What is the role of coherence (QUD) in coreference?

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July 15, 2016
What about Ralph?

- Craige’s example from Monday
  
  (11) Ralph saw a man enter the convenience store.

- Which referent is more salient?

- How do different anaphors work in this context?
He watched him carefully while he decided on what purchases to make. The man was wearing very fancy clothing and had a strong presence.

- **WHO was mentioned next?**
  - $p(\text{referent} = \text{Ralph}) = .22$
  - $p(\text{referent} = \text{man}) = .78$

- **HOW were they mentioned?**
  - $p(\text{"He"|referent=Ralph}) = .5$
  - $p(\text{"Ralph"|referent=Ralph}) = .5$
  - $p(\text{"He"|referent=man}) = .14$
  - $p(\text{"The man"|referent=man}) = .86$
Different anaphoric expressions

Ralph saw a man enter the convenience store. The man was wearing a mask. was wearing a strange hat. Ralph saw a man enter the convenience store. He followed the man into the store. was wearing a mask and proceeded to rob the store. 

\[ p(\text{ref}=\text{Ralph} \mid \text{"The man"}) = 0 \]
\[ p(\text{ref}=\text{man} \mid \text{"The man"}) = 1.0 \]

\[ p(\text{ref}=\text{Ralph} \mid \text{"He"}) = 0.5 \]
\[ p(\text{ref}=\text{man} \mid \text{"He"}) = 0.5 \]

→ Pronouns don’t simply pick out the most salient referent!
Pronoun production & interpretation

How to reconcile:

- strong bias to re-mention the man
- only half of pronouns interpreted to refer to the man
- very few pronouns produced to refer to the man

Problem: Thinking of pronoun interpretation as a search

Instead: Consider how a pronoun is generated within a model of speaker production

Bayes’ Rule

\[ p(\text{ref} | \text{pronoun}) \sim p(\text{pronoun} | \text{ref}) \ p(\text{ref}) \]
Pronouns with Bayes

\[ p(\text{ref} \mid \text{pronoun}) \sim p(\text{pronoun} \mid \text{ref}) \cdot p(\text{ref}) \]

- Not a model of pronoun interpretation, just a mathematical truth
- But it highlights several points:
  - Pronoun interpretation as comprehenders’ expectations of what a speaker would do
  - Possibility of low \( p(\text{pronoun} \mid \text{ref}) \) but not low \( p(\text{ref} \mid \text{pronoun}) \), if big enough prior \( p(\text{ref}) \)
  - Pronoun interpretation ≠ pronoun production
Bayes’ Rule

\[ p(\text{ref} | \text{pronoun}) = \frac{p(\text{pronoun} | \text{ref}) p(\text{ref})}{\sum_{\text{ref}} p(\text{pronoun} | \text{ref}) p(\text{ref})} \]

Bayes-derived values

\[
\begin{align*}
\text{p(Ralph | “He”)} & = \frac{.5 \times .22}{.5 \times .22 + .14 \times .78} = .501 \\
\text{p(man | “He”)} & = \frac{.14 \times .78}{.5 \times .22 + .14 \times .78} = .498
\end{align*}
\]

Observed values:

Ralph saw a man enter the convenience store. He

\[ p(\text{Ralph} | “\text{He}”) = .5 \]
\[ p(\text{man} | “\text{He}”) = .5 \]
Bayes

\[ p(\text{ref} | \text{pronoun}) \sim p(\text{pronoun} | \text{ref}) \cdot p(\text{ref}) \]

- What factors influence which probability?

- named “Ralph”?
- subject “Ralph”?
- topic “Ralph”?

The referent mentioned next is the one who is

As in Roberts (2003, 2004), the antecedent of a pronominal anaphoric trigger must be maximally salient. Hence, it must lie on the Right Frontier for the node in which the trigger is introduced.
Other story continuation data in this vein

Expt 1: Implicit Causality

Semantic bias of the verb influences coherence expectations and, in turn, patterns of coreference

Mary annoyed Sue. _______

Mary scolded Sue. _______

Mary babysat Sue. _______

Mary annoyed Sue. She _______

Mary scolded Sue. She _______

Mary babysat Sue. She _______

estimate who gets mentioned and how: p(ref), p(pro | ref)

compare to observed interpretation: p(ref | pro)
$p(\text{ref} | \text{pronoun}) \sim p(\text{pronoun} | \text{ref}) \cdot p(\text{ref})$

$\rightarrow$ verb semantics influence mention and interpretation

[IC1] Mary annoyed Sue. (She) _____
[IC2] Mary scolded Sue. (She) _____
[non-IC] Mary babysat Sue. (She) ______
\[ p(\text{ref} | \text{pronoun}) \sim p(\text{pronoun} | \text{ref}) \ p(\text{ref}) \]

\[ \rightarrow \text{Verb semantics does not influence pronominalization} \]

(Fukumura & van Gompel, 2010; Kehler et al., 2008; Miltsakaki 2007; Rohde 2008; Stevenson et al., 1994)

[IC1] Mary annoyed Sue. _____
[IC2] Mary scolded Sue. _____
[non-IC] Mary babysat Sue. _____
Bayesian approach

\[ p(\text{ref} | \text{pronoun}) \sim p(\text{pronoun} | \text{ref}) \cdot p(\text{ref}) \]

- Verb semantics influence salience of mention (p(ref)) but not the likelihood of pronominalization (p(pronoun|ref)).

- As with Ralph example, we find a tight fit between observed pronoun interpretation biases and Bayes-derived estimates.

- But how does coherence/QUD influence p(ref)?
## Annotating coherence relations

### Expt1: Implicit Causality

<table>
<thead>
<tr>
<th>Ryan hates Amy. She cheated on him.</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greg corrected Sally. Sally got mad.</td>
<td>Result</td>
</tr>
<tr>
<td>Elizabeth scolded Alan. She did so loudly.</td>
<td>Elaboration</td>
</tr>
<tr>
<td>Scott thanked Jessica. He then proceeded to travel home and went to bed.</td>
<td>Occasion</td>
</tr>
<tr>
<td>Jared congratulated Debbie. She didn't seem to appreciate his congratulations.</td>
<td>Violated Expectation</td>
</tr>
<tr>
<td>Stephanie annoyed David. David annoyed everyone else.</td>
<td>Parallel</td>
</tr>
</tbody>
</table>

Same annotation scheme for Non-IC passages
Verbs -> coherence -> coreference

IC1 (e.g. annoy)

IC2 (e.g. scold)

Non-IC (e.g. babysit)

→ IC verbs generate expectations for upcoming Explanation (if none preceding, see Simner & Pickering 2005)
→ Analogous to coherence expectations, are there also expectations about upcoming questions?
Coherence Relations (Mann & Thompson, 1988; Webber & Joshi, 1998; Hobbs, 1990; Kehler, 2002; Asher & Lascarides, 2003; Webber, 2006; reviews in Knott, 1996 and Hutchinson, 2005)

Comprehenders use general inferencing to identify the relationship between two propositions

Mary scolded John. She did so loudly.
Mary scolded John. He was late again.

Question-Under-Discussion models (Roberts, 1996; Van Kuppevelt, 1995; Büring, 2003; Larsson, 1998; Ginzburg & Sag, 2000)

An utterance is coherent insofar as it answers a question relevant to the proceeding discourse

Mary scolded John. She did so loudly.
Mary scolded John. He was late again.
"An implicit question is a question which the speaker anticipates will arise in the listener's mind on interpreting preceding utterances (or some non-linguistic events occurring in the discourse).

... In this paper, however, we will largely leave undiscussed the way in which these questions arise as the result of the interaction of given contextual information and a given model of the addressee."

(van Kuppevelt, 1995, p. 117)
Verbs -> coherence/QUD?

Expt2: IC in monologue and dialog

Task: imagine a phone conversation, write either

Monologue continuation
Friend: Mary scolded/babysat John. ________.  

Dialog continuation
Friend: Mary scolded/babysat John.
You: ____________________?

- Participants: 75 monolingual English speakers
- Materials: 40 IC verbs and 40 non-IC verbs
- Evaluation: judges annotated relation & question
| Friend: Ryan hates Amy.  
You:  What has she done?  |
| Expt2: IC in monologue and dialog |
| Friend: James charmed Amber.  
You:  Did she blush?  |
| Explanation |
| Friend: Greg corrected Sally.  
You:  When did this happen?  |
| Result |
| Friend: Laura values Luis.  
You:  Does Luis value Laura?  |
| Elaboration |
| Friend: Craig reproached Kate.  
You:  What happened next?  |
| Parallel |
| Occasion |

Note: no violated expectation questions  
(see Hunter & Abrusán, forthcoming)
Results: Explanation ~ Why

IC verbs: bias to Explanations and to the question Why

→ Beyond Explanations?
verb aspect -> coherence/QUD?

- Moens & Steedman 1988
  - Perfective describes an event as completed
  - Imperfective describes an event as ongoing

- Predictions:
  - Relations/QUDs that require an end state favored following perfective (e.g., Occasion, What next?)
  - Other relations/QUDs favored following imperfective
verb aspect -> coherence/QUD?

Exp3: aspect in monologue and dialog

Task: imagine a phone conversation, write either

**Monologue continuation**
Friend: John handed/was handing a book to Bob. ___.

**Dialog continuation**
Friend: John handed/was handing a book to Bob.
You: ________________?

- Participants: 75 monolingual English speakers
- Materials: 40 transfer verbs (perfective/imperfective)
- Evaluation: judges annotated relation & question
<table>
<thead>
<tr>
<th>Explanation</th>
<th>Result</th>
<th>Elaboration</th>
<th>Parallel</th>
<th>Occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friend: Heather refunded $30 to Roger.</td>
<td>Friend: Amanda shifted some poker chips to Scott.</td>
<td>Friend: Tim was floating a life vest to Jessica.</td>
<td>Friend: George was slapping a beachball to Sarah.</td>
<td>Friend: Keith mailed a fruitcake to Barbara.</td>
</tr>
<tr>
<td>You: Why did she owe him money?</td>
<td>You: How did Scott react?</td>
<td>You: Where were they?</td>
<td>You: Did she hit it back?</td>
<td>You: Did she throw it away?</td>
</tr>
</tbody>
</table>
Results: coherence ~ QUD

Occasion

\[\sim\]

What next

Explanation

\[\sim\]

Why

Perfective

Imperfective

% Monologue continuations

Aspect

% Dialog continuations

Aspect

Error Bars: +/- 1 SE

Perfective

Imperfective

% Monologue continuations

Aspect

% Dialog continuations

Aspect

Error Bars: +/- 1 SE

Perfective

Imperfective

% Monologue continuations

Aspect

% Dialog continuations

Aspect

Error Bars: +/- 1 SE
Targeted manipulation of verb aspect shifts distributions of coherence relations and QUDs in similar ways.

Is anaphora sensitive to this manipulation of aspect?
Different distributions of relations yield different coreference patterns
Expt4: story continuations with QUD

- Task: write a story continuation
- Instructions: Answer the question “why” or “what happened next?” (between subjects)

John handed a book to Bob. He ________________.

- Predictions:
  - “Why?” → more Explanations → Source bias
  - “What happened next?” → more Occasions → Goal bias
“Why?”

“What next?”

→ Materials held constant but different coreference pattern via QUD
Real-time interpretation

Expt5: QUD reading time

Task: read passages one word or phrase at a time

Instructions: expect follow-on sentences that answer *Why?* or *What next?* (between subjects)

Source-referring pronoun

Jessica served chili to Emily. She explained to Emily

[WHY] ... in the kitchen that morning that everyone needs to try chili once.

[WHAT-NEXT] ... in the kitchen that night that the secret to chili is real jalapenos.

Goal-referring pronoun

Jessica served chili to Emily. She explained to Jessica

[WHY] ... in the kitchen that morning that she can only eat soft foods.

[WHAT-NEXT] ... in the kitchen that night that the chili was a bit too spicy.

At disambiguating name, does processing speed reflect QUD?
Results: QUD -> coreference

Jessica served chili to _Emily. She explained to _Emily ...

Jessica served chili to _Emily. She explained to _Jessica ...

→ Predicted interaction between QUD and coreference
Interim summary

- Bayesian model of pronoun interpretation reconciles competing biases of WHO to mention versus HOW
- Contextual cues (verb semantics, verb aspect) that influence coherence also influence QUD
- Coreference sensitive to coherence/QUD
- Next: Is coherence/QUD sensitive to coreference?
Coreference -> coherence?

When to update $p(\text{coherence relation})$?

- Mary annoyed John. **Mary had been bragging too much.**
- Mary annoyed John. **She had been bragging too much**
- Mary annoyed John. **He avoids talking to her.**

- Subject-referring pronoun $\rightarrow$ subject-biased relations
- Object-referring pronoun $\rightarrow$ object-biased relations

$$p(\text{coh} | \text{referent}) \sim p(\text{referent} | \text{coh}) \ p(\text{coh})$$
Pronominal form -> coreference -> coherence

Full-stop shows prior coherence distribution: $p(\text{coh})$

Pronoun prompt is predicted to yield more subject-biased relations & fewer object-biased relations, via a Bayesian update: $p(\text{coh} | \text{referent})$

Subject-biased verbs (‘annoy’)

- Subject-biased relation: Explanation
- Object-biased relation: Result

Expt6: IC & pronouns on coherence

Full-stop prompt: John annoyed/scolded/babysat Bill. _____.

Pronoun prompt: John annoyed/scolded/babysat Bill. He ___.

form of reference -> coreference -> coherence

Full-stop prompt: **John annoyed Bill. _____**.

Pronoun prompt: **John annoyed Bill. He ____**.
Pronominal form $\rightarrow$ coreference $\rightarrow$ coherence

- Full-stop shows prior coherence distribution: $p(\text{coh})$

- Pronoun prompt is predicted to yield more subject-biased relations & fewer object-biased relations, via a Bayesian update: $p(\text{coh} \mid \text{referent})$

- For transfer-of-possession contexts
  - Subject-biased relations: Explanation, Elaboration, Violated Expectation
  - Object-biased relation: Occasion, Result
Again, a (fully ambiguous) pronoun can influence distribution of coherence relations
What is the role of coherence (QUD) in coreference?

- Coherence and QUD similarly sensitive to cues in the context:
  \[ p(\text{coherence} | \text{context}) \sim p(\text{QUD} | \text{context}) \]

- Coherence and QUD influence salience of referents via the prior:
  \[ p(\text{referent} | \text{pronoun}) \sim p(\text{pronoun} | \text{referent}) \quad p(\text{referent}) \]

- Bidirectional relationship between Coherence/QUD and coreference:
  \[ p(\text{QUD} | \text{referent}) \sim p(\text{referent} | \text{QUD}) \quad p(\text{QUD}) \]
Thanks!