Psychological background to Linguistic Theory

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UMass Amherst
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Course goals

- **Survey** of theories / questions in psycholinguistics: *speech perception, lexical access, syntactic* and *semantic processing.*

- **Hands-on** introduction to experimental research: How to think like an experimentalist, how do develop and test *psychological theories of language.*

- **Hands-on** introduction to two useful tools for running and analyzing experiments: **PCIbex** and **R.**
Psycholinguistics - what is it?

Morphology!

Phonology!

Syntax!

Phonetics!

Semantics!

Social context!

Pragmatics!
Brian’s pet peeve!

Psycholinguistics \neq Experimental work
Psycholinguistics

==

Study of the psychological/neural mechanisms that make human beings language users
What are we going to see?

→ General perspectives + theory building
→ Sensory perception
→ Categorization
→ Memory
→ Inference
→ Prediction
→ Learning and representation
Core reading: Foundational reading that provides useful context for class discussion.

We will start by reflecting on the 'inverse problem' as it applies to perception. The inverse problem refers to the observation that in many domains, sensory data underdetermine the contents of perception. This presents a sort of 'poverty of the stimulus' problem for psycholinguists. How do we overcome the inverse problem in perception?


Add’l reading: Recommended if the topic is of particular interest.
Each week: You will have a range of expected ways to advance your training. These will include:

- Critically reading and digesting assigned readings, and commenting on them in the course Google Doc.

- Doing expected lab / hands-on training component. This will vary week by week, but will include running experiments, analyzing data, doing short-write-ups. Focus is on small, incremental contributions to training rather than large ‘lab’ assignments.

- Think about your own project!
Aspirational goal

**Ideally:** You will use this course to develop a psycholinguistic perspective/hypothesis in an area of your choosing, and propose an experiment to test some aspect of your hypothesis.

- **You do not need** to run an experiment to satisfy the capstone requirement.

- **But** we can pay for pilot experiments (up to 250$) so that you *can* run it if you like. Be ambitious!

- To get the money, you must submit a successful **grant proposal** to Brian/Shota by April 3rd.

- **Get started early!** Talk to Brian/Shota about your ideas in Weeks 1-4, and we will direct you to relevant literature.
Ice-breaker: What is language?

You all study **language**: What is **language** to you? If you develop an analysis of some aspect of language, what kind of claim are you making?
In *Aspects of a Theory of Syntax* (1965), Chomsky argued that:

→ Linguistic analysis is more than just a description of language structure. It is a description of an individual speaker’s knowledge (*linguistic competence*).

→ Grammars are something in the mind of a speaker. The structure associated with a linguistic stimulus corresponds to a *representation* in a speaker’s mind.

→ Good linguistic analyses should describe a speaker’s knowledge and a means by which she could achieve that knowledge.

→ Linguistics should be understood as a branch of **Biological and Cognitive Sciences**.
Competence vs. Performance

→ Chomsky introduced a distinction between linguistic competence and linguistic performance

→ **Linguistic competence**: a speaker’s knowledge of her language.

→ **Linguistic performance**: the use of linguistic knowledge in the course of speaking / listening.

Key quote (Chomsky, 1965):

*Linguistic theory is concerned primarily with an ideal speaker-listener, in a completely homogeneous speech-community, who knows its language perfectly and is unaffected by such grammatically irrelevant conditions as memory limitations, distractions, shifts of attention and interest, and errors (random or characteristic) in applying his knowledge of the language in actual performance.*
→ Important to distinguish **behavior** from the underlying **system** that generates the behavior.

→ Chomsky has consistently argued that the system - not the behavior itself - is the object of study in linguistics:

Key quote (Chomsky, 1965):

*Observed use of language or hypothesized dispositions to respond, habits, and so on, may provide evidence as to the nature of this mental reality, but surely cannot constitute the actual subject matter of linguistics, if this is to be a serious discipline.*
More recent perspectives

I-Language: *Internal language*, the state of an individual language user’s mind. Chomsky (1986) argues this is the object of study of linguistic theory.

E-Language: *Externalized language*, all other (typically common-sense) conceptions of language, such as the list of forms used in a particular speech community, a sociopolitical object, ...
Fig. 2. A schematic representation of organism-external and -internal factors related to the faculty of language. FLB includes sensory-motor, conceptual-intentional, and other possible systems (which we leave open); FLN includes the core grammatical computations that we suggest are limited to recursion. See text for more complete discussion.
Psycholinguistics as **comparative** project
Psycholinguistics as comparative project

Superlinguistics: does formal linguistic theory provide unifying description in other areas of cognition, such as music, animal communication...?
The house across the street is burning.
An example: Natural language constituency

Fig. 5-6. Frequency of transitional errors in two types of sentences (after N. Johnson, 1963).

Fodor, Bever & Garrett (1974)
An example: Natural language constituency

→ **Dichotic listening**: Auditory stimulus presented in one ear, click presented in the other ear.

→ Participants are asked to report where they hear the click.

→ They tend to ‘hear’ the click as occurring between words, and between major syntactic boundaries.

There once was a young rat named Arthur

-2 -1 0 1 2
Fig. 2. A schematic representation of organism-external and -internal factors related to the faculty of language. FLB includes sensory-motor, conceptual-intentional, and other possible systems (which we leave open); FLN includes the core grammatical computations that we suggest are limited to recursion. See text for more complete discussion.
Magnetoencephalography

SQUID* sensor array aligned to cortical surface of the brain

Axons in the cortical surface of the brain

Direction of electric current in active axon

SQUID sensor detects magnetic field of current

* Superconducting Quantum Interface Device
Ding et al. (2016)
“But my research goal is to develop an analysis of [thing X] in [language Y]! How can that possibly be related to brains?!”
David Marr’s Vision (1982)

Marr’s three levels:

→ **Computational level:** Describes the why of an information processing system, characterizes the function it seeks to compute.

→ **Algorithmic level:** Describes the how of an information processing system, characterizes the representations and algorithms it uses.

→ **Implementational level:** Describes the circuits in which the algorithm is implemented.
Example: Sorting a list

\[ [10, 2, 8, 5, 1] \rightarrow [1, 2, 5, 8, 10] \]

→ **Computational level:** Arrange \( n_1, \ldots, n_k \) such that \( n_{i-1} < n_i \).
Example: Sorting a list

\[ [10, 2, 8, 5, 1] \rightarrow [1, 2, 5, 8, 10] \]

→ **Computational level**: Arrange \( n_1, \ldots, n_k \) such that \( n_{i-1} < n_i \).

→ **Algorithmic level**: Pass through the list and compare each \( n_{i-1} \) and \( n_i \); if \( n_i < n_{i-1} \), then swap integer positions, and continue through the list. Repeat until no swaps are made (**Bubble Sort algorithm**).
Example: Sorting a list

\[ [10, 2, 8, 5, 1] \rightarrow [1, 2, 5, 8, 10] \]

→ **Computational level:** Arrange \( n_1, \ldots, n_k \) such that \( n_{i-1} < n_i \).

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→ **Implementational level:** Circuit diagram showing how this is digitally implemented.
Approach at different levels is necessary!

→ Original Donkey Kong is run on the MOS6502 microchip, on the Atari, Commodore 64, and Apple I.

→ Jonas & Kording (2017) measured the behavior of every single part of the chip as it ran Donkey Kong: 1.5 GB per second worth of data. They submitted this data to state of the art Neuroscience/Machine-learning methods for analyzing neural computation.

→ They were unable to recover satisfactory understanding of the structure of any of the programs running on these chips by just looking at the actions on the chip.
Failure to recognize this theoretical distinction between *what* and *how* also greatly hampered communication between the fields of artificial intelligence and linguistics. Chomsky’s (1965) theory of transformational grammar is a true computational theory in the sense defined earlier. It is concerned solely with specifying what the syntactic decomposition of an English sentence should be, and not at all with how that decomposition should be achieved. Chomsky himself was very clear about this—it is roughly his distinction between competence and performance, though his idea of performance did include other factors, like stopping in midutterance—but the fact that his theory was defined by transformations, which look like computations, seems to have confused many people. Winograd (1972), for example, felt able to criticize Chomsky’s theory on the grounds that it cannot be inverted and so cannot be made to run on a computer; I had heard reflections of the same argument made by Chomsky’s colleagues in linguistics as they turn their attention to how grammatical structure might actually be computed from a real English sentence.
→ **Computational level**: Describes the why of an information processing system, characterizes the function it seeks to compute.

→ **Algorithmic level**: Describes the how of an information processing system, characterizes the representations and algorithms it uses.
Representations and representations

\[ [11, 20] \rightarrow [31] \]

→ **Computational level:** Addition of two numbers.
Representations and \textit{representations}

\[ [11, 20] \rightarrow [31] \]

\[ \rightarrow \text{Computational level:} \text{ Addition of two numbers.} \]

\[ \rightarrow \text{Algorithmic level:} \text{ Depends on \textit{representation} of numbers. Arabic numerals, Binary numerals, Roman numerals all have distinct rules for doing basic addition with them.} \]
→ **Computational level:** Define the grammatical sound-meaning relationship:

![Diagram](image)

→ **Algorithmic level:** Representation of DP used by any given speaker ‘at runtime’
Representations and *representations*

Grothe, 2003
Representations and representations

Grothe, 2003
→ **Functionalism** is the approach to psychology that holds that mental states can be defined functionally by the effects they can have on other mental states, or on behavior.

→ Arose in contrast to **structuralism**, which emphasized introspective methods / analysis of conscious experiences.

→ Functionalism can also be contrasted with **reductionism**, which holds that it is essential to understand the brain itself in order to understand the mind, since the latter is (presumably) a result of the former.
→ Can’t understand what’s going on by analyzing the circuits alone? **Don’t worry yet.**

→ We can model/explain the system by describing it at an intermediate level of description, describing parts that functionally interact with each other (barrels, Donkey Kong, Mario, and so on).
A too-simple but useful heuristic view

→ **Computational level:**
- Competence theory: What is the function that relates sound and meaning?

→ **Algorithmic level:**
- Psycholinguistic theory: What are representations used by speakers in real-time, and how are they computed?

→ **Implementational level:**
- Neurolinguistic theory: What are the neural circuits that implement psycholinguistic algorithms?
What makes us different?

Fig. 2. A schematic representation of organism-external and -internal factors related to the faculty of language. FLB includes sensory-motor, conceptual-intentional, and other possible systems (which we leave open); FLN includes the core grammatical computations that we suggest are limited to recursion. See text for more complete discussion.
What makes us different?

Opinion

Symbols and mental programs: a hypothesis about human singularity

Stanislas Dehaene 1,2,* Fosca Al Roumi, 1 Yair Lakretz, 1 Samuel Planton, 1 and Mathias Sablé-Meyer 1
Mathy & Feldman (2012)

Highly patterned sequence—
12 items in 4 chunks

Moderately compressible sequence—
7 items in 4 chunks

Incompressible sequence—
4 items in 4 chunks
Symbols and mental programs: a hypothesis about human singularity

Stanislas Dehaene, Fosca Al Roumi, Yair Lakretz, Samuel Planton, and Mathias Sablé-Meyer

(i) **Symbols, mental programs, and languages.** We propose that humans are characterized by a specific ability to attach discrete symbols to mental representations and to combine those symbols into nested recursive structures called mental programs, the compositional rules of which define a language of thought. Humans develop multiple such languages of thought in various domains (linguistic, musical, mathematical…).

(ii) **Conceptual productivity through compositionality.** Symbolic composition allows humans to create new concepts by recursive composition of existing ones (e.g., square = four-sided figure with equal sides and equal angles).

(iii) **Mental compression.** Understanding a sequence, a pattern, or a shape consists of compressing it into a compact mental object by inducing a short mental program capable of reproducing it.

“Dendrophilia”