



Grounded cognition

Brief introduction to language

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What are the research questions for this course?

- How is the knowledge (in our minds) grounded in our bodies?
- In anything else?
- What are concepts?
- What is the relation between cognition and language?
- What is the relationship between multimodal representations and symbols?
- How does language affect our cognition?
- ...

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Language – some important concepts

- Purpose: communication
- Uniquely human ability
 - modality independent
- Variety of natural languages (evolution)
- Evolutionary aspects: which precursors?
 - Theory of mind
 - Semiotics – signs, meaning
- Relation to the brain: Language-specific area(s)?



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Unique properties of natural languages

- Hierarchical structure
- Productivity (limited symbols, unlimited messages) - recursion
- Arbitrary symbolic reference
- Discreteness (elementary linguistic units are indivisible)
- Displacement
- Vocal channel that allows articulation (typical, not crucial)
- Additional properties:
 - vagueness
 - use of metaphors
 - context dependency



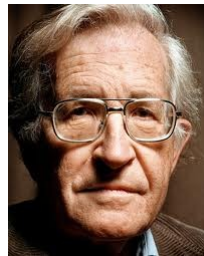
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Key questions: Knowledge and language

- What is knowledge (semantic memory)?
- How do we represent the outside world in our mind?
- Does the world exist out there, independently of our minds?
- Is the world structured? If so, how?
- How do we process the representations in our minds?

Language – “an interface” to our mind:

- What is the knowledge of language?
- How is it acquired?
- How is it put to use?
- Relation b/w language and cognition?



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Chomsky's (1928-) storyline

- **Universal Grammar** (1960s)
 - syntax (at least partially) inborn,
 - based on “poverty of the stimulus” argument
 - language acquisition device (only in humans)
 - Principles and parameters
- **Transformational generative grammar**
 - Deep structures and surface structures
- **Minimalist program** (since 1990s)
 - language as a system that relates meaning and sound
 - rules of grammar observed are only the consequences

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Research disciplines studying language

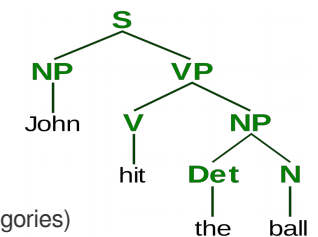
- (developmental) psycholinguistics
- Neurolinguistics
- Descriptive linguistics
- Theoretical linguistics
- Comparative linguistics (historical linguistics)
- Cognitive linguistics (cognitive semantics)
- Socio-linguistics
- Computational linguistics

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Language components

Components:

- **Phonology:** cat → /kæt/
- **Grammar:**
 - morphology: anti|abort|ion|ist|s
 - syntax: *John hit the ball* → N (V ((D) (N)))
- **Semantics:** agent - action - patient (semantic categories)
- **Pragmatics** (speaker's intention)



Hierarchy of building blocks:

phonemes → syllables → words → phrases → sentences → pragmatics (discourse) ...

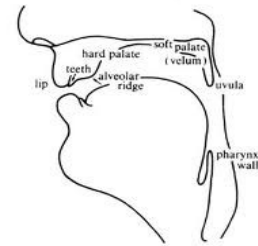
- language is hierarchical

Language has recursive structure (right branching, center embedding)

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Phonology

- mediated by auditory (sensory) modality
- Phoneme = basic discrete unit of sound (categorical perception)
- speech perception is multimodal (McGurk effect, 1976)
- speech sounds are subserved by different neural substrates than nonspeech (e.g. Binder et al., 2000)
- universal discriminatory ability, subject to sensitivity (critical) period
- each language uses only a subset of the “phonetic pool”



Points of articulation (Ladefoged, 1975:3)

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Grammar

- Syntax provides means for sentence disambiguation (case-role assignment)
- Interacts with semantics during parsing in sentence comprehension
 - mixed empirical evidence regarding the separability
- played a crucial role in generative grammar tradition (Chomsky) – close link to logic and its formalisms
- grammaticality judgment
 - Classical view = binary (grammatical sentence must comply with rules)
 - Statistical view = graded
 - compare: “We went to school.” “To school we went.” “Went we school to.”
 - sensitivity depends on language (word-order based vs inflective languages)

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Semantics

- Morpheme = basic unit that conveys meaning
- The most important and most difficult aspect of language
- What is meaning? How is it represented?
- Theories of semantics – referential, or non-referential:
 - **Realist semantics** – there exist objects (physical or mental) that are the meanings of linguistic expressions. Meanings are “in the world.”
 - Extensional ~ meanings are objects in the world (Frege, Tarski)
 - Intensional ~ meanings are mappings to possible worlds (Kripke)
 - **Cognitive semantics** – meanings are “in the head”, created during one’s experience with the world.
 - prototype theory (Rosch, 1983) → basic level categorization first
 - consistent with grounded theories of cognition

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Computational models of language processing

- **symbolic**
 - since 1950 (onset of computer era, **generative** linguistics)
 - based on **symbolic grammar** (e.g. context-free grammar, CFG)
 - emphasis on language **competence**
- **statistical**
 - **probabilistic grammars** (e.g. context-free grammar ~ Chomsky hierarchy)
 - statistical parsing (depends on grammar specification)
 - training on parsed (annotated) corpora
- **Connectionist (incl. deep learning)**
 - since 1985: „modern” PDP paradigm (in neural net)
 - **no grammar available**
 - statistical properties **exploited**
 - emphasis on **performance** (higher consistence with human behavior)

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Symbol systems

- work with abstract tokens (symbols)
- manipulated via explicit rules
- data and processes are separated

S : NP VP; Formal grammar G = (S, N, T, P)
 VP : VI | VT OP; *Initial symbol*: S (sentence)
 NP : the N; *Nonterminals*: NP, VP, OP, N, VI, VT
 OP : the N; *Terminals*: the, boy, dog, cat, barked, slept, ...
 N : boy | cat | *Rewriting rules*: P
 dog;
 VI : barked | slept;
 VT : bit | fed;

Generated sentences: the boy slept. the dog bit the cat. ...

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Dominance of rules in 1950-1980

Chomsky (1957): “Colorless green ideas sleep furiously.”

- It is a well-formed sentence (compared to e.g. “Ideas colorless sleep furiously green.”), despite its non-existence in corpus =>
- “statistical properties of language are not central to the characterization of linguistic knowledge”
- “what matters, is rules of grammar”

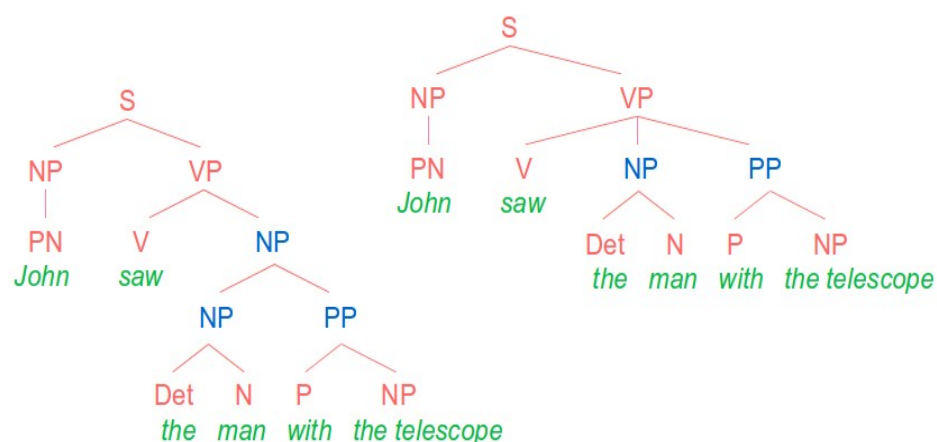
NP = noun phrase
 VP = verb phrase
 RC = relative clause
 ...

S	→	NP VI . NP VT NP .
NP	→	N N RC
RC	→	who VI who VT NP who NP VT
N	→	boy girl cat dog Mary John boys girls cats dogs
VI	→	barks sings walks bites eats bark sing walk bite eat
VT	→	chases feeds walks bites eats chase feed walk bite eat

Note: Transition probabilities are specified and additional constraints are applied on top of this framework.

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Syntactic sentence parsing



Who was holding the telescope in either case?

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Rules versus statistics

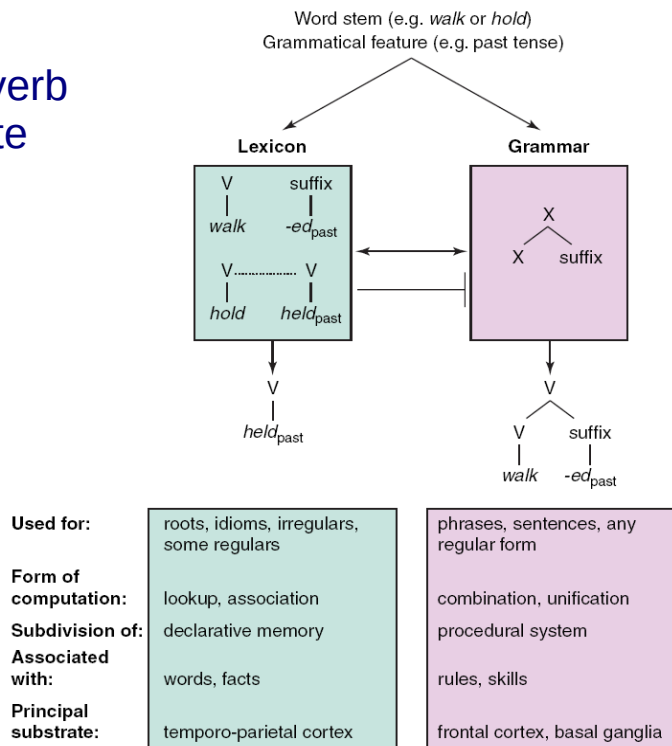
- **Rules** – abstract, symbolic level
 - in humans: may require conscious processes
 - e.g. in math (second language learning?)
- **Statistics** – frequency effects
 - symbolic level (as in statistical NLP)
 - subsymbolic level (as in ANN models)
 - in humans: likely to be unconscious (implicitly learned)
 - sequential learning (incl. non-adjacent dependencies)

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English past verb tense debate

Two accounts:

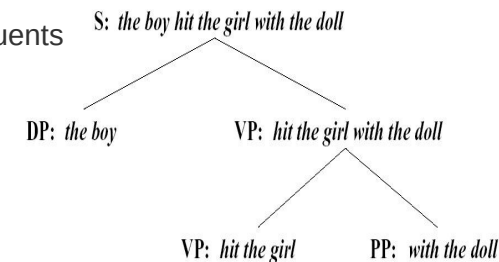
- **Symbolic** - two pathways
- **Connectionist** - single pathway



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Symbolic and connectionist approaches: comparison

- **symbolic**
 - explicit grammar
 - explicit manipulation with constituents
 - no memory problem
 - no problem with recurrence
 - no robustness
- **subsymbolic**
 - implicit grammar (emergence)
 - holistic processing
 - memory problem, recurrence problem (gradedness)
 - cognitive plausibility (robustness)



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Representation of word meaning

- **Symbol grounding problem:** "How can the meaning become intrinsic to the agent, rather than being dependent on external interpreter?" (Harnad, 2000)
- **Grounded theories:** word meaning is a multi-modal representation drawing on sensory-motor features (acquired during experience)
 - strong context dependency (e.g. the meaning of 'small')
- **Distributional theories:** word co-occurrence (context) in the text provides word meaning (Landauer & Dumais, 1997; Burgess & Lund, 1997)
 - require huge corpora, but match well human judgments
- What unifies the two views is the important role of **statistics** (as opposed to generative linguistics view)

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Major theories of language development

- universal trajectory across languages
- **Behaviorist** (Skinner)
 - learning (nurture) by associations, imitation and reinforcement
- **Nativist** (Chomsky)
 - Nature is crucial (universal grammar hypothesis)
 - Language parameters are triggered by environment
- **Cognitive developmental** (Piaget)
 - Nature is crucial but no specific inborn mechanism (as part of the developmental process) is specified
 - Language develops according to stages of cognitive development
- **Interactionist** (Vygotsky)
 - Nurture is crucial, but namely social interaction

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