Introduction to Brain & Behaviour
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Week 7 Lecture 32: Language in the Human Brain

Hello and welcome to the course, Introduction to Brain and Behaviour. I am Doctor Ark Verma from IIT Kanpur, and this is the week 7 of the course. We are going to talk about the language in Human Brain.

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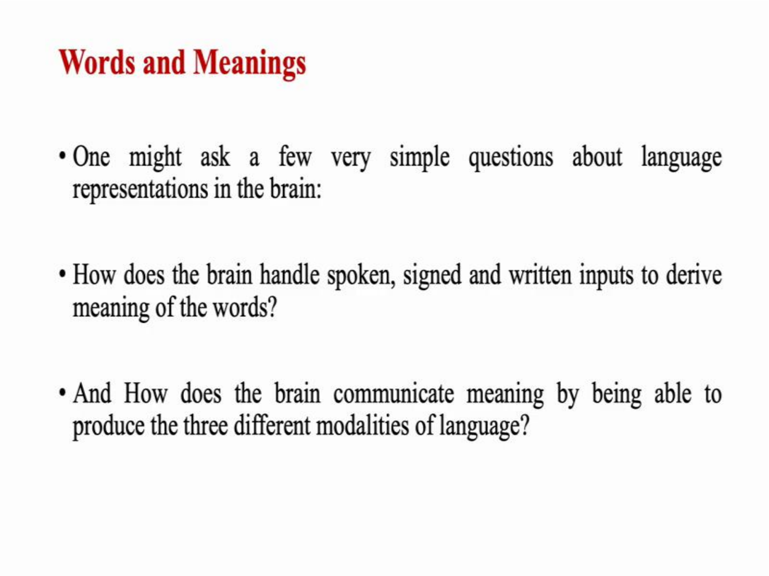

Now one might ask a very few simple questions about languages in or the representation of language in the brain. Say for example, how does the how does the brain handle spoken, signed and written inputs to derive the meaning of words? Also for example, how does the brain communicate by meaning by being able to produce the three different modalities of language? A simple concept that has been useful in understanding the representation of language in the human brain is that of the mental lexicon.

A mental lexicon can be thought of as a store of information in brain or mental store of information in brain that includes information about words that we know of. It includes semantic information that is information related to meaning of the words. It includes syntactic information that include basically about what are the different forms of the word possible you know past tense, present tense, continues tense and so on.

Also it includes in detail information about word forms, depending upon the modality it includes. For example if you think of mental lexicon that includes a you know word form information in both in terms of sounds and scripts, then it will have visual form information as well and it will have auditory information as well. Now this is where several theories of language basically have argued that the mental lexicon plays a important role in language processing.

Some theories argue for a single mental lexicon for both language comprehension and production. While some other theories have argued for separate mental lexica for language comprehension and production. Okay? So again, there is a little bit of a debate about this. Now overall, the basic concept of the mental lexicon is that you can think of it as a store of information about words that, let us say exist in the brain.

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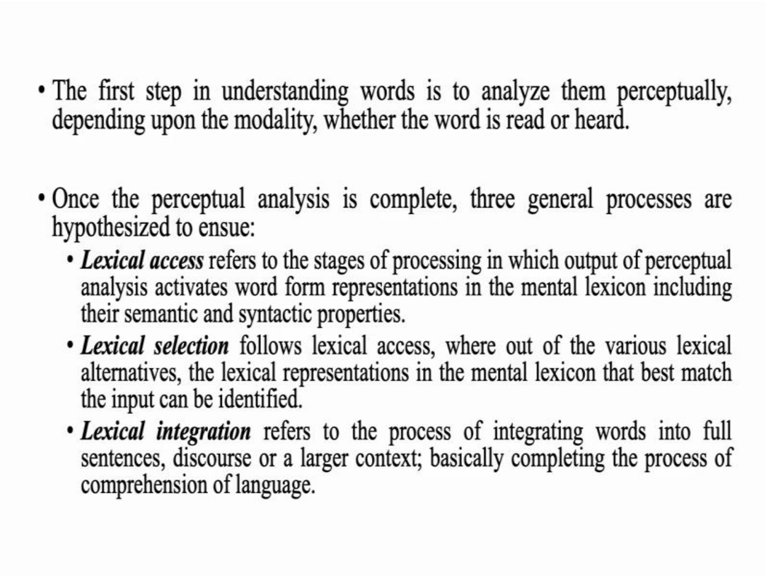

Now the first step in understanding words is to be able analyse them perceptually, depending upon the modality, such as whether the word is listened to, or it is read. Now once this initial perceptual processing is done, there are three general processes that are hypothesized to begin. Lexical access. Now it refers to the stage of processing in which the output of the perceptual analysis whether it is visual output or auditory output is (act) supposed to activate the word form representations in the mental lexicon.

Whenever I say in the mental lexicon, there can be visual forms of the words stored as well and auditory forms of the words stored as well. Now basically what output has come in, say for example, on the basis of the input whether you are reading the word then it will be visual input, whether you are listening to the word then it will be an auditory input. This visual or auditory input of the word form, how does the word sound like or how does the word look like, will be matched to the representation same kind of representation from the mental lexicon.

See how do we remember words? We remember them as sounds, we sometimes also we obviously also remember them as spells, so the visual form. So, basically lexical access is accessing the word form information from the metal lexicon of the word irrespective of the modality, whether it is a visual modality or auditory modality. The second is as soon as you (start) you know you arrive at, you are performing this process of lexical access, not only the best match of the visual input or auditory input that you getting is getting activated. Some partial matches, some semantically related font or logically candidates will also get activated.

The process of lexical selection is required then. Basically it involves the selection of the best match of the input, irrespective of the various lexical alternatives that may happen activated. Now lexicon integration refers to the process of integrating words into full sentences. Once you have sort of reached the word and you have selected, then you have to integrate this word to the representation of the entire sentence. Remember let us say let us take an example of a sentence like you know, I planted the old man planted a tree across the bank.

Now once you hear the word bank, then you have activated the lexicon form etcetera, you have to match it with whether it is you know it is basically congruent with the entire sentence or not. So, lexical integration is needed basically which means integrating of word into fuller sentences. And then the sentences include discourses and the larger context. Basically completing the process of comprehension of language. Because unless you integrate the word with the sentence and the sentence with the overall narrative, you are not going to be able to comprehend any language.

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- Grammar or syntax are he rules using which the words or the lexical items are organized in a particular language to produce the intended meaning.
- Let's consider the mental lexicon in some more detail:
- A typical individual has knowledge of about 50,000 words and can easily recognize and produce about 3 words per second. It seems therefore that the mental lexicon is organized in a highly efficient manner.
- Several organizational principle are in operation in the mental lexicon.
  - For instance: one of the first representational unit in the mental lexicon is the ***morpheme*** i.e. the smallest meaningful unit in a language.
  - A second, organizational principle is that words in the mental lexicon are organized by frequency, i.e. more frequent words are accessed more quickly and accurately as compared to the low frequent words.
  - Finally, another organizational principle is that of lexical neighborhood, wherein words that differ from any single word by only one phoneme or just by one letter are referred to as belonging to the same neighborhood. Studies have indicated that words that have more neighbors are identified more quickly than words that have fewer neighbors.

Now grammar or syntax are the rules which the words or the lexical items using which the words or the lexical items are organized in a particular language to produce the intended meaning. Now let us consider the mental lexicon in some more detail. Now a typical individual has knowledge of about some 50,000 words and can easily recognize and produce up to 3 words per second.

It seems therefore that the mental lexicon must have been organized in a very efficient manner because even though you have 50,000 entries let us say in your mental lexicon, you can almost without fail automatically and very quickly, access whatever words that you want to speak, even you let us say impromptu conversation. Now so this basically tells us that this organisation of the mental lexicon must be really you know efficient.

Let us look at some of the organizational principle of the mental lexicon. For instance, one of the first representational unit in the mental lexicon is the morpheme. The morpheme is the smallest meaningful unit in a language. Basically there are two kinds of morpheme words. Once you start reading words, we start analysing words. You can analyse the words into morphemes.

I will give you an example, the word player is composed of 2 morphemes one is play and other is ER. Play is can be considered to be an isolated or say say for example a standalone word that is has its own meaning and therefore it can be referred to as a lexical morpheme. Er on the other hand, the word Er is plainly a suffix and is basically used for grammatical purposes. Standing alone it does not have its own meaning and therefore it will always have to exist along with another word, so Er is basically referred to as a bound morpheme or a grammatical morpheme.

Similarly you can analyse different words as consisting of number of free morphemes and bound morphemes. So, basically one of the organisational principles in the mental lexical is basically as per you know as by the virtue of morphemes. How many morphemes does a word contain? A word like play contains a single morpheme and word like player or played or playful contains more than one morpheme.

Another organizational principle of the mental lexical is that the words in the mental lexicon are organized by frequency. Frequency basically means how often do you come across a given word? It is measured in quantities like frequency per million words. Suppose you have heard a lot of words and let us say at every million words you hear, what is the frequency of the word player? Does it occur 5 times out of a million, 500 times out of a million, or 5000 times out of a million? That number is the frequency per million of the word.

Now, different words in the mental lexical out of the 50,000 words will have different frequencies. Frequency therefore is one of the organizing principle of the mental lexicon basically index in the form that frequent words or the word that are more frequent are accessed more quickly, they are recognised more quickly, they are read out aloud more quickly. Which tells us that they are probably somewhere at the periphery where they can very quickly be accessed.

So, one of the ways of organizing the mental lexicon is via frequency. Another organizational principle in the mental lexicon is that of lexical neighbourhood. Basically neighbourhood means neighbourhood consist of those words that differ from any single word by only one phoneme or just by one letter, and are referred to as belonging to the same neighbourhood. Let us say the example of a word cat.

Now the word cat, bat, mat, rat, etcetera are just differing from each other by one letter or just by one sound. These will be supposed to be in the same neighbourhood. Now studies have indicated that words have more, so studies have indicated that words that have more neighbours are more easy to activate and they are recalled more quickly, identified more quickly, as compared to words that have fewer neighbours.

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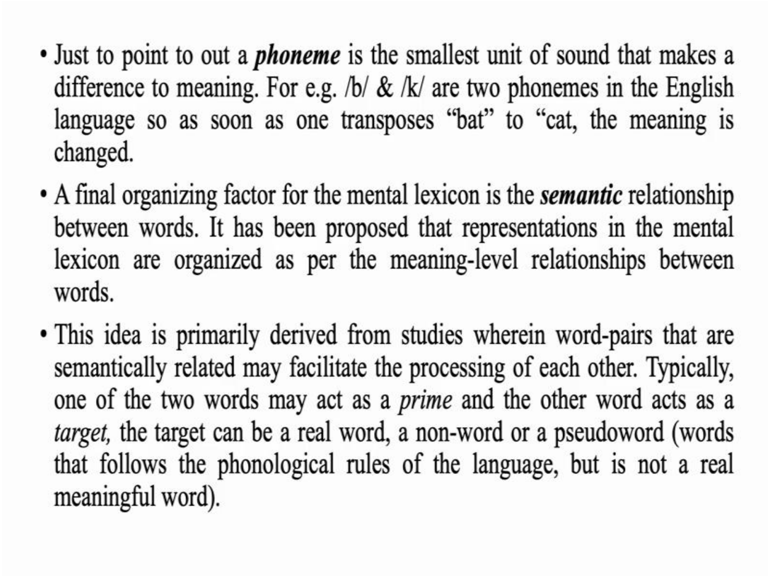

Now just to point to out that a phoneme is the smallest unit of sound that makes difference to meaning. Say for example I was giving you example of the word cat. Cat would change one phoneme from /k/ to /b/, it becomes bat, meaning has changed. You change one more phoneme from /b/ to /m/, it becomes mat, another again the meaning is changed. So, one single sound that once you changed it will alter the meaning of the exact word is referred to as the phoneme.

A final organizing principle in the mental lexicon is the semantic relationship between words. Different words can have different kinds of semantic relationships. Basically it has been proposed that the representations in the mental lexicon are organized as per the meaning-level relationships. Okay? Now one of the one of the paradigms that scientist have used in order to investigate and understand the meaning-level or the semantic relationship between the words is the priming paradigm.

Typically what happens in prime paradigm is that there are you take word pairs, one of which both of which are semantically related to each other, or one of the words will be used as a target, where as another can be used as a prime. In place of the target word you can also use a different real world or a non-word or a pseudo word. A pseudo word is basically a word that can be pronounced but does not have any meaning.

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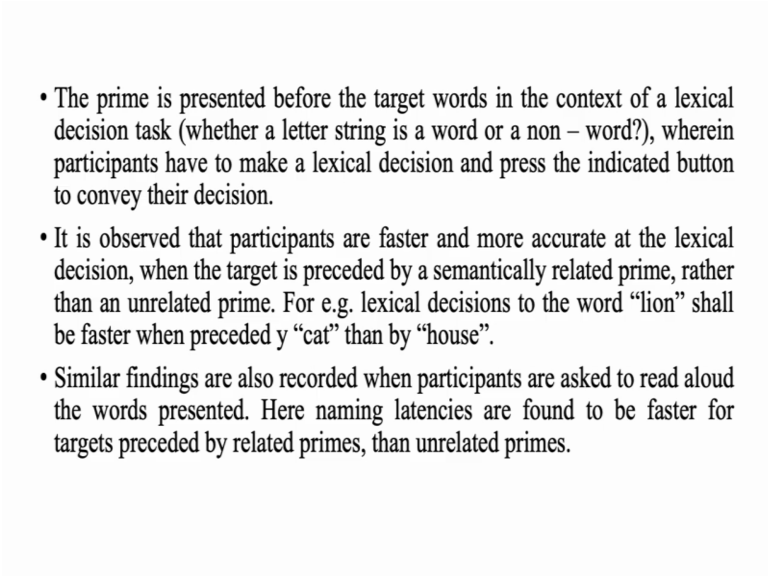

Now, typically in the priming paradigm, a prime is presented before the target words in context of a lexical decision task. So lexical decision task is being done wherein you are supposed to answer whether a presented letter string is a meaningful word or not? Now, it is it has been observed that participants are faster and more accurate at the lexical decision when the target is preceded by a semantically related prime rather than an unrelated prime. Let us take an example, lexical decision to the word lion shall be faster when “lion” is preceded by the word “cat” than when it is preceded by the word “house”, even though there might be match at the level of frequency, etcetera.

Now similar findings are also recorded when participants are asked to read aloud the words presented. Here naming latencies for target words are found faster if they are preceded by related primes, than unrelated primes. So, you can see the semantic relationships of words plays a very important role in the organisation of words in the mental lexicon.

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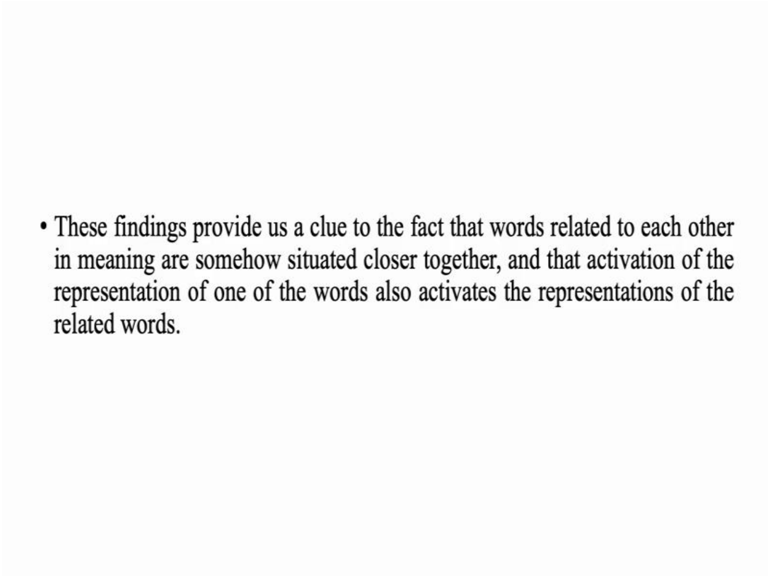

Now these findings can provide us a clue to the fact that words related to each other in meaning are somehow situated close to each other in the mental lexicon. And also the fact that if one of the words is activated from this neighbourhood, other words will also get activated which are semantically similar, or may share meaning aspects with the target.

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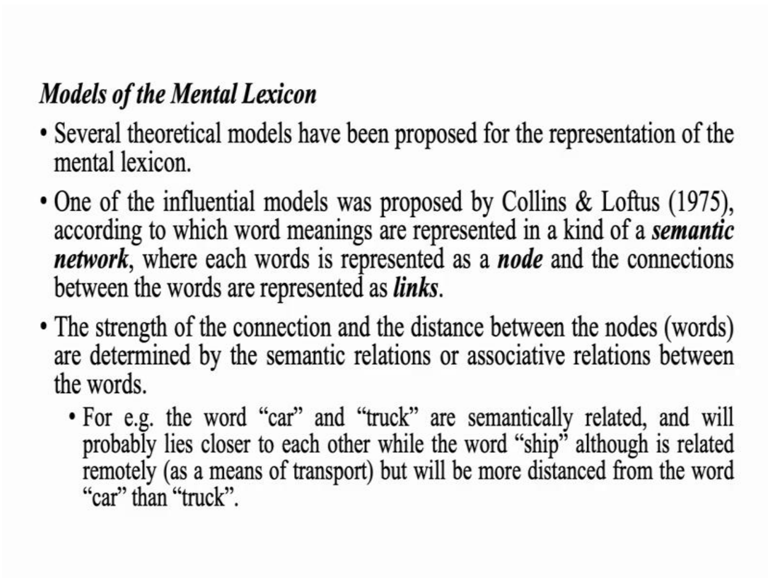

Now let us look at some models of the mental lexicon. Several theories have been proposed to basically you know theorise about the representation of the mental lexicon. One of the influential models was proposed by Collins & Loftus in 1975, which was referred to as the semantic networks theory. Now, according to the semantic networks theory, word meanings are represented in a kind of a semantic network, where each word is represented as a node and the connections between each of these words are represented as links.

The strength of the connection between this different nodes or different words are determined by the kind of semantic relationship or associative relationship that is shared between the given words. For example the word "car" and "truck" are semantically related, and they will be probably situated closer to each other in the semantic network because they share other features as well. Whereas the word “ship”, even though semantically similar to the word “car” in the sense that both are means of transport, the level of similarity between “car” and “ship”, versus “car” and “truck” is very different.

Car and truck are much more similar, so they are situated much more closer to each other as oppose to car and ship which are although have by virtue of function they are both modes of transport, but other features are very very different, so even though ship will be attached to the word car, it will be situated much further off in this semantic network, as opposed to the word truck which would be situated much closer to the word car.

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- Although the semantic-network model has been extremely influential, the matter of how the words are organized is a matter under investigation.
- Moreover, there are several other models that have been proposed to understand how conceptual knowledge is represented.
- Some models propose that words that co-occur in our language may prime each other (for e.g. fountain & pen) and other have suggested that concepts are represented by their semantic features or their semantic properties.
  - For e.g. the word “dog” has several semantic properties like its “animate”, “has fur”, “has four legs”, “barks” etc.
- Such models have to answer the question of how the words would get activated? Or how many features need to get activated to activate the target concept or Which features are necessary and dispensable in order to activate the target concept?

Although the semantic network model has been extremely influential, in understanding you know the basically how words are (written) how words are organised, it is basically still a matter under investigation. Also there are several other models that have also proposed to understand how the conceptual knowledge about words is represented in the brain. For example, some models proposed that words co-occur in our language, that words which co-occur in the language maybe able to prime each other.

For example, the words fountain and pen are you know they are not semantically related to each other but they occur each other but they occur together lot of times. For example a lot of people say, I still use a fountain pen. So whenever the word fountain may be occurred, the word pen will be prime. It will automatically become available for selection. Some others have suggested that concepts are represented more by their semantic features or their semantic properties.

So, for example you can analyse a concept in terms of its features. So for example the word “dog” can be analysed in terms of few semantic properties like it is animate, it has fur, it has four legs, it barks etcetera. So, people can ask questions like you know or these models will need to specify, say for example, how the words will get activated from features or how many features do you actually need to activate the target concepts.

Say for example just has fur, or just as animate can activate many other words other than the word dog. So, you probably need one distinguishing feature activating which you can directly reach the word dog. Say for example barks. We know that dogs bark and as soon as the word bark is presented we can automatically and very quickly activate the word dog. Okay?

Another question that brings models will probably needs to specify is that, which features are necessary and which features are dispensable in order to activate the target concept, as we just saw the word the feature bark cannot be dispensed with if you want to activate the concept of the word dog.

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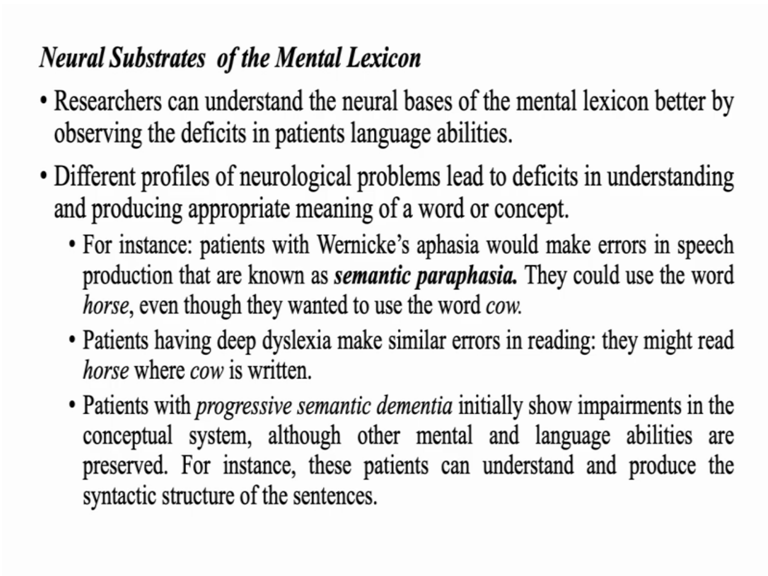

Let us talk a little bit about neural substrates of the mental lexicon. Now researchers can understand the neural basis of the mental lexicon better by observing the deficits in patient's language abilities. Different profiles of neurological problems can lead to deficits in understanding and producing the appropriate meaning or of a word or a concept. For instance, patients suffering with Wernicke's aphasia would sometimes make errors in speech production that are known as semantic paraphasia. In semantic paraphasia, they could use the word horse, even though they intended to use the word cow.

Now you can see the word "cow" and "horse" might be semantically related because they share features but the patient is unable to activate the target word. Patients having deep dyslexia can also similar patterns in reading. They might read the word horse even though the word cow is written. Patients with progressive semantic dementia initially show impairments in the conceptual system, although other mental and language abilities might be preserved. For instance, these patients can understand and produce the syntactic structure of the sentences.

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- This deficit has been linked with progressive damage to the temporal lobes, mostly focused in the left hemisphere. However, the superior regions of the temporal lobe, involved with hearing and speech were spared.
- Patients with semantic dementia have difficulty assigning objects to a semantic category; also they often name a category when asked to take the name of an exemplar. For instance, if asked to name a "horse" they could speak "animal" and on seeing a picture of a "sparrow" they would name "bird".
- Neurological evidence from a variety of disorders support the idea of semantic networks because words that have similar meanings may get confuses, substituted or lumped together to form a category, as could be predicted by the use of semantic network theory.

This deficit has been linked with progressive damage to the temporal lobes, mostly in the left hemisphere. However, the superior regions of the temporal lobe, involved with hearing and speech were also spared. Patients with semantic dementia have difficulty assigning objects to a semantic category, also they name often sometimes name a category when asked to name the give the name of an exemplar.

Say for example, if you ask them to name an animal they will say "horse" (in even) and if you ask ask them to you know if you show them a picture of a horse and ask them to name it they will probably not be able to say horse but they will ready to say "animal". On seeing a picture of "sparrow" they would not be able to say sparrow but they probably will say "bird".

Now, neurological evidence from a variety of disorders basically support the idea of semantic networks because words that have similar meanings may get confused, substituted or sometimes lumped together to form a similar category, as predicted by the use of semantic network theory.

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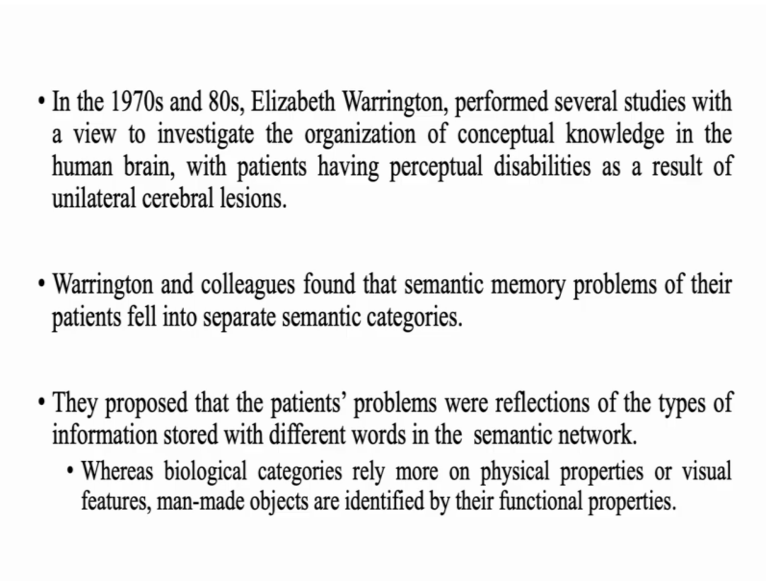

In 1970s and 80s, Elizabeth Warrington, performed several studies with a view to investigate the organization of conceptual knowledge in the human brain. And she had patients with different perceptual disabilities as a result of and she used patients with perceptual disabilities as a result of unilateral cerebral lesions. Now, Warrington and colleagues found that semantic memory problems of their patients often fell into separate semantic categories.

Basically they proposed that patients either had problems with the reflection of the you know with the biological categories or with (semant) or with man-made categories. So, they proposed that patients' problems were simply reflections of the types of information stored within with different words in the semantic network. So, the idea is that they are not able to activate one specific kind of information rather than one specific type of word.

So, they say that whereas biological categories rely more on physical properties or visual features, man-made objects are identified mainly by their functional properties. Say for example, what is a hammer used for, or a scissor used for, is a better question to ask than say for example just describing their visual properties.

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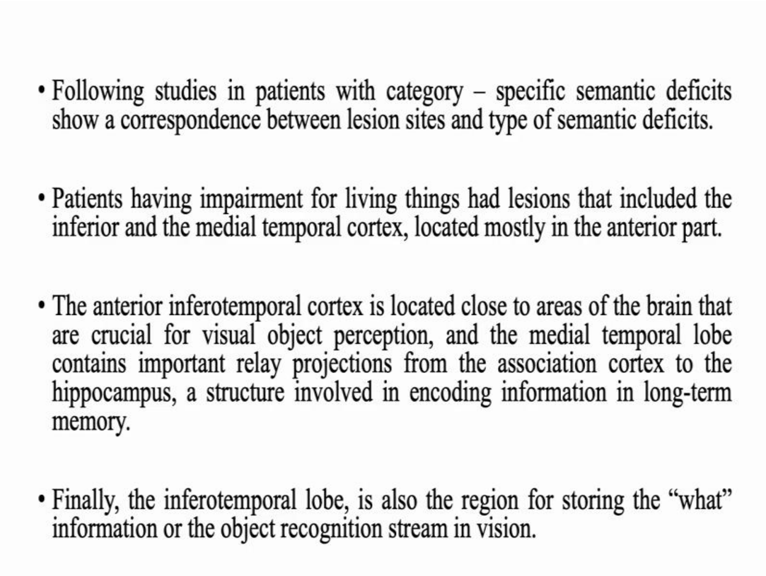

Following studies in patients with category specific semantic deficits, it basically reveals a correspondence between lesion sites and the types of semantic deficits observed. For example, patients (()) (20:10) have impairment for living things had lesions that included the inferior and medial temporal cortex, located mostly in the anterior parts.

The anterior inferotemporal cortex is located close to the areas of the brain that are crucial for visual object perception, and the medial temporal lobe contains important relay projections from the association cortex to the hippocampus, a structure involved in encoding information in the long-term memory.

Finally the inferotemporal lobe is also the region for storing the "what" information about the object recognition stream in vision. So, here you can see how these are how these different areas can come together to to allow us access information about living things.

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- The lesion information for patients with impairments for man-made things is less clear, mainly because of lesser data. However, the left frontal and parietal areas seem to be involved in this kind of semantic deficit.
- These area overlap with areas of the brain that are engaged with sensorimotor functions, which may be involved in the representation of actions that can be undertaken when man-made artifacts such as tools are used.
- Correlations between the type of semantic deficit and the area of the brain lesion are consistent with the hypothesis that proposes that the patients problems are a reflection of the types of information stored with different words in the semantic network.
- More specifically, whereas the biological categories (fruits, food, animals) rely more on the physical properties or visual features for identification; the man-made objects are identified mainly by their functional properties

The lesion information for patients with impairments for just man-made things is less clear, simply because there is being less data. However, the left frontal and parietal areas seem to be involved in this kind of semantic deficit. Now these areas overlap area overlap with areas of the brain that are engaged with sensorimotor functions, which may be involved in the representation of actions that you typically do with these man-made artefacts such as tools you know, what do you do with a hammer, what do you do with a scissor, and so on.

Now correlation between the type of semantic deficit, that is semantic deficit for either man-made things or living things, and the area of the brain that is lesion, are consistent with the hypothesis that proposes that patient’s problem are indeed a reflection of the different types of information stored with different words in the semantic network.

More specifically, whereas biological categories rely more on the physical properties or visual features the man-made objects are identified mainly by their functional properties. And so areas which are engaged in analysing these functional properties should be affected when lesions, when deficits are identifying man-made properties.

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- The said hypothesis, proposed by Warrington & colleagues, has found mixed evidence in its support and opposition.
- For instance, Martha Farah & James McClelland (1991) came out with a computational model of object recognition that supported their hypothesis.
- However, research done by Alfonso Caramazza reported findings that challenged Warrington and colleagues' assumptions.
- More specifically, they found that for most of these early studies the stimuli did not include well-controlled linguistic material. For e.g. when living things and man-made things were compared, several studies did not control the stimuli on factors like visual complexity, visual similarity, frequency of use, and the familiarity of objects.

This hypothesis proposed by Warrington & colleagues, has found a mixed evidence in its support and opposition. For example, Martha Farah & James McClelland proposed a computational model of object recognition that seems to agree with this hypothesis. On the other hand research through research by Alfonso Caramazza has reported findings which challenged Warrington and colleagues' assumptions. More specifically, they actually found that for most of these early studies the stimuli that were included (did not) were not well-controlled on linguistic parameters like frequency of use, familiarity and also things like visual complexity and similarity.

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- Caramazza proposed an alternate account according to which a semantic network is organized along the conceptual categories of animacy and inanimacy. He proposed that selective damage in brain damaged patients basically reflected the evolutionarily adapted domain specific knowledge systems that are subserved by different neural mechanisms.
- Further, neuroimaging studies in normal individuals investigate the semantic representations in more detail.
- For e.g. Alex Martin and colleagues (1996) at the National Institute of Mental Health (NIMH) conducted fMRI studies combined with PET methodology to investigate the intriguing dissociations in normal individual of the kind we just discussed in case of neurological patients.
  - When participants read the names of or answered questions about animals, or even when they named pictures of animals, the more lateral aspects of fusiform gyrus and the superior temporal sulcus were activated along with the left medial occipital lobe.

Caramazza proposed an alternate account according to which a semantic network is organized along the conceptual categories of animate and inanimate, animacy and inanimacy. He proposed that selective damage in brain damaged patients is basically reflected basically reflects the evolutionarily adapted domain specific knowledge systems that are subserved by different neural mechanisms.

So, basically the idea is that knowledge about living things is stored separately and is taken care of by separate neural areas. Knowledge about man-made category is stored separately and is taken care of by different neural areas. Neuro imaging studies in normal individuals in that investigated semantic representations in more detail, actually you know sort of converge on this kind of idea.

Let us take an example, Alex Martin and colleagues in the National Institute of Mental Health conducted FMRI studies combined with PET methodology to investigate the intriguing dissociations in normal individuals of the kind that we have just talked about in brain damage patients. So what they found was, that when participants were reading the names of or answered questions about animals, or even when they were naming picture of animals, the more lateral aspects of the fusiform gyrus and the superior temporal sulcus were activated along with the left medial temporal lobe.

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- On the other hand, when participants identified and names tools, activations were observed in the more medial aspect of the fusiform gyrus, the left middle-temporal gyrus, and the left premotor area, a region that is also activated by imagining hand movements.
- These findings are consistent with the idea that in the human brain conceptual representations of living things and man-made things rely on separable neural circuits engaged in the processing of perceptual versus functional information.
- Further, more recent studies of the representations of conceptual information indicate that there is a network that connects the posterior fusiform gyrus in the inferior temporal lobe to the left anterior temporal lobes.
  - For instance, Tyler and colleagues (Taylor et al., 2011) at the University of Cambridge studied the representation and processing of concepts of living and non-living things in patients with brain lesions to the anterior temporal lobes and in unimpaired participants using FMRI, EEG & MEG measures.

On the other hand, when participants identified names and names of tools, activations were observed in more medial aspects of the fusiform gyrus, the left middle-temporal gyrus, and the left premotor area, a region that is also activated by imagining hand movements. So, basically areas that are involved in some kinds of motor activities. Now these findings are consistent with the idea that in the human brain conceptual representations of living things are made, and man-made things rely on separable neural circuits engaged in processing of perceptual versus functional features.

Further, more recent studies of the representations of conceptual information indicate that there is indeed a network that connects the posterior fusiform gyrus in the inferior temporal lobe to the left anterior temporal lobes. For instance, Tyler and colleagues at the University of Cambridge studied the representation and processing of concepts of living and non-living things in patients with brain lesions to the anterior temporal lobes and in unimpaired participants using FMRI, EEG & MEG measures.

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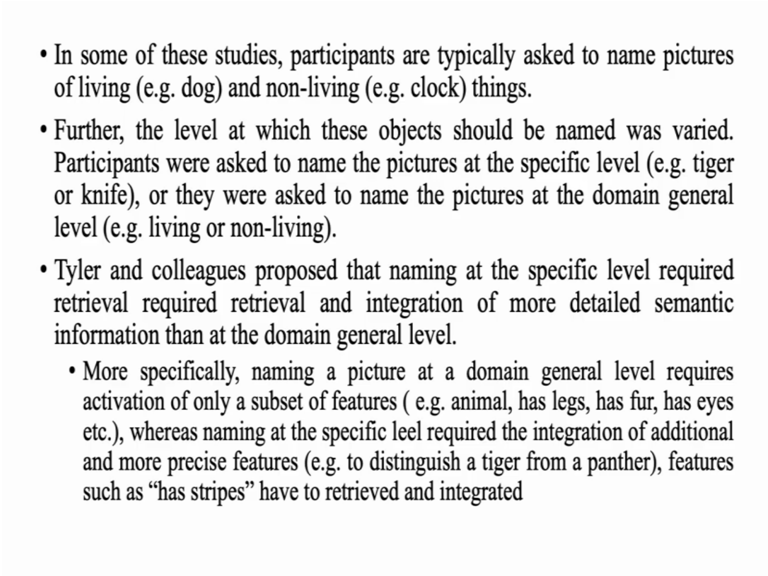

In some of these studies, participants were typically asked to name pictures of living and non-living things. Say for example, a dog or a clock. Further, the level at which these objects should be named was varied. So, you could either name the object at a more generic level or a more specific level. Say for example you can say tiger versus knife, or you could say living versus non-living.

Now, Tyler and colleagues proposed that naming at the specific level would require retrieval and integration of more detailed semantic information than just at the domain general level. When you are just saying living versus non-living. More specifically, naming a picture at a domain general level requires the activation of only a subset of features, so if something is an animal it must have legs, fur, eyes, tail etcetera.

Whereas naming any specific level required the integration of additional and more precise features such as (what are) such as you would need a more detailed idea of the features when more to distinguish let us say a tiger from a panther or a Alsatian from a Doberman etc. Now, so basically the idea is that naming something at a more specific level incurs more incurs more you know load. Now so it may be more difficult to select the features that distinguished…

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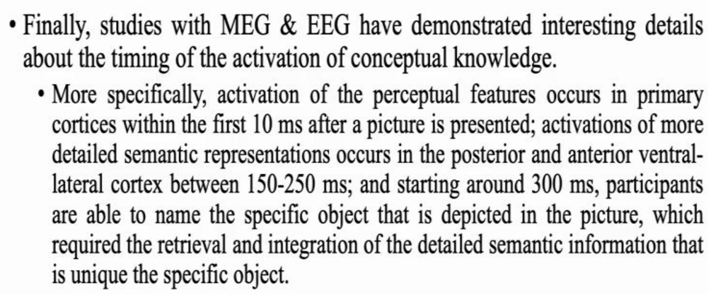

Finally, MEG (nee) MEG and EEG studies have demonstrated interesting details about the timing of the activation of conceptual knowledge. More specifically, it showed that the activation of perceptual features occurs in primary cortices within the first 10 milliseconds of the picture being presented. Activations of more detailed semantic representations occur in the more posterior anterior ventral lateral cortex typically between 150 to 250 milliseconds.

And starting around 300 milliseconds, participants are able to name the specific object that is depicted in the picture, which basically required the retrieval and integration of detailed semantic information that is unique to a specific object. So, you can see basically the time where actually says that you saw happening in the (serial) in the most serial manner and it is also there is a degree of hierarchical processing here.

Hierarchical in the sense, at first simple features are activated, then only more complicated and semantically detailed features are activated. And one those are activated totally then you can eventually be able to name that merge. So, this is something that is very very important. Okay? So, I have talked I think that is enough for today’s lecture.

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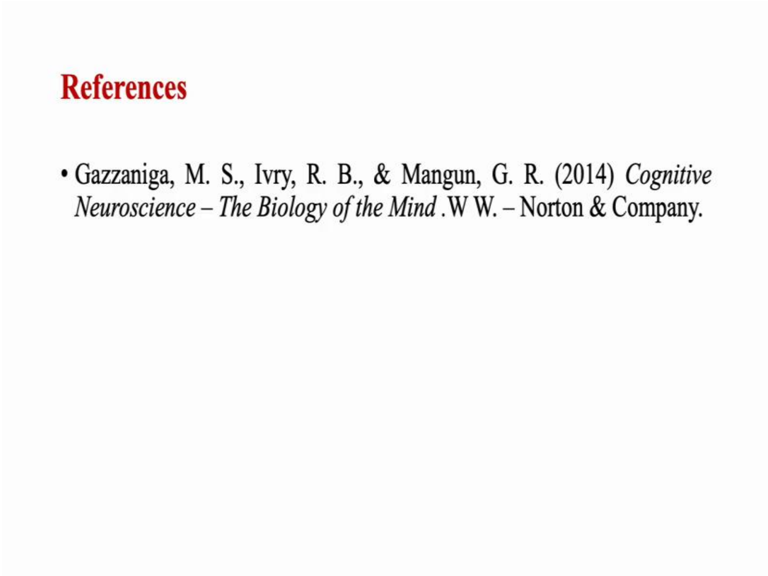

I will move to the next part of language processing in the coming lecture.