The Menu Bar

• Administrivia:
• Lab 4 due April 9

Agenda:
• Lexical semantics: the meanings of words: how hard can it be?
• Tense and time (if there’s time)
Word sense

- The benevolent alien race that visits earth.
- Their great book is entitled *How to Serve Humans*
Predicate-arguments to thematic roles

- Use *linking rules*
- These say whether, e.g., Subject is the agent...
- Is there a theory for this?
- How do we build this knowledge?
Predicate-argument structures for *lose*

lose1 (Agent: animate, 
    Patient: physical-object)

lose2 (Agent: animate, 
    Patient: competition)

Agent        <=> subj
Patient      <=> obj
Iraq lost the battle.

*Ilakuka centwey ciessta.*

[Iraq] [battle] [lost].

John lost his computer.

*John-i computer-lul ilepelyessta.*

[John] [computer] [misplaced].
Word sense disambiguation with Source Language Semantic Class Constraints
(co-occurrence patterns)

\[ \text{lose}_1(Agent, Patient: \text{competition}) \iff \text{ciessta} \]

\[ \text{lose}_2(Agent, Patient: \text{physobj}) \iff \text{ilepelyessta} \]
Is there enough data?

- Break
Levin classes (3100 verbs)

- 47 top level classes, 150 second and third level

- Based on pairs of syntactic frames.
  
  John broke the jar. / Jars break easily. / The jar broke.
  John cut the bread. / Bread cuts easily. / *The bread cut.
  John hit the wall. / *Walls hit easily. / *The wall hit.

- Reflect underlying semantic components
  contact, directed motion,
  exertion of force, change of state

- Synonyms, syntactic patterns, relations
Another alternation example

- Another example: Causative/inchoative
  - The window broke
  - John broke the window
  - The rabbit suddenly appeared
  - *The magician appeared the rabbit

- Benefactive:
  - Sue carved a toy out of wood for Hansel
  - Sue carved hansel a toy out of wood
  - Sue carved some wood into a toy for Hansel
  - *Sue carved Hansel some wood into a toy

- Middle formation:
  - The whale frightens easily
  - *The whale sees easily
Alternations..

- Sue broke the vase/ The vase broke (change-of-state)
- The vase broke easily
- Conative: *Sue broke at the vase

- Bill cut the bread/ *The bread cut (change-of-state, no “telic” endpoint)
- The bread cut easily
- Bill cut at the bread

- Mary touched the cat / *The cat touched
- *The cat touched easily (no change-of-state)
- *Mary touched at the cat

- Joe kicked the tire / *The tire kicked
- *The tire kicked easily
- Joe kicked at the tire
- Alternations can be lang-specific: "break" is a causative/inchoative in English, but not Italian.
Lexical Gaps: English to Chinese

- break → ?
- smash → da po - *irregular pieces*
- shatter → da sui - *small pieces*
- snap → pie duan - *line segments*
Intersective Levin classes
So we want...
Thematic Roles

- E w,x,y,z Giving (x) ^ Giver(w,x) ^ Givee(z, x) ^ Given(y,x)
- E w,x,z Breaking (x) ^ Breaker(w,x) ^ Broken(z,x)

A set of roles:
- agent, experiencer, force, theme, result, content, instrument, beneficiary, source, goal,...

The dog ate the cheeseburger.
What is cheeseburger?
The sniper shot his victim with a rifle.
What is rifle?
Schank's Conceptual Dependency

- Eleven predicate primitives represent all predicates
- Objects decomposed into primitive categories and modifiers
- But few predicates result in very complex representations of simple things

\[
\text{Ex}, y \ A\text{trans}(x) \land \text{Actor}(x, \text{John}) \land \\
\text{Object}(x, \text{Book}) \land \text{To}(x, \text{Mary}) \land \text{P\text{trans}}(y) \land \\
\text{Actor}(y, \text{John}) \land \text{Object}(y, \text{Book}) \land \text{To}(y, \text{Mary})
\]

John caused Mary to die vs. John killed Mary
Selection via sortal hierarchy

- John ate a clam
- They served clams

“logical” form: \( \exists x, y, e [ \text{eat}(e) \land \text{eater}(e, y) \land \text{eaten}(e, x) \land \text{john}(y) \land \text{clam}(x) \land \text{past}(e)] \)

- So...
Sortal hierarchy (‘ontology’)
Selection via sortal hierarchy

1. eater([Eating],[Being])
2. eat([Eating])
3. eaten([Eating],[Food])
4. server([Serving],[Being])
5. serve₁([Serving])
6. served([Serving],[Food])
7. john([Person])
8. they([Person])
9. mussel₁([Food])
10. mussel₂([Creature])
But...

- Which airlines serve Denver?
- You ate glass on an empty stomach
- Metonomy: What airlines fly to Boston?
But how can we/computer learn this?

- Two parts: pred-arg linking to thematic roles – which verbs do what
- Selectional restrictions
pour vs. fill

- Different linking entails semantic difference - when in Object position, the Goal seems "affected" in a way not so in the PP
- *Fill*: Cause X to become full of Y by means of causing Y to be in X
- *Pour*: Cause X to go in a downward stream into Y
- *Fill* has two events: a state change (the glass) and a location change (the water)
- *Pour* has one event: location change
- The Main-change argument gets Old-Info structure and main event status. Main event of *Fill*: state change of glass
Look! He’s sebbing!

Look! A seb!

Look, some seb!

/seb/ means MIXING

/seb/ means BOWL

/seb/ means STUFF

KEY HUMAN COMPETENCE:

One-shot integration of syntax & semantics
The Problem of Ambiguity

Possible Hypotheses

- Rabbit (whole object)
- Animal (superordinate)
- Flopsie (individual)
- Furry (property)
- Ear (part)
- Walk by (activity)
- Undetached rabbit parts ......
Two Bootstrapping Proposals

- Children use syntactic cues to verb meaning (Gleitman 1990)

- Children use (verb) meaning to figure out how its arguments are realized in the syntax of the language (Pinker 1989)
Semantic Bootstrapping
(Pinker 1984)

Semantic Bootstrapping involves the pairing of a situational context with some syntactic pattern.

- Kids learn syntax by first learning the semantic argument structure of the verb.
  - SWIM = one participant (the “swimmer”)
  - EAT = two participants (“eater”, “eatee”)
  - TAKE = two/three participants (“taker”, “takee”, and “person taken from”...)

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Gleitman: Not So Fast, Pinker...

Temporal ambiguity       Situation ambiguity       Mental unobservable!

... more than just real-world observation...

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Syntactic Bootstrapping
(Landau and Gleitman 1986, Naigles 1990)

Syntactic frames provide evidence for meaning:

$H_1$: arm wheel

$H_2$: cause to squat
Verbs Classes Grouped by Cause Feature

$H_i$  Verb Class

$H_I$  Externally Caused ($touch$, $load$)

$F_1$: He touched the glass.

$* F_0$: The glass touched.

$H_0$ Internally Caused ($laugh$, $glimmer$)

$* F_1$: He laughed the child.

$F_0$: He laughed.

$H^*$ Externally Causable ($open$, $break$)

$F_1$: He opened the door.

$F_0$: The door opened.

$Hypothesis$ $space$ $H$

$Hi$ in $H$

Evidence $x$ in $X = \{0, 1\}$

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One-shot learning

within a Bayesian framework.

Syntactic Evidence    Semantic Evidence    | Evidence $x$

Linguistic Theory

$H = \{H_1, H_2, \ldots\}$

Prior: $p(H_i)$

Likelihood $p(x|H_i)$

BAYESIAN

Acquisition Device

$\textit{Acquired Lexicon}$

$\langle \textit{seb} \rangle$ means $\textit{Posterior: }$

\[
p(H_i|x) = \frac{p(x|H_i)p(H_i)}{p(x)}
\]

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Learning Value of Verbs Cause Feature

**Syntactic Theory:**
\[
H = \{H_1, H_0, H_\ast\}
\]

**Prior:**
\[
p(H_i) = 0.333
\]

**Likelihood**
\[
p(x|H_i)
\]
\[
x = F_0 \quad x = F_1
\]
\[
H_1 & 0.05 & 0.95 \\
H_0 & 0.95 & 0.05 \\
H_\ast & 0.50 & 0.50
\]

**Acquired Lexicon**

**Syntactic Evidence:**
/He glipped the balloon/
\[
x = F_1
\]

**Posterior**
\[
p(H_i|x)
\]
\[
p(H_i|x=F_1)
\]
\[
= \frac{(0.95)(0.33)}{(0.05+0.95+0.50)(0.33)}
\]

\[
p(H_1|x=F_1) = 0.633
\]
\[
p(H_0|x=F_1) = 0.033
\]
\[
p(H_\ast|x=F_1) = 0.333
\]
Syntactic Evidence X:
/He glipped the balloon/
/X gorped Y/, /X gorped Y/
/X sebbed Y/, /Y sebbed/
/X meefed Y/\(^5\), /Y meefed/
/Y foomed/\(^6\)

Syntactic Theory:
\(H = \{H_1, H_0, H^*\}\)
Prior \(p(H_i)\)
Likelihood \(p(x/H_i)\)

Bayesian Language Acquisition Device

Acquired Syntactic Knowledge

| Lexicon: | Evidence X | \(p(H_1|X)\) | \(p(H_0|X)\) | \(p(H^*|X)\) |
|---------|------------|--------------|--------------|--------------|
| /glip/  | F1         | .633         | .033         | .333         |
| /gorp/  | F1, F1     | .781         | .002         | .217         |
| /seb/   | F1, F0     | .137         | .137         | .724         |
| /meef/  | F1\(^5\), F0 | .712        | 5e-6         | .288         |
| /foom/  | F0\(^6\)   | 2e-8         | .979         | .021         |
Bayesian Learning at the Syntax-Semantics Interface

**Syntactic Evidence**
/X is gorping Y into Z/
/X is pilking Z with Y/
/Look! jebbing!/

**Semantic Evidence**
Person pours water into a glass, filling it

**Linguistic Theory**

\[ H = \{ H_1, H_2, \ldots \} \]
Prior: \( p(H_i) \)
Likelihood \( p(x/H_i) \)

**Acquired Lexicon**

\[
\begin{array}{ccc}
  & p(\text{POUR}|x) & p(\text{FILL}|x) & p(\text{MOVE}|x) \\
/gorp/ & .880 & .000 & .101 \\
/pilk/ & .001 & .989 & .000 \\
/ljebl/ & .463 & .463 & .005 \\
\end{array}
\]
How to get ‘real semantics’ in?
**Verb meanings are logic programs (LPs):**

**General:**
- `cause(e)`

**One args x:**
- `move(x), rotate(x), move-dn(x), move-up(x)`
- `supported(x), liquid(x), container(x)`

**Two args x,y:**
- `contact(x,y), support(x,y), attach(x,y)`
  (if `cause(e)=1`)

<table>
<thead>
<tr>
<th>Verb</th>
<th>Logic Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>/lower/</td>
<td>1 1<em>101** 11</em></td>
</tr>
<tr>
<td>/raise/</td>
<td>1 1<em>011** 11</em></td>
</tr>
<tr>
<td>/rise/</td>
<td>0 1<em>01</em>**</td>
</tr>
<tr>
<td>/fall/</td>
<td>0 1<em>10</em>**</td>
</tr>
</tbody>
</table>

**Hypothesis space $H$:** All LPs

**Evidence $X$:** Bit Vector Examples
(e.g. 1 1010100 110)
Learning Semantic Features

Semantic “Theory”: (3 bits)

Hypothesis space \( H \): 27 LPs

\[
q \quad H_i \\
0 \quad 000, 001, 010, 011 \\
\quad 100, 101, 110, 111 \\
1 \quad 00*, 01*, 10*, 11* \\
\quad 0*0, 0*1, 1*0, 1*1 \\
\quad *00, *01, *10, *11 \\
2 \quad 0**, 1**, *0*, *1*, **0, **1 \\
3 \quad ***
\]

Priors \( p(H_i) = 1/27 \)

Likelihood \( p(x|H_i) = \{2^{-q} \text{ if } x \text{ in } H_i \} \)

\[
\begin{align*}
p(x=000|H_{000}) &= 1 \\
p(x=000|H_{00*}) &= .5 \\
p(x=000|H_{0**}) &= .25 \\
p(x=000|H_{***}) &= .125 \\
p(x=001|H_{000}) &= .30 \\
p(x=001|H_{00*}) &= .15 \\
p(x=001|H_{0**}) &= .07 \\
p(x=001|H_{***}) &= .03 \\
p(x=010|H_{000}) &= .00 \\
p(x=010|H_{00*}) &= .64 \\
p(x=010|H_{0**}) &= .16 \\
p(x=010|H_{***}) &= .04 \\
p(x=011|H_{000}) &= .70 \\
p(x=011|H_{00*}) &= .09 \\
p(x=011|H_{0**}) &= .01 \\
p(x=011|H_{***}) &= .001 \\
p(x=100|H_{000}) &= .00 \\
p(x=100|H_{00*}) &= .00 \\
p(x=100|H_{0**}) &= .00 \\
p(x=100|H_{***}) &= 1.0
\end{align*}
\]

Semantic Evidence:

/look! Glipping!/ X1=000
/look! Gorping!/ X2=000,001
/look! Sebbing!/ X3=000,000,000
/look! Meefing!/ X4=000,101,010,111,000

Bayesian Language Acquisition Device

Acquired Semantic Knowledge

Lexicon:

<table>
<thead>
<tr>
<th>/glip/</th>
<th>p(H_{000}/X)</th>
<th>p(H_{00*}/X)</th>
<th>p(H_{0**}/X)</th>
<th>p(H_{***}/X)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.30</td>
<td>.15</td>
<td>.07</td>
<td>.03</td>
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<td>.00</td>
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<td>.16</td>
<td>.04</td>
</tr>
<tr>
<td>/seb/</td>
<td>.70</td>
<td>.09</td>
<td>.01</td>
<td>.001</td>
</tr>
<tr>
<td>/meef/</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>1.0</td>
</tr>
</tbody>
</table>
But... what are the possible arguments?

- Predicate-arguments can be complicated...can we crank it out?
- Argument structure is syntax
- There are no specialized mechanisms of ‘thematic role assignment’
- Everything is really predication
Hale-Keyser: arguments are syntax
The basic form

spec

comp
H & K: The framework

- There are only three places a verb argument can come from
  - The complement or specifier of a “basic” lexical item
  - An external “addition”
  - As for “basic lexical items” there are four types: N, V, A, P
  - Why so few thematic roles? Because so few basic lexical items (entity-instance, event, state, relation)
N,V,A,P

- N takes no arguments
- V are predicational, and take one argument, a complement.
- P are relational, and take two arguments
- A are predicational, and take one argument, but require some help; thus an A is always the complement of a verb, which then projects for an external arg.
Hale-Keyser Incorporation

- 4 Fundamental Primitives Yield Different Argument Structures

V-N

V-A

V-P

V-P-N

V

N /glow/

V /open/

A /book/

V /put/

P /on/

N /book/

P /shelf/

N /shelf/

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HK Allows Us to Discard Thematic Roles

- Agent, Patient, Theme, Instrument, Goal, ...
  *derived from positions in structural configurations.*

- V-N:  • V-A  • V-P

```
V  N
 /glow/
  /door/
    theme

V_become
 /open/

A

V
 /book/

P
 /on/

N
 /shelf/

theme
goal
```
What can N get us?

• Intransitive verbs:

```
VP
  V  N
```

Nouns cannot project arguments. A noun (run, laugh, play, cough, snore, burp) incorporates into the verb. An external argument is adjoined to \( v \). Thus, rather than having cognate N and V copies in the lexicon, verbs are derived by *syntax*.
Unergatives vs. Simple Transitives

- Unergatives: no external agent *The child laughed
  - [NP [v [V+N (N)]]]
  - No verbs like *The clown laughed the child / *The alfalfa sneezed the colt (The N complement to V has incorporated, where would the “object NP” reside?)
  - [NP [V+N (N) NP?]]

- Simple transitive (non-creation) *The clown made the child laugh
  - [NP [v [NP [V+N (N)]]]]
  - Extensions: get+A (I got drunk, I got Josh drunk)
    - But not for get+N (I got the measles, *I got Josh the measles)
Explaining Gaps in the Lexicon

• *It cowed a calf, *It dusted the horses blind, *It machined the wine into bottles (cf. The cow had a calf, the dust made the horses blind, the machines put the wine into bottles)

• The above items would be the result of the external subject incorporating into the verb, which is ruled out by the syntax elsewhere (items raise & incorporate up, but not down)

• If all “denominal” verbs are the result of incorporation of the complement to the V head, rather than unconstrained “category change”, these non-verbs are predicted
V: Verbs of Creation: The simple case

- bake a cake, make trouble, build a house, have puppies

- V has a complement NP(=DP). External argument is projected and adjoined to v.
P gives *put*-type Verbs

- The P frame has a specifier and complement. The whole P-complex is a verb complement. An external argument is projected and adjoined.
P gives locatum-type verbs

- With a bare N as the PP complement, the N conflates with the P, which conflates with the V, giving *saddled the horse*, *boxed the gift*, *roofed the house* (all have P-meaning)
Implementation

(define-verb-class "PUT VERBS: put verbs (Section 9.1)"
"putting entity at some location (but not to or from)"
'(arrange immerse install lodge mount place position put set situate sling stash stow)
(list '(* the water put into a bowl))
'(+ he put the water into the bowl)
(vp ()
  (v* (v put (feature CAUSE))
    (pp (n the water)
      (p* (p into (feature MOVELOCATION))
        (n a bowl)))))))
Argument Structure: The Moral

- No specialized mechanism of “thematic role assignment”. Everything is predication.
- Do these mechanisms of derived verbs happen in the syntax with everything else, or “prior to lexical insertion”, e.g. “in the lexicon”? What do you think? Should this distinction matter?