

Natural Language Processing: How do humans process language?

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Outline

1 Motivation

2 Models of human language

3 Practical Connections to NLP

Motivation

What does NLP have to do with humans, at all?

Fundamental questions of linguistics

- What do you know when you know a language?
- What do you know when you understand an utterance?

Too much theory is bad? But why?

- “Every time I fire a linguist, the performance of the speech processing system goes up.” (Frederick Jelinek)
- Does it mean we should refrain from linguistic inspiration?
 - (NLP already does that. Ask a linguist.)
- Cf. the good, bad, and ugly parts of artificial neural networks

Linguists and Engineers tend to have different focus

- Computational: what is explained?
 - Description of linguistic performance vs. explanation of linguistic competence
- Algorithmic: how is it done?
 - Cognitive realism, computational complexity/efficiency
- Implementational: how is it realized?
 - Neurological plausibility

What this lecture is about

A very short introduction to:

- Grammar theory
 - What is language built of?
- Cognitive linguistics
 - How does language work in the mind?

Get a better understanding of what should work in language processing

- After all, it's natural language processing
- Comparison gives confidence:
 - NLU system behaviour vs. L1 acquisition
 - Observation of similar effects/errors, e.g., garden path sentences
 - Human performance is the ultimate (utopic?) benchmark!
 - We're not inventing something new...

We don't yet know how human language really works

- Very conflicting hypotheses, most of which work only on a computational level
- New ideas:
 - Shallow processing
 - Distributed, implicit, usage-based knowledge
 - Computational construction grammar
 - Computational semantics (λ calculus)

Some words of caution

Be warned!

- This is will be an extremely rough, simplified, and incomplete overview
- It is biased in favour of Cognitive Linguistics (and a bit against Generative Grammar)
- Linguistic theory is not rigorously formal
 - “Theory” = “proposed descriptive model”, not “axiomatic system”
- Be aware of written-language bias!

Models of human language

Some examples from different areas of linguistics and cognitive science

Cognitive abilities develop in similar ways

- Typical progress:
 - Statistical learning (expectation & surprise)
 - Inductive learning (categorization & abstraction)
 - Social learning (imitation, intention, theory of mind)
- Sensomotory system has an important influence in learning!
- Critical periods vs. extreme robustness

Language learning tends to follow a U-shaped progress

- Phases:
 - Simplification: How do you do dese...work/tortillas/in English
 - Overgeneralization: Yesterday I didn't painting; it noises
 - Restructuring How do you...make this/like it; how...do cut it
- Cf. exploration vs. exploitation in reinforcement learning
- Computational and associative learning

Models of human language

Creolization processes



Figure: Hotel room signs in Tok Pisin (Papua New Guinea)

[https://commons.wikimedia.org/wiki/File:Tok-Pisin_New-Guinea-Pidgin_Pidgin-English_Melanesian-Pidgin_Papua-New-Guinea-Hotel-Room-Door-Sign_\(DSC_3096\).jpg](https://commons.wikimedia.org/wiki/File:Tok-Pisin_New-Guinea-Pidgin_Pidgin-English_Melanesian-Pidgin_Papua-New-Guinea-Hotel-Room-Door-Sign_(DSC_3096).jpg)

Is *langage*¹ special?

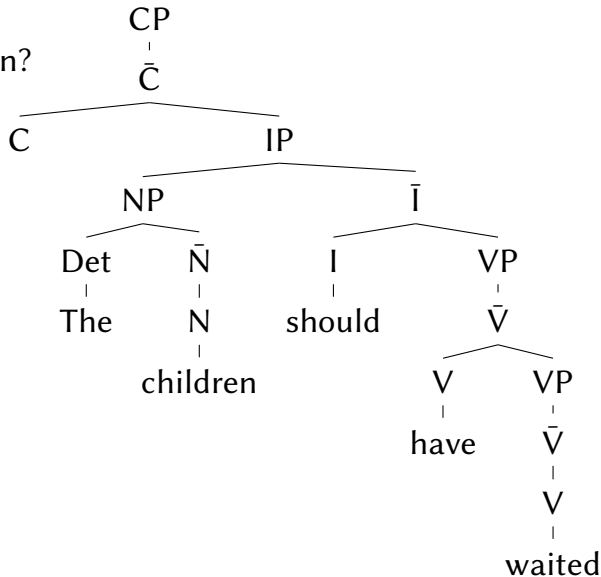
- Is language based on common cognitive mechanisms?
 - Categorization, association, memory, hierarchy...
- Or is there a specialized, innate language mechanism?
 - Mental grammar, language acquisition device, Universal Grammar

¹This is not a typo, but French.

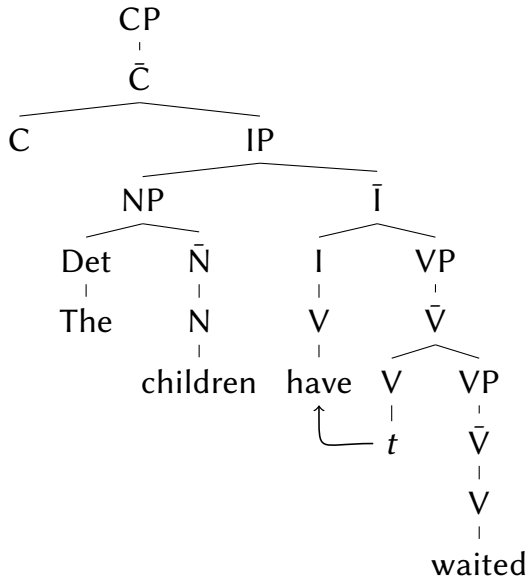
Generative Grammar = trees + transformations

- Grammatical construal in terms of rules
 - from deep structure to surface structure
- Explaining all languages in terms of principles and parameters
 - Solution to fast, one-shot L1 acquisition

Triangles in the brain?



Triangles in the brain?



Criticism of this kind of analysis

- Explicitely not empirical (at least by Chomsky)
 - Against “behaviourism”, focus on competence
 - Tends to categorize everything in terms of recursive symbolic structures
 - Good for English – what about Chinese? Pirahã? *Conversational English*?
- Computationally complex, cognitively... difficult to explain

Pushing the Boundaries of Generative Grammar

Language processing is basically an inverse problem:

- Colorless green ideas sleep furiously
- The Sally hugged him the Thomas
- Time flies like an arrow
- The apartment that the maid who the service had sent over was decorated
- Keine Kopfverletzung ist zu harmlos um sie nicht zu ignorieren

Language is conveying mental state through symbols

- Grammar is only an “artifact” to structure the transportation of mental state
 - Or: only an instrument for performative utterance
- Semantics from a cognitive perspective: meaning is...
 - perspectivic (relative to utterance context)
 - dynamic (system changes with environment)
 - encyclopedic (association with experiences & culture)
 - determined by usage (a system derived from concrete experience)

Some cognitive approaches to semantics and grammar

- How is meaning represented?
 - Prototypes, radial networks, schemata, ...
 - Metaphor
- How is meaning expressed through form?
 - Construction grammar, grammatical construal, usage-based grammar...
 - Information structure

Information Structure (aka Information Packaging)

Conveying more information beyond denotation

- Intonation can focus different parts of an utterance
 - John only introduced Bill to Sue
 - John only introduced Bill to Sue
 - John only introduced Bill to Sue
 - John only introduced Bill to Sue
- Differences in meaning independent of linguistic form!

Constructions that relate meaning in conversation²

- Different pragmatic practices are associated with:
 - As for John, he lost his wallet
 - What happened was that John lost his wallet
 - What John did was lose his wallet
 - It was John who lost his wallet
 - What John lost was his wallet

²See Martin Hilpert's lectures: https://www.youtube.com/watch?v=PJecXZp_SYw

Constructions everywhere

- Constructions are patterns whose form or meaning is not strictly predictable from their components:
 - He has whiffled my borogroves completely vorpal again
 - *The knife chopped the carrots into the salad
- Embedded items are coerced:
 - There was cat all over the road
 - She smiled herself an upgrade

Metaphors

Not just arbitrary idioms and poetry!

- We understand things in terms of metaphor, and use it all the time³
- Abstract term = container
 - An argument has a hole, has less substance, does not have content
 - To find something in an argument
- Argument = journey
 - The content of the argument proceeds, path to the core of the argument, the direction has no substance

³See *Metaphors we live by* by John Lakoff

Acquiring meta-linguistic intuition

- Observe your own & others using language
- If you're interested: go to the linguistics department; e.g.,
 - [Sprache und Kognition](#)
 - [Grammatiktheorie & Sprachtypologie](#)
 - [Sprachen der Welt](#)
- Also useful: more languages (for grammar, not talking)

Applications

What does theory have to do with NLP, at all?

Overall assessment

- We have now already seen some ideas that agree:
 - Statistical learning (“usage based”)
 - Associative learning (“context based”)
 - Shallow processing (no creation of deep structures)

Now: some works of theory transfer from linguistics to NLP

Modeling Information Structure In A Cross-Linguistic Perspective⁴

- Formalized version HPSG + Information structure
- Improve machine translation across multiple languages
- *Information structure facilitates fluency in contiguous speech*

⁴ [doi: 10.5281/ZENODO.818365](https://doi.org/10.5281/ZENODO.818365)

Computational construction grammar for visual question answering⁵

- Based on computational construction grammar
- Mapping questions onto their executable semantic representations
- *Constructions succinctly capture form-meaning pairs in a domain*

⁵[doi: 10.1515/lingvan-2018-0070](https://doi.org/10.1515/lingvan-2018-0070)

Head-Driven Statistical Models for Natural Language Parsing⁶

- Actual parsing using a Generative Grammar formalism
- Probabilistic context-free grammars to lexicalized grammars
- Parse tree represented as sequence of decisions corresponding to a head-centered, top-down derivation of the tree
- *UG isn't dead yet*

⁶[doi: 10.1162/089120103322753356](https://doi.org/10.1162/089120103322753356)

Linguistic Assessment Criteria for Explaining Language Change⁷

- ... A Case Study on Syncretism in German Definite Articles.
- Evolution of the German definite article paradigm
- Agent-based simulation of communicative interactions (“language games”), implemented with Fluid Construction Grammar
- *CxG can provide explanations for variation & change*

⁷[doi: 10.1163/22105832-13030106](https://doi.org/10.1163/22105832-13030106)

Psychologically Motivated Text Mining⁸

- Corpus-based learning of patterns of metaphorical framing
- Detection of the structure of metaphorical associations through clustering
- *Metaphors are useful and detectable empirically*

⁸[arXiv: 1609.09019](https://arxiv.org/abs/1609.09019)

More Cognitive Linguistics

Cognitive approach to natural language processing

- Several essays, mostly on semantics in NLP
- *Word association, disambiguation, frequency estimation, stylistic analysis...*

Metaphor: A Computational Perspective⁹

- Introduction & special topics on metaphor in AI, NLP, and corpus linguistics
- “Researchers can build figurative-language processing systems that are practical and efficient and cognitively plausible”

⁹[doi: 10.2200/S00694ED1V01Y201601HLT031](https://doi.org/10.2200/S00694ED1V01Y201601HLT031)

Thank You!

Implementations are waiting for you.

Next: ???

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