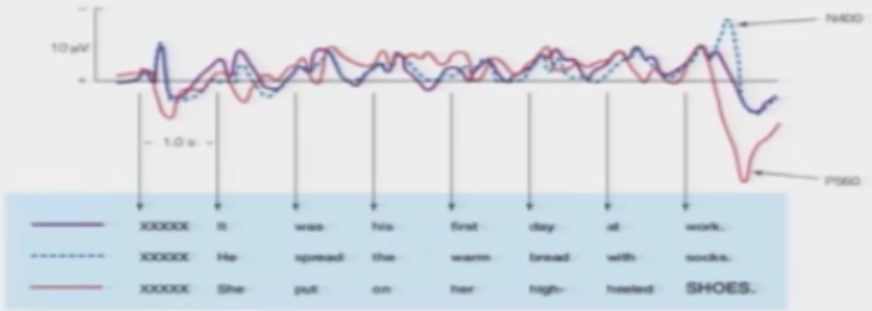

FIGURE 11.16 ERPs reflecting semantic aspects of language.
ERP waveforms differentiate between congruent words at the end of sentences (work in the first sentence) and anomalous last words that do not fit the semantic specifications of the preceding context (socks in the second sentence). The anomalous words elicit a large negative deflection (plotted upward) in the ERP called the N400. Words that fit into the context but are printed with a larger font (SHOES in the third sentence) elicit a positive wave (P560) and not the N400, indicating that the N400 is not generated simply by surprises at the end of the sentence.

Image: Gazzaniga, Ivry & Mangun (2014). Cognitive Neuroscience: The Biology of the Mind. Page. 491.

This is an example figure from Gazzaniga, you can see here this is the N400, okay, this is where the N400 is there, this negative peak at around 400 millisecond, okay, so he spread the warm bread with socks, that is where you are seeing that, it was his first day at work, he spread the warm bread at socks, as soon as socks happens, she put on her high heel shoes, so there you see there is no thing, you can see these sentences, so there are no N400 for the first and the third sentence, but there is a N400 at around the time day here socks with the dotted line.

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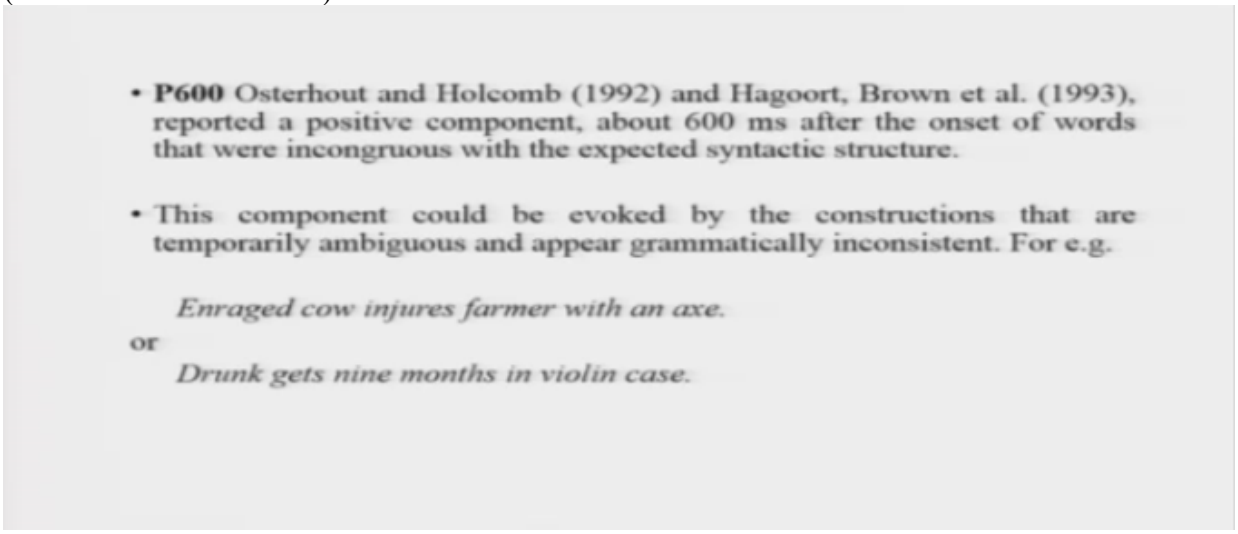

Now another ERP component that has been observed is P600, Osterhout and Holcomb and later Hagoort Brown and colleagues, they actually reported a positive ERP component around about 600 milliseconds after the onset of critical word, that were incongruous with the expected syntactic structure, so N400 was coming at semantic anomalies, P600 usually comes up with syntactic anomalies, if a word is placed there which is not licensed by the syntax of that particular language, so for example enraged cow injures farmer with an axe, okay, it's a temporarily ambiguous sentence or drunk gets 9 months in violin case, these kind of phrases, these words are grammatically inconsistent, because you don't exactly know what to make out of this, is the cow using with an axe as an instrument or the farmer is having with an axe, you need to remember all the parsing lectures, with an axe is the propositional phrase it could either get attached to farmer or it could get attached to enriched cow, if you attached it to enriched cow it leads to problem, you need to attach it to the second one to the injured, to the farmer, so this is why you can expect a P600 coming up right about here.

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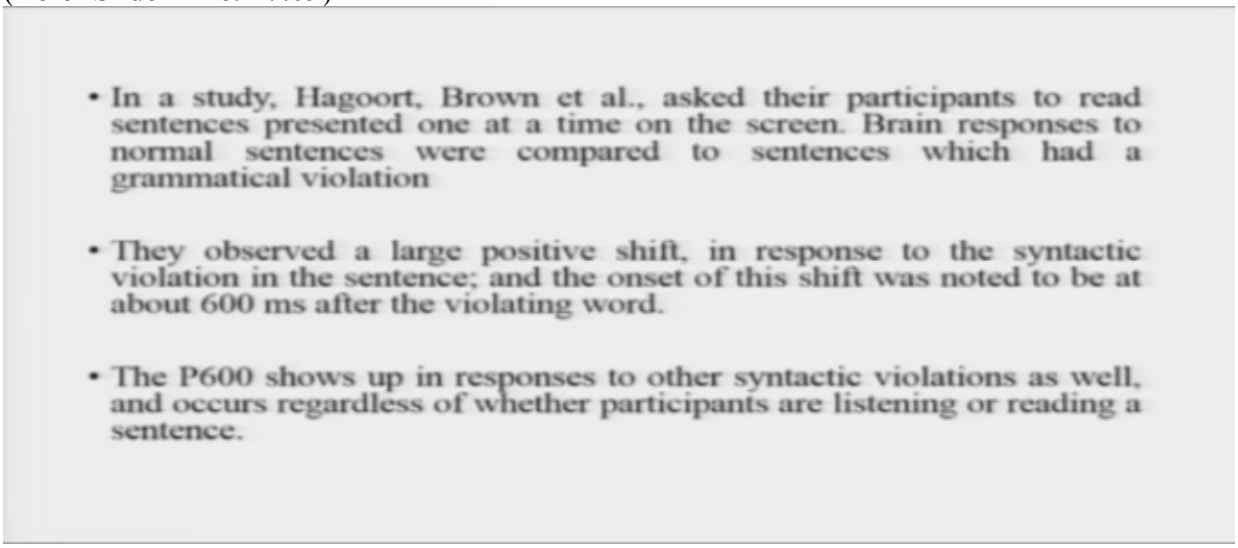

In a study that Hagoort Brown and colleagues did, they ask their participants to read the sentences presented one at a time on the screen and they measured the brain responses to normal sentences versus to sentences like the ones which we just read.

They observed a large positive shift especially which was responsive to the syntactic violation in the sentence, and the onset of this shift was to be, was observed to be around 600 milliseconds after the violating word, okay, so within axe around there you can observe this shift.

The P600 basically is shows up in responses to other kind of syntactic violations as well, and it occurs regardless of whether participants are listening or reading, so independent of modality.

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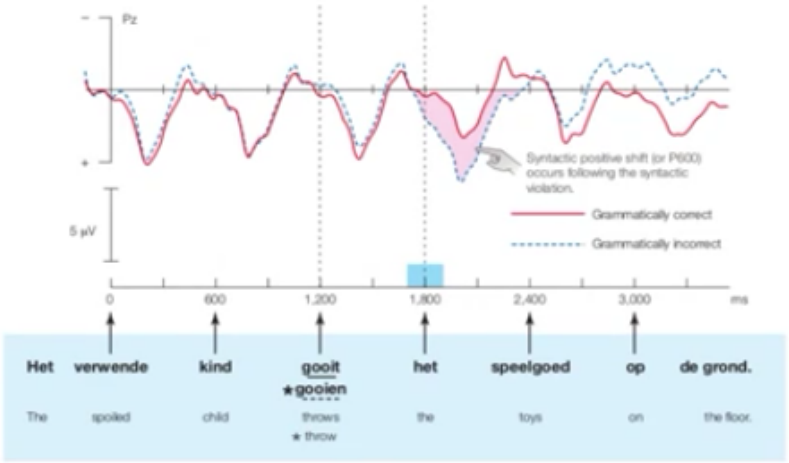

FIGURE 11.17 ERPs reflecting grammatical aspects of language.
ERPs from a parietal (Pz) scalp recording site elicited in response to each word of sentences that are syntactically anomalous (dashed waveform) versus those that are syntactically correct (solid waveform). In the violated sentence, a positive shift emerges in the ERP waveform at about 600 ms after the syntactic violation (shaded). It is called the syntactic positive shift (SPS), or P600.

Image: Gazzaniga, Ivry & Mangun (2014). Cognitive Neuroscience: The Biology of the Mind. Page. 492.

This is where you can see, there are two examples so one is in Dutch, and the other is translation, so het, verwende, kind, gooien or gooit, het, speelgoed, op, de grond, so this is Dutch, basically here the word that is being used is gooit, but gooien should be used, so gooien throws or throw, so the spoiled child throws the toys on the floor versus the spoil child throw the toys on that, so something that is not syntactically licensed will you know lead up to the P600, immediately after 600 milliseconds of that you see the P600 coming up, so this is happening, this words are coming at around 1200 milliseconds, you see that the P600 is kind of coming at around 1800 or little bit further than the 1800 milliseconds mark, so this is P600.

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- Syntactic processing of sentences is also found to be reflected in other ERP components as well.
- Munte et al. (1993) & Friederici et al. (1993), described a negative wave over the left frontal areas of the brain, termed the Left Anterior Negativity (LAN); which has been reported when words violate the required word category in a sentences (for e.g. "when red eats") or when the morphosyntactic features are violated (for e.g. "he mow").
- The LAN has almost similar latency as the N400 but a different voltage distribution over the scalp.

Now this syntactic processing or syntactic you know violations have also been reported to lead up to other kinds of components as well, say for example Munte and colleagues and Friederici and colleagues in 1993 described a negative wave over the left frontal areas of the brain and they termed this as a left anterior negativity, anterior because frontal and it's a negative peak which has been reported when words violate the required category, so noun is expected a verb comes in, that is where you can expect the LAN to come up, okay.

So the LAN has almost a similar latency as the N-400, but it has a different voltage distribution over the scalp, so this is also one of the things that has been observed,
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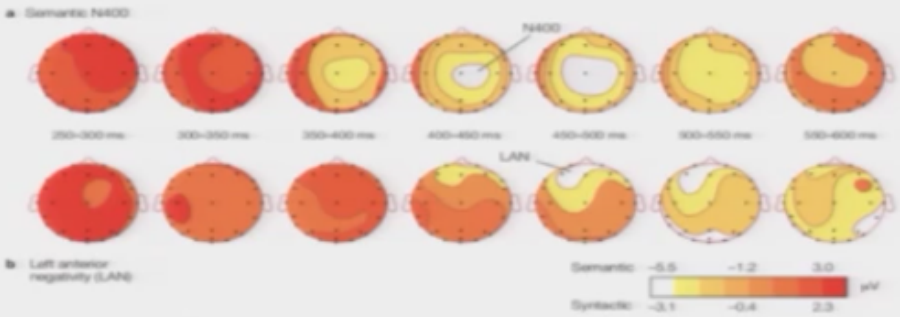

Image: Gazzaniga, Ivry & Mangun (2014). Cognitive Neuroscience: The Biology of the Mind. Page. 492.

here you can see say for example that the distribution of the N400 versus the distribution of the left anterior negativity, you can see the time is frame is around similar, so N400 is happening within N400 to 450 milliseconds, LAN is happening between 450 to 500 milliseconds, but you see that the geographical location, sorry, yeah the spatial location in the brain is slightly very different, so the distribution of LAN is more in the frontal areas, whereas the distributional of N400 is more in the temporal areas, where this is the top view of the brain, so this is the temporal area basically where this is there, and the temporal area more towards the left side.

Here you can see it's happening in the anterior area of the brain, okay, so that is where even though there are similar effects they are kind of indexing to different kinds of qualitatively different kinds of effects.

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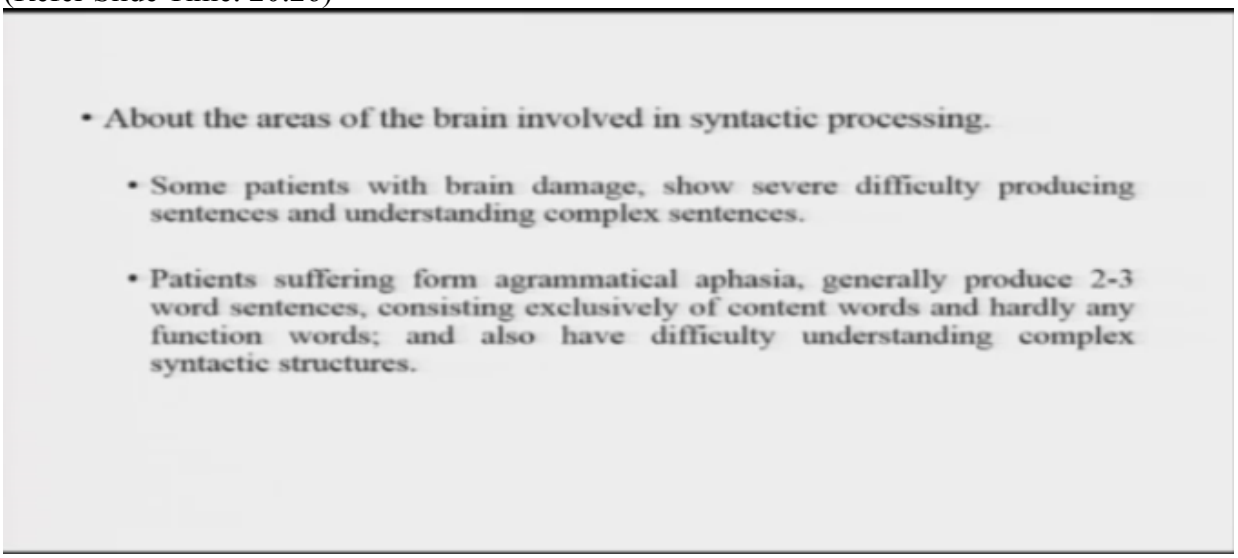

About the areas of the brain involved in syntactic processing, so some other kinds of research is also happened which kind of talks about the especially you know especially which areas of brain are there, so what has been shown is some patients with brain damage show severe difficulty in producing sentences and also understanding complex sentences, patients suffering from agrammatical aphasia, generally produce 2 to 3 word sentences consisting sometimes exclusively of content words now and so objectives, no propositions or articles and so on. And they also show have, you know, quite a lot of difficulty understanding complex syntactic structures.

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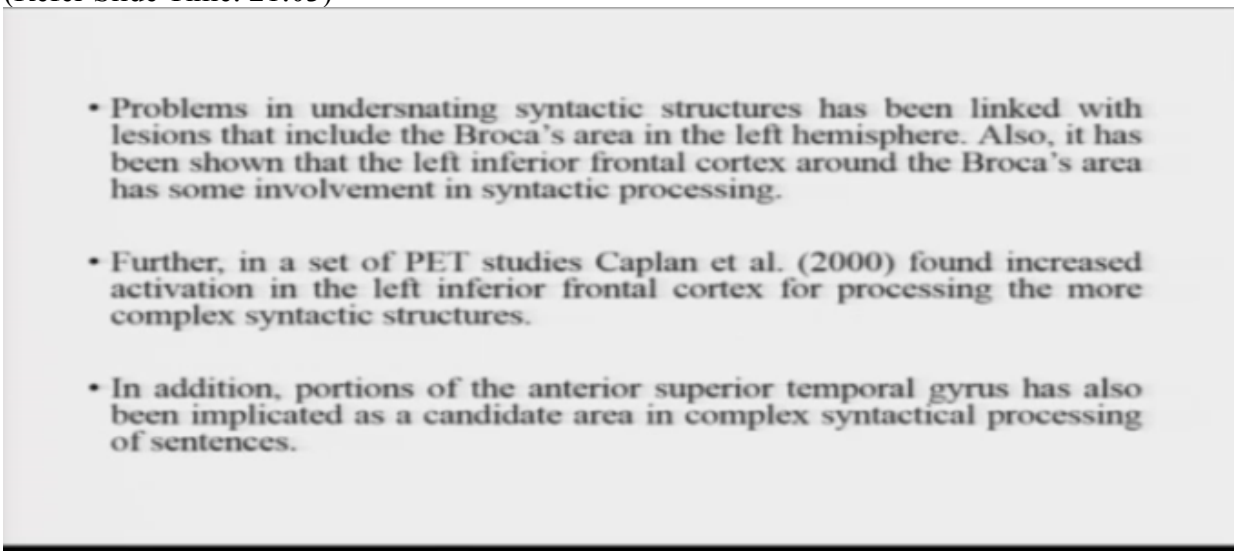

Problems in understanding syntactic structure has actually been linked to lesions that happen in the Broca's area in the left hemisphere, also it has been shown that the left inferior frontal

cortex around the Broca's area has more involvement in syntactic processing, so this syntactic processing is at fault both in production and comprehension, the Broca's area is usually implicated, so if I were to you know draw this for you,

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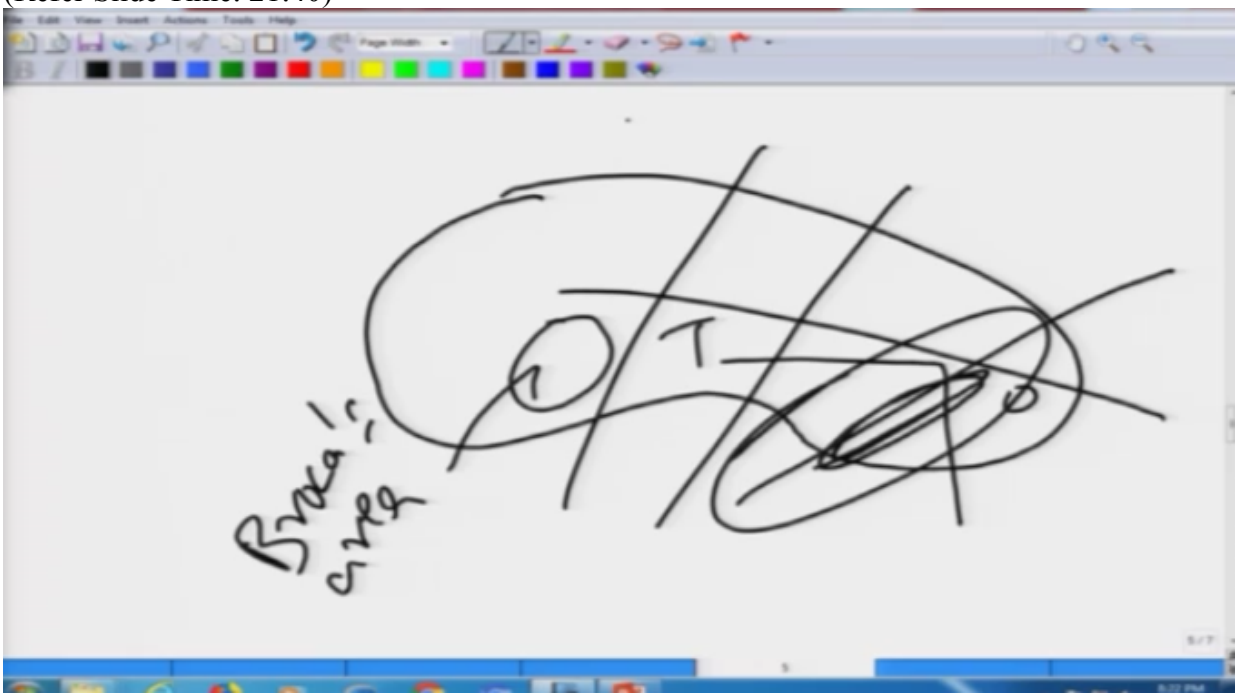

this is where the Broca's area would lie, this is where the Broca's area would lie, broadly I mean, why? Because this is anterior, this is in the frontal lobe, and this is inferior, I mean it's in the bottom and it's basically, yeah, so the inferior left usually happens with the left, so left inferior frontal lobe that's the Broca's area.

Further in a set of PET studies Caplan and colleagues have found out increase activation in the left inferior frontal cortex were processing complex syntactic structure, so this is the area which is also tags if you are reading a more complicated present activated signal, then those globally ambiguous garden part sentences, okay, while you know suggesting the baby plate on the floor those kind of things.

In addition portions of the anterior superior temporal gyrus, so superior temporal gyrus we've seen that in a figures earlier, and the interior part of it is also been implicated as a candidate area in complex syntactic processing, so this area is also kind of being involved.

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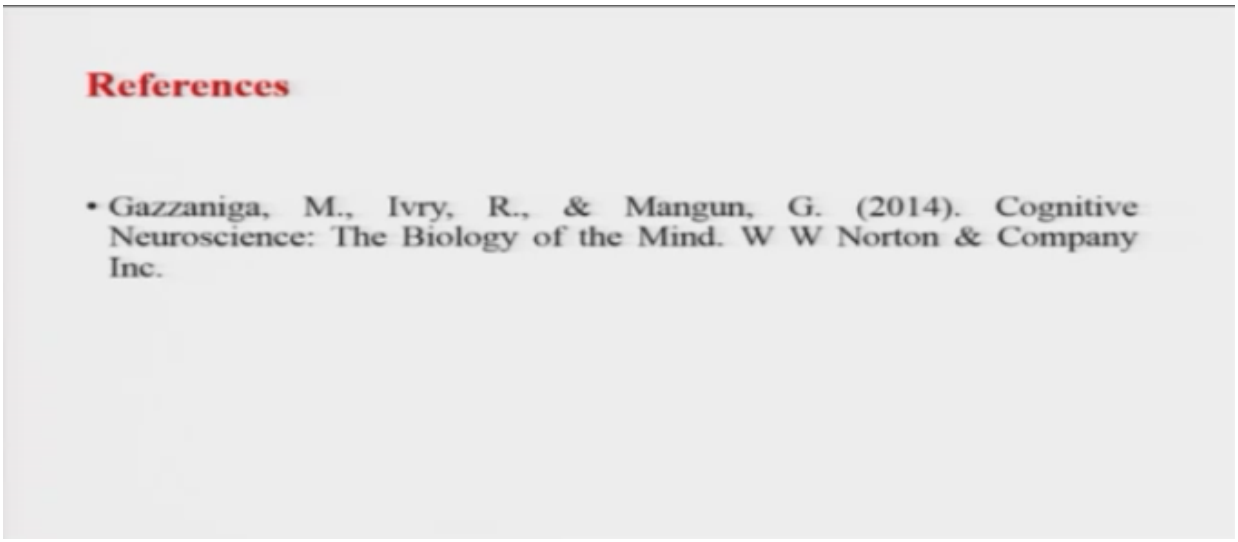

This is basically all about the syntactical processing and the areas that might be involved in syntactic processing. I'll talk to you about something else, some other neural basis in the next lecture. Thank you.

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