Theories of Language Comprehension: India and Beyond

Dr Jayashree Aanand Gajjam

Centre of Excellence for Indian Knowledge System,
IIT Kharagpur

Sentence Processing

-Introduction

-Some Earlier Ideas:

Verb Complexity Hypothesis   -verb island hypothesis
exp1,2,3,4

Correspondence hypothesis of language comprehension

Derivational Theory of Complexity   things influencing sentence processing
-sentence length
-structure
-The Hearer: Structural Processing   -interuuptions

-passive
-negative

-new info
-omission of surface markers

-backward processing
-repetation

Models of Sentence Processing:

- Left-to-Right Processing/ Incremental Parser

- Top-down Vs. Bottom-up Processing/ Induction Vs. Deduction method

- Informed Guesses

- Bever's Assumptions or Four Rules of thumb

Sentence Processing: Introduction

Sentence processing involves special linguistic abilities.

Most of the times, linguistic faculties and cognitive faculties overlap. We cannot separate one from the other. In general, a hearer finds a sentence difficult to process if it goes beyond certain 'psychological' limits.

Recovering a phonological representation and lexical retrieval are the two steps in sentence processing that are the precursors to syntactic processing, or parsing.

Some Earlier Hypotheses on Sentence Processing:

1. Verb Complexity Hypothesis

2. Correspondence Hypothesis of Language Comprehension

3. Derivational Theory of Complexity

1. Verb Complexity Hypothesis

Verb Complexity Hypothesis:

The nature of the verb (simplicity or complexity) in a sentence affects the comprehension (speed/ accuracy/ overall understanding).

Verb is a Maypole: Verb is the most important part in a sentence. All words revolve around it.

Verbs describe straightforward events. The words that take part in the event are denoted by agent, object, instrument, etc.

Ex: John boiled the potatoes on the stove in the kitchen and grilled the meat in the garden while he was watching his favorite episode on TV.

1. Verb Complexity Hypothesis

Verbs are Versatile:

1. Verbs have the multiple meanings.

Ex. Catch the ball! **VERSUS** Let's catch up tomorrow!

Ex: Buying the product! **VERSUS** I don't buy what you are saying!

Ex: Commit to the task! **VERSUS** Committing a mistake! **VERSUS** Committing a suicide!

2. Verbs have multiple constructions.

Ex: I gave her a book **VERSUS** I gave a book to her.

Ex: Yuvraj plays cricket VERSUS Yuvraj plays Gibbs.

Ex: Do you walk everyday? VERSUS Do you walk your dog?

Ex: I expect my luggage remain safe VERSUS I expect my luggage very soon.

1. Verb Complexity Hypothesis

When someone hears a sentence, they pay particular attention to the verb. The moment they hear it, they look up the entry for this verb in a mental dictionary. The dictionary will contain a list of the possible constructions associated with that verb (Fodor, 1968) based on which a hearer draws the sentence meaning.

They've a temper some of them – particularly verbs, they're the proudest – adjectives you can do anything with, but not verbs.'
-by Humpty Dumpty to Alice in *'Through the Looking Glass'* (Lewis Carroll)

1. Verb Complexity Hypothesis

Verb Island Hypothesis : suggests that younger children have **isolated islands of the verbs** in their minds, that are not linked up with other words yet. As they grow older, they start generalizing this knowledge to attach many more word with it.

Ex:

Eat → Drink → Dine → Sit → Swallow → Gulp → Digest → Chew →

- This hypothesis resembles the **'Mental Fog' view** of Language learning in children

1. Verb Complexity Hypothesis

Experiment 1:

The theory suggests that if a verb has only one construction, readers process it faster than the verbs that have multiple constructions. Tested by Fodor, Garret, and Bever.

Ex:

 Kick (You just kicked my dog!) (Verb-Object)

versus

Expect (I expect you not to kick my dog.) (I expect my dog remain safe.) (I expect my dog very soon.= waiting for my dog)

1. Verb Complexity Hypothesis

Experiment 2:

It is found in the Lexical Decision Task that the reaction time is less for the simple words after readers are shown simple verbs. On the contrary, reaction time has increased for the same words after they are shown the versatile verbs.

This suggests that a versatile verb takes up more processing time/ cost that affects their performance for the next word.

Ex:

Kick   **dog**   glit   → (Faster reaction time during Dog)

Expect   **dog**   glit   → (Slower reaction time during Dog)

1. Verb Complexity Hypothesis

Experiment 3:

Some researchers did not find the same effect.

If a hearer activates only one favored construction in his mind after listening to the versatile verb (rather than activating multiple constructions) , the reaction time remains unaffected. (Ford, 1982)

This means, both simple and versatile verbs are processed similarly.

Ex:

Kick = Expect (Same amount of processing)

1. Verb Complexity Hypothesis

Experiment 4:

Some researchers have found that versatile verbs *do* take longer to process. They concluded that problem in processing is not due to multiple constructions, but due to lack of clarity about **who did what to whom**.

Ex:

Sheldon sent Debbie the letter.

Sheldon sent the letter to Debbie.

Sheldon sent Debbie to her home.

1. Verb Complexity Hypothesis

Summary:

✓ Verbs are the most important part in a sentence.

✓ Versatile verbs take longer to process when it does not match readers expectations. In other cases, both simple and versatile verbs require same amount of processing.

"Perhaps a hearer is like a car-driver, driving behind a bus. She has certain expectations about what the bus in front is likely to do. It can go straight on, turn left or turn right, and she is ready to respond appropriately to any of these. But she might be taken by surprise if the bus reversed. "

- Jean Aitchison, 'The Articulate Mammal'

2. Correspondence Hypothesis of Language Comprehension

The theory postulates a close correspondence between:

1. the form of a transformational grammar, and

2. the operations employed by someone when they comprehend speech.

The sequence of rules used in the grammatical derivation of a sentence corresponds *step by step* to the *sequence of psychological processes* that are executed when a person processes the sentence (Hayes 1970).

| Grammatical rules | ⟷ | Psychological processes |

Ex: John and I boiled the potatoes on the stove in the kitchen. [(John and I) (boiled) (the potatoes) (on the stove) (in the kitchen)]

Correspondence Hypothesis is soon found to be unlikely.

3. Derivational Theory of Complexity

New theory came up as a contradiction to Correspondence Hypothesis, i.e.

'**Derivational theory of Complexity**'.

No one-to-one correspondence between speaker's mental processes and grammatical operations.

If more transformations were involved – the more difficult it would be to comprehend.

Given by George Miller, 1962

Experiments:

Passive sentences take longer to process than active sentences due to one extra transformation.
(Ex: The cat chased the rat. The rat was chased by the cat.)

Negative sentences take longer to process than affirmative sentences.
(Ex: I gave it you. VS. I did not give it to you)

Passive negatives take the most time to process.
(Ex: The player was not treated properly during the match.)

Models of Sentence Processing:

Models of Sentence Processing:

Models of Sentence Processing:

Ex:

John and Rita would have

reached the movie theatre

within time, if they had

listened to their friend about

the traffic in the city during

the evening hours which had

kept them waiting on the

roads for more than half an

hour causing them to...

Models of Sentence Processing:

Left-to-Right Processing/ Incremental Parser:

Very neat and orderly theory, as against the earlier chaotic theories.

Fodor and Garret, 1966 showed the emptiness of both Correspondence Hypothesis and Derivational Theory of complexity in their crushing paper at the Edinburgh University conference. They proved that:

a. Hearers start processing what they hear as soon as a speaker begins talking (approximately after 200 milliseconds). They do not wait till the end of a sentence.

b. Human language processor is more powerful and more commonsensical than we imagine. A listener works through a sentence **step-by-step**. If he encounters an ambiguity, he may make a **provisional decision**, while still keeping other possibilities in mind. When he is **all certain**, then he makes a final decision about the sentence meaning.
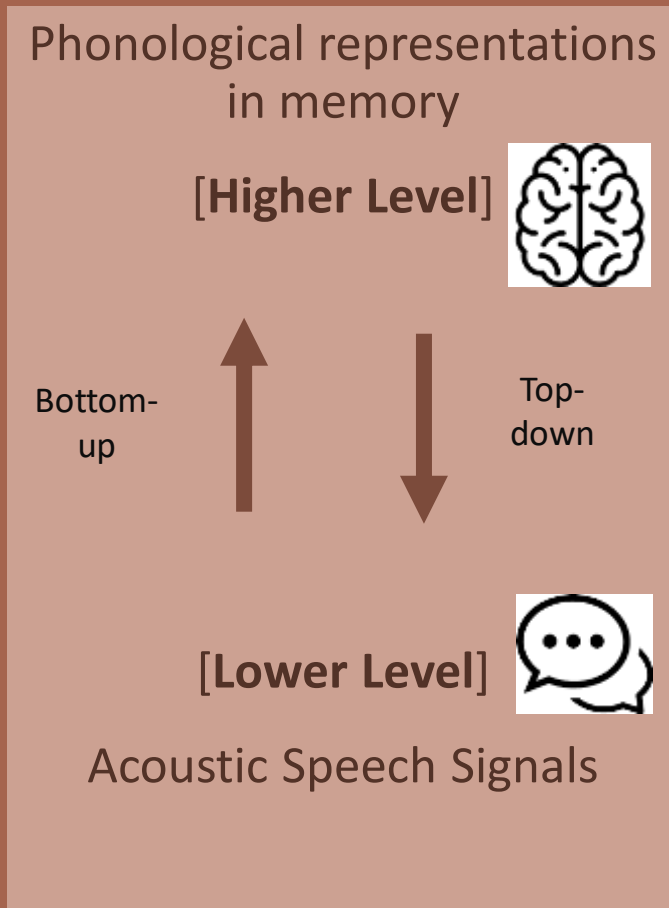
Models of Sentence Processing:

Models of Sentence Processing:

Left-to-Right Processing/ Incremental Parser:

➤ For incremental processing, a reader follows a strategy- known as '**immediacy principle**'.

➤ It says that, he uses as much interpretive work as he can, even based on partial information, rather than waiting until they have all the information. Just and carpenter, 1980

Models of Sentence Processing:

Phonological representations in memory

[**Higher Level**]

Bottom-up

Top-down

[**Lower Level**]

Acoustic Speech Signals

Models of Sentence Processing:

Top-down Vs. Bottom-up Processing/
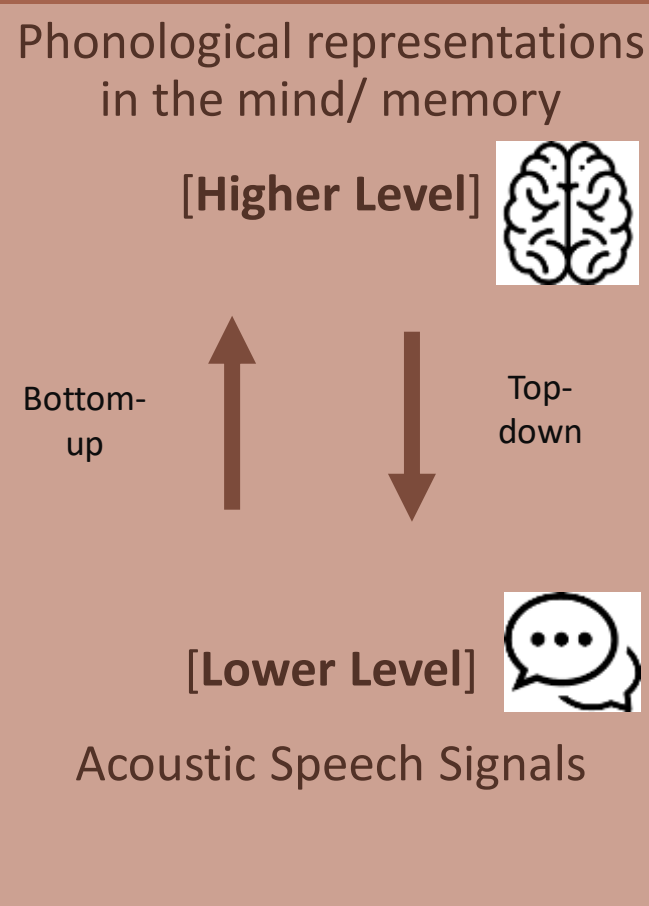
Induction Vs. Deduction method:

Bottom-up are those mental operations that analyze the acoustic properties of a given speech stimulus. They activate a set of potentially matching phonological representations.

Information flows from lower to higher level representations.

Top down processes are those mental operations that use information in long-term memory to try to select the best possible candidate from among the set of candidates activated by the bottom-up processes. This may be especially important when the bottom-up information is ambiguous or degraded.

Information flows from higher to lower level representations.

Models of Sentence Processing:

Phonological representations
in the mind/ memory

[**Higher Level**]

Bottom-up

Top-down

[**Lower Level**]

Acoustic Speech Signals

Models of Sentence Processing:

Top-down Vs. Bottom-up Processing/

Induction Vs. Deduction method:

Bottom-up processes are used to recognize sounds (phonemes) and words. **Top-down processes** are used to retrieve from the context and whole words.

These two terms are used from Computer Science.
Bottom-up processes= Data Driven (based on the physical evidence) Readers try to assemble the words that they listen.
Top-down processes= Knowledge Driven (based on external information) Readers impose their expectations while reading a sentence.

Models of Sentence Processing:

Phonological representations in the mind/ memory

[**Higher Level**]

+

[**Lower Level**]

Acoustic Speech Signals

Models of Sentence Processing:

Informed Guesses:

Which among the 'top-down' or 'bottom-up' approach a listener takes when they process sentences?

Both viewpoints combine together.

When someone hears a sentence, he often latches on to outline clues, and 'jumps to conclusions' about what she is hearing. This is known as 'Informed Guesses'.

Models of Sentence Processing:

Sentence Processing:
Bever's Assumptions OR Four Rules of Thumb

Models of Sentence Processing:

Sentence Processing:
Bever's Assumptions OR Four Rules of Thumb

A listener has some expectations when they hear a sentence. Tom Bever was the first psychologist to work on this topic (Columbia University, 1970).

Hearers approach a sentence in English language with at least **4 basic assumptions.** They devise a *strategy* (Rules of Thumb) guided by their assumptions for dealing with what they hear.

Models of Sentence Processing:

S= Sentoid + Sentoid

S= [NP-V-(NP)]+[NP-V-(NP)]

Sentence Processing:
Bever's Assumptions OR Four Rules of Thumb

Assumption 1:

'Every sentence consists of one or more sentoids or sentence-like chunks, and each sentoid normally includes a noun phrase followed by a verb, optionally followed by another noun phrase.'

Thus, a listener always divides any sentence into a structure of: **[Noun phrase- Verb- (Noun phrase)]** which is known as *Canonical Sentoid Strategy*. This helps us when there are no acoustic signals to divide a sentence.

Ex: John gave (a guitar to Mary for her birthday).

This strategy starts in children around the age of 2 years.

Models of Sentence Processing:

S= Sentoid + Sentoid

S= [NP-V-(NP)]+[NP-V-(NP)]

S= [Actor-Action-Object]…

Sentence Processing:
Bever's Assumptions OR Four Rules of Thumb

Assumption 2:

'In a noun phrase–verb–noun phrase sequence, the first noun is usually the actor and the second the object.'

English language has a strict word-order such as Actor-Action-Object (also known as Subject-Verb-Object). Thus a hearer interprets the sentence in this sequence unless he has a strong indication of the contrary.

Ex: John gave (a guitar to Mary for her birthday).

On contrary, A guitar is given by John….. These sentences take longer to comprehend as proved by Slobin's 'Picture verification' experiment (1966) where he showed pictures to the participants and read the sentences. The Actor- Action- Object sentences were comprehended more quickly.

Models of Sentence Processing:

S= Sentoid + Sentoid + Sentoid

S= Main Clause + Subordinate Clauses

Sentence Processing:
Bever's Assumptions OR Four Rules of Thumb

Assumption 3:

'When a complex sentence is composed of a main clause and one or more subordinate clauses, the main clause usually comes first.'

Thus, a reader interprets the first clause as the main clause and the latter clauses as the subordinate ones, unless he has a clear indication to the contrary.

Ex:

John gave a guitar to Mary for her birthday which he bought four years back in Mississippi when he was visiting his musician uncle who plays across the globe.

Versus

The guitar that was bought four years back in Mississippi when John visited his musician uncle who plays across the globe, John gave it to Mary for her birthday.

Models of Sentence Processing:

Sentence Processing:
Bever's Assumptions OR Four Rules of Thumb

Assumption 4:

'Sentences usually make sense.'

A hearer believes that people generally say things that are sensible.

This strategy is the most powerful of all from the linguistic point of view. In certain circumstances, this strategy can overrise all the other strategies.

Thus readers follow: 'Use your knowledge of the world to pick the most likely interpretation of the sentence you are hearing.'

Some Variables that Influence Sentence Processing:

Sentence length: Longer sentences are difficult to process. It is difficult to retain the information in the working memory. Before the speaker reaches the end, the hearer is likely to have forgotten the first part.

Interaction of length with structure of a sentence: Listeners prefer to deal with a sentence, sentoid by sentoid (phrase by phrase). As soon as one phrase is heard, a hearer forgets the syntax and retains only the gist of it. The hearer '*wipes the slate clean and starts afresh'* for the next sentoid (Fodor, 1974). Some argue that, a hearer retains the information of the earlier sentoid if he thinks that it will help him in further processing. Thus, some of the contents are retained in the memory (Flores d'Archaid, 1988).

Interruptions: An interrupted structures are difficult to process than an uninterrupted ones. (The old car is finally gone. vs The old car, that was bought 30 years ago, is finally gone.)

Compression of information: If only small amount of new information is coming in, humans process it better as compared to when lots of information is being presented. Because, humans need thinking space to let the information '*sink in*'.

Some Variables that Influence Sentence Processing:

Repetition of Items: It is difficult to process a sentence which contains the same word twice. (John gave Mary the guitar. **John** bought **the guitar** two years back.)

Backward Processing: It gets difficult if a reader has to process the sentence by going backward. It is a both psychological and linguistic feature. (Grosu, 1974) (The guitar that was bought two years back, was gifted to Mary.)

Omission of surface markers: It is a partly linguistic and partly psychological factor. The fewer clues available for recognizing a structure, the more difficult it will be to identify. Just as a picture of a face which lacks a nose may take longer to recognize than one with eyes, nose and mouth all complete, so a sentence with a word seemingly missing will take longer to comprehend (Fodor et al. 1968 & 1974; Hakes 1971). (He said the truth was missing. Vs. He said **that** the truth was missing.)

Presence of a Negative: In general, negative sentences take longer to comprehend than affirmative ones.

Passive Sentences: Passive Sentences take longer to process than the active sentences.

Some Cues Used by a Hearer
to Process the Sentence Structure:

A hearer uses the linguistic and/or extra-linguistic cues (strategies) to build a syntactic structure of a sentence, with minimal efforts, using minimal knowledge, to reduce the burden on his working memory- owing to the limitations of information processing mechanisms. Some strategies are as follows:

1. Minimal Attachment:

2. Late Closure:

3. Pragmatic Reasoning:

4. Preferences in Perception:

5. Prosody:

6. Visual Context:

Sentence Processing Mechanisms
used by a hearer/ reader:

Minimal Attachment:

▪ Also known as '**Minimal Attachment Linear Order Principle**'. It says, "When more than one structure is licensed and consistent with the input, build the structure with the fewest nodes. "

▪ The theory suggests that a hearer or a reader initially processes a sentence as if it has a simplest syntactic structure that is consistent with the input he has available at that moment. Lyn Frazier and Janet Dean Fodor, 1978 Especially done when there is syntactic ambiguity. A hearer prefers attaching new items in a sentence immediately, using a fewer syntactic nodes.

Ex:

S1: *The girl knew the answer by heart.* VS S2: *The girl knew the answer was wrong*.

S1: *Ernie kissed Mercie and her sister… VS S2: Ernie kissed Mercie and her sister gave her a present.*

Experiments suggest that S1 is read faster than S2, which tells that S1 is consistent with Minimal Attachment, while S2 requires building a new constituent structure.

Sentence Processing Mechanisms
used by a hearer/ reader:

Minimal Attachment:

Eye tracking experiments suggest that *Garden Path sentences* have more eye movements (more fixations) at the point where parsing error is identified.

Minimal attachment is also evident in the sentences in the *second language*. Although, it is a universal processing strategy.

The structural preferences of a hearer is based on his information processing limitations.

Sentence Processing Mechanisms
used by a hearer/ reader:

Late Closure:

- Means, closing late. It says, "Do not postulate an unnecessary structure. If possible, continue to work on the same phrase or clause as long as possible."

- A hearer attaches the new upcoming words in a sentence with the phrase currently being processed rather than with the structures farther back in a sentence. It is also known as **Recency**. Lyn Frazier and Janet Dean Fodor, 1978

- It is a Structure Building Strategy. Some syntactic ambiguities are resolved by Late Closure.

Ex:

Tom said that Bill had taken the trash out yesterday. (Yesterday → attaches to 'taking the trash out', and not to 'said') Vs. *Tom said yesterday that Bill had taken the trash out*.

Jessie put the book Kathy was reading in the library. (In the library → a hearer prefers attaching it to 'reading' rather than 'putting', even though it may get attached to either of those.)

Flona discovered on Monday that the dog had hurt its foot. (On Monday → 'discovered', not to 'hurt') Vs. Flona discovered that the dog had hurt its foot on Monday.

Sentence Processing Mechanisms
used by a hearer/ reader:

Late Closure:

It is a Syntax-first Approach in Sentence Processing.

Ex*:*

Since Jay always jogs a mile *seems like* a short distance *to him*.

(Eye-fixations on the last few words were longer than the earlier ones. This suggests that readers have misinterpreted 'mile' by attaching it to 'jog'.)

Sentence Processing Mechanisms
used by a hearer/ reader:

Late Closure:

- It reduces the burden on the working memory during parsing.

- Generally, it was assumed that Late Closure is an innate and universal faculty (like Minimal Attachment). But researchers have found that: while most of the Late Closure techniques prefer modifying the more recent phrase etc. (= Low Attachment), Spanish speakers prefer the High Attachment interpretation (= modifying the farther phrase).

Sentence Processing Mechanisms
used by a hearer/ reader:

Pragmatic Reasoning:

A hearer processes the given sentence to derive intended meaning using his capacity of Pragmatic reasoning. He has memories for reasoning in practical (Pragmatic) situations. These memories are based on past experiences about an event, critical thinking, aims or goals, etc. Using his knowledge, a hearer *infers the intended meaning* in a particular context.

Gumperz (1992) uses the term 'contextualization' to discuss how we use our background knowledge to navigate through conversations.

Ex:

Jones owns a Porsche. It fascinates him.

Alice, if you eat, I will give you a chocolate. (If Alice has a chocolate, we infer that she had already eaten.= Conditional Sentence) **Real-world knowledge**

Sentence Processing Mechanisms
used by a hearer/ reader:

Pragmatic Reasoning:

Thus, Sentences in isolation do not give much meaning. A hearer uses context + real-world knowledge to derive the intended meaning. Experiment by Rayner, Garrod, and Perfetti, 1992

Ex: The girl did not wear white in the wedding. (Girl= the bride)

Ex: The times are bad. I can't leave my job now. (= Job pays money which can be used in the difficult times.)

Sentence Processing Mechanisms
used by a hearer/ reader:

Pragmatic Reasoning:

Using real-world knowledge:

Ex:

- Little Johnny was very upset. He had lost his toy train. Then he found it. It was in his pocket.
- I saw the soldiers aim at the women, and I saw several of them fall.
- The council refused the men a permit because they advocated violence.
- Sue went to put the key under the doormat. When she lifted it up, a cockroach quickly scampered across the path.

Sentence Processing Mechanisms
used by a hearer/ reader:

Preferences in Perception:

▪ A hearer has certain kind of preferences while listening to a sentence, that a particular verb should be followed by a particular argument (or a complement).

Ex:

I think you have eaten the cake I gave you.

John has been thinking about his job a lot.

She missed her match due to heavy traffic.

Bill had received a medal for serving the country.

▪ It is based on the ***subcategorization frames of a verb***. Animate objects are able to move and carry out an action, as against inanimate objects. So, when a sentence starts with an animate object, a hearer expects that the action is carried out by it.

Ex: A lion is sleeping Vs. *A dream is sleeping.

Sentence Processing Mechanisms
used by a hearer/ reader:

Preferences in Perception:

Preferences can also be syntactic or semantic.

Syntactic:

She missed her match due to heavy traffic.

Bill had received a medal for serving the country.

Semantic:

She was stunned and rose from her chair.

She watered the plants, especially the rose.

Sentence Processing Mechanisms
used by a hearer/ reader:

Preferences in Perception:

If the upcoming words do not match a hearer's preferences, it will take longer to process. Sometimes, even lead to failure in comprehension.

Ex:

The old man washed the boat. (Easier comprehension due to verb-argument consistency)

The old man the boat.

(=loaded the boat) (Takes longer to process due to inconsistency. Old-man can be considered as the pair of adjective-noun according to the Minimal Attachment strategy. In that case, the latter phrase 'the boat' lacks the verb leading to incomprehension.)
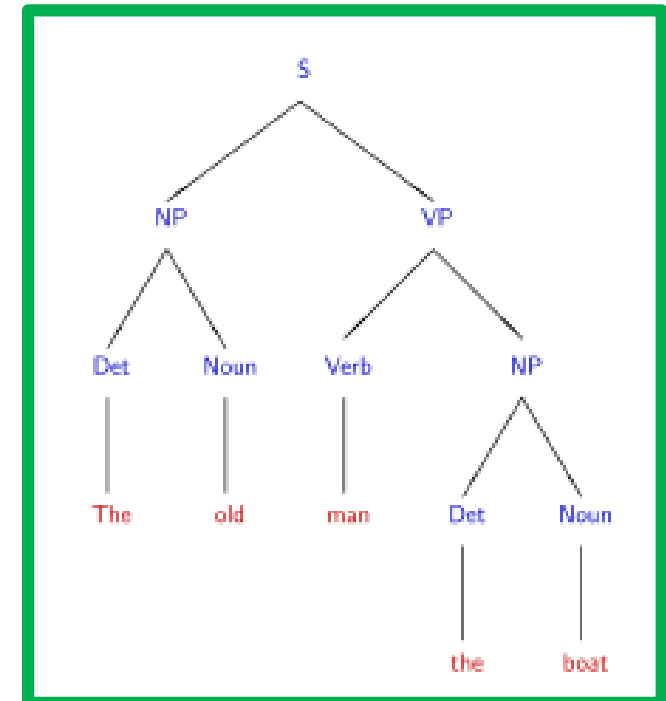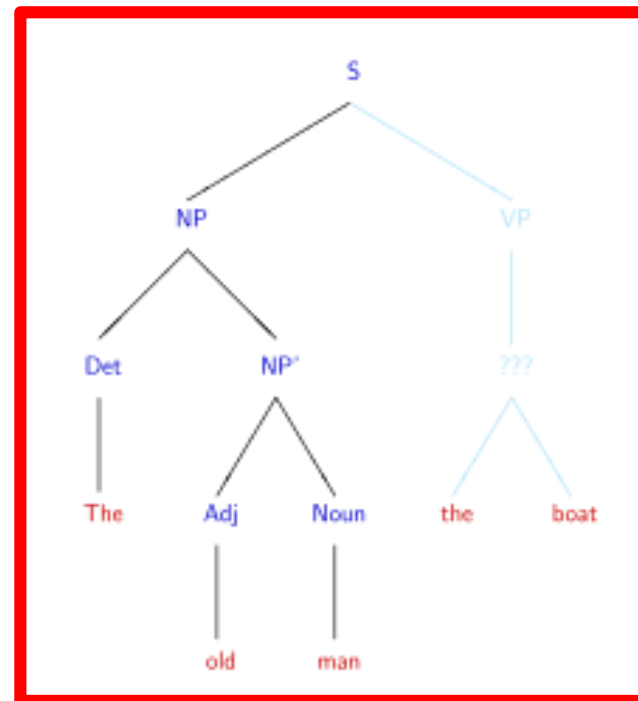
Sentence Processing Mechanisms
used by a hearer/ reader:

Prosody:

In speech, a hearer uses the information regarding the tone of voice of the speaker, his sentence intonation, and word stress (also speed and loudness) to derive the intended word meaning. It is useful when the sentence has different meaning from its basic meaning.

The theoretical research has started in 1960s and 1970s by the philosophers of language.

J. L. Austin (1962) and John Searle (1969) produced a great deal of the framework upon which the study of pragmatics is based. This helps us to understand non-literal language consisting of sarcasm, metaphors, irony, etc.

Sentence Processing Mechanisms
used by a hearer/ reader:

Prosody:

Ex:

I like it when my son rolls his eyes on me. (Sarcasm)

"Yeah, right!" (Sarcasm)

You should definitely watch the movie if the theatre has a good air-conditioning. (Sarcasm)

My wife is a flight attendant but she's terrified of heights. (Irony)

Life is a race. (Metaphor)

Health is wealth. (Metaphor)

Sentence Processing Mechanisms
used by a hearer/ reader:

Visual Context:

Gestures, facial expressions, head-nodding, etc. are the cues used by both speaker and listener to convey the intended meaning. They are known as *'backchannel signals'*. They are collective set of signs used for conveying some message. Sometimes, gestures are complex. Gestures are often similar, but seldom universal. They have cultural, social, or geographic features.

They are extremely important in children's language learning. Later on, they are used especially in conversations.

Visual Context:
Facial expressions convey wide range of emotions and feelings. Some of them are natural and universal. (happy, surprised, disgusted, excited, angry, confusion, attention, distress, love, annoyance, admiration, doubt, bewilderment, determination...)

Sentence Processing Mechanisms
used by a hearer/ reader:

Visual Context:

We use gestures to convey variety of types of messages:

✓ in indicating or referring to self, others, this one, that one: by pointing with a finger, upward head nod, cross eye signaling…

✓ while greeting: hello, goodbye – by moving the hands and arms…

✓ requests/commands: come, go, stop, sit, don't do – by moving the hands…

✓ insults: the sticking out of the tongue by children, rolling eyes by adults…

✓ answers: yes, no, I don't know – by moving the head…

✓ evaluations: good/perfect – by making a circle with the thumb and index finger…

✓ success/ victory: by making the V letter with two fingers…

✓ descriptions: tall, short, long – by use of the hands and arms…

Key Takeaways:

❑ **Hypotheses of sentence processing**: Verb Complexity Hypothesis, Correspondence Hypothesis, and Derivational Theory of Complexity

❑**Sentence Processing Models**:

-       Left-To-Right Processing OR Incremental Processing

-       Top-Down and Bottom-Up Approach OR Induction and Deduction Method (Informed Guesses)

❑ **Bever's Assumptions or Four Rules of Thumb** (of Sentence Processing)

❑ **Some cues** used by a comprehender: Minimal Attachment, Late Closure, Pragmatic Reasoning, Preferences in Perception, Prosody, and Visual Context:

Reading Material

As per Module 1.

Extra:

1. Meaning of hand gestures in different cultures: https://blog.busuu.com/what-hand-gestures-mean-in-different-countries/

2. For Minimal attachment: https://www.psychology-lexicon.com/cms/glossary/46-glossary-m/13786-minimal-attachment-strategy.html

3. Prosody helps in sentence comprehension (advanced level articles): https://compass.onlinelibrary.wiley.com/doi/pdf/10.1111/j.1749-818X.2009.00150.x and https://cpb-us-w2.wpmucdn.com/web.sas.upenn.edu/dist/f/584/files/2020/05/Dahan_WIRECogSci_2015_ProsodyLanguageProcessing.pdf

4. The Top-Down and Bottom-Up Approach https://www.investopedia.com/articles/investing/030116/topdown-vs-bottomup.asp#:~:text=Each%20approach%20can%20be%20quite,setting%2C%20budgeting%2C%20and%20forecasting. For general understanding: https://www.geeksforgeeks.org/difference-between-bottom-up-model-and-top-down-model/

5. Incremental sentence processing (download the article from): https://aclanthology.org/J75-4017/