Language Prediction and Integration

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We’ll meet twice a week, for the first half of semester
- Wednesday 12-14
- Friday 10-12
- One “special session” on Monday, 13 May, 14-16
  - Guest lecture by Roger Levy, UCSD

Requirements:
- One oral presentation of 1-2 papers, 45-60mins duration
- Send me slides (PDF) the day before your presentation
- Active participation during the 30min discussion time
People understand language highly incrementally. Furthermore, evidence suggests people find it easier to process incoming material that is likely in context. Prediction: are comprehenders actively predicting what comes next, or Integration: is it simply easier to integrate incoming words that are licensed by the preceding context?

What aspects of the context – lexical, syntactic, semantic, conceptual – are:
(a) used for prediction, or
(b) facilitate integration?
Early evidence for eager comprehension

- Participant repeats back speech as he hears it
  - Close shadowers (~10% of people) can repeat what they hear at a delay of only 250 ms (normal ~500 ms)
  - 250 ms = 1 syllable, i.e. close shadowers are processing the incoming material at the level of individual syllables
- Changes/omissions/additions made by participants were almost always structurally appropriate

Examples
- Original: It was beginning to be light enough so I could see...
  Repeated: It was beginning to be light enough so that I could see...
- Original: He had heard at the brigade...
  Repeated: He had heard that at the brigade ...

Ask participants to fill in the blanks:

I went to the ________ and bought some milk and eggs. I knew it was going to rain, but I forgot to take my ________, and ended up getting wet on the way ________.

Cloze probability is the likelihood of a particular word occurring in a particular context.

(a) My brother came inside to ________.
(b) The children went outside to ________.

“play” is plausible in both sentences, but is 1st choice 90% of the time in (b) never the first choice for (a).
Rayner & Well (1996) directly investigated the influence of contextual constraints on reading.

(a) The woman took the warm cake out of the oven. (high – 93%)
(b) The woman took the warm cake out of the stove. (med – 33%)
(c) The woman took the warm cake out of the pantry. (low – 3%)

Low-constraint words were fixated longer than high and medium.
High-constraint words were skipped more often than low and medium.
There is abundant evidence that cloze probabilities correlate with reading times.
- High cloze words are read faster, skipped more, than low cloze words.

But cloze is an off-line production task:
- many low probability words are never produced
- participants have more time to determine likely words

Cloze indexes predictability, and is a predictor of reading times, but doesn’t tell us much about how readers might actually predict upcoming words.
Syntactic and semantic processes are partially revealed by signature patterns in EEGs: Event-Related Potentials (ERPs)

Syntactic Anomaly: P600 or SPS

“The spoilt child throw(s) the toy on the ground”
‘They wanted to make the hotel look more like a tropical resort. So along the driveway they planted rows of ...’

R. medial central

tulips

palms

5\mu V

0 400 800 ms

trends in Cognitive Sciences
Many reading studies demonstrate how different aspects of syntactic and semantic context influence the reading time of words.

- But these are measure on the word of interest.
- Makes it difficult to distinguish integration from prediction.

Is there some way to determine what people might be predicting, before they encounter a word?

YES! The visual world paradigm!
Parsing as Prediction

The boy will move the ...
The boy will eat the ...

Language Prediction & Integration
But hang on a second ..

- Is this really “prediction”?

- What kind of experiments might be more convincing to address these doubts?

- Can we use the paradigm to investigate other kinds of prediction?

- Even if it is prediction, is it limited to, or even determined by the visual context?
**Anticipation in Visual Worlds**

On-line mediation of visual attention by spoken language

Rapid use of:
- morpho-syntax, verb semantics and world knowledge
- trigger anticipation of role-fillers

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<thead>
<tr>
<th>SVO</th>
<th>Der Hase (nom)</th>
<th>frisst eats</th>
<th>gleich soon</th>
<th>den Kohl (acc) the cabbage (acc)</th>
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</thead>
<tbody>
<tr>
<td>OVS</td>
<td>Den Hasen (acc)</td>
<td>frisst eats</td>
<td>gleich soon</td>
<td>der Fuchs (nom) the fox (acc)</td>
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Compositional Prediction

A

B

The man will ride the motorbike.
The girl will ride the carousel.
The man will taste the beer.
The girl will taste the sweets.
Intonation

- Rapid use of: intonation, verb semantics and world knowledge
- Trigger anticipation of role-fillers
- Related: found use of contrastive stress in target identification: “Now click on the RED bowl”

What’s anticipated?

- Does anticipatory gaze ... 
  - reflect general linguistic processes?
  - or is it limited to visible objects?

- Cross-modal, lexical decision in restricted linguistic contexts
  - Decision targets were plausible or not:
    - “The woman baked ...”
      - “Pizza” (plausible)
      - “Palm” (implausible)

- Displays contain an appropriate target object or not
Procedure

Restrictive context: “The woman baked ...”
Faster decisions for predictable targets with no scene

With scene displayed:
- Faster decisions when target was appropriate
- Slower when displayed object was appropriate

Strong support that anticipation is a general mechanism

But expectations are grounded in the scene
Depicted events

- German SVO/OVS sentences
- Initial structural and role ambiguity

Die Prinzessin
The princess (amb.)
wäscht
washes
offensichtlich
apparently
den Piraten.
the pirate (obj).

Die Prinzessin
The princess (amb.)
malt
paints
offensichtlich
apparently
der Fechter.
the fencer (subj).

Knoeferle et al., 2005, Cognition
Scene Events

- Rapid use of depicted events to anticipate role-fillers
- Claim: scene immediately influences comprehension, and can inform disambiguation
- Replicated: With natural events, blank screen & moving actions

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Summary so far ...

- Peoples visual attention in a related scene reflects comprehension of the unfolding speech signal:
  - Referential: people looks at scene objects that are likely referents for spoken nouns
  - Anticipatory: listeners predict which scene referents are likely to me mentioned
    - Compositionally determined by prosody, the syntactic structure, and semantic properties of the verbs arguments.
    - Evidence that prediction is not limited to scene objects
- Visual attention in scenes offers an index of predictive language comprehension processes.
Predicting Words

Kinds of Contexts


Visually Situated Prediction


Discourse Events & World Knowledge

- Klinton Bicknell, Jeffrey L. Elman, Mary Hare, Ken McRae, Marta Kutas. Effects of event knowledge in processing verbal arguments. Journal of Memory and Language. 63 (2010) 489–505


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<thead>
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On Friday ...

- Computational models of prediction

- Review relevant parsing algorithms and probabilistic language models

- Review connectionist models of language (SRNs) that are highly predictive in nature:
  - Why is prediction important
  - What kinds of prediction do these models make
Getting the papers

- You can download (temporarily!) the complete set of papers from: <removed>
- You should familiarize yourself with each paper, before it is presented
  - Think of specific questions about
    - the hypotheses, their assumptions, and whether they make sense
    - the experimental design – does it really address the hypothesis
    - the methods and measures – are they appropriate
    - the stimuli/materials – are there confounds, are they sensible
    - the interpretation – is it justified from the data, are the conclusions convincing, did this take us beyond what we knew, does it constrain theories of prediction?