Introduction to Brain & Behaviour
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Week 7 Lecture 35: Neural Models of Language

Hello and welcome to the course introduction to Brain and Behaviour. I am Doctor Ark Verma from IIT Kanpur. This is the seventh week of the course and we are going to talk about Neural Models of Language.

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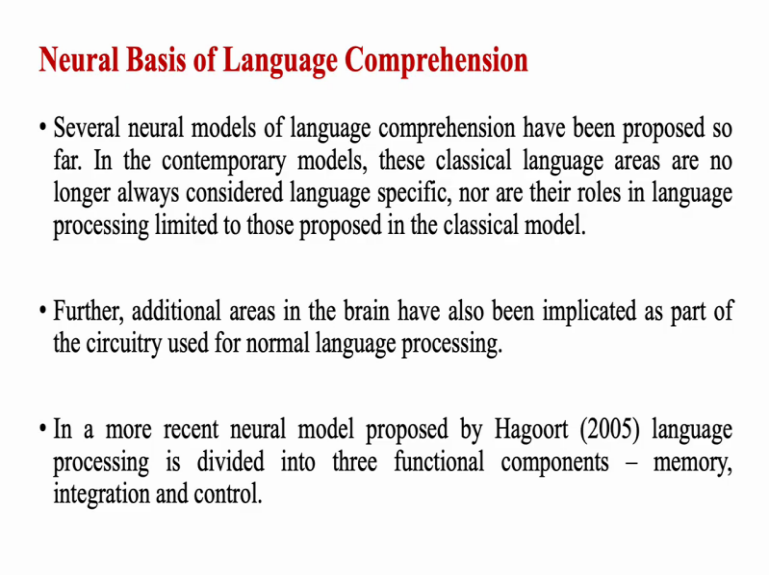

Now several neural models of language comprehension have been proposed so far. In the contemporary models, however that these these classical language areas are no longer always considered language specific, nor are their roles in language processing limited to those proposed in those in the earlier classical models. An example of a classical model would be (())(00:45) model of a language processing which in which you may remember that there was Broca's area, there was Werneck's area, and there is a conceptual area.

Basically all the three of them are connected and if (different) the pattern connectivity between these areas are ruptured, then different profiles of aphasia immerge. So but the difference is that in more contemporary models in as in understanding of neuroscientist have increased people are sort of the opinion that whatever areas have been have been included in the neural network of areas that understand and produce language, basically what happens is that none of these areas are exclusively dedicated to the linguistic processing. Or for that or for that matter none of these areas are doing only language processing.

They are probably doing involved in other parts as other activities as well. Further, additional areas have also been added and also been implicated as part of the circuitry that is used for normal language processing. Now in a more recent neural model that was proposed by Hagoort and colleagues in 2000 in 2005 language processing can be divided into 3 types of functional components, memory, integration and control. Let us look at them in some more detail.

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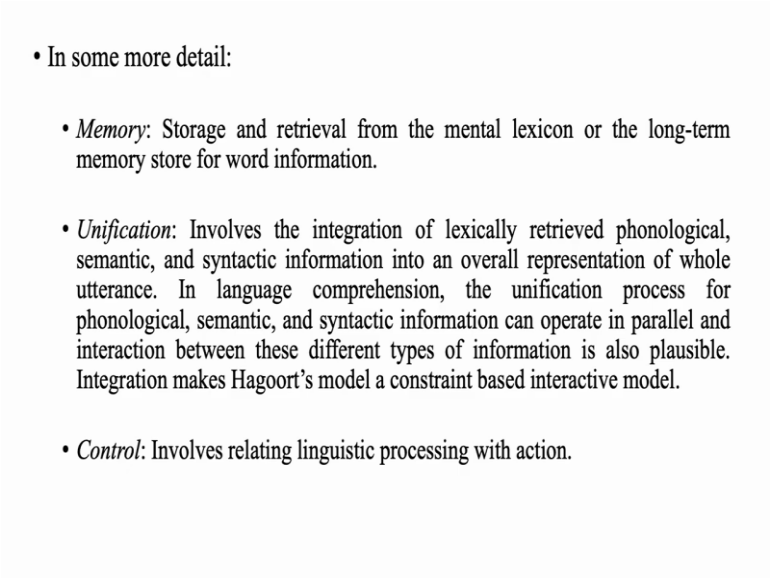

Now, memory or area or the asset of memory basically involves storage of information in the mental lexicon and retrieval of information from the mental lexicon basically the long-term basically the lexicon access make a long term memory store for word information. Unification, unification basically involves the integration of lexically retrieved phonological, semantic, and syntactic information into an overall representation of whole utterances.

In language comprehension, the unification process for phonological, semantic, and syntactic information can operate in parallel with each other and the interaction between these different types of information is also plausible. Integration makes Hagoort's model a constraint based interactive model. Now, control basically deals with the aspect when you know linguistic processing is combined with an action. Say for example, if you are a bilingual, you have to choose between two kinds of language acts.

Language act producing of act of producing language in your first language versus act of producing language in your second language basically and also switching between the two languages as and when the need arises. So, all three of these processes together are seen to form whatever the entire language network is supposed to do and there will be areas of the

brain that will be performing these different tasks, in a sort of an inter-connected manner. Let us see this in some detail.

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- As per this model, the temporal lobes are implicated as being important for storage and retrieval of mental representations of words.
- The phonological and phonetic properties of words are supposed to be stored in the central to posterior superior temporal gyrus (STG) extending to the superior temporal sulcus (STS), and semantic information is distributed over different parts of the left, middle and inferior temporal gyri.
- The processes that are involved in integrating phonological, lexical-semantic, and syntactic information are supposed to engage frontal areas of the brain, including Broca's area or the left inferior frontal gyrus (LIFG).
- The LIFG seems to be involved in three kinds of integrative processes: semantic unification in Brodmann's area 47 and BA45, syntactic unification in BA45 and BA44, and phonological unification in BA44 and BA 46.

Now, as per this model, the temporal lobes are implicated as being important for storage and retrieval for mental representation of words. The (phono) mental representation of words. The phonological and phonetic properties of words are supposed to be stored in the central to posterior superior temporal gyrus extending up to the superior temporal sulcus, and the semantic information is distributed is supposed to be distributed over different parts of the left, middle and inferior frontal gyri. Inferior temporal gyri sorry.

Now, the processes that are involved in integration of phonological, lexical lexical semantic, and syntactic information are supposed to engage the frontal areas of the brain, including Broca's area or the left inferior frontal gyrus. This left inferior frontal gyrus also seems to be involved in three kinds of integrative processes first is semantic unification in Brodmann's area 47 and 45, syntactic unification in areas 45 and 44, and phonological and phonological unification in Brodmann's area 44 and 46.

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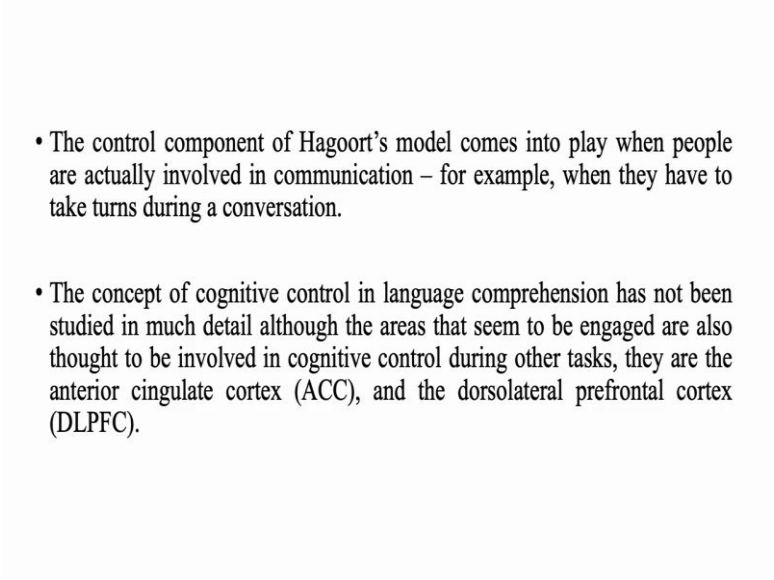

The control component of Hagoort's model involves model basically comes into play when people are actually involved in communication. For example, when they have to take turns during a conversation. There is where the control part also comes into place. Now the concept of cognitive control in language comprehension has not been studied in much detail although the areas that seem to be engaged are also thought to be involved in cognitive control during other tasks.

Say for example, the same areas of the brain that are involved in bold task scenarios might also be involved in you know in situations where two languages have to be used inter-changingly. They are the anterior cingulate cortex, and the dorsolateral prefrontal cortex. So, these are the areas that are probably that are assigned the task of control.

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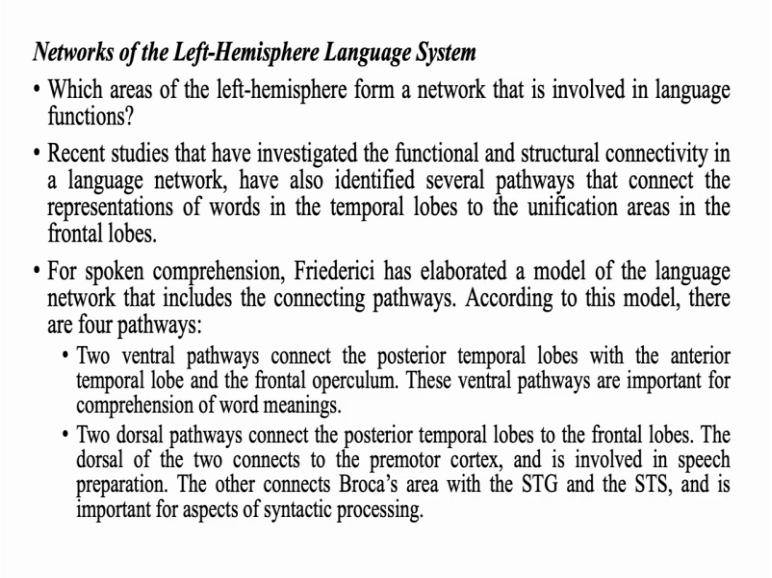

Now, let us look at the network of the Left-Hemisphere Language System in a in bit more detail. Which you can ask which areas of the left-hemisphere form a network that is involved in language functions? Now, recent studies have shown and they have investigated the functional and structural connectivity in the language network, have identified several pathways that connect the representation of words in the temporal lobes to the unification areas in the frontal lobes.

Say for example, for spoken comprehension, Friederici has elaborated a model of language network that includes the connecting pathways. According to this model, there are four kinds of pathways. There are two ventral pathways which connect the posterior part of the temporal lobes to the anterior temporal lobe and the frontal operculum. These ventral pathways are important for comprehension of word meanings.

The two dorsal pathways connect the posterior temporal lobes to the frontal lobes and the dorsal of the two and between them dorsal of the two connects, directly to the premotor cortex, and is involved in speech preparation. The other connects the Broca's area with the superior temporal gyrus and the superior temporal sulcus and is involved aspects of syntactic processing.

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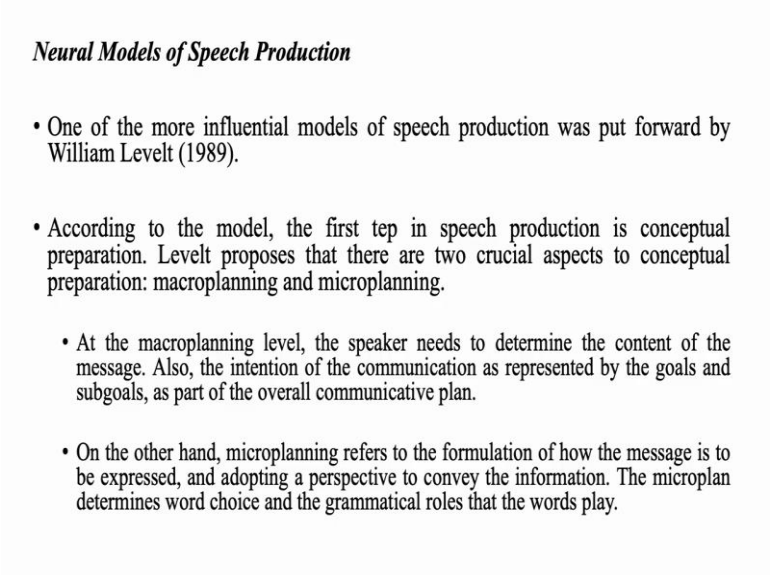

Let us talk a little bit about Neural Models of Speech Production. Now one of the more influential models of speech production was put forward by William Levelt in 1989. According to this model, the first step in speech production is conceptual preparation. Okay? Levelt proposes that there are two crucial aspects of conceptual preparation one is macro planning and other is microplanning. At the level of macro planning, the speaker needs to determine the content of the message.

What do I want to say? Suppose I have to you know present a weather report, what do I know about the weather, what is the weather now, and so on. You know nowadays lot of people are are making video blogs. And another things that they need to decide probably before starting the blog is to think about what broadly they want to talk about in there video blog. Okay? At here the intention of the communication as presented by goals and sub goals is becomes part of this overall communicative plan. That is the macro level.

On the other hand, at the micro planning level basically one needs to formulate how how the message is to be expressed, adopting a particular kind of perspective to convey the information. Okay? So you are suppose you want to present the weather as nice or you just not you know you are not liking the weather and you want to put the criticize the assets of the weather. The microplan would determine the word choice which words are used and the grammatical role and how will you use them? Past tense, present tense, continues tense, how?

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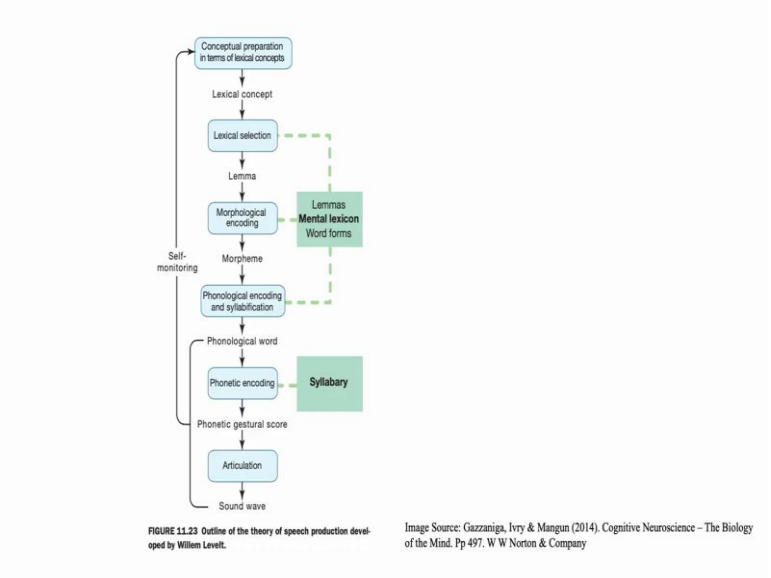

FIGURE 11.23 Outline of the theory of speech production developed by Willem Levelt.

Image Source: Gazzaniga, Ivry & Mangun (2014). Cognitive Neuroscience – The Biology of the Mind. Pp 497. W W Norton & Company

So, this is here you can say William Levelt's model. So it starts at the level of conceptual preparation, in terms of lexical concept. The idea is basically lexical concept are concepts for which your language has a word. So for example, if you want to talk about a female elephant, English does not really have a specific word for female elephant. So, it will basically use female and elephant but it has a word for a female horse, so there it will use the word a horse, it will use the word mare. So, mare is the is the word that depicts a female horse.

So, basically the conceptual preparation will happen it will align all the lexical concepts. Basically whatever I wanted to say and do I have the words for it or not and these words are lexical concepts. Because several lexical concepts can be activated simultaneously, there is a need for something called lexical selection. Once you have selected the correct word then you go to what is called a lemma level. And a lemma level is where, again it is a hypothetical level which basically contains information about the syntactical and semantic aspect of the selected word. Okay?

Once you have the lemma level, say for example, you have decided that I am going to talk about the word eat and I am going to talk about it in continuous tense, then eating is the word that needs to be selected. Going further what will happen is, morphological encoding will happen. And morphological encoding is nothing, it is basically activating the morphemes of a language, so I want to talk about the word concept eat, I want to talk about it in continuous sense, so the word that suits it is eating.

Eating is composed of two morphemes one is eat, which is a free morpheme, a lexical morpheme and the other is ing, which is basically a bound grammatical morpheme, that has

to function with the word eat. So, this is called morphological encoding. From here you kind of come to the identification of the two separate morphemes. Once you have identified the morphemes then basically what you will do is you will engage with phonological encoding basically activating the sounds that we compose those morphemes.

Once you have activated the sounds, say for example eat, then basically you will have to syllabify them. You will have to arrange them in articulatable chunks, which are you know sort of (weight) which are basically in forms of syllables. So, eating basically has two syllables E and ting. Okay? So, even though the morphing morphological composition is eat plus ing the syllabic composition is E and ting. Okay? So, you have to you kind of have to become aware of that.

Once you have activated the syllables and you have organised them nicely, what forms or what comes out is the phonological word, which is basically what you hear. So, here you can see from the aspect of phonological word you can see that there is this self-monitoring because from here itself you can hear almost yourself speak the word. Once the phonological word is prepared then you can move on to phonetic encoding, which is basically moving your articulators, etcetera.

Preparing them that okay this is how this is what has to be produced, and the programs for articulating each of these words have to be put in order. That is basically what is a phonetic gestural score, which is a program for executing the word. Finally you do the articulation. You create the sound wave which again you can hear. So this is just a brief description of Levelt's model of speech production.

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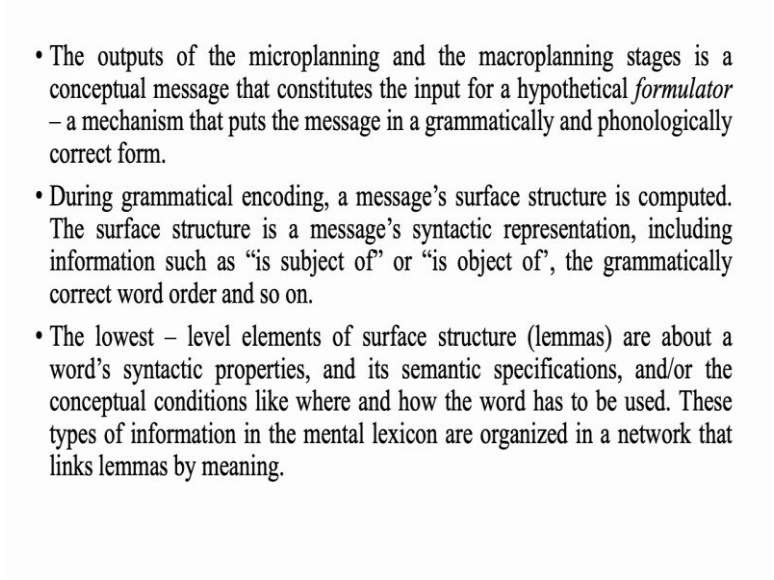

So, let us just go and visit it in some detail. Now the outputs of the macro planning and the micro planning stages is a conceptual message that constitutes the input for a hypothetical formulator which is a mechanism that puts the message in a grammatically and phonologically correct form. During the grammatical encoding, a message's surface structure is computed.

The surface structure is basically the message or the gist of the this you know syntactic representation, including information such like X is a subject of or Y is an object of', and that needs to be very well specified in the by the use of the grammatical word order and so on. The lowest level elements of this surface structure that is the lemmas which are these words are about a word's syntactic properties, and its semantic specifications. And also the conceptual conditions like where and how the word has to be used.

You know I was talking about the word eating, where do you want to use the word? Eating is doing something. So the first it cannot start you know start with a word eating. So, John likes eating. Maybe that is that makes more sense. So, all of these details need to be really worked out. Now, these types of information in the mental lexicon are organized in a network that link lemmas by meaning. So, what each of these lemmas mean, how are they used etcetera, can be organised in the mental lexicon itself.

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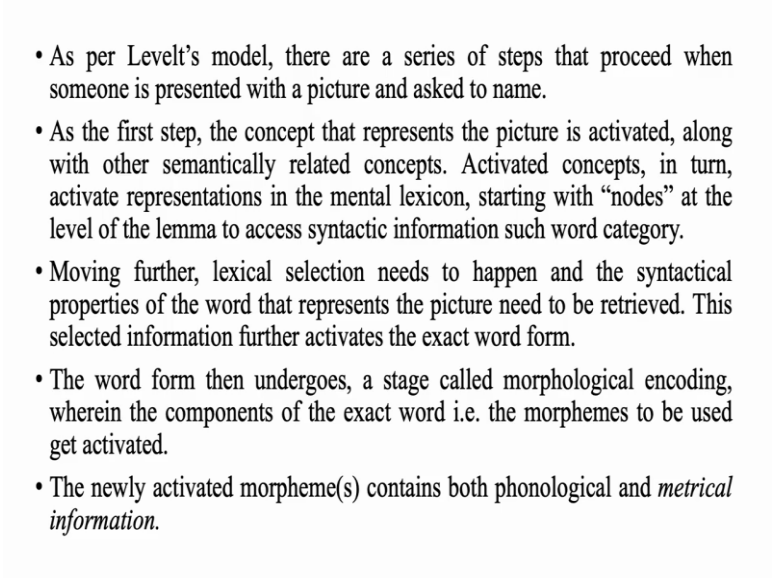

As per Levelt's model, as you have seen, there are a series of steps that proceed when someone is presented with a picture and asked to name. As a first step, the concept I have just, I have already explained to you while the picture was there, but I will just kind of going through this. Okay? As the first step, the concept that represents the picture is activated, along with other semantically related concepts.

Activated concepts, in turn activate representations in the mental lexicon, starting with nodes at the level of the lemma to access syntactic information such as word category. Moving further, lexical selection needs to happen and the syntactical properties of the word that represents the picture need to be retrieved. So, you know what is the picture that you have seen.

If you have seeing a picture of a verb, let us say something is cutting something, then you have to remember that okay this syntactic information is that this is a verb. It is a continuous form of the word and so on. The word form then goes through a stage called morphological encoding, wherein the components of the words the exact words the morphemes need to get activated. The newly activated morphemes contain both phonological and metrical information. Basically how it has been said.

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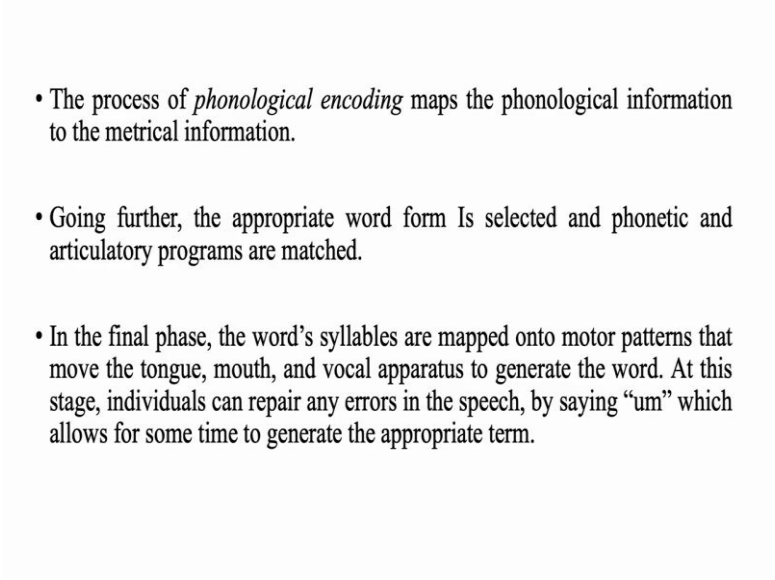

Then, broadly we are going to the process of phonological encoding which maps the phonological information to the metrical information just like syllabification. Going further, the appropriate word form is selected and the phonetic and articulated programs are matched and then you are ready to produce. In the final phase, the word's syllables are mapped onto motor patterns, how that articulation will be done.

And that move the tongue, mouth, and vocal apparatus to the to generate the word. At this stage, individuals can repair any errors in the speech, by saying "um". Maybe I am saying this incorrectly let me correct this and reattempt this one. Okay? So this sort of allows them to regenerate the appropriate term.

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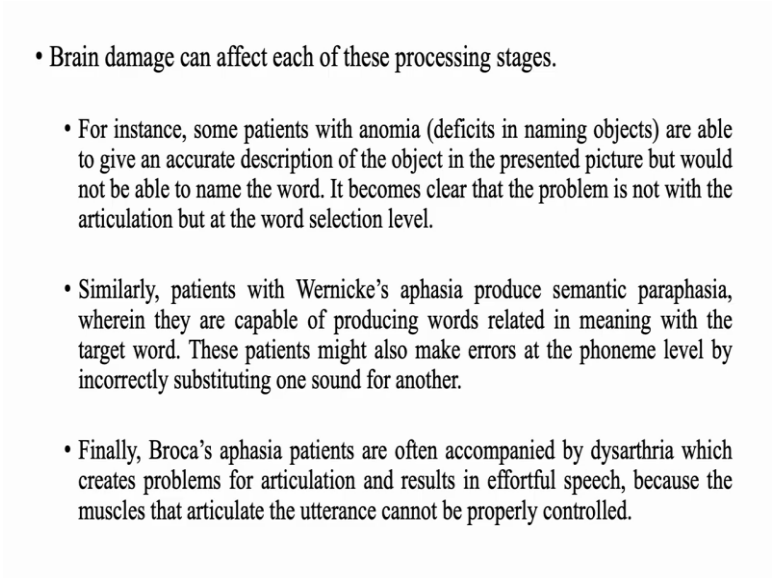

Now, brain damage can actually affect each of these processing stages. For instance, some patients who suffer with the disease called anomia have deficits in naming objects. They are able to give accurate descriptions of the object in the present picture, but would not be able to name the word. It becomes clear that the problem is not with the articulation, but at the word level. Similarly, patients with Wernicke's aphasia produce semantic paraphasia, as we have talked earlier, wherein they are capable of producing words related in meaning with the target word but not the target.

These patients also make errors at the phoneme level by incorrect incorrectly substituting one sound for another. Finally, Broca's aphasia patients are often accompanied by problems like dysarthria, where it creates problems in articulation and results in effortful speech, because the muscles that articulate the utterance cannot really be properly controlled.

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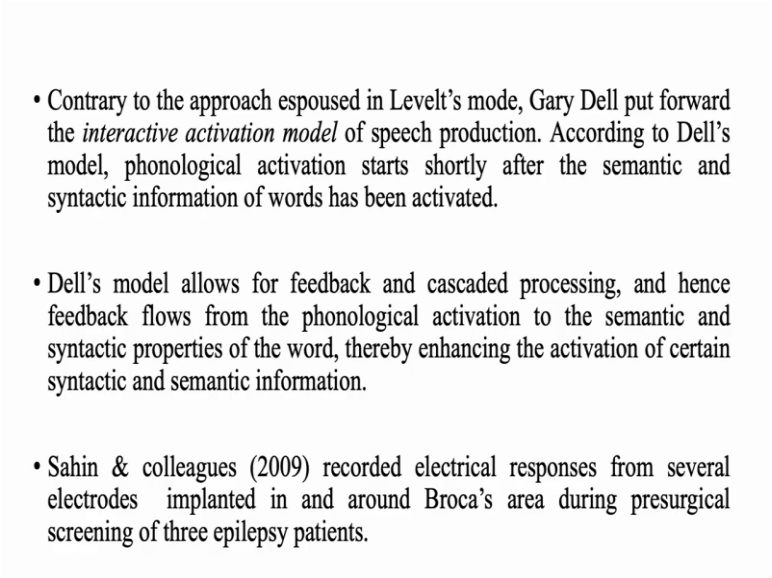

Now, contrary to the approach espoused in Levelt's mode, Gary Dell put forward the interactive activation model of speech production. According to Dell's model, phonological activation starts shortly after the semantic and syntactic information of word of words has been activated.

Dell's model allows for feedback and cascaded processing, and hence basically what happens in this model is that feedback flows from the phonological activation to the semantic properties of word, thereby enhancing the activation of the certain target words. Sahin and colleagues in 2009 recorded electrical responses from several electrodes implanted in and around the Broca's area, during presurgical screening of three epilepsy patients.

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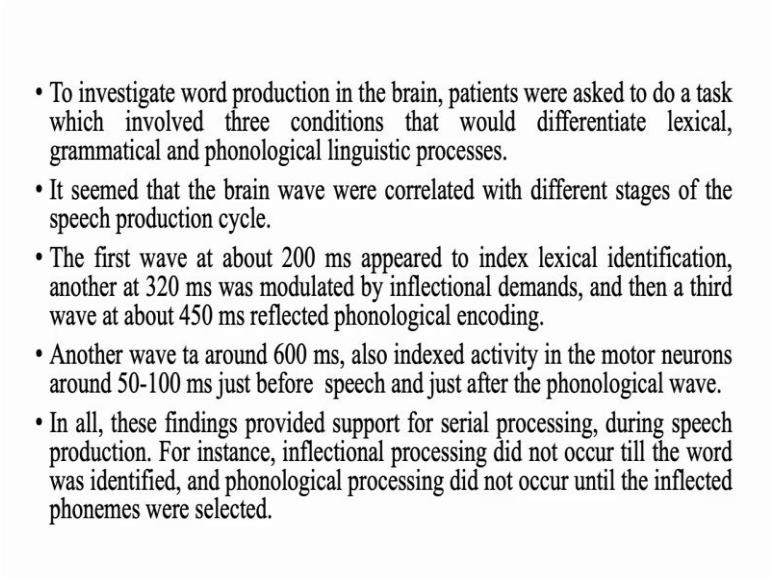

To investigate word production in the brain, these patients were asked to do a task which involved three conditions that would differentiate lexical, grammatical and phonological linguistic issues, linguistic processes. It seemed that the brain waves were correlated with different stages of the speech production cycle. At the first, the first wave accord at about 200 milliseconds, it appeared to index lexical identification. Another wave came up at 320 milliseconds and was modulated by inflectional demands.

And the third wave at around 450 milliseconds basically reflected phonological encoding. So, basically what we can see here is that as per levels stages of memory, this probably is happening in serial. So, at 200 milliseconds lexical identification, then inflectional demands lemma level at 320. 450 milliseconds you can see phonological encoding changes. Another wave happens at around 600 milliseconds, which basically indexes the activity of motor neurons. So now you are already in the articulation phase.

So, in all, basically you can see that these findings actually provide support for serial processing, during speech production. So, the evidence probably lies more in favour of Levelt's model. Now for instance, inflectional processing is not occurring you know till the word was identified. So it is not preceding the lexical identification phase, but is happening after it. And phonological processing is not occurring until the inflected phonemes were selected. So, you can see that there is a degree of serial processing involved here.

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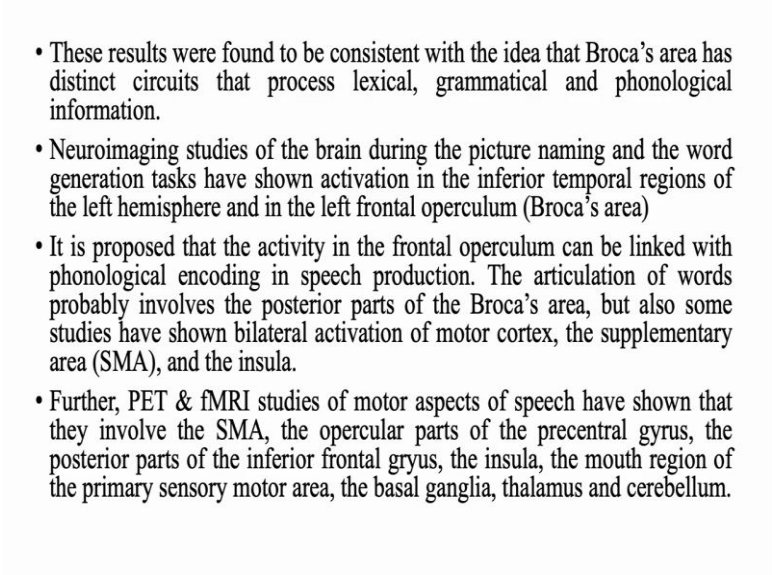

Now, these results were found to be consistent with the idea that the Broca's area has distinct circuits that process lexical, grammatical and phonological information. Neuroimaging studies of the brain during picture naming and the word generation tasks have shown that activation in the inferior temporal regions of the left hemisphere and in the left frontal operculum. So basically picture naming in was these areas.

It has been proposed that the activity in the frontal operculum can be linked with phonological encoding in speech production. The articulation of words probably involves the posterior parts of the Broca's area, but also some studies have shown bilateral activation of the motor cortex, the supplementary motor area and the insula.

Further, PET & fMRI studies of motor aspects of speech have shown that they involve the supplementary area, the opercular parts of the precentral gyrus, the posterior parts of the inferior frontal gyrus, the insula, the mouth region of the primary sensory motor area, the basal ganglia, and the cerebellum. So, you can see that the entire gambit of areas that are involved in motor processing in general, are also involved in speech production.

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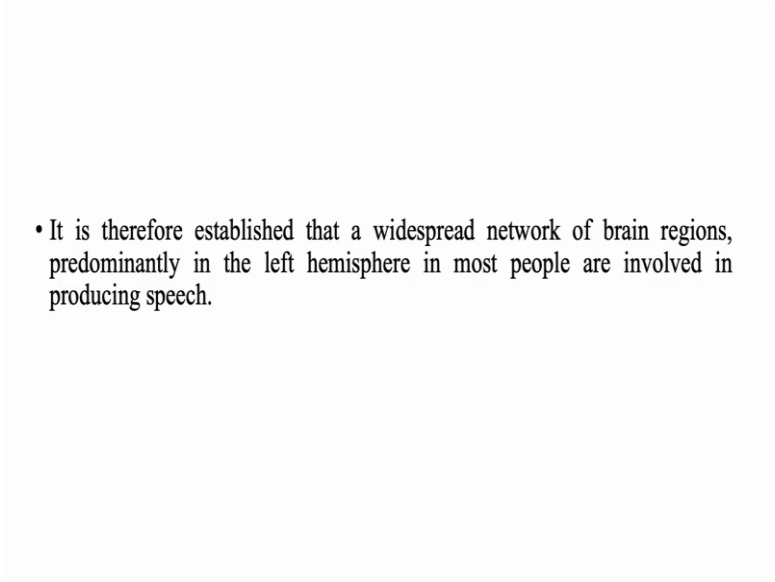

It is therefore established if you look at this in a wholistic sense that it is a widespread network of brain regions, predominantly allocated in the left hemisphere is basically what is involved in most people for production of speech. This is the last lecture of 7thweek. I hope that you have understood neural aspects of language processing in this week. I will meet you next week with another chapter. Thank you.

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