The acquisition of lexical meaning

A plea for naturalism
Some last-minute thoughts

• I’m quite jealous of the speech people
  – For the rather precise formulation of the problems
  – For the relatively clear nature of the data (speech signals)

• Today, a part of language acquisition where goals/issues/methods are less homogenous: learning word meanings
The big picture

• At a certain point in development, children start acquiring mappings between word forms and meanings (≠ referents)

• Whatever other mechanisms are needed (constraints, tracking statistics, social mechanisms), these meanings must be understood by the child as potential communicative content independently of the language
The big picture

• The assumption of independent understanding (cf. Brown 1958, Macnamara 1972, ...)

• Trivially true: otherwise no way in

• But: how does the learner get to an independent understanding of the situation and what is in it?
The big picture

• Note: a different question from how to zoom in on the actually communicated meanings (which has been studied a lot)

• Looking at how to arrive at some independent understanding of the situation is a blind spot in acquisition studies - we know precious little about it

• Insight about this has bearing on the question how to get to the actually communicated meanings and their mappings to words
The assumption of independent understanding

- Let
  - $A$ be set of all possible concepts
  - $I$ be set of independently understood actual concepts
  - $C$ be set of hypothesized communicated concepts

  - $C$ is a subset of $I$
  - $I$ is a subset of $A$
The assumption of independent understanding

- **Filters** for acquiring word meanings:
  - Constraints (Markman 1994)
  - Social inference (Baldwin 1991)
  - Syntactic bootstrapping (Gleitman 1990)
  - Cross-situational learning (Pinker 1989)

- All take $I$ and create a subset $C$ (sometimes in mapping elements of $I$ to linguistic material)

- $I$-to-$C$-mechanisms
- But $I$ is presupposed
The assumption of independent understanding

- How to get from A to I?
- A-to-I-mechanisms:
  - Perception
  - Understanding (joint) activities
  - Understanding mental states
- Blind spot of linguists
- Understandable: not a linguistic issue
- Only addressed by Gleitman (1990)
The assumption of independent understanding

• But if the assumption is a logical necessity and not even linguistic by itself, why bother researching it?
• Because knowing what is in / is crucial for understanding the relative importance of /-to- C mechanisms.
  – Different /s call for different filtering mechanisms
• A plea for naturalism: A-to-/ mechanisms can be investigated on the basis of experiments and models but observational data gives us a naturalistic ground truth.
Going from A to I

• What can be in I?
• Looking at one A-to-I mechanisms
  – Visual perception
• In a constrained setting: videotaped interaction of mothers and daughters (1;4) playing a game of putting blocks through holes
• Then: mapping to language
• Joint work with Afsaneh Fazly, Aida Nematzadeh and Suzanne Stevenson (CogSci 2013)
Going from A to I

• Defining A: what can the learner represent
  – Object categories and properties like color and shape (block, bucket, red, square)
  – Actions and spatial relations (grab, move, in, on)
  – In predicate-argument formats: grab(mother, (yellow, square, block))

• Obviously, grossly simplifying
  – Universality of conceptualization, focus on basic level, only game-related objects, participants, properties, actions and relations
Experiment

- Experiment: visual perception
- We define \( I \) as all actions taking place at some moment, and the objects involved.
  - As coded by two coders, in blocks of 3 seconds not hearing the language
  - Assuming all game-related activities are perceived by the child visually
  - In total: 152 minutes of video, 32 dyads
  - Language: Dutch, CDS later transcribed
<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>&lt;nothing happens&gt;</td>
</tr>
<tr>
<td></td>
<td><em>Een. Nou jij een.</em>&lt;br&gt;‘one. now you (do) one’</td>
</tr>
<tr>
<td>0.03</td>
<td><code>position(mother, toy, on(toy, f bor))</code>&lt;br&gt;<code>grab(child, b-ye-tr)</code>&lt;br&gt;<code>move(child, b-ye-tr, on(b-ye-tr, f bor), near(b-ye-tr, ho-ro)), mismatch(b-ye-tr, ho-ro)</code></td>
</tr>
<tr>
<td></td>
<td><em>Nee daar.</em>&lt;br&gt;‘No there’</td>
</tr>
<tr>
<td>0.06</td>
<td><code>point(mother, ho-tr, child)</code>&lt;br&gt;<code>position(child, b-ye-tr, near(b-ye-tr, ho-ro)), mismatch(b-ye-tr, ho-ro)</code></td>
</tr>
<tr>
<td></td>
<td><em>Nee lieverd hier past ie niet.</em>&lt;br&gt;‘No sweetheart, it won’t fit here’</td>
</tr>
</tbody>
</table>
Experiment

• This gives us insight in what might be in the independent understanding of the situation.
• So: how does it map to language?
• Looking at words that refer to elements of C, i.e. things that can be conceptualized:
  – Object labels (block, table), properties (red, round)
  – Actions (grab, move), spatial relations (in, fit)
• Two ways: descriptive statistics and a modeling experiment
Experiment

- **Descriptive statistics**: how often is there an element $m$ in $I$ that a word $w$ in the simultaneous utterance (within 3 second window) refers to?
- And how often is the word $w$ present when the element $m$ it refers to is in $I$?

<table>
<thead>
<tr>
<th>$w$ &amp; $m$</th>
<th>$m$ when $w$</th>
<th>$w$ when $m$</th>
<th>$w$ &amp; $m$</th>
<th>$m$ when $w$</th>
<th>$w$ when $m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pak: grab</td>
<td>0.58</td>
<td>0.01</td>
<td>Rood: red</td>
<td>1.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Uit: out</td>
<td>0.26</td>
<td>0.18</td>
<td>Emmer: bucket</td>
<td>0.38</td>
<td>0.01</td>
</tr>
<tr>
<td>Passen: match</td>
<td>0.87</td>
<td>0.06</td>
<td>In: in</td>
<td>0.66</td>
<td>0.16</td>
</tr>
</tbody>
</table>

- Already insightful: asymmetry between ‘$m$ when $w$’ and ‘$w$ when $m$’. Learner should **not expect** every element in $I$ to be expressed.
**Experiment**

- **Computational model**: how strong does the association between each word and its meaning get
- Fazly, Alishahi & Stevenson’s (2010) model
- Tracking cross-situational co-occurrence between words and elements of a situation
  - Where the situation is the set \( I \) in the 3-second window within which the utterance falls.
  - In total 2492 utterances

```
situation \{ point, hole, triangular, ... mismatch \}
utterance \{ nee, lieverd, hier, passen, ie, niet \}
```

\( P(m|w) \):

```
\|
block  red  triangular  move  on  mismatch  hole  match
\|  \\
\|  \\
\|  \\
\|  \\
\|  \\
\|  \\
\|  \\
```

\( w = \text{passen} \) (‘fit’)

\( P(m|w) \):

```
\|
block  red  triangular  move  on  mismatch  hole  match
\|  \\
\|  \\
\|  \\
\|  \\
\|  \\
\|  \\
\|  \\
\|  \\
```
Experiment

- Looking at four (meaning-defined) classes of words
  - Actions, spatial relations, object categories, properties
- For every word, looking at the ranking (AP) of and probability mass (SCP) assigned to the correct meaning
- SCP: overall low
- AP: good for property labels, increasingly bad for object categories, spatial relations and actions
Experiment

• Key insights:
  – I sometimes **lacks** the communicated concept and many concepts are in I but **not verbalized**
  – This **varies** from word to word
  – In modeling: this **dilutes** the probability distributions and gives a **low reliability** for making mappings (esp. for some words)
  – This should guide our research into the mechanisms used for acquiring word-meaning mappings (**I-to-C mechanisms**)
Implications for experimental work

• The fact that subjects can use certain mechanisms in certain situations, *doesn’t mean* they actually use it in lexical meaning acquisition.

• This interpretive step *diminishes* if we approximate the parameters of the actual situations more closely in experiments.

• Experimental work can shed further light on
  – The nature & content of *I* and *A*-to-*I* mechanisms
  – Which *I*-to-*C* mechanisms are *relevant in the context* of actual *Is*
Implications for modeling work

• Similar points & recommendations hold here

• On top: computational modeling can help work out the intricacies of going from A to I, from I to C and from C to language on the basis of naturalistic data.
Final thoughts

• Obviously, there’s much more to be said about the A-to-I mechanisms.
  – Culture-dependent ways of constructing reality (assuming A is universal and I contains culture-specific ways of conceptualizing reality)
  – Maturation of types of A that are available (physical > intentional > embedded intentional)

• Study of acquisition of meaning needs to take a more holistic scope and naturalistic vantage point to understand the mechanisms involved
  – alongside, not instead of an analytical, teasing-apart approach
Acknowledgements

• Funded by NWO Promoties in de geesteswetenschappen
• Experiments are joint work with Afsaneh Fazly, Aida Nematzadeh and Suzanne Stevenson
• Data was made available by Marinus van IJzendoorn and Marianne Bakermans-Kranenburg
• Thanks to the audience and organizers of this workshop!
Experiment 2

• Experiment 2: understanding plans & goals
• Builds on the visual perception experiment:
  – Chains of events directed to a certain object lead to a certain spatial end-state of the object
  – E.g.: \texttt{grab(mother,block)} \rightarrow \texttt{move(mother,block,on(floor),near(hole))} \rightarrow \texttt{letgo(mother,block)} \rightarrow \texttt{in(block,bucket)}
  – Infer the goal from the chain (at every moment)
• Adds referents where they are lacking
• But doesn’t help build stronger associations