

**Psych 156A/ Ling 150:**  
**Acquisition of Language II**

**Lecture 2**  
**Introduction:**  
**Mechanism of Language Acquisition**

**Announcements**

Start working on HW1 (due: 4/19/12)

Be looking over the review questions for introduction

Readings for next time:  
 Werker (1995) + (recommended) Swingley (2009)

**What's being learned:**  
**Patterns or "rules" of language = grammar**

**A distinction: Prescriptive vs. Descriptive Grammar Rules**

**Prescriptive:** what you have to be taught in school, what is prescribed by some higher "authority". You don't learn this just by listening to native speakers talk.

"Don't end a sentence with a preposition."  
 "'Ain't' is not a word."

### A distinction: Prescriptive vs. Descriptive Grammar Rules

Descriptive: what you pick up from being a native speaker of the language, how people actually speak in their day-to-day interactions. You don't have to be explicitly taught to follow these rules.

The dwarf is who Sarah first talked *with*.

"You're horrible!" "No, I *ain't* - I'm Hoggle!"



### Possible objections to a mental rule set

"Why should I believe I store a set of rules unconsciously in my mind? I just understand sentences because they make sense."

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"Why should I believe I store a set of rules unconsciously in my mind? I just understand sentences because they make sense."

But why do some sentences make sense and others don't?

Hoggle has two jewels.  
\*Two Hoggle jewels has.



### Possible objections to a mental rule set

Why can we recognize patterns even when some of the words are unknown?

'Twas brillig, and the slithy toves  
did gyre and gimble in the wabe...



### Possible objections to an unconscious rule set

"When I talk, the talk just comes out - I'm not consulting any rule set."

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Analogy: wiggling your fingers

When you want to wiggle your fingers, you "just wiggle them".

But your finger-wiggling intention was turned into commands sent by your brain to your muscles, and you're never conscious of the process unless something interferes with it. Nonetheless, there *is* a process, even if you're not aware of it.

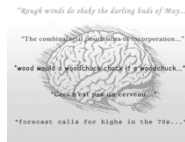
### Main points

Language acquisition is a process that involves inferring a structured system from the available input.

How do we explain how this process works?



### Levels of Representation Marr (1982)



### Describing vs. Explaining in Vision

"...it gradually became clear that something important was missing ...neurophysiology and psychophysics have as their business to *describe* the behavior of cells or of subjects but not to *explain* such behavior....What are the problems in doing it that need explaining, and what level of description should such explanations be sought?" - Marr (1982)



### On Explaining (Marr 1982)

"But the important point is that if the notion of different types of understanding is taken very seriously, it allows the study of the information-processing basis of perception to be made *rigorous*. It becomes possible, by separating explanations into different levels, to make explicit statements about what is being computed and why..."

### On Explaining (Marr 1982)

"But the important point is that if the notion of different types of understanding is taken very seriously, it allows the study of the information-processing basis of perception to be made *rigorous*. It becomes possible, by separating explanations into different levels, to make explicit statements about what is being computed and why..."

Our goal: Substitute "language learning" for "perception".

### The three levels

#### Computational

What is the goal of the computation?

#### Algorithmic

How can this computational theory be implemented?  
What is the representation for the input and output,  
and what is the algorithm for the transformation?

#### Implementational


How can the representation and algorithm be realized physically?

### The three levels: An example with the cash register

**Computational**  
What does this device do?  
Arithmetic (ex: addition).  
Addition: Mapping a pair of numbers to another number.

$(3,4) \rightarrow 7$  (often written  $(3+4=7)$ )

**Properties:**  
 $(3+4) = (4+3)$  [commutative]  
 $(3+4)+5 = 3+(4+5)$  [associative]  
 $(3+0) = 3$  [identity element]  
 $(3+ -3) = 0$  [inverse element]




True no matter how numbers are represented: this is what is being computed

### The three levels: An example with the cash register

**Computational**  
What does this device do?  
Arithmetic (ex: addition).  
Addition: Mapping a pair of numbers to another number.

**Algorithmic**  
What is the input, output, and method of transformation?  
Input: arabic numerals (0,1,2,3,4...)  
Output: arabic numerals (0,1,2,3,4...)  
Method of transformation: rules of addition, where least significant digits are added first and sums over 9 have their next digit carried over to the next column




$$\begin{array}{r} 99 \\ + 5 \\ \hline \end{array}$$

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$$\begin{array}{r} 99 \\ + 5 \\ \hline 14 \end{array}$$

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$$\begin{array}{r} 1 \\ 99 \\ + 5 \\ \hline 4 \end{array}$$

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$$\begin{array}{r} 1 \\ 99 \\ + 5 \\ \hline 104 \end{array}$$




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Method of transformation: rules of addition

**Implementational**  
How can the representation and algorithm be realized physically?  
A series of electrical and mechanical components inside the cash register.




### The three levels: An example with a sandwich

**Computational**  
What is the goal?  
Make a peanutbutter and jelly sandwich.

**Properties:**


- slices of bread containing both peanutbutter and jelly
- number of bread slices: 2
- sandwich is sliced in half
- crusts are left on
- jelly type: grape
- peanutbutter type: crunchy
- etc.



### The three levels: An example with a sandwich

**Computational**  
What is the goal?  
Make a peanutbutter and jelly sandwich.


**Algorithmic**  
What is the input, output, and method of transformation?  
Input: ingredients (peanutbutter, jelly, bread slices), tools (knife, spoon)  
Output: completed, edible sandwich with the required properties  
Method: Use the spoon to put jelly on one slice & spread it with the knife. Use the spoon to put peanutbutter on the other slice & spread it with the knife. Put the two slices of bread together, with the spread sides facing each other. Cut the joined slices in half with the knife.



### The three levels: An example with a sandwich

**Computational**  
What is the goal?

Make a peanutbutter and jelly sandwich.




**Algorithmic**  
What is the input, output, and method of transformation?

Input: ingredients (peanutbutter, jelly, bread slices), tools (knife, spoon)  
Output: completed, edible sandwich with the required properties  
Method: PBJ-making steps.

**Implementational**  
How can the representation and algorithm be realized physically?

Directing your younger sibling to follow the steps above to make you a sandwich.

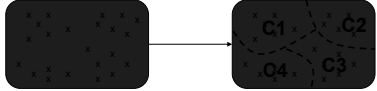


### Mapping the Framework: Algorithmic Theory of Language Learning

Goal: Understanding the "how" of language learning

First, we need a computational-level description of the learning problem.

Computational Problem: Divide sounds into contrastive categories



### Mapping the Framework: Algorithmic Theory of Language Learning

Goal: Understanding the "how" of language learning

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Computational Problem: Divide spoken speech into words

húwzəfrɛjdəvðəbɪgbædwɔlf

↓


húwz əfrɛjd əv ðə bɪg bæd wɔlf  
who's afraid of the big bad wolf

### Mapping the Framework: Algorithmic Theory of Language Learning

Goal: Understanding the "how" of language learning

First, we need a computational-level description of the learning problem.

Computational Problem: Map word forms to speaker-invariant forms




**Mapping the Framework:  
Algorithmic Theory of Language Learning**

Goal: Understanding the "how" of language learning

First, we need a computational-level description of the learning problem.

Computational Problem: Identify grammatical categories

"This is a DAX." 


DAX = noun

**Mapping the Framework:  
Algorithmic Theory of Language Learning**

Goal: Understanding the "how" of language learning

First, we need a computational-level description of the learning problem.

Computational Problem: Identify the concept a word is associated with (Word-meaning mapping)

"I love my daxes." 


*Dax* = that specific toy, teddy bear, stuffed animal, toy, object, ...?

**Mapping the Framework:  
Algorithmic Theory of Language Learning**

Goal: Understanding the "how" of language learning

First, we need a computational-level description of the learning problem.

Computational Problem: Identify the rules of word order for sentences.



Jareth juggles crystals

Subject Verb Object

English

Subject Verb Object

Kannada

Subject  $I_{Object}$  Verb Object

German

Subject Verb  $I_{Subject}$  Object  $I_{Verb}$

**Mapping the Framework:  
Algorithmic Theory of Language Learning**

Goal: Understanding the "how" of language learning

Second, we need to be able to identify the algorithmic-level description:

Input = sounds, syllables, words, phrases, ...

Output = sound categories, words, words with affixes, grammatical categories, sentences, ...

Method = statistical learning, prior knowledge about how human languages work, ...



### Recap: Levels of Representation

Language acquisition can be viewed as an information-processing task where the child takes the native language input encountered and uses it to construct the adult rule system (grammar) for the language.

Main idea: The point is not just to describe what children know about their native language and when they know it, but also how they learned it.

Three levels:

- computational: what is the problem to be solved
- algorithmic: what procedure will solve the problem, transforming input to desired output form
- implementational: how is that procedure implemented/instantiated in the available medium

### Computational Modeling: Understanding the Mechanism

Computational Level:

Theoretical linguistic studies can often tell us what needs to be learned about language. Experimental studies can often tell us about when children seem to know different kinds of language knowledge. This defines the goal of language acquisition:

Learn the appropriate what by the appropriate when.

### Computational Modeling: Understanding the Mechanism

Algorithmic Level:

But how do we know what the input is, what the output ought to look like, and what method(s) children use to get from the input to the output?



### Computational Modeling: Understanding the Mechanism

Algorithmic Level:

Input: The CHILDES database has a wealth of child-directed speech transcripts and videos from a number of different languages. This can help us figure out what children's input looks like.

<http://chilides.psy.cmu.edu/>

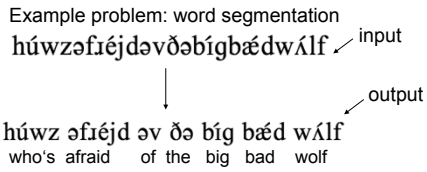
**CHILDES** Child Language Data Exchange System



### Computational Modeling: Understanding the Mechanism

Algorithmic Level:

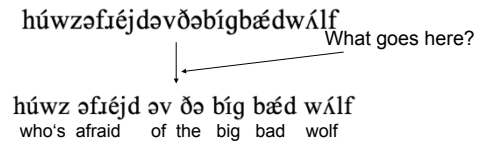
Output: Theoretical linguistics and experimental studies can tell us what the output should look like by observing adult and child knowledge of various linguistic phenomena.



### Computational Modeling: Understanding the Mechanism

Algorithmic Level:

Method: Computational modeling can often help us figure out how children are getting from the input to the output.




### Computational Modeling: What a "Digital" Child Can Tell Us

We can construct a model where we have precise control over these:

- The hypotheses the child is considering at any given point [hypothesis space]

"I love my daxes."




Dax = that specific toy, teddy bear, stuffed animal, toy, object, ...?

### Computational Modeling: What a "Digital" Child Can Tell Us

We can construct a model where we have precise control over these:

- The hypotheses the child is considering at any given point [hypothesis space]
- How the child represents the data & which data the child uses [data intake]

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Dax = that specific toy, teddy bear, stuffed animal, toy, object, ...?

### Computational Modeling: What a “Digital” Child Can Tell Us

We can construct a model where we have precise control over these:

- The hypotheses the child is considering at any given point [hypothesis space]
- How the child represents the data & which data the child uses [data intake]
- How the child changes belief based on those data [update procedure]

*dax = that specific toy more probable*

*dax = any object less probable*


### Computational Modeling: What a “Digital” Child Can Tell Us

Models are most informative when they're grounded empirically.

This is why most models make use of the child-directed speech data available through databases like CHILDES.

Many models will try to make cognitively plausible assumptions about how the child is representing and processing input data:

- Processing data points as they are encountered
- Assuming children have memory limitations (ex: memory of data points may decay over time)



### General Modeling Process

(1) Decide what kind of learner the model represents (ex: normally developing 6- to 8-month-old child learning first language)

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### General Modeling Process

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- (2) Decide what data the child learns from (ex: Bernstein corpus from CHILDES) and how the child processes that data (ex: divide speech stream into syllables)
- (3) Decide what hypotheses the child has (ex: what the words are) and what information is being tracked in the input (ex: transitional probability between syllables)

### General Modeling Process

- (1) Decide what kind of learner the model represents (ex: normally developing 6- to 8-month-old child learning first language)
- (2) Decide what data the child learns from (ex: Bernstein corpus from CHILDES) and how the child processes that data (ex: divide speech stream into syllables)
- (3) Decide what hypotheses the child has (ex: what the words are) and what information is being tracked in the input (ex: transitional probability between syllables)
- (4) Decide how belief in different hypotheses is updated (ex: based on transitional probability between syllables)

### General Modeling Process

- (5) Decide what the measure of success is

ex: making correct generalizations

- Knowing that *dax* refers to all teddy bears, even ones the child hasn't seen before

ex: achieving a certain knowledge state by the end of the learning period

- Recognizing words in a fluent speech stream

### The goal of modeling

Remember: the goal is generally to see if a particular learning strategy (as described by the hypothesis space, data intake, and update procedure) will allow the child to go from the input to the output. This then tells us about the process of language acquisition (the algorithmic level of explanation).

húwzəfɪɛjdəvðəbɪgbædwɔ̃lf

↓      ↗ What goes here?

húwz əfɪɛjd əv ðə bɪg bæd wɔ̃lf

who's afraid    of the big bad wolf

### Recap: Mechanism of Acquisition

One of the main goals of the study of language acquisition is to explain it, rather than just describe it.

There are three different levels of explanation, according to Marr: the computational level, the algorithmic level, and the implementational level.

The algorithmic level focuses on the process (the "how") of acquisition, and computational modeling is a technique that can be used to investigate different strategies a child might use to learn language.

### Questions?



Use the rest of this class period to look over the review questions and work together on HW1. You should be able to do all the introductory review questions and up through question 2 on HW1.