Psych 215L: Language Acquisition

Lecture 17

Poverty of the Stimulus IV: Anaphoric *One*

Domain-general & domain-specific

Language acquisition may not just one or the other.

Three components of a learning theory, any of which can be either domain-general or domain-specific:

Representations of the data
- co-occurrence probabilities of acoustic signal vs.
  - phonemes, morphemes, syntactic trees

Data learned from
- filters that exclude data beyond the first 10 seconds vs.
  - filters that exclude data beyond the first clause

Updating process
- Bayesian updating vs.
  - language-specific updating process

Case study: Anaphoric *One*

Involves both a syntactic structural component (what structure does *one* refer to) and a semantic interpretation component (what does *one* refer to in the world).

As adults, we have strong intuitions about the interpretation, which tells us what our unconscious intuitions are about the structure.

Anaphoric *one* = a use of *one* that references some previous structure/string

I followed the debate about acquisition but not the one about syntax.

one interpretation = "debate"

* I ran the car into the side of the road but not the one of the house.

one interpretation should = "side", but the sentence doesn't sound right….why not?

Case study: Anaphoric *One*

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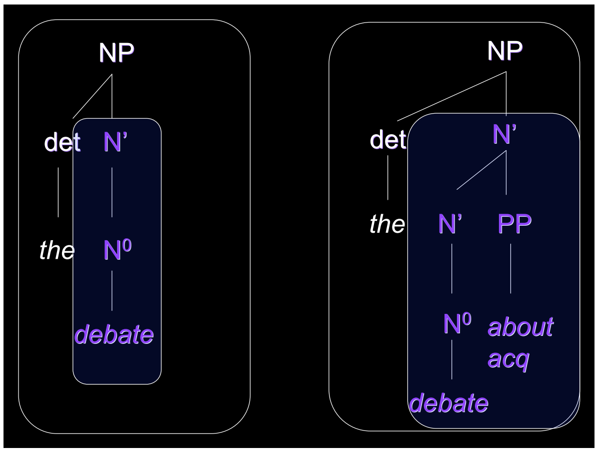
As adults, we have strong intuitions about the interpretation, which tells us what our unconscious intuitions are about the structure.

How linguists explain this:

One must refer to a structure that is larger than a simple noun (N^0). Linguists sometimes call this larger structure N'.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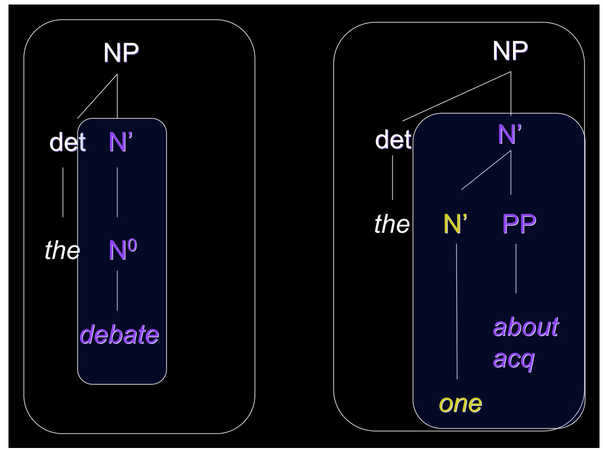
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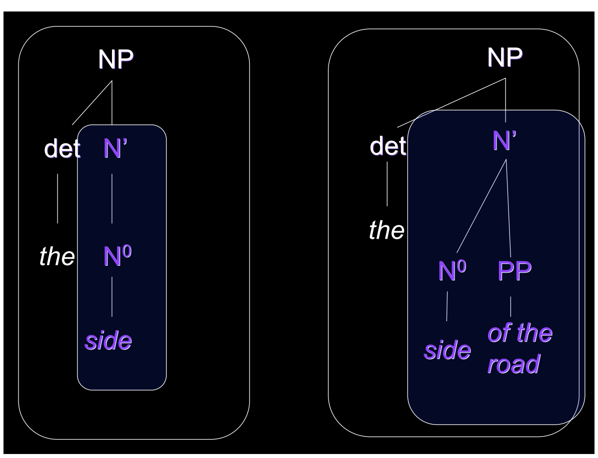
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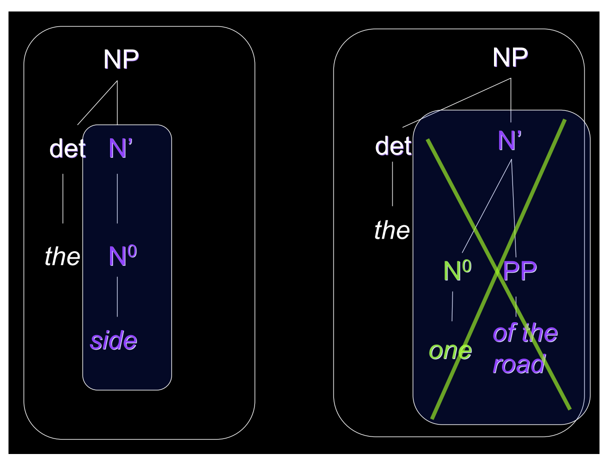
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More Adult Knowledge

"Jack likes this ball. Lily likes that one."

one = ball

"Jack likes this red ball. Lily likes that one."

one = *red ball* or *ball*?

More Adult Knowledge

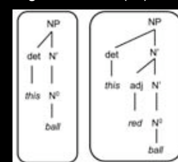
"Jack likes this ball. Lily likes that one."

one = ball

"Jack likes this red ball. Lily likes that one."

one = red ball

Linguists say: *one* should always refer to the same kind of structure. How are both of these strings the same (N')?



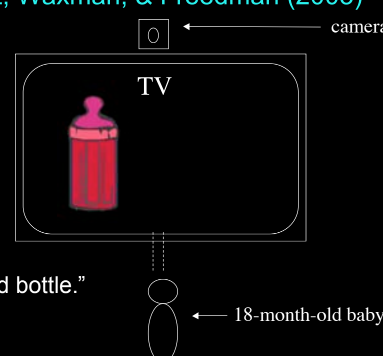
Question: How do children learn this?

Should be able to use information about both the linguistic antecedent of *one* (the string *one* replaces) and the referent of *one* (what *one* refers to in the world) since both of these come into play when interpreting *one*.

Classic response from linguists (Baker 1978, Hornstein & Lightfoot 1981, Crain 1991): Very little data available that clearly indicates *one* cannot be anaphoric to a N^0 structure (that is, few data are unambiguous). Children must somehow know something about the structure of anaphoric *one* beforehand.

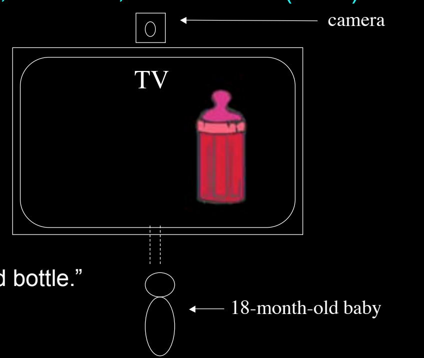
Recent response from computational modelers (Regier & Gahl 2004): Actually, children can learn this from the available data if the hypothesis space is simply *one* refers to N^0 vs. *one* refers to N'. The key is to cleverly use data that are ambiguous between the two hypotheses, instead of only using unambiguous data for what *one* refers to N'.

18-month-old behavior: Lidz, Waxman, & Freedman (2003)



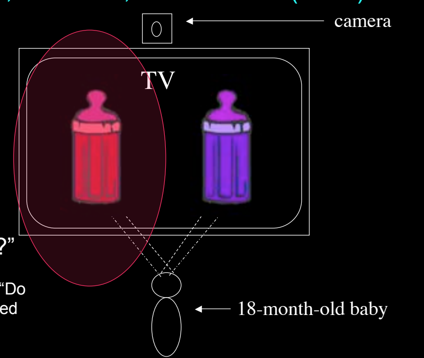
"Look! A red bottle."

18-month-old behavior: Lidz, Waxman, & Freedman (2003)



"Look! A red bottle."

18-month-old behavior: Lidz, Waxman, & Freedman (2003)



"Do you see another one?"

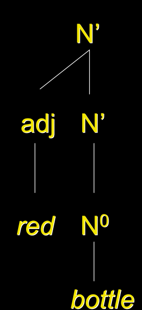
(Same results as "Do you see another red bottle?")

18-month-old behavior: Lidz, Waxman, & Freedman (2003)

18-month-olds have looking preference for red bottle.

LWF (2003) interpretation & conclusion:

Red bottle preference = semantic consequence of syntactic knowledge that *one* = [*red bottle*]$_{N'}$. 18-month-olds, like adults, believe *one* has an N' antecedent (since *red bottle* can't be N^0).



Estimates of children's data (what 18-month-olds heard)

Unambiguous data 10

"Jack wants a red ball. Lily doesn't have one for him."

Lily has a ball, but not a red ball.

one = red ball, and *one* refers to N'

Type I Ambiguous data 183

"Jack wants a red ball. Lily has one for him."

Lily has a red ball.

one = ball OR *one = red ball*, *one* refers to N^0 OR N'

Type II Ambiguous Data 3805

"Jack wants a ball. Lily has one for him."

Lily has a ball.

one = ball, *one* refers to N^0 OR N'

Regier & Gahl (2004): A Model for how to learn the interpretation of *one*

Main idea: A Bayesian learner is a domain-general learning mechanism that would be able to use both Unambiguous and Type I Ambiguous data

Using Type I Ambiguous data:

"Jack wants a red ball, and Lily has *one* for him."

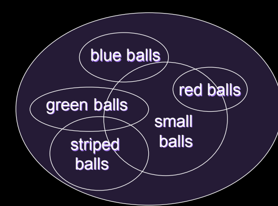
All the relevant knowledge for anaphoric *one* can be derived from knowing whether the property red is important for the referent (the ball, in this case) to have. (If the ball is always red, *red* is important and part of the string *one* refers to - and *red ball* is unequivocally N'.)

Basic strategy: Keep track of how often the referent that *one* refers to has the property mentioned in the potential antecedent (e.g. How often is the ball red?)

Bayesian expectations: The referents of *one*

If the property mentioned in the potential antecedent (e.g. *red*) is not important, the set of objects (e.g. balls) that *one* refers to should look something like this.

all balls

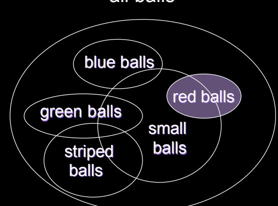


"…*red ball*…*one*…"

Bayesian expectations: The referents of *one*

If instead the property mentioned in the potential antecedent (e.g. *red*) is important, the set of objects (e.g. balls) that *one* refers to should look something like this.

all balls



"…*red ball*…*one*…"

Bayesian reasoning about referents

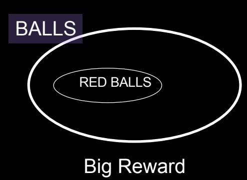
If the referents of *one* keep having the property mentioned in the potential antecedent (e.g. the balls keep being red when the phrase *red ball* is the potential antecedent), this is a conspicuous coincidence if the property isn't actually important. The Bayesian learner encodes this automatically and rewards the hypothesis that thinks the referent of *one* should be a red ball.

The reward is based on the relative size of the sets of potential referents (e.g., all balls vs. red balls).

Bayesian reasoning about referents

If red balls are a really small part of all the balls, it's really conspicuous that red balls keep being picked out. So, the Bayesian learner strongly rewards the hypothesis that the property red is actually important (i.e., that *red ball* is the antecedent).

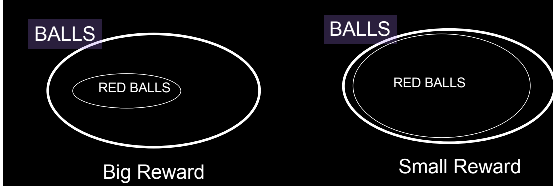
"…red ball…one…"



Bayesian reasoning about referents

If instead red balls are a really large part of all the balls, it's not really that conspicuous that red balls keep being picked out. So, the Bayesian learner weakly rewards the hypothesis that the property red is actually important (i.e., that *red ball* is the antecedent).

"…red ball…one…"



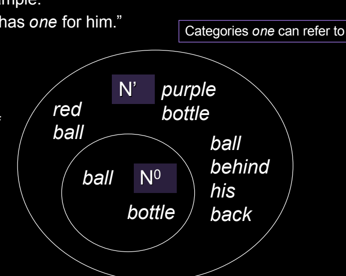
But what about the rest of the data?

One strength of Bayesian models are their ability to use all kinds of data, as long as the data are evenly mildly informative. So what about the Type II ambiguous data? Are these data informative? If so, it seems like a domain-general learner would use them as they make up the bulk of the data.

But what about the rest of the data?

Type II ambiguous data are informative if we think about the hypothesis space of potential antecedent strings for anaphoric *one*.

Type II Ambiguous data example:
"Jack wants a ball, and Lily has *one* for him."
one = *ball*, *one* = N^0 OR N'



Because of the layout of the hypothesis space (one hypothesis covers a subset of the strings the other covers), the Size Principle will favor the smaller hypothesis when the data are ambiguous.

Upshot: Type II Ambiguous data are informative about the syntactic category *one* refers to.

But maybe we wish they weren't…

Important Caveat: The smaller syntactic category hypothesis is that *one* refers to the category N^0. (Oops!) This means that the Type II Ambiguous data favor the incorrect syntactic hypothesis. Semantic consequence: any property that might be mentioned in the potential antecedent (e.g. *red*) won't matter because that property would be part of the larger N' category, not the N^0 category.

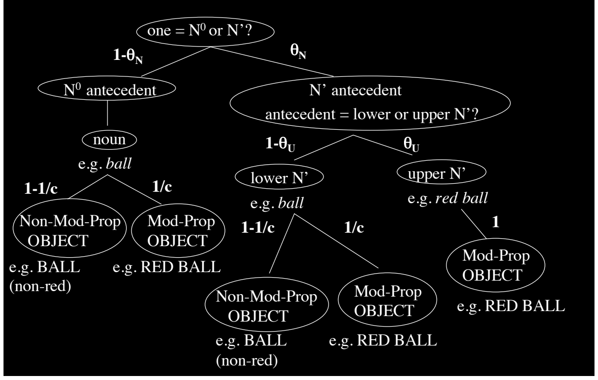
More pointedly, these data make up the bulk of the data to children - what would happen if a Bayesian learner used all the available informative data (Unambiguous, Ambiguous Type I, and Ambiguous Type II)?

An Equal-Opportunity Model

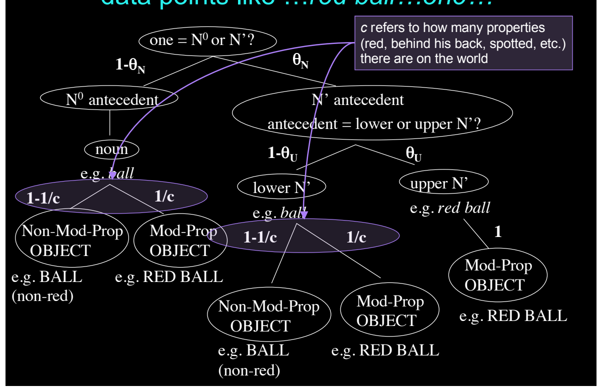
Generative model that learns by trying to construct the grammar that was used to generate the data ("analysis by synthesis").

Assumption: All data are generated by having *one* refer to an antecedent that is either an N^0 or N' string (θ_N). If an N' string is chosen and a property is mentioned in a potential antecedent, *one* can refer either to the smaller/lower N' (without the property, e.g. *ball*) or the larger/upper N' (with the property, e.g. *red ball*) (θ_U).

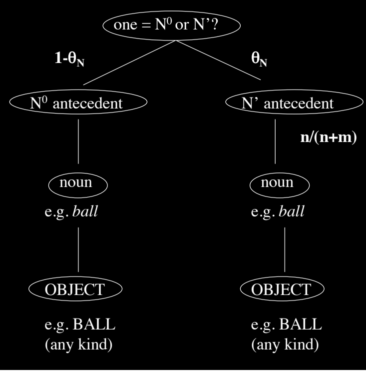
An Equal-Opportunity Model: Generating data points like …*red ball…one…*



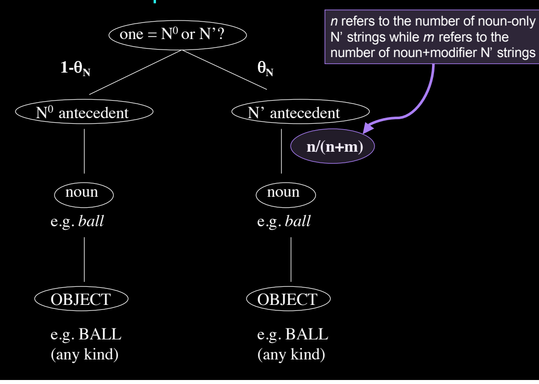
An Equal-Opportunity Model: Generating data points like …*red ball…one…*



An Equal-Opportunity Model: Generating data points like *…ball…one…*



An Equal-Opportunity Model: Generating data points like *…ball…one…*



Updating the Equal-Opportunity Learner

Unambiguous Data

$$\theta_N = \frac{\alpha + (data_N + 1)}{\alpha + \beta + (totaldata_N + 1)}, \alpha = \beta = 0.5 \qquad \theta_U = \frac{\alpha + (data_U + 1)}{\alpha + \beta + (totaldata_U + 1)}, \alpha = \beta = 0.5$$

Type I Ambiguous Data

$$\theta_N = \frac{\alpha + (data_N + l_{N-Type1})}{\alpha + \beta + (totaldata_N + 1)}, \alpha = \beta = 0.5 \qquad \theta_U = \frac{\alpha + (data_U + l_{U-Type1})}{\alpha + \beta + (totaldata_U + 1)}, \alpha = \beta = 0.5$$

Type II Ambiguous Data

$$\theta_N = \frac{\alpha + (data_N + l_{N-Type2})}{\alpha + \beta + (totaldata_N + 1)}, \alpha = \beta = 0.5$$

Updating the Equal-Opportunity Learner

Unambiguous Data, from $\theta_N = \theta_U = 0.5$

1 unambiguous data point, c = 5 (5 potential properties in the world)

$\theta_N = \theta_U = 0.75$

Type I Ambiguous Data, from $\theta_N = \theta_U = 0.5$

1 type I ambiguous data point, c = 5 (5 potential properties in the world)

$\theta_N = 0.625$, $\theta_U = 0.666$

Type II Ambiguous Data, from $\theta_N = \theta_U = 0.5$

1 type II ambiguous data point, n/m = 1/2 (two string types, of which a simple noun string (*ball*) is 1)

$\theta_N = 0.417$, $\theta_U = 0.5$

EO Model: Interpreting Anaphoric *One*

For a given utterance involving anaphoric *one* where there is more than one potential N' antecedent (e.g., …*red ball*…*one*…):

(1) Decide if the antecedent should be N^0 or N', using θ_N.
(2) If the antecedent is N^0, the referent is any object regardless of property (e.g., any ball)
(3) If the antecedent is N', decide if the antecedent is the smaller/lower or larger/upper N', using θ_U.
(4) Based on this decision, pick out the appropriate referent (e.g., lower = *ball*, so referent is any ball; upper = *red ball*, so referent is a red ball)

Initial probability of adult interpretation (choose N', choose upper N'):
$\theta_N * \theta_U = 0.5 * 0.5 = 0.25$.
Good learning means this probability increases over time.

EO Model: Results with generous parameter value estimates

Probability of choosing *one* anaphoric to N' is low. But if the learner happens to do that, probability of choosing the correct N' is high. Making the parameter values less generous only exacerbates the problem. Upshot: Equal-Opportunity Learner has a problem.

Back to models that don't use all the available informative data

Main point: Using some of the ambiguous data is better than ignoring it all (similar to what Regier & Gahl 2004 found). A data filter is useful for the learner…so how could a learner implement one sensibly?

About the data filter

Ignore some of the ambiguous data, but not all of it.

Domain-specific or domain-general?
Pearl & Lidz say: "Given that this filter requires the learner to single out a specific type of potentially informative data to ignore, and the property of this ignored data involves whether the potential linguistic antecedent has a modifier, we consider this filter to be specific to language learning. As such, it seems reasonable to consider it a domain-specific filter."

About a child implementing the data filter

Pearl & Lidz say: "It seems fairly obvious that the learner cannot (and probably should not) come equipped with a filter that says 'ignore type II ambiguous data' without some procedure for identifying this data. What we really want to know is whether there is a principled way to derive this filter. Specifically, we want the filter that ignores type II ambiguous data to be a consequence of some other principled learning strategy."

About a child implementing the data filter

A domain-general idea: Learn in cases of uncertainty.

Type II Ambiguous data (…*ball*…*one*…) doesn't count as uncertain because in the local context (that is, for that one data point), the referent of *one* isn't uncertain - the antecedent is the simple noun (*ball*) and the referent is the object corresponding to that noun (ball). (However, at the global level (for deciding the syntactic category *one* is anaphoric with), this data point is uncertain.)

Type I Ambiguous data (…*red ball*…*one*…), however, is uncertain in the local context because it is unclear which string *one* is anaphoric with (*red ball, ball*) and so unclear what the referent is.

Upshot: "Learn in cases of local uncertainty" would cause the child to use Type I Ambiguous data and ignore Type II Ambiguous data…which then makes it possible to learn anaphoric *one*.

Pearl & Lidz conclusions

"The case of anaphoric *one* demonstrates the interplay between domain-specificity and domain-generality in language learning. What we have seen is that a domain-general learning procedure can be successful in this case, but crucially only when paired with domain-specific filters on data intake. Moreover, we have suggested that the particular domain-specific filter that yields the best result can plausibly be derived from a domain-general learning strategy."

"…emphasized the efficacy of data intake filtering on learners. Filtering the data is, in some sense, a counterintuitive approach to learning because it discards potentially informative data. Moreover, eliminating data can lead to a data sparseness problem. However, in order to find the correct generalizations in the data in our case, we found that eliminating some data was more effective than using it all. The right generalizations are hiding in the data, but paying attention to all of the data will make them harder to find."