The standard way to represent anaphoric dependency is to co-index the anaphor with its antecedent (e.g. A man\#1 came in. He\#1 sat down). Semantic rules interpret such indices as variables.

The asymmetric notation (man\#1 ... he\#1) reflects the fact that the anaphor (he\#1) depends for its reference on the antecedent (a man\#1), not vv. In English-based dynamic semantics this asymmetry is captured as follows:
- any expression updates the input context to an output context
- specifically, an indexed indefinite description (e.g. a man\#1) updates the input value of its index to an output value that satisfies the description (e.g. a man\#1 updates the value of x\#1 to a man)
- an indexed anaphor refers to the input value of its index (e.g. in the above discourse, the anaphor he\#1 refers to the man introduced by the indefinite antecedent a man\#1).

Prediction: Natural language anaphors refer to current values of variables.

Is this really how it works?

- WORRY 1. Putative variable-like indices have no audible reflex in any natural language, e.g. no language contrasts he\#1\textsubscript{37} vs. he\#1\textsubscript{123}.

- WORRY 2. Languages do have contrasting anaphors, but these are not interpreted like variables of formal logics—e.g. 3\textsuperscript{rd} person zero vs. pronoun in Mandarin; or 3\textsuperscript{rd} person proximate v. obviative inflections in Kalaallisut. Yet anaphora in such systems is rendered unambiguous by mechanisms that variable-based theories have no logical tools to explicate.

- WORRY 3. Since every sentence adds to the set of potential antecedents, anaphora resolution (i.e. identifying the intended antecedent) should get increasingly more difficult as discourse progresses. Yet, intuitively, in a long text (e.g. 'War and Peace' or 'Lord of the Rings') the last pronoun is just as easy to resolve as the first.

This talk (Bittner 2014a)

- BASIC IDEA: Anaphora resolution is always easy because default anaphors (i.e. 3\textsuperscript{rd} person pronouns, inflections, or zeros) refer to entities that are currently salient in discourse. This is a small set that changes, but does not grow (like the set of currently salient objects viewed from a moving train).

- PREVIOUS ATTEMPTS to implement this common-sense idea (centering theory of Sidner 1983, Kameyama 1986, Brennan et al. 1987, Grosz et al 1995, and related work) have been criticized into oblivion, for good reasons (see e.g. Kehler 1997). However, the basic idea still makes intuitive sense.

- THIS TALK: Update semantics offers logical tools for a new implementation, which fits both the facts of typologically diverse anaphoric systems (including Mandarin, Kalaallisut, and English) and standard assumptions of directly compositional theories (e.g. Categorial Grammar).

- PREDICTION: Default anaphors refer to currently salient discourse referents.
Outline

1. Grammatical centering systems
2. Mandarin zero 3rd as top-level anaphora
3. Kalaallisut 3rd person inflections as top-level anaphora
4. English 3rd person pronouns as shallow anaphora
5. Concluding remarks

1.1 Crosslinguistic observations

- **Obs. 1** Grammatical CENTERING SYSTEMS disambiguate anaphora by tracking ranked discourse referents in the center and background of attention (linguistic analog of focal vs. peripheral vision).

- **Obs. 2** Key part of a centering system are TOP-LEVEL ANAPHORS, which refer to currently top-ranked discourse referents (drefs), i.e.
  - top-ranked dref in the center (T-dref), or
  - top-ranked dref in the background (⊥-dref)

- **Obs. 3** In nominal centering systems, top-level anaphors always function as ARGUMENTS (subjects, objects, or possessors), never as modifiers (e.g. obliques).

1.2 Mandarin: Topic chaining system

Mandarin Chinese discourse consists of TOPIC CHAINS (TC, e.g. Tsao 1979, Chu 1998, Li 2005). A typical TC begins with a TOPIC UPDATE (np⊤), which introduces a topical dref. This is followed by n COMMENTS, each with a zero anaphor — i.e. missing subject (⊤-v), object (⊤-v), or possessor (⊤-n) — which refers to this dref.

(1) \[ [\text{topic-update } (\text{np}^\top), \text{comment}_1 (\cdot, n)] \\
   [\cdot \text{comment}_2 (\cdot, v), \text{comment}_3 (\cdot, v)]_{\text{TC}} \]

i. Xiàoli niánqìng piàoliang , gōnzúò yē hǎo .
   Xiaoli\(^\top\) young pretty , job also good .
   Xiaoli\(^\top\) is young and pretty . She\(^\top\) has a good job , too.

ii. Suírán yǒu ge nánpéngyou , kěshí bù xiǎng jiéhūn .
   though \(v\) have cl. boyfriend , but not \(v\) wish get.married .
   Although she\(^\top\) has a boyfriend , she\(^\top\) doesn't wish to get married.
1.3 Mandarin: ‘Bifocal’ topic chain

(2) i. Na-liang chē, jiāqián tài gui, yánse yě bù hǎo, that-CAR price too high, color also not good.
   Lisi bù xǐhuàn.
   Lisi 不 like CAR.
   That car is too expensive and it has an ugly color. Lisi 不 doesn’t like it.

ii. Zuòtàn qū kān-le , hǎi kái-le yīhuì, yesterday go look-PNC even drive-PNC M0 while ,
   hǎishí bù xǐhuàn , méi méi.
   still not like CAR, not buy CAR.
   Yesterday he went to look at it, and even took it, out for a spin.
   He still didn’t like it, (so) he didn’t buy it.

1.4 Kalaallisut: Obviation system

- Kalaallisut subject/object/possessor are expressed by PERSON INFLATIONS
- For 3rd person, topical (T) v. background (⊥) status gramm. marked by:
  - T-form v. ⊥-form of 3rd person inflection
  - ni ‘3s.’ v. -q(t) ‘3s.’ (a.k.a. ‘proximate 3rd’ v. ‘obviative 3rd’)
- MATRIX MOOD marks illocutionary force in relation to T-subject, e.g.
  - go ‘DEC’⊥ for assertion of at-issue fact abt. T-subject
  - go ‘DEC’⊥ for assertion of at-issue fact abt. (T-subject, ⊥-object)
- DEPENDENT MOOD marks context-setting or elaborating updates
  - ga ‘fct,’ v. -mm ‘fct,’ for not-at-issue fact about T v. ⊥
  - gu ‘hvp,’ v. -pp ‘hvp,’ for hypothesis about T v. ⊥
  - gaang ‘hab,’ v. -gaang ‘hab,’ for not-at-issue habit of T v. ⊥
  - ilu ‘ela,’ v. -tu ‘ela,’ for elaboration of T v. ⊥
- FULL NP’s (a.k.a. ‘subject’, ‘object’, ‘possessor’) are recentering updates, i.e. updates of T- or ⊥-ancestors for anaphoric 3- or 3⊥ inflections.

1.5 Kalaallisut obviation in discourse

(3) i. Ilaanni angutí-tuqa-p nulia-ni kisimi-i-qatig(i-p) a-a
   once man-old-ERG wife-3s⊥ alone-be-with-DEC T⊥-3s 3s
   Once an old man was alone with [his ∷ wife]⊥,
   irnini piniar-riar-sima-mm-at.
   [son-3s⊥]⊥ hunt-go-prf-DEC T⊥-3s 3s
   because [his ∷ son]⊥ had gone hunting.

ii. Aavi-ruqaa isisaa-lir-mm-at
   walrus-big⊥ be-visible-begin-DEC T⊥-3s 3s
   When a big walrus showed up,
   hunt-intend-EEL T⊥-3s 3s [kayak-3s⊥]⊥ go-down-to-begin-DEC T⊥-3s 3s
   he ∷ wanted to go after it⊥ and headed down to [his ∷ kayak]⊥.

1.6 Kalaallisut obviation in discourse (ctd.)

(3) iii. Nulli-at a-intir-aluar-pa-a
   [wife-3s⊥,ERG]⊥ forbid-in.vain-DEC T⊥-3s 3s
   [His ∷ wife]⊥ tried to stop him⊥,
   kisimi-i-mm-at avala-qqu-na-gu.
   alone-be-DEC T⊥-3s 3s set.out.tell-not.EEL T⊥-3s 3s
   begging him⊥ not to set out because he⊥ was alone.

iv. Uii-at=li a-tusar-uma-na-gu
   [husband-3s⊥,ERG]⊥ but listen-want-not.EEL T⊥-3s 3s
   But he ∷ (lit. [her ∷ husband]⊥), refusing to listen to her⊥,
   aavi-ruqaa naalip-pa-a.
   harpoon-DEC T⊥-3s 3s
   harpooned the great walrus⊥.
2.1 Simple Update with Centering (UC₀)

Update semantics (Veltman 1996):
‘You know the meaning of a sentence if you know the change it brings about in the information state of anyone who accepts the news conveyed by it.’

Centering-based anaphora (Bittner 2001ff; cf. Grosz et al. 1995)
- update keeps track of ranked drefs in center & background of attention
- entity-level anaphoric terms: $T$ (ctr), $T'$ (2nd ctr), $\bot$ (bck), $\bot'$ (2nd bck)
- set-level anaphoric terms: $T^\bot$ (ctr set), $\bot^\bot$ (bck set)

<table>
<thead>
<tr>
<th>central drefs</th>
<th>backgr. drefs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\langle a_1, a_2, ..., a_n \rangle$</td>
<td>$\langle b_1, b_2, ..., b_m \rangle$</td>
</tr>
</tbody>
</table>

$T$, $T'$ $\bot$, $\bot'$ $T^\bot$, $\bot^\bot$

$dref hierarchy$

2.2 Mandarin: ‘Bifocal’ topic chain in UC₀

i. That car $T$ is too expensive ... (initial input)
   $\text{that-cl. car}^T$, $\text{price}^L$ too high
   $\langle x \rangle \text{car}(x), x \in \bot^\bot$; $\langle x \rangle \text{price}(x, T), \text{too.high}(x)$;
   $\langle \bot, \bot, \bot \rangle$ $\langle \bot, \bot, \bot \rangle$
   and it $T$ has an ugly color. $\text{Lisi}^T$ doesn’t like it $T$.
   $\text{color}^T$ also not good, $\text{Lisi}^T$ not like $T$
   $\langle x \rangle \text{color}(x, T), \not\text{good}(x)$; $\langle x \rangle \text{lisi}(x), x \in \bot^\bot, \not\text{like}(x, T)$;
   $\langle \bot, \bot, \bot \rangle$ $\langle \bot, \bot, \bot \rangle$

ii. (Yest.) he $L$ went to look at it $T$ and even took it, out for a spin. ...
   $\text{look}^L$, $\text{PNC}$, even $\text{drive}^L$, $\text{PNC}$ $\text{M}_{\text{a.while}}$ ...
   $\langle \text{go.look.at}(\bot, T) \rangle$; $\langle \text{drive.a.while}(\bot, T) \rangle$; ...
   $\langle \bot, \bot, \bot \rangle$ $\langle \bot, \bot, \bot \rangle$

2.3 Mandarin: Topic shift in UC₀

i. Jiajia $T$ is sick. She $T$ ran a fever last night.
   $\text{Jiajia}^T$ sick $\text{PNC}$, yesterday night then $\text{run.fever}$
   $\langle x \rangle \text{jiajia}(x), x \in \bot^\bot, \text{sick}(x)$; $\langle \bot, \bot, \bot \rangle$
   $\langle \bot, \bot, \bot \rangle$

ii. Lisi $L$ knew [her $T$ mom] $T$ was busy, so he $L$ didn’t want to tell her $L$.
   $\text{Lisi}^L$ know $\text{[3s$_p$.$\text{mom}^L$]$L$ very busy, not }\text{tell}^L$ $\text{3s$_L$}$
   $\langle x \rangle \text{lisi}(x), x \in \bot^\bot$; $\langle x \rangle \text{mom}(x, T), \text{know.busy}(T, x)$; $\langle \text{tell}(T, \bot) \rangle$
   $\langle \bot, \bot, \bot \rangle$ $\langle \bot, \bot, \bot \rangle$
2.4 Toward a fragment of Mandarin

Sample lexical entries for Mandarin:

- **basic entries** for verbs, e.g.
  
<table>
<thead>
<tr>
<th>verb</th>
<th>entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>sick</td>
<td>$snp: \lambda x_sx(s(\langle x \rangle))$</td>
</tr>
<tr>
<td>like</td>
<td>$snp: \lambda x_sx(\langle x \rangle)$</td>
</tr>
</tbody>
</table>
  
  (intransitive verb)

- **lexical centering operators** saturate arguments with top-level anaphors

<table>
<thead>
<tr>
<th>operator</th>
<th>entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>( )</td>
<td>$snp: \lambda \theta_snp[snp]$</td>
</tr>
<tr>
<td>( )</td>
<td>$snp: \lambda \theta_snp[snp]$</td>
</tr>
</tbody>
</table>
  
  (zero T-subject)

- **derived entries** for verbs with ‘zero anaphora’, e.g.

<table>
<thead>
<tr>
<th>verb</th>
<th>entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>like</td>
<td>$snp: \lambda x_sx(\langle x \rangle)$</td>
</tr>
<tr>
<td>( )</td>
<td>$snp: \lambda \theta_snp[snp]$</td>
</tr>
</tbody>
</table>
  
  (zero T-object)

- **Hence derived entries** for verbs with ‘zero anaphora’, e.g.

<table>
<thead>
<tr>
<th>verb</th>
<th>entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>like</td>
<td>$snp: \lambda x_sx(\langle x \rangle)$</td>
</tr>
<tr>
<td>( )</td>
<td>$snp: \lambda \theta_snp[snp]$</td>
</tr>
</tbody>
</table>
  
  (zero $\perp$-subject & T-object)

3.1 Kalaallisut obviations: (3i) in $UC_0$

i. Once an old man$^+$ was alone with [his$^+$ wife]$^+$, ...

<table>
<thead>
<tr>
<th>entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>man-old-ERG$^+$</td>
</tr>
<tr>
<td>alone-be-with-dec$^+$</td>
</tr>
<tr>
<td>[his$^+$ wife$^+$]</td>
</tr>
</tbody>
</table>

   $\langle(x, T)\rangle$; $\langle(alone.with(x, T))\rangle$

   $\langle(\cdot), (\cdot)\rangle$

   ... because [his$^+$ son]$^+$ had gone hunting.

<table>
<thead>
<tr>
<th>entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>hunt-go-prf-fct$^+$</td>
</tr>
<tr>
<td>[his$^+$ son$^+$]</td>
</tr>
</tbody>
</table>

   $\langle(gone.hunting(x, T))\rangle$

   $\langle(\cdot), (\cdot)\rangle$

   $\langle(\cdot), (\cdot)\rangle$

3.2 Kalaallisut background update: (3ii) in $UC_0$

ii. When a big walrus$^+$ showed up, ...

<table>
<thead>
<tr>
<th>entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>big-walrus$^+$</td>
</tr>
<tr>
<td>be.visible-begin-fct$^+$</td>
</tr>
</tbody>
</table>

   $\langle(x, T)\rangle$; $\langle(show.up(x, T))\rangle$

   $\langle(\cdot), (\cdot)\rangle$

   ... he$^{-}$ wanted to go after it$^{-}$ and headed down to [his$^-$ kayak$^{-}$]

<table>
<thead>
<tr>
<th>entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>hunt-intend-ela$^+$</td>
</tr>
<tr>
<td>[his$^-$ kayak$^{-}$]</td>
</tr>
</tbody>
</table>

   $\langle(got.down.to(x, T))\rangle$; $\langle(head.down.to(x, T))\rangle$

   $\langle(\cdot), (\cdot)\rangle$

Outline

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4. English 3rd person pronouns as shallow anaphora
5. Conclusion
3.4 Toward a fragment of Kalaallisut

- entries for \textit{verb roots}, e.g.
  - sick- \[ \langle s \{ (\text{\textit{s}PN}) \rangle : \lambda \_x : \text{\textit{sick}}(x) \rangle \] (intransitive root)
  - like- \[ \langle s \{ (\text{\textit{s}PN}) \rangle : \lambda \_x : \text{\textit{like}}(x, y) \rangle \] (transitive root)
- \textit{infectinal centering} by \textit{mood} + 3\textsuperscript{rd} person inflections, e.g.
  - \textit{dec}-3s \[ \langle s \{ (\text{\textit{s}PN}) \rangle : \text{\textit{dec}}(x) \rangle \] (at issue fact about \textit{T})
  - \textit{dec-3s.3s} \[ \langle s \{ (\text{\textit{s}PN}) \rangle : \text{\textit{dec}}(x) \rangle \] (at issue fact about \textit{T})
  - \textit{fct}-3s-t \[ \langle s \{ (\text{\textit{s}PN}) \rangle : \text{\textit{fct}}(x) \rangle \] (n.a.i fact about input \textit{T})
  - \textit{fct-3s.3s} \[ \langle s \{ (\text{\textit{s}PN}) \rangle : \text{\textit{fct}}(x) \rangle \] (n.a.i fact about input \textit{T})

- hence entries for \textit{verb words}, e.g.
  - like-dec-3s.3s \[ \langle s \{ (\text{\textit{s}PN}) \rangle : \text{\textit{like-dec}}(x) \rangle \] (at issue fact about \textit{T})

4.1 Anaphora resolution in English

- \textit{coherence}-driven? (Hobbs 1979) motivated e.g. by Winograd’s (4):
  4. The city council denied the demonstrators a permit because …
     a. … they feared violence. \textit{(they = the city council)}
     b. … they advocated violence. \textit{(they = the demonstrators)}
- \textit{parallelism}-driven? (Sidner 1983) motivated e.g. by Kehler’s (5):
  5. Margaret Thatcher admires Hilary Clinton, and George W. Bush absolutely worships her. \textit{(her = Hilary Clinton)}
- \textit{attention}-driven? (Kameyama 1986, Brennan et al 1987, Grosz et al 1995) motivated e.g. by Kameyama’s (6a, b):
  6a John hit Bill. Mary told him to go home. \textit{(him = John)}
  6b Bill was hit by John. Mary told him to go home. \textit{(him = Bill)}
4.2 Kehler (2002): Attention + Coherence

Kehler 2002: pronoun interpretation is based on the interaction of two aspects of interpretation:

(i) linguistic properties of the linguistic form (e.g. a pronoun signals that the referent is salient in the current state of discourse)
(ii) pragmatic process of establishing coherence for three types of relations: causal (e.g. (4)); resemblance (e.g. (5)); contiguity (e.g. (6a, b))

(4) The city council denied the demonstrators a permit because they feared/advocated violence.

(5) Margaret Thatcher admires Hilary Clinton, and George W. Bush absolutely worships her.

(6a) John hit Bill. Mary told him to go home.

(6b) Bill was hit by John. Mary told him to go home.

4.3 Pronouns as shallow anaphora in UC₀

**Contiguity relation (Occasion):**

Kehler’s (7), problem for static centering theories ([BFP], [GJW]), but not UC₀:

\( \langle \emptyset, \ldots, \oslash, \bullet \rangle \) (initial input: \( \oslash = \text{Terry}, \bullet = \text{Tony} \))

(7) i. Terry\(^\uparrow\) set out for an outdoor excursion on Monday.

\( \top \times \) marina\(^\top\) x, \( x \in \downarrow \); \[set.out(t)\];

\( \langle \oslash, \ldots, \oslash, \bullet \rangle \)

ii. He\(^\uparrow\) was excited about trying out his\(^\top\) new sailboat\(^\top\).

\( \top \times \) new.sailboat.of(x, \( t \)); \[excited.about.trying.out(t, \downarrow)\]

\( \langle \oslash, \ldots, \oslash, \bullet \rangle \)

iii. He\(^\uparrow\) wanted Tony\(^\top\) to join him\(^\top\) on a sailing expedition.

\( \top \times \) tony(x), \( x \in \downarrow \); \[want.to.join.on.sailing.exp(t, \downarrow)\]

\( \langle \oslash, \bullet, \ldots, \oslash, \bullet \rangle \)

4.4 Pronouns as shallow anaphora in UC₀ (ctd)

\( \langle \oslash, \bullet, \ldots, \oslash, \bullet \rangle \) (output of (7.iii))

iv. The\(^\top\) marina\(^\top\) ...

\( \top \times \) marina\(^\top\) x, use(t, x); \[use(t, x)\];

\( \langle \emptyset, \ldots, \oslash, \bullet \rangle \)

... is actually very close to Tony\(^\top\)'s house\(^\top\).

\( \top \times \) house.of(x, \( x \in \downarrow \)); \[house.of(x, \top)\]; [very.close.to(t, \downarrow)]

\( \langle \emptyset, \ldots, \oslash, \bullet \rangle \)

v. He\(^\top\) called him\(^\top\) at 6 AM.

\( \top \times \) x = \( t \); \[call.at.6AM(t, \downarrow)\];

\( \langle \emptyset, \ldots, \oslash, \bullet \rangle \)

vi.? He\(^\top\) was sick and furious with him\(^\top\) for waking him\(^\top\) up so early.

\[sick(t); \top ≠ \downarrow \]; [furious.with(t, \top), wake.up(\top, \top)]

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5 Conclusion

- **Default anaphors** (e.g. 3rd person pronouns, argument-filling inflections, or ‘zeros’) refer to currently salient entities.
- In centering systems, default anaphors are top-level (i.e. to top-ranked entities: \( \top \) or \( \bot \)), e.g. Mandarin \( \bot \) like, Kalaallisut ‘like-fct-3s-3s’. Anaphora is generally unambiguous.
- English pronouns are shallow anaphors (to salient entities: \( \top, \top', \bot, \bot' \)). Gender presuppositions & coherence establishment usu. resolve ambiguity.
- In addition, all languages have descriptive anaphors (to sets: \( \top \Rightarrow \), \( \bot \Rightarrow \)). These are expressed by full noun phrases with not-at-issue content, e.g. Mandarin/Kalaallisut ‘[Cat and dog]\( \top \) came in. Cat\( _\top \Rightarrow \) was hungry’, or English ‘[A cat and a dog]\( \top \) came in. [The\( _\top \Rightarrow \) cat] was hungry’.

References

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References (ctd)


How about a 10 min break?