Psych 150/ Ling 155: Psychology of Language

Lecture 4

Representation: Sentences

Announcements

Be working on HW1 and the review questions — remember that you're encouraged to work together on the homework!

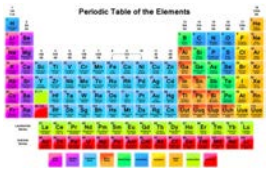
There is a second update to question 7, clarifying the instructions for classifying the affixes.

Sentences

http://mimiandeunice.com/2011/09/23/sentenced-to-death/

Sentences — Combinatoric power

"Achieving a vocabulary of 60,000 words or more is an impressive learning feat. But it's not nearly as impressive as the fact that you readily *combine* these words deftly and creatively. To get a quick feel for the scale of combinatorial possibilities language offers, consider chemistry: with a measly 118 elements in the periodic table, there are *trillions* of known molecules that combine these elements." - Sedivy 2014, p.185



Sentences — Creativity

Convey entirely new ideas that have never been expressed before

Some tulips are starting to samba across the chessboard.



Sentences — Creativity

But you can't just string the words together in any order…

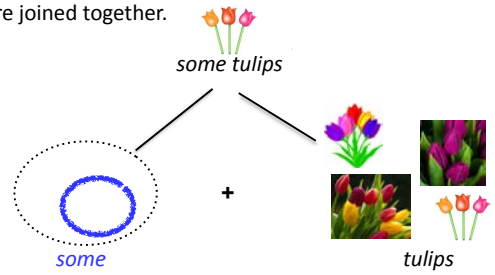
across starting tulips samba chessboard to are the some

Syntax

The rules for how words can be combined to express different meanings. A set of rules for a language = a grammar.

Syntax

Key component: Compositionality
There are fixed rules for combining words in terms of their form that result in fixed meaning relationships between the words that are joined together.



Syntax is separate from meaning

But syntactic rules aren't completely determined by meaning — there are ungrammatical utterances that seem to have a perfectly coherent meaning.

Jareth put the cape on.
Jareth put on the cape.

Jareth put it on.
*Jareth put on it.

Syntax is separate from meaning

But syntactic rules aren't completely determined by meaning — there are ungrammatical utterances that seem to have a perfectly coherent meaning.

Sarah gave a ring to the Wiseman.
Sarah gave him a ring.

Sarah donated a ring to the Wiseman.
*Sarah donated him a ring.

Syntax is separate from meaning

But syntactic rules aren't completely determined by meaning — there are ungrammatical utterances that seem to have a perfectly coherent meaning.

Jareth made Hoggle leave.
Jareth let Hoggle leave.
Jareth saw Hoggle leave.
*Jareth wanted Hoggle leave.

*Jareth made Hoggle to leave.
*Jareth let Hoggle to leave.
*Jareth saw Hoggle to leave.
Jareth wanted Hoggle to leave.

Syntax is separate from meaning

But syntactic rules aren't completely determined by meaning — there are ungrammatical utterances that seem to have a perfectly coherent meaning.

Hoggle poked at the wall.
Hoggle hit at the wall.
*Hoggle touched at the wall.

*Hoggle poked the stick against the wall.
Hoggle hit the stick against the wall.
*Hoggle touched the stick against the wall.

Syntax is separate from meaning

Point: Syntactic rules are a separate piece of linguistic knowledge we learn for our native language in order to construct grammatical utterances from words in our language.

Syntax

What do syntactic rules look like?
They should allow us to compactly capture the patterns of word combinations we observe.

Let's look at a sample of word combinations that can appear in this position: ___ was happy.

The penguin was happy.
A kitty was happy.
An ant was happy.
My owl was happy.
Your monkey was happy.
His bear was happy.
One bunny was happy.

Syntax

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All of these can be captured by the pattern Determiner Noun.
So we can have a single rule to describe this pattern, as long as we use grammatical category labels.

Syntax

What do syntactic rules look like?
They should allow us to compactly capture the patterns of word combinations we observe.

For this reason, syntactic rules are typically described in terms of units that are more abstract than words, such as grammatical categories like Noun, Verb, Adjective, Determiner, and so on.

Grammatical categories

How do we tell which words belong to which grammatical categories?
We look for words that behave similarly (can appear in the same places), and we then assume these words are the same category of word.

"This is a DAX."

DAX = noun

Other nouns = bear, toy, teddy, stuffed animal,…

Grammatical categories

How do we tell which words belong to which grammatical categories?
We look for words that behave similarly (can appear in the same places), and we then assume these words are the same category of word.

"I was DAXing this bear."

DAX = verb

Other verbs = hug, hide, fix…

Grammatical categories

How do we tell which words belong to which grammatical categories? We look for words that behave similarly (can appear in the same places), and we then assume these words are the same category of word.

"This bear is the DAXest."

DAX = adjective

Other adjectives = cute, silly, ugly, …

Grammatical categories

How do we tell which words belong to which grammatical categories? We look for words that behave similarly (can appear in the same places), and we then assume these words are the same category of word.

"This bear is standing DAX the table."

DAX = preposition

Other prepositions = on, in, under, above, …

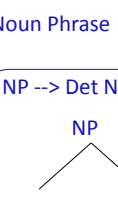
Back to syntactic rules…

For this reason, syntactic rules are typically described in terms of units that are more abstract than words, such as grammatical categories like Noun, Verb, Adjective, Determiner, and phrases that are constructed from these grammatical categories.

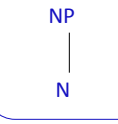
Some syntactic rules

Noun Phrase

NP --> Det N

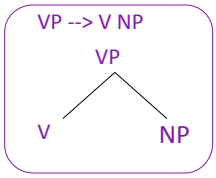


NP --> N

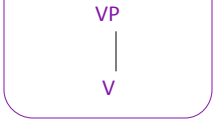


Verb Phrase

VP --> V NP



VP --> V

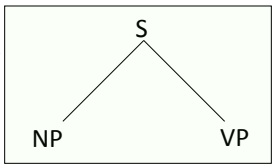


Some syntactic rules

A sentence often consists of a Noun Phrase followed by a Verb Phrase

S --> NP VP ← Phrase Structure Rule

Phrase Structure Tree →



Some syntactic rules

Noun Phrase	Verb Phrase
Hoggle	slept
The chicken	tricked the guards
Seven goblins	left
Sarah	said that Ludo thought that pixies were nasty
A feeling	kicked the bucket
The strangest story that you ever did hear	got drunk on dwarf wine

Some syntactic rules

Noun Phrase	Verb Phrase
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6 Sentences

Some syntactic rules

Noun Phrase	Verb Phrase
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36 Sentences

A tiny little grammar

5 Rules

- S --> NP VP
- NP --> Det N
- NP --> N
- VP --> V NP
- VP --> V

9 Words

Det: *the, four, some*

N: *goblins, crystals, peaches*

V: *understood, ate, approached*

468 Sentences

A tiny little grammar

5 Rules

- S --> NP VP
- NP --> Det N
- NP --> N
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30 Words

10 Determiners

10 Nouns

10 Verbs

122,100 Sentences

Structure determines meaning

One way that we know syntactic structure underlies the meanings we have for word combinations: The same linear order of words can have multiple meanings. This is because each meaning is associated with a distinct structure.

Structure determines meaning

Last night I shot an elephant in my pajamas.
- Groucho Marx

Usual interpretation: I'm in my pajamas as I shoot.

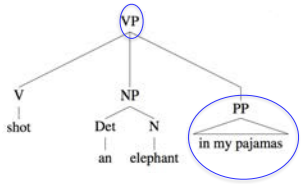
Amusing interpretation: The elephant is in my pajamas.

What he was doing in my pajamas, I'll never know.

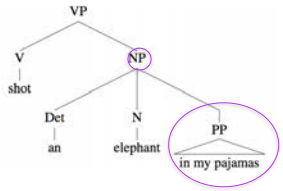
Structure determines meaning

Last night I shot an elephant in my pajamas.
- Groucho Marx

I'm in my pajamas as I shoot.



The elephant is in my pajamas.



Structure determines meaning

Cute penguins and kitties should go first.

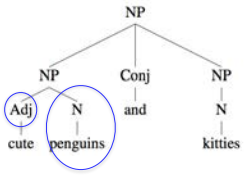
One interpretation: Cute penguins + kitties of all kinds.

Another interpretation: Cute penguins + cute kitties.

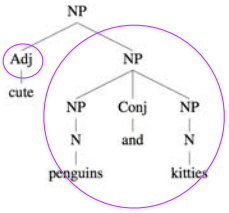
Structure determines meaning

Cute penguins and kitties should go first.

Cute penguins + kitties of all kinds.



Cute penguins + cute kitties.



Structure determines meaning

I like the little elephant's trunk.

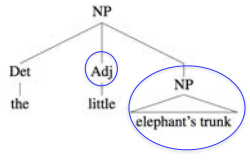
One interpretation: The elephant's trunk is little.

Another interpretation: The trunk belongs to the little elephant.

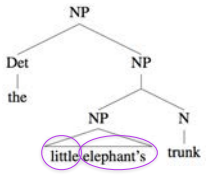
Structure determines meaning

I like the little elephant's trunk.

The elephant's trunk is little.



The trunk belongs to the little elephant.



Structure determines meaning

"Time flies like an arrow"

How many interpretations can you find?

Some hints:
time = Noun or Verb

flies = Noun or Verb

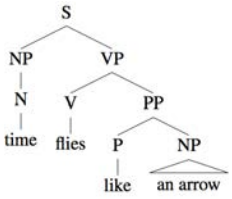
like = Verb or Preposition

Remember: This phrase may not be a complete sentence.

Structure determines meaning

"Time flies like an arrow"

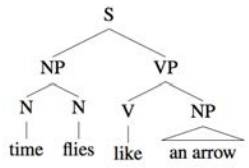
#1 (more typical): Time flies in the way that an arrow flies.



Structure determines meaning

"Time flies like an arrow"

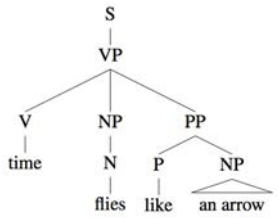
#2: Time flies (a type of fly) enjoy an arrow.



Structure determines meaning

"Time flies like an arrow"

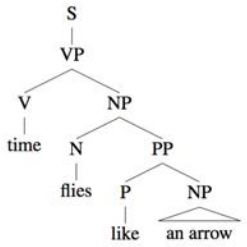
#3: Time flies the way you would time an arrow.



Structure determines meaning

"Time flies like an arrow"

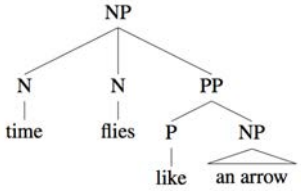
#4: Time those flies that are similar to an arrow.



Structure determines meaning

"Time flies like an arrow"

#5: Flies that are time flies as well as being similar to an arrow.



So let's get back to different ways of building structure…

Rules for structure: Some aspects

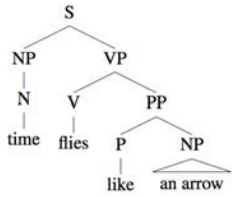
Knowledge of structure is generative, which means that whatever we know about language structure allows us to recognize and generate new examples of never-before-encountered sentences.

Some tulips are starting to samba across the chessboard.



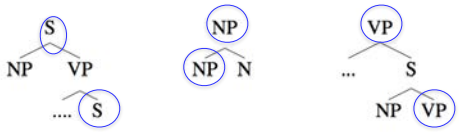
Rules for structure: Some aspects

Knowledge of structure is hierarchical, which means it needs to reflect that words group together into larger units, which themselves can group together into larger units.



Rules for structure: Some aspects

The generative and hierarchical qualities of languages allow for recursion, which is a special operation where a unit can include another unit of the same kind inside itself.



Embedded sentences

Additional VP Rule

Hoggle thought Sarah ate the peach.
VP → V S

Can be used to create a sentence-inside-a-sentence = example of ***recursion***

Combine with S --> NP VP, to get recursion:

S --> NP VP --> NP V S

Embedded NPs

We can also see this property in English noun phrases
NP → NP's Noun

Sarah's friend is a dwarf.
Sarah's friend's uncle is a dwarf.
Sarah's friend's uncle's neighbor is a dwarf.

Embedded sentences

Additional VP Rule

Hoggle thought Sarah ate the peach.
VP → V S

Ludo said Hoggle thought Sarah ate the peach.
The fairy claimed Ludo said Hoggle thought Sarah ate the peach.
The Wiseman's birdhat hoped the fairy claimed Ludo said Hoggle thought Sarah ate the peach.

Infinitely many sentences can be generated!

Complementizer

Complementizer (Comp): words like THAT, IF, and WHETHER that allow one sentence to be the subject or object of another sentence

Hoggle realized that Sarah ate the peach.
Whether Sarah ate the peach didn't matter.

S' → Comp S
VP → V S'
S → S' VP

Complementizer

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VP → V S'
S → S' VP

Example of Recursion 1:
S expands to include S'
S' expands to include S

S → S' VP → Comp S VP

Complementizer

Complementizer (Comp): words like THAT, IF, and WHETHER that allow one sentence to be the subject or object of another sentence

Hoggle realized that Sarah ate the peach.
Whether Sarah ate the peach didn't matter.

S' → Comp S
VP → V S'
S → S' VP

Example of Recursion 2:
S expands to include VP
VP expands to include S'
S' expands to include S

S → S' VP → S' V S' → S' V Comp S

A slightly bigger grammar

9 Rules

S --> NP VP
S --> S' VP

NP --> Det N
NP --> N

VP --> V NP
VP --> V
VP --> V S
VP --> V S'

S' --> Comp S

Sentences it can generate:

Hoggle likes jewels.

A slightly bigger grammar

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Sentences it can generate:

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S --> NP VP

NP --> N VP --> V NP

A slightly bigger grammar

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Sentences it can generate:

Hoggle likes jewels.

S --> NP VP

NP --> N VP --> V NP

N V NP

Hoggle likes jewels.

A slightly bigger grammar

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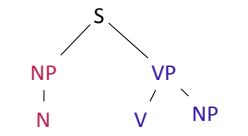

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Sentences it can generate:

Sarah thought that she solved the Labyrinth.

A slightly bigger grammar

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A slightly bigger grammar

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Sentences it can generate:

Sarah thought that she solved the Labyrinth.

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NP --> N VP --> V S'

A slightly bigger grammar

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Sarah thought that she solved the Labyrinth.

S --> NP VP

NP --> N VP --> V S'

N V S'

Sarah thought S' --> Comp S

A slightly bigger grammar

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VP --> V NP
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VP --> V S
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S' --> Comp S

Sentences it can generate:

Sarah thought that she solved the Labyrinth.

S --> NP VP

NP --> N
N
Sarah

VP --> V S'
V S'
thought Comp S

A slightly bigger grammar

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Sentences it can generate:

Sarah thought that she solved the Labyrinth.

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NP --> N
N
Sarah

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V S'
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that

A slightly bigger grammar

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Sentences it can generate:

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Sarah

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V S'
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A slightly bigger grammar

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Sentences it can generate:

Sarah thought that she solved the Labyrinth.

S --> NP VP

NP --> N
N
Sarah

VP --> V S'
V S'
thought that S --> NP VP

A slightly bigger grammar

9 Rules

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A slightly bigger grammar

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Sentences it can generate:

Sarah thought that she solved the Labyrinth.

S --> NP VP

NP --> N
N
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VP --> V S'
V S'
thought that NP VP
NP --> N VP --> V NP

A slightly bigger grammar

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Sentences it can generate:

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NP --> N VP --> V S'
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Sarah thought that NP VP
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N V NP
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A slightly bigger grammar

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A slightly bigger grammar

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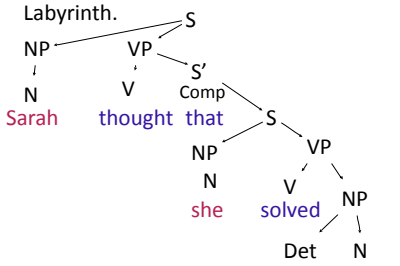

the Labyrinth

Figuring out structure: bottom-up

9 Rules

S --> NP VP
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Sarah thought that Hoggle was a cheat.

Figuring out structure: bottom-up

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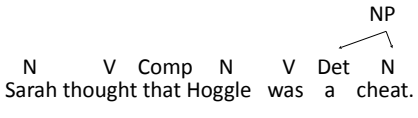

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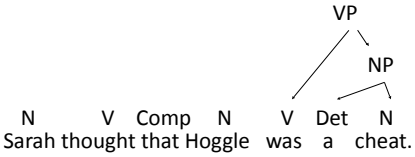

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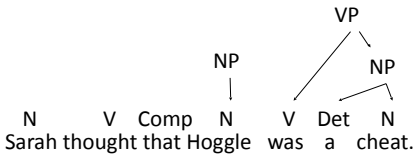

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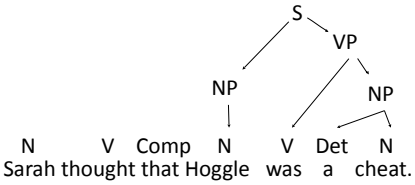

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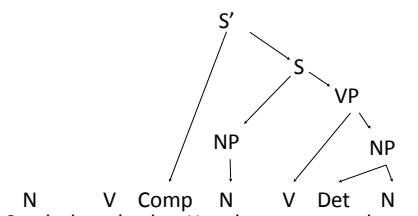

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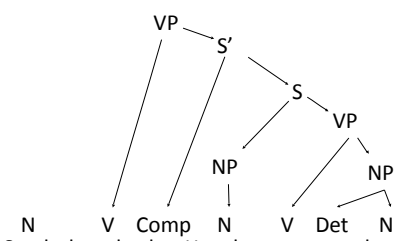

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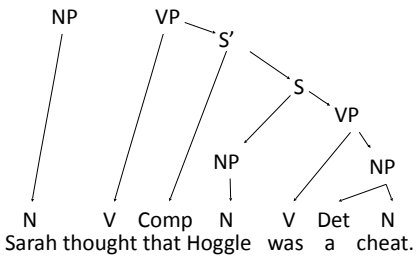

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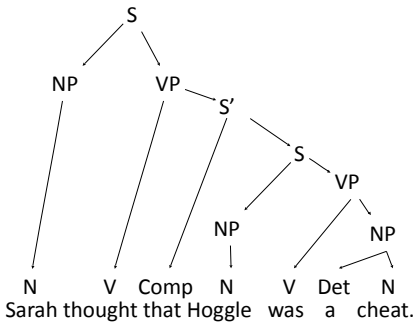

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That Hoggle lied surprised Sarah.

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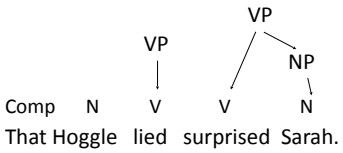

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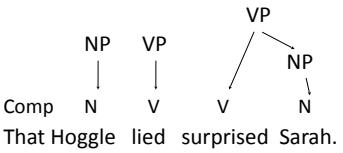

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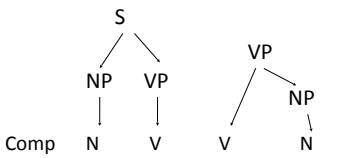

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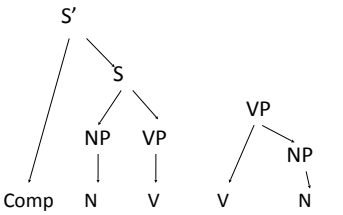

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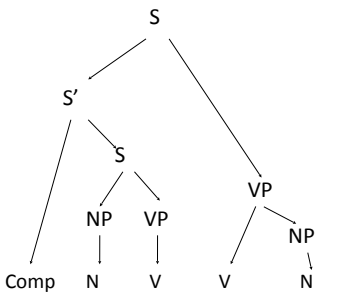


Dependencies

When we look closely at syntax, we find that our knowledge of the structure of language goes beyond how to group words together into units that form a sentence.

Sometimes, there seems to be a relationship between a unit and a position in the sentence that it's not near.

The penguin that I love just left a mess on the floor.

Dependencies

penguin has two aspects associated with it:

(1) I love *it*

(2) *It* just left a mess on the floor.

The penguin that I love just left a mess on the floor.

Dependencies

penguin has two aspects associated with it:

(1) I love *it*

(2) *It* just left a mess on the floor.

Each seems to correspond to a VP.

[$_S$ [$_{NP}$ The penguin [$_{S'}$ that I [$_{VP}$ love]]] [$_{VP}$ just left a mess on the floor]].

Dependencies

penguin has two aspects associated with it:

(1) I love *it*

(2) *It* just left a mess on the floor.

So we actually understand it as the object of *love* and the subject of *left*.

[$_S$ [$_{NP}$ The penguin [$_{S'}$ that I [$_{VP}$ love]]] [$_{VP}$ just left a mess on the floor]].

Dependencies

penguin has two aspects associated with it:

(1) I love *it*

(2) *It* just left a mess on the floor.

The entire NP *The penguin that I love* is the subject of the VP *just …floor*, using the S —> NP VP rule.

[$_S$ [$_{NP}$ The penguin [$_{S'}$ that I [$_{VP}$ love]]] [$_{VP}$ just left a mess on the floor]].

Dependencies

penguin has two aspects associated with it:

(1) I love *it*

(2) *It* just left a mess on the floor.

We describe the situation for *that I love* as there being a gap after *love* that *the penguin* is linked to. That's why we understand it as the object of *love,* too.

[$_S$ [$_{NP}$ The penguin [$_{S'}$ that I [$_{VP}$ love __]]] [$_{VP}$ just left a mess on the floor]].

Dependencies

penguin has two aspects associated with it:

(1) I love *it*

(2) *It* just left a mess on the floor.

So, there's a dependency between *the penguin* and the gap after *love,* which would usually be a regular NP. (*I love the penguin, cheese, kings, …*)

[$_S$ [$_{NP}$ The penguin [$_{S'}$ that I [$_{VP}$ love __]]] [$_{VP}$ just left a mess on the floor]].

Dependencies

penguin has two aspects associated with it:

(1) I love *it*

(2) *It* just left a mess on the floor.

We describe *that I love* as an object-relative clause, since the relative clause *that I love* has its object position linked to *the penguin*.

[$_S$ [$_{NP}$ The penguin [$_{S'}$ that I [$_{VP}$ love __]]] [$_{VP}$ just left a mess on the floor]].

Dependencies

penguin has two aspects associated with it:

(1) *It* loves me.

(2) *It* just left a mess on the floor.

We can have subject-relative clauses, too — *the penguin* is the subject of the relative clause *that loves me*.

[$_S$ [$_{NP}$ The penguin [$_{S'}$ that __ [$_{VP}$ loves me]]] [$_{VP}$ just left a mess on the floor]].

Dependencies

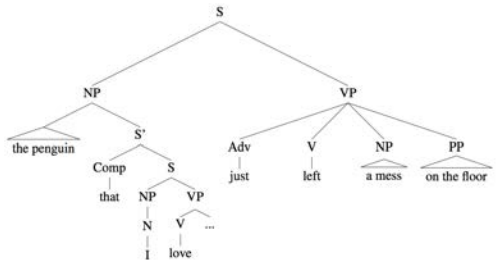
In general, an indeterminate number of words can appear between a phrase and the position it's understood in (its gap) — so, these relationships are called *long-distance dependencies*.

We can see this in object-relative and subject-relative clauses, as well as questions that have a *wh-word* at the beginning:

What did the penguin see __ ?
What did the penguin see the fish do __ ?
What did the penguin see the fish jump into __ ?
What did the very cute penguin that I love see a silly fish that looked extremely tasty jump into __ ?

Sentence structure

So, not only do we know how to build relationships between units that are next to each other (local relationships), but we also know how to build relationships between units that are not (global relationships).



Structure of sentences recap

The structure of sentences (syntax) involves more than simply the meaning of the words. It involves rules about how the words themselves are allowed to go together.

The system that adults (unconsciously) know seems to be generative and hierarchical, and allows recursion.

In addition to knowledge about how to put units together in local relationships, adult knowledge also involves how to construct long-distance relationships between units.

You should be able to do all of the introductory & representation review questions and all of HW1.