Eye-tracking for Sociolinguistics

Vishal Arvindam & Ailís Cournane
Welcome!

- Goals of the Workshop
  - Overview of Eye Tracking, stressing:
    - why it is a useful method
    - what linguistic linking hypotheses look like
  - Overview of current and potential applications in sociolinguistics
  - Example study of gender in reading processing
  - Demonstration of an eye tracking in action

- Who are we?

- Who are you?
Guiding Questions Eye Tracking can help answer:

- How do we take in and interpret language variation as listeners?
- How are links between linguistic and social information represented and associated in the mind?
- What are the cognitive processes involved in language use?
- How does sociolinguistic perception unfold in real time?

Note most sociolinguistic studies have focused on production of variation, but eye tracking is about perception/comprehension.
What is Eye Tracking?

• Eye Tracking uses the light reflected on the participant’s eyes to track where they are looking, for how long, and what their eye-movement patterns are.
Why use eye movements for linguistic research?

Eye movements are:

- 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 in real-time
- reflective of both shifts in attention and expectations about upcoming input, i.e. as speakers we are always predicting, based on experience
What is the relation between what we’re measuring (eye movement behaviour) and what we really care about (socio-psycho-linguistics)?

- link between eye movement patterns and comprehension process
  - generally: as linguistic input unfolds, listener’s attention will shift to objects/words 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 for your study 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
One of the major methods used in psycholinguistic research is reading tracking – when reading (~processing) sentences, what do participants do?

Vishal will talk about this in detail, so we’ll set it aside for now.
Major Paradigm 1: Visual World

- A second major paradigm uses the visual world with language presented auditorily.
- Researchers time-lock visuals to audio and measure how language stimuli affect visual behaviours (~comprehension)
- ROIs (Regions of interest) need to be defined:

![Image from Allopenna, Magnuson, Tanenhaus (1998)](FIG. 3. An example of a stimulus display presented to participants.)
Major Paradigm 1: Visual World

- 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. (J. Degen)

- Ambiguity resolution (Alloppenna et al. 1998):

![Graph showing fixation probability over time since target onset](image-url)
Eye Tracking Experiments for Social Processing

- Most comprehension experimental methods in sociolinguistics (and more widely in linguistics) make use of listeners and explicit tasks.
- Listening, and reacting in an explicit task (e.g. making a judgement), reflects many cognitive subprocesses.
- Reflection time (even very brief!) invites people to (un)consciously adjust behaviours, and masks stages of processing which may be of importance for our understanding of the phenomena under investigation.
Advantages of Eye Tracking for Socio-Linguistic Questions

- Implicit measure: uses activities similar to reading online, looking at pictures or watching TV
  - May reduce “observer paradox” issues

- Time-sensitive measure: measures the reaction, not the reflection (M.Maia, p.c.)
  - Access to fine-grained, subconscious reactions to stimuli

- Visual World: Variable-to-World, measures assumptions about the social world based on audio cues
Most work in Sociolinguistics focuses on production data. Increasingly, researchers are looking at perception and comprehension (e.g., Drager, 2010).

Most existing studies using online measures in sociolinguistics focus on questions of sociophonetic variation in speech perception (e.g., Koop et al. 2008; D’Onofrio, accepted; McGowan, 2010)
Koops et al. (2008)

- Investigated whether perceived speaker age affects processing of vowels (PIN~PEN) involved in a change in progress.

- Using eye tracking, they found that participants fixated longer on a lexical competitor when played a less conservative token and when shown an older face.

- In other words, processing of the word appeared to take longer when the sound encountered was inconsistent with the most probable variant to be produced by the person in the photograph.
D’Onofrio (accepted)

- Tested implicit awareness of TRAP-backing (TRAP~LOT) in American English and its social associations with:
  - Baseline (no social information given for speaker)
  - Californian origin (an all TRAP-backing state)
  - Valley Girl persona (stereotyped with +++ TRAP-backing)
  - Business Professional persona (no TRAP-backing)

- Forced lexical choice paradigm using eye tracking. Presented 4 orthographic words in the “visual world” and picked the word that matched the auditory stimuli (ambiguous sock/sack);
  - E.g., did you hear *sack* or *sock*?

- Listeners in Californian condition were significantly more likely than listeners with no speaker information to look toward the TRAP word upon first hearing an ambiguous TRAP-LOT stimulus, indicating an early and relatively automatic expectation of TRAP-backing from a Californian speaker. Valley Girl condition trended in this direction.

- Evidence for automatic, implicit influence of social primes
Guiding Questions Eye Tracking can help answer:

- How do we take in and interpret language variation as listeners?

- How are links between linguistic and social information stored and represented in the mind?

- What are the cognitive processes involved in language comprehension?

- How does sociolinguistic perception unfold over time?
How can this method serve your research questions?

- Let’s take 10 minutes to actively think about our own research areas and consider how eye tracking might serve our research questions!
- 5 to think, 5 to share
- Then we’ll take a 5 minute break.
Part 2: Moving Beyond Sound
Sentence Processing

Subfield of psycholinguistics that studies mechanisms involved in how we interpret sentences in real time, or “on the fly”

Modularity versus Interactivity

Does the system initially consider only syntactic information or does it consider all potentially relevant sources of information?

**Modular:** Syntactic structures are assigned to words without any consideration of prior knowledge, visual or social context

**Interactive:** Immediate use of all relevant information (i.e. syntactic, semantic, discourse, context, social knowledge/expectations)

Refer to Ferreira & Çokal (2015) for in depth review
1. The baseball player cut himself accidently 😊
2. The baseball player cut herself accidently. ⬗

3. After buying a new, comfortable strapless bra at the store, the cheerleader went to meet a friend 😊
4. After buying a new, comfortable strapless bra at the store, the hunter went to meet a friend. ⬗

**Why?**

Stereotypical gender is inferred probabilistically based on world knowledge (Kreiner et al., 2008) \hspace{1cm} Stereotypical gender is categorically stored in the lexical entry and activated automatically (Kennison & Trofe, 2003)

Motivation

• Intuitively, gender (stereo)typicality is **probabilistic and graded**

![Figure 1: Scatter plot of real gender ratios against normative judgments.](Garnham, Doehren & Gygax, 2015)

\[ r = 0.849, \ N = 205, \ p < 0.001 \]

• Our intuition, or statistical awareness, is scarily accurate
1. How sensitive are we to gender typicality in real time processing i.e. to what degree does gender typicality predict eye-movements?

2. What might be the nature of representation such gender information?
Eye-tracking while Reading

The baseball player cut herself accidentally.
Eye-tracking while Reading

The baseball player cut herself accidentally.
Eye-tracking while Reading

The baseball player cut herself accidentally.
Eye-tracking while Reading

**first fixation duration:** length in milliseconds (ms) of first fixation target region

The baseball player cut *herself* accidentally.
Eye-tracking while Reading

**first pass duration**: sum of fixations in ms on a region from first entering a region of interest from the left until leaving it to the right (i.e., moving forward in the sentence) or to the left

The baseball player cut *herself* accidentally.

Unexpected first fixation and first pass reading times reflect real world inferences (Sturt, 2003).
Experiment 1: Gender Norming

- Online survey using SurveyMonkey
  - N = 42 (32 female, 6 male, 4 non-binary)
  - M (age) = 20

- The survey consisted of 150 role nouns (e.g. nurses, doctors).

- Participants were asked to estimate, on an 11 point scale, “the extent to which the presented social and occupational groups consist of men and women”.

- A subset of 30 nouns were selected ranging in gender typicality from 0 to 1 with increments of 0.05.

<table>
<thead>
<tr>
<th>Boy</th>
<th>Baseball player</th>
<th>Chef</th>
<th>Artist</th>
<th>Model</th>
<th>Nurse</th>
<th>Girl</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.2</td>
<td>0.35</td>
<td>0.5</td>
<td>0.65</td>
<td>0.8</td>
<td>1</td>
</tr>
</tbody>
</table>

Male  Female
Experiment 2: Eye-tracking

- N = 48 (36 female, 8 male, 4 non-binary)
- M (age) = 19

**Design**
- 1 x 3 (gender typicality x reflexive pronouns)
- Within subjects
- 3 counter-balanced list (45 test items and 55 fillers)

5. X embarrassed **himself** | **herself** | **themselves** | 2

\[ X \rightarrow \text{boy, baseball player, janitor, author, dancer, librarian, kindergarten teacher, girl} \]

2. Sturt (2003) shows that reflexives are structurally bound as predicted by Binding Principle A.
Predictions

• If graded gender typicality information is used online, we predict the reading times on the pronouns to covary with typicality.

• Early effects of gender typicality (i.e. on the first fixation and first pass reading times) on the pronouns indicate automatic and immediate use of typicality information and suggests lexical basis.
Results:
First fixation

Table 1. Summary of LME coefficient estimates, standard errors (in parentheses) and associated t-values for log first fixation reading times at the critical region. Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

<table>
<thead>
<tr>
<th>Pronoun</th>
<th>Results from LME³ Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Himself</td>
<td>β = 0.17(±0.04),  t = 4.31***</td>
</tr>
<tr>
<td>Herself</td>
<td>β = -0.11 (±0.04),  t = -2.90**</td>
</tr>
</tbody>
</table>

Results: First pass

Table 2. Summary of LME coefficient estimates, standard errors (in parentheses) and associated t-values for log first pass reading times at the critical region. Signif. Codes:  0 ‘***’ 0.001  ‘**’ 0.01  ‘*’ 0.05  .’ 0.1  ‘ 1

<table>
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<tr>
<th>Pronoun</th>
<th>Results from LME Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Himself</td>
<td>$\beta = 0.20 \ (\pm 0.05), \ t = 4.38^{***}$</td>
</tr>
<tr>
<td>Herself</td>
<td>$\beta = -0.14 \ (\pm 0.05), \ t = -2.6^*$</td>
</tr>
</tbody>
</table>
Results:
Total reading time

<table>
<thead>
<tr>
<th>Pronoun</th>
<th>Results from LME Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Himself</td>
<td>$\beta = 0.44 , (\pm 0.08), , t = 5.2^{***}$</td>
</tr>
<tr>
<td>Herself</td>
<td>$\beta = -0.36 , (\pm 0.09), , t = -4.00^{***}$</td>
</tr>
</tbody>
</table>

Table 3. Summary of LME coefficient estimates, standard errors (in parentheses) and associated t-values for log total reading times at the critical region. Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
• Social information affects processing at the sentential level
  a. Stereotypical gender information systematically affects anaphora resolution
  b. Eye movements can be predicted by gender typicality
  c. Effects arise very early in processing indicating that use of social information immediate, unconscious and automatic.

• Eye-tracking enables us to ask detailed questions about the time course of processing of social variables and probe their cognitive representation
Future Directions

Psycholinguists and sociolinguists can and should work together to:

• understand the cognitive mechanisms through which sociolinguistic variation is processed
• explore links between different levels of grammar and social information
• improve methods of data collection and analysis
Thank you!

- Dr. Brian Dillon, Dr. Lyn Frazier and the rest of the Cognitive Science of Language Lab at University of Massachusetts, Amherst
- Dr. Ailís Cournane and the rest of the Child Language Lab at NYU
- YOU!
Results: First Pass (Themselves)

Table 4. Summary of LME coefficient estimates, standard errors (in parentheses) and associated t-values for log first pass reading times at the critical region. Signif. Codes: * * * 0.001 ** 0.01 * 0.05 . 0.1

<table>
<thead>
<tr>
<th>Pronoun</th>
<th>Results from LME Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Themselves (quadratic)</td>
<td>$\beta = 0.23 \pm 0.16$, $t = 1.42$</td>
</tr>
</tbody>
</table>
Results: Total Time (Themselves)

Table 5. Summary of LME coefficient estimates, standard errors (in parentheses) and associated t-values for log total reading times at the critical region. Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

<table>
<thead>
<tr>
<th>Pronoun</th>
<th>Results from LME Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Themselves (quadratic)</td>
<td>$\beta = 0.5 \pm 0.23$, $t = 2.16^*$</td>
</tr>
</tbody>
</table>
Results: Go Past (Spillover i.e. adverb)

Table 6. Summary of LME coefficient estimates, standard errors (in parentheses) and associated t-values for log go past reading times at the critical region. Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

<table>
<thead>
<tr>
<th>Pronoun</th>
<th>Results from LME Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Themselves</strong></td>
<td>( \beta = 0.87 \ (\pm 0.27), \ t = 3.26^{**} )</td>
</tr>
</tbody>
</table>