

# Cognitive Systems

Foundations of Information Processing  
in Natural and Artificial Systems

Lecture 12

Language production and understanding



## Language production and understanding

- lexicon
- syntax
- semantics
- pragmatics
- categorization
- conceptualization

Source: John R. Anderson, Cognitive psychology and its implications, Ch. 12.

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## Language Comprehension

Three stages:

- (1) perceptual processes
  - encoding of acoustic or written message
- (2) parsing
  - transformation of words into mental representation and association of meaning
- (3) utilization
  - using mental representation of the sentence's meaning

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## Parsing

- Constituent structure  
<a noun phrase> <action> <a noun phrase>  
<a noun phrase> was <action> by <a noun phrase>
- Knowledge of language structure helps us distinguish  
the doctor shot the lawyer  
the doctor was shot by the lawyer

We have not learned to interpret all possible full sentence patterns; but we have learned to interpret sub-patterns or phrases and to combine sub-patterns; this helps us to recognize meaning.

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## Example Passages

- Form A  
During World War II, even fantastic schemes received consideration if they gave promise of shortening the conflict.
- Form B  
During World War II even fantastic schemes received consideration if they gave promise of shortening the conflict.

The identification of constituent structures is important to the parsing of a sentence

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## Internal Representation

- After processing / understanding phrases, subjects know the meaning of a phrase but they forget the individual words in that phrase  
Now that artists are working fewer hours oil prints are rare  
Now that artists are working in oil prints are rare
- Words in the last constituent are recognized more easily

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## Immediate Interpretation

- We extract meaning from words as they arrive (we do not wait until the end of a phrase or sentence to decide how to interpret a word).
- Eye movement experiments: the time subjects spend fixating a word is proportional to the amount of information provided by the word
- Some of the interpretation is only possible at the end of the phrase (connecting the remaining pieces)

In processing sentences, we try to extract as much information as possible from each word and spend some additional wrap-up time at the end of each phrase.

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## Example

Flywheels are one of the oldest mechanical devices known to man. Every internal-combustion engine contains a small flywheel that converts the jerky motion of the pistons into a smooth flow of energy that powers the drive shaft.

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## The Use of Syntactic Cues

- Word order
  - The dog bit the cat
  - The cat bit the dog
- Function words
  - The boy whom the girl liked was sick
  - The boy the girl liked was sick
  - The boy the girl and the dog were sick

Ambiguity: relative clause or conjunction?

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## Function Words

- The zebra which the lion that the gorilla chased killed was running.
- The zebra the lion the gorilla chased killed was running.
- Two tasks:
  - comprehend and paraphrase the sentence
  - listen for a particular phoneme (e.g. [g] (in gorilla))
- Subjects took longer to indicate hearing [g] when presented with sentences of the second type.  
Explanation: less attention left over from the comprehension task

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## Word Order vs. Inflection

- Him kicked the girl
  - The girl kicked he
- (Word order suggests one interpretation, inflection suggests another interpretation)
- English speakers use the word order cue ('Him' becomes the agent, 'girl' the object in the first sentence)
- German speakers use the inflection cues.
- Comprehenders use the syntactic cues of word order and inflection to help interpret a sentence.

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## Semantic Considerations

- Tarzan: "Jane fruit eat"  
We know what Tarzan means through the semantics of the words, despite the incorrect syntax
  - The cat chased the mouse.
  - The mouse chased the cat.
- Three-year old children interpreted both statements in the sense of the first statement.

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## Semantic Considerations (II)

- John was buried and died  
More than 60% of the subjects paraphrased the statement in the conventional order of events
  - John had a drink and went to the party
  - John went to the party and had a drink
- Sometimes people rely on the plausible semantic interpretation of words in a sentence

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## Integration of Syntax and Semantics

Disambiguation of ambiguous phrases:

*"landing planes"*: 1) planes that are landing  
2) to land planes

- If you walk too near the runway, landing planes are ...
  - If you've been trained as a pilot, landing planes are ...
- First sentence is easy to continue (no conflict between syntax and semantics)

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## Integration of Syntax and Semantics (II)

- Chased the dog the eraser  
Syntax: the eraser does the chasing  
Semantics: the dog does the chasing
- Most American speakers prefer to go by syntax (*the eraser chased the dog*), some go by semantics (*the dog chased the eraser*).
- People integrate both semantic and syntactic cues to come up with an interpretation for a sentence

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## Neural Indicators of Syntactic and Semantic Processing

- Evidence for separate processing of semantics and syntax (event-related potentials – ERP)
  - **Control**: *Jill entrusted the recipe to friends before she suddenly disappeared*
  - **Syntactic Anomaly**: *Jill entrusted the recipe friends before she suddenly disappeared*
  - **Semantic Anomaly**: *Jill entrusted the recipe to platforms before she suddenly disappeared*
  - **Double Anomaly**: *Jill entrusted the recipe platforms before she suddenly disappeared*
- ERP recordings indicate different responses in different locations to syntactic versus semantic violations.

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## Ambiguity

- Ambiguous words
  - Ambiguous syntactic constructions
- John went to the bank
- Flying planes can be dangerous
- Permanent ambiguity  
(flying: adj or verb)
- The old train the young
- Transient ambiguity  
(train: verb or noun)
- The old train left the station

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## Principle of Minimal Attachment

- Sentences are interpreted in a way that involves minimal complication to its phrase structure

The horse raced past the barn fell

Early assignment of main verb

The woman painted by the artist fell

We don't become aware of transient ambiguity when it is resolved within the same phrase

When comprehenders come to a point of ambiguity in a sentence, they adopt one interpretation which they will have to retract if it is later contradicted

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## Lexical Ambiguity

- The man was not surprised when he found several spiders, roaches, and other bugs in the corner of the room

bug: (1) insect, (2) electronic listening device

When an ambiguous word is presented, subjects select a particular meaning within 700 ms

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## Modularity vs. Interactive Processing

- Do we first process syntax, second semantics or are syntax and semantics combined at all levels of processing?

1. The woman painted by the artist was very attractive to look at
2. The woman that was painted by the artist was very attractive to look at
3. The sign painted by the artist was very attractive to look at
4. The sign that was painted by the artist was very attractive to look at

"by the artists" takes longer to read in 1. than in 2. (original agent-action interpretation must be revised)

"by the artist" also takes longer to read in 3. than in 4. (although signs are inanimate and cannot paint)

Evidence for purely syntactic processing before semantic processing (modular processing): first linguistic knowledge, second world k. ??

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## Modularity vs. Interactive Processing (II)

but:

- The evidence examined by the lawyer turned out to be unreliable  
is not more difficult to read than
- The evidence that was examined by the lawyer turned out to be unreliable
- Thus, people **are** able to select correct interpretation when it is **not** semantically possible to interpret the noun (*evidence*) as an agent of the verb.
  - the initial syntactic decisions are not made without reference to syntactic factors.
- Subjects appear to be able to use semantic information immediately to guide syntactic decisions.

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## Next Semester

### Cognitive Systems II

- Methods from Psychology, Neuroscience, Informatics
- Cognitive Architectures and Modeling Approaches
- Case Studies in Cognitive Modeling
- Challenges for Cognitive Science

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