Eye-tracking in language research

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Eye movements as a window onto language comprehension

- speech perception
- word recognition
- syntactic ambiguity resolution
- pronoun resolution
- prosody
- pragmatics (scalar implicature processing, use of common/privileged ground, contrastive inferences)
Eye movements as a window onto language comprehension

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Why eye movements?

- ballistic, i.e. not subject to control
- implicit measure of comprehension, i.e. participants are not aware of their eye movements
- closely time-locked to speech events, i.e. can be used with continuous speech
- reflect both shifts in attention and expectations about upcoming input
Linking hypothesis

- link between **eye movement patterns** and **comprehension process**

  generally: as linguistic input unfolds, listener’s attention will shift to objects in the display as they become relevant
  → shift in attention is typically followed by saccadic eye movement (with a 200ms delay for programming and executing the saccade)

- formulating an explicit linking hypothesis is **hard**
  - typically, predictions are qualitative (a target region is expected to be fixated **earlier** or **more** in one condition than another)
  - sometimes, predictions are quantitative
Problems in generating linking hypothesis

- What is being predicted?
  - probability of saccade
  - probability of saccade at particular point in time
  - time spent fixating a region
  - ...

- Eye movement patterns are a function of many factors
  - location of fixation at time \( t - 1 \) (\( t - 2? t - 3? \))
  - time from onset of last fixation
  - listener’s task-dependent goal
  - relative salience of objects in display
  - (hopefully) variables of interest
  - ...

Put the apple

1-referent context
Put the apple on the napkin

1-referent context
Put the apple on the napkin

1-referent context

2-referent context
Put the apple on the napkin in the box

1-referent context

2-referent context
Put the apple *on the napkin in the box*

*Put the apple that’s *on the napkin* in the box*

1-referent context

2-referent context
Spoken language comprehension is both *interactive* and *incremental*; non-linguistic visual information can influence expectations about syntactic parses as early as this information is contextually available.
Spoken word recognition

Allopenna, Magnuson, and Tanenhaus (1998)

Target = beaker
Cohort = beetle
Unrelated = carriage

Look at the cross. Click on the beaker.
Anticipatory eye movements Altmann and Kamide (1999)

The boy will move/eat the cake

Listeners make anticipatory saccades based on expectations about likely continuations.
Rapid *pragmatic* inference? Sedivy et al. (1999)

- reference resolution via contrastive inference (Quantity-2 maxim)
- size contrast between only one pair of objects makes pre-nominal modification felicitous for that pair (over-informative otherwise)

*Pick up the big duck.*
Rapid pragmatic inference.

“Pick up the big duck.”

increased looks to target object before POD (noun) suggests comprehenders rapidly draw contrastive inferences based on informativeness considerations
Pick up the *big* duck.

late POD
Two contrasts: late POD

“Pick up the big duck.”
“Put the big duck on the bottom.”

- same as just discussed
“Put the big duck on the bottom.”

- same as just discussed
- egocentric and non-egocentric view make same predictions
- egocentric view predicts late POD
- non-egocentric view predicts early POD
Rapid use of ground information

Fixations to Target

Early contrast POD effect for privileged condition

- big
- duck

Fixations over time in milliseconds (ms):

- Proportion of fixations
- Time (ms): 0 to 1200

Graph showing the proportion of fixations for different conditions.
Scalar implicatures

(1) Mary: Who did John date?
Sarah: He dated some of the girls on his swim team.
\[\leadsto\] He dated some, but not all of the girls on his swim team.

- generalization: use of a statement with a weak element (on a scale of a strong and a weak element) implicates the negation of the stronger statement
Why experiments on scalar implicature?

- Traditionally: a) are scalar implicatures defaults or b) does pragmatics follow semantics?
  - a) Default model (Levinson, 2000)
  - b) Literal-First hypothesis (Huang & Snedeker, 2009)
- More recently, in light of conflicting evidence: what are the contextual factors that affect scalar implicature processing?
(2) Mary: Who did John date?
Sarah: He dated some of the girls on his swim team.
   a. *Upper-bound interpretation:* He dated *some, but not all,* of the girls on his swim team.
   b. *Lower-bound interpretation:* He dated *some, and possibly all,* of the girls on his swim team.

- cancelability of scalar implicatures exploited in experimental studies
- display: different regions correspond to different interpretations
“Point to the girl that has some/all/two/three of the socks/soccer balls”
“Point to the girl that has some/all/two/three of the socks/CCER balls”
“Point to the girl that has some/all/two/three of the socks/CCer balls”
“Point to the girl that has some/all/two/three of the socks/soccer balls”

- measure: eye movements
- predictions:
  - default: same pattern in all conditions (fast convergence on target after quantifier)
  - 2-stage: delayed looks to target only for “some”
“Point to the girl that has some/all/two/three of the so...”
“Click on the girl who has some of the balls/all of the balloons.”
- Semantic interpretation of *some* (some and possibly all) does not disambiguate
- Pragmatic interpretation of *some* (some but not all) does
- *all* disambiguates (literal control)
looks to target increase 200-300ms after quantifier onset (both for *some* and *all*)
→ rapid computation of the implicature
Scalar implicature & number terms  
Degen and Tanenhaus (under review)

- view of scalar inference (and quantifier process more generally) as a matter of probabilistic constraint-based interpretation
- with increasing support for the implicated content, the upper-bound interpretation is computed more quickly (and vice versa)

### Hypotheses

1. Non-scalar alternatives like number terms can interfere with speed of implicature processing.

2. When number terms are available as alternatives, processing of *some* is delayed, especially for very small (subitizable) sets where naming of set size is almost automatic.
Gumball paradigm
Gumball paradigm
You got some of the blue/orange gumballs

Conditions:
- number alternatives present or absent
- quantifier some, all, (two, three, four, five)
- target set size big (4/5) or small (2/3)
- POD early or late
Results I - early vs. late POD, numbers absent

- in quantifier window, looks to target increase in early, but not late condition
- big sets receive more looks than small sets
- no effect of quantifier (no delay for some)
- note: baseline differences; rate effects
Results II - number presence effect

Overall delays (for both *all* and *some*) when number terms are available alternatives, but larger delays for *some* than for *all*.
Visual world eye-tracking is a powerful tool for studying incremental language processing embedded in rich visual contexts. Beware the linking hypothesis.


