

Anaphora without indices: Dynamics of centering

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Abstract

The standard way to represent anaphoric dependencies is to co-index the anaphor with its antecedent in the syntactic input to semantic rules, which then interpret such indices as variables. Dynamic theories (e.g. Kamp's DRT, Heim's File Change Semantics, Muskens's Compositional DRT, etc) combine syntactic co-indexation with semantic left-to-right asymmetry. This captures the fact that the anaphor gets its referent from the antecedent and not vice versa. Formally, a text updates the input state of information to the output state. In particular, an indexed antecedent updates the entity assigned to its index, and the output entity is then picked up as the referent by any subsequent co-indexed anaphor.

The elephant in the room is that the all-important indices have no audible reflex in any natural language—e.g. no language contrasts he_{17} vs. he_{123} . Adding to the embarrassment, actual anaphoric contrasts are not interpreted like contrasting variables in formal logics—e.g. *zero* (i.e. missing argument) vs. *pronoun t_a* in Mandarin Chinese; or *proximate* vs. *obviative* 3rd person in languages with grammatical obviation (e.g., *-ni* vs. *-a* in Kalaallisut). Yet actual anaphoric systems render anaphora unambiguous (Mandarin, Kalaallisut), or much less ambiguous than predicted (English), by mechanisms that index-based theories have no tools to explicate. A yet another mystery for index-based theories is why anaphora resolution does not get increasingly harder as discourse progresses, since every sentence adds to the set of potential antecedents. Yet, intuitively, in a long novel a pronoun at the end is just as easy to resolve as a pronoun in paragraph one.

Intuitively, this is because a pronoun refers to a *salient* antecedent, and the set of currently salient antecedents changes but does not grow. Previous attempts to implement this common-sense idea (*centering theory* of Grosz *et al* 1995 and related work) have been criticized into oblivion (see e.g. Kehler 1997). But the basic idea still makes intuitive sense. In this talk, I use formal tools of update semantics to propose a new implementation, which fits both the facts of actual anaphoric systems and the assumptions of directly compositional theories (e.g. CCG).

Outline

1. Grammatical centering systems
2. Mandarin in *Update with Centering*
3. Kalaallisut in *Update with Centering*
4. English in *Update with Centering*
5. Conclusion

1 GRAMMATICAL CENTERING SYSTEMS

• TENTATIVE UNIVERSALS

Obs. 1 *Centering systems* disambiguate anaphora by grammatically tracking the current center & background of attention. (cf. focal vs. peripheral vision).

Obs. 2 Anaphors refer to the *top-ranked discourse referent* on the relevant tier—e.g. *top-ranked center-stage* (\top -dref) or *top-ranked in the background* (\perp -dref).

Obs. 3 Nominal centering distinguishes *subcategorized arguments*—i.e. subjects, objects, and possessors. (Optional adjuncts are not eligible for top rank on any tier)

• MANDARIN CHINESE: main unit of discourse is a *topic chain*—i.e. chain of clauses sharing the same topic (\top -dref)—not a sentence (Tsao 1979, Chu 1998, Li 2005).

- (1) $[[i \text{ topic-update } (\underline{np}^\top), \text{comment}_1 (\top n)]$
 $[ii \text{ comment}_2 (\top v), \text{comment}_3 (\top v)]]_{\top\text{-chain}}$
- i. Xiǎoli niánqīng piàoliang , gōnzuò yě hǎo .
 Xiǎoli[⊥] young pretty , \top job also good
 Xiǎoli[⊥] is young and pretty. She \top has a good job, too.
- ii. Suīrán yǒu ge nán péngyou , kěshì bù xiǎng jié hūn .
 although \top have CL boyfriend , but \top NOT wish get.married
 She \top has a boyfriend, but \top doesn't wish to get married. [Li:185]
- (2) $[[s_i \text{ topic-update } (\underline{np}^\top), \text{comment}_1 (\top n), \text{comment}_2 (\top n), \text{comment}_3 (\underline{np}^\perp v_\top)]$
 $[s_{ii} \text{ comment}_4 (\perp v_\top), \text{comment}_5 (\perp v_\top), \text{comment}_6 (\perp v_\top), \text{comment}_7 (\perp v_\top)]]_{\top\text{-chain}}$
- i. Nà-liàng chē , jiàqián tài guì , yánsè yě bù hǎo , Lìsì bù xǐhuan .
 that-CL car[⊥] , \top price too high , \top color also NOT good , Lìsì[⊥] NOT like \top
 That car[⊥] is too expensive and it \top 's an ugly color. Lìsì[⊥] doesn't like it \top .
- ii. Zuótiān qù kàn-le , hái kāi-le yíhuì , háishì bù xǐhuan ,
 yesterday \perp go look \top -PNC, even \perp drive \top -PNC $M_{a,while}$, still NOT \perp like \top ,
méi mǎi .
 NOT \perp buy \top
 Yesterday he \perp went to take a look at it \top . He \perp even took it \top out for a spin,
 but he \perp still didn't like it \top . He \perp didn't buy it \top . [Li:2]+[fw]

• KALAALLISUT: arguments expressed as *pronominal affixes* (pn); two forms of 3rd person pn-arguments: *proximate* for \top v. *obviative* for \perp (e.g. *-ni* '3S \top ' v. *-a* '3S \perp '); full np's interpreted as re-centering updates, setting local context for pn-arguments.

Context for (3)-(3'): Yesterday the children \top had a dog-sled race.

- (3) *Ole-p ikinnuguta-a ajugaa-ga-mi nuannaar-pu-q.*
 Ole-ERG \perp [friend-3S \perp] \top win-FCT \top -3S \top happy-DEC \top -3S
 Ole \perp 's friend \top won, so she \top (= friend) was happy.
- (3') *Ole-p ikinnugun-ni ajugaa-mm-at nuannaar-pu-q.*
 Ole-ERG \top [friend-3S \top] \perp win-FCT \perp -3S \perp happy-DEC \top -3S
 Ole \top 's friend \perp won, so she \top (= Ole) was happy.
- (4)i. *llaanni anguti-tuqa-p nulia-ni kisimi-i-qatig(i-p)a-a*
 once man-old-ERG \top [wife-3S \top] \perp alone-be-with-DEC \top \perp -3S.3S
 Once an old man \top was alone with his \top wife \perp ,
irnir-tik piniar-riar-sima-mm-at.
 [son-3P \perp] \perp hunt-go-prf-FCT \perp -3S \perp
 because their \top \perp son \perp was away on a hunting trip.
- ii. *Aavi-rsuaq isissaa-lir-mm-at*
 walrus-big \perp visible-begin-FCT \perp -3S \perp
 When a big walrus \perp showed up,
piniar-niar-llu-qu qain-ni atir-vigi-lir-pa-a.
 hunt-intend-ELA \top -3S \perp kayak-3S \top go.down-to-begin-DEC \top \perp -3S.3S
 (ELA \top : elaboration of \top)
 he \top headed down to his \top kayak to go after it \perp (*lit.* \top intending to ...).
- iii. *Nuli-ata inirtir-aluar-pa-a*
 [wife-3S \perp .ERG] \top forbid-in.vain-DEC \top \perp -3S.3S
 His \perp wife \top tried to stop him \perp ,
kisimi-i-mm-at avala-qqu-na-gu.
 alone-be-FCT \perp -3S \perp set.out-tell-not.ELA \top -3S \perp
 begging \top him \perp not to set out because he \perp was alone.
- iv. *Uj-ata=li tusar-uma-na-gu*
 [husband-3S \perp .ERG] \top listen-want-not-not.ELA \top -3S \perp
 But he \top (*lit.* her \perp husband \top) refused to listen to her \perp and
aavi-rsuaq nalip-pa-a.
 walrus-big \perp harpoon-DEC \top \perp -3S.3S
 \top harpooned the great walrus \perp .
- v. *Nali-mm-a-ni upa-annar-pa-a qaja-a tulur-lu-gu.*
 harpoon-FCT \perp -3S \perp .3S \top turn.on-just-DEC \top \perp -3S.3S kayak-3S \perp gore-ELA \top -3S \perp
 As soon as he \perp hit it \top , it \top turned on him \perp , \top goring his \perp kayak \perp with its tusks

2 MANDARIN IN UPDATE WITH CENTERING

- UPDATE WITH CENTERING (e.g. UC $_0$ in Appendix)
- **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 2011; cf. Dekker '94, Groenendijk *et al* '95)
 - (a) update keeps track of current *perspective* = center-stage + background
 - (b) *persp. concepts* for top four drefs: \top (ctr), \top' (2ry ctr), \perp (bck), \perp' (2ry bck)
 - (c) otherwise *descriptive* anaphora via \top° (ctr-stage set) & \perp° (background set)

$$\begin{array}{ccc} \text{center-stage} & \text{background} & \\ \langle \langle \underline{a}_1, a_2, \dots, a_n \rangle, \langle \underline{b}_1, b_2, \dots, b_m \rangle \rangle & & \rightsquigarrow \text{perspective} \\ \top \quad \top' & \perp \quad \perp' & \\ \underbrace{\hspace{10em}}_{\top^\circ} & \underbrace{\hspace{10em}}_{\perp^\circ} & \end{array}$$

- MANDARIN CHINESE: From discourse (2) to UC $_0$ (see also Bittner 2011b)
- (5)i. That car \top is too expensive and it \top 's an ugly color. Lisi \perp doesn't like it \top .
 (input) that-CL car \top , \top price too high,
 $\top[x \text{ car}\langle x, \top \rangle, x \in \perp^\circ]$; $\top[x \text{ price}\langle x, \top \rangle, \text{too.high}\langle x \rangle]$;
 $\langle \langle \perp \rangle, \langle \dots, \equiv \rangle \rangle$ $\langle \langle \perp \rangle, \langle \dots, \equiv \rangle \rangle$ $\langle \langle \perp \rangle, \langle \perp, \dots, \equiv \rangle \rangle$
 \top color also NOT good, Lisi \perp NOT like \top
 $[x \text{ color}\langle x, \top \rangle, \sim\text{good}\langle x \rangle]$; $[x \text{ lisi}\langle x \rangle, x \in \perp^\circ, \sim\text{like}\langle x, \top \rangle]$;
 $\langle \langle \perp \rangle, \langle \bullet, \$, \dots, \equiv \rangle \rangle$ $\langle \langle \perp \rangle, \langle \bullet, \$, \dots, \equiv \rangle \rangle$
- ii. (Yesterday) he \perp went to take a look at it \top . He \perp even took it out for a spin, ...
 \perp go look \top -PNC, even \perp drive \top -PNC $M_{a.\text{while}}$, ...
 $[go.\text{look.at}\langle \perp, \top \rangle]$; $[drive.a.\text{while}\langle \perp, \top \rangle]$; ...
 $\langle \langle \perp \rangle, \langle \bullet, \$, \dots, \equiv \rangle \rangle$ $\langle \langle \perp \rangle, \langle \bullet, \$, \dots, \equiv \rangle \rangle$
- (6)i. *Jiajia bing le, zuotian wanshang jiu fa.shao.* [Li:89]
 Jiajia \top sick SFP, yesterday night then \top run.a.fever
 Jiajia \top is sick. She \top ran a fever last night.
- ii. *Lisi zhidao ta-de mama hen mang, mei gan gaosu ta,*
 Lisi \top know 3S \top 's mom \perp very busy, NOT \top dare tell 3S \perp ,
dai ta qu kan-le jizhen, da-le zhen.
 \top take 3S \top , go see-PNC ER \perp , \perp do-PNC injection
 Lisi \top knew her \top , mom \perp was busy, so he \top didn't want to tell her \perp . He \top just took her \top to the ER \perp (*lit.* to see ER \perp) and they \perp gave her \top an injection.

• Toward CCG + UC₀ FRAGMENT OF MANDARIN– **basic entries** for verbs, e.g.

bing | s\np: $\lambda_{\Sigma_{se}}[sick\langle x \rangle]$ (intransitive verb)
xihuan | s\np\np: $\lambda_{\Sigma_{se}}\lambda_{\Sigma_{se}}[like\langle x, y \rangle]$ (transitive verb)

– lexical **centering operators**

$\tau(\cdot)$ | s/(s\np): $\lambda P(P \tau)$ (missing τ -subject)
 $\perp(\cdot)$ | s/(s\np): $\lambda P([\tau \neq \perp]; P \perp)$ (missing \perp -subject)
 $(\cdot)_{\tau}$ | (s\np)/(s\np\np): $\lambda R\lambda_{\Sigma_{se}}([\tau \neq \tau]; R \tau x)$ (missing τ -object)
 $(\cdot)_{\perp}$ | (s\np)/(s\np\np): $\lambda R\lambda_{\Sigma_{se}}([\tau \neq \perp]; R \perp x)$ (missing \perp -object)

– Hence **derived entries** for verbs with ‘missing arguments’, e.g.

$\tau xihuan$ | s\np: $\lambda_{\Sigma_{se}}[like\langle \tau, y \rangle]$ (missing τ -subject)
xihuan _{τ} | s\np: $\lambda_{\Sigma_{se}}([\tau \neq \tau]; [like\langle x, \tau \rangle])$ (missing τ -object)
 $\perp(xihuan)_{\tau}$ | s: $[\tau \neq \perp]; [like\langle \perp, \tau \rangle]$ (missing \perp -subject & τ -object)

3 KALAALLISUT IN UPDATE WITH CENTERING

• KALAALLISUT: From discourse (4) to UC₀ (see also Bittner 2011a)

(7)i. Once an old man ^{τ} was alone with his _{τ} wife ^{\perp} ,
 once man-old-ERG ^{τ} [wife-3S _{τ}] ^{\perp} alone-with-DEC _{τ} -3S.3S
 $\tau[x]$ old.man $\langle x \rangle$; [x] wife.of $\langle x, \tau \rangle$; [alone.with $\langle \tau, \perp \rangle$]
 $\langle \langle \odot \rangle, \langle \rangle \rangle$ $\langle \langle \odot \rangle, \langle \heartsuit \rangle \rangle$
 \vdots
 $\langle \langle \odot_n \rangle, \langle \rangle \rangle$

because their _{τ} son ^{\perp} was away on a hunting trip.

[son-3P _{τ}] ^{\perp} hunt-go-prf-FCT _{\perp} -3S _{\perp}
 $[x]$ son.of $\langle x, \tau + \perp \rangle$; [gone.hunting $\langle \perp \rangle$]
 $\langle \langle \odot \rangle, \langle \uparrow, \heartsuit \rangle \rangle$

ii. When a big walrus ^{\perp} showed up,

[walrus-big ^{\perp} be.visible-begin-FCT _{\perp} -3S _{\perp}]
 $[x]$ big.walrus $\langle x \rangle$; [show.up $\langle \perp \rangle$]
 $\langle \langle \odot \rangle, \langle \uparrow, \heartsuit \rangle \rangle$

he _{τ} went down to his _{τ} kayak to go after it _{\perp} .

hunt-intend-ELA _{τ} -3S _{\perp} kayak-3S _{τ} go.down-to-begin-DEC _{τ} -3S.3S
 $[intend.to.hunt\langle \tau, \perp \rangle]$; [x] kayak.of $\langle x, \tau \rangle$; [go.down.to $\langle \tau, \perp \rangle$]
 $\langle \langle \odot \rangle, \langle \uparrow, \heartsuit \rangle \rangle$

iii. His ^{\perp} wife ^{τ} tried to stop him _{\perp} ,

[wife-3S _{\perp} .ERG] ^{τ} forbid.in.vain-DEC _{τ} -3S.3S
 $[x]$ $x = \tau$; $\tau[x]$ wife.of $\langle x, \perp \rangle$, $x \in \perp^{\neq}$; [$\tau \neq \perp$]; [try.to.stop $\langle \tau, \perp \rangle$];
 $\langle \langle \heartsuit, \odot \rangle, \langle \odot, \uparrow, \heartsuit \rangle \rangle$

begging _{τ} him _{\perp} not to set out because he _{\perp} was alone.

alone-be-FCT _{\perp} -3S _{\perp} set.out-tell-not.ELA _{τ} -3S _{\perp}
[alone $\langle \perp \rangle$]; [beg.not.to.set.out $\langle \tau, \perp \rangle$]

iv. But he ^{τ} (*lit.* her ^{\perp} husband ^{τ}) refused to listen to her _{\perp} and

[husband-3S _{\perp} .ERG] ^{τ} listen-want-not.ELA _{τ} -3S _{\perp}
 $[x]$ $x = \tau$; $\tau[x]$ husband $\langle x, \perp \rangle$, $x \in \perp^{\neq}$; [refuse.to.listen.to $\langle \tau, \perp \rangle$]
 $\langle \langle \odot, \heartsuit, \odot \rangle, \langle \heartsuit, \odot, \uparrow, \heartsuit \rangle \rangle$

harpooned the great walrus ^{\perp} .

walrus-big ^{\perp} harpoon-DEC _{τ} -3S.3S
 $[x]$ big.walrus $\langle x \rangle$, $x \in \perp^{\neq}$; [$\tau \neq \perp$]; [harpoon $\langle \tau, \perp \rangle$]
 $\langle \langle \odot, \heartsuit, \odot \rangle, \langle \uparrow, \heartsuit, \odot, \uparrow, \heartsuit \rangle \rangle$

v. As soon as he ^{\perp} hit it ^{τ} , it _{τ} turned on him _{\perp} ,

harpoon-FCT _{\perp} -3S _{\perp} .3S _{τ} turn.on-just-DEC _{τ} -3S.3S
 $\tau[x]$ $x = \perp$; [x] harpoon $\langle x, \tau \rangle$, $x \in \tau^{\neq}$; [$\tau \neq \perp$]; [turn.on $\langle \tau, \perp \rangle$];
 $\langle \langle \uparrow, \odot, \heartsuit, \odot \rangle, \langle \odot, \uparrow, \heartsuit, \odot, \uparrow, \heartsuit \rangle \rangle$

 _{τ} puncturing his _{\perp} kayak ^{\perp} with its _{τ} tusks.

qaja-a tulur-lu-qu.
kayak-3S _{\perp} gore-ELA _{τ} -3S _{\perp}
 $[x]$ kayak $\langle x, \perp \rangle$; [puncture.w.tusks $\langle \tau, \perp \rangle$]
 $\langle \langle \uparrow, \odot, \heartsuit, \odot \rangle, \langle \uparrow, \odot, \uparrow, \heartsuit, \odot, \uparrow, \heartsuit \rangle \rangle$

• Toward CCG + UC₀ FRAGMENT OF KALAALLISUT (as in Bittner 2011a)– **verb roots**, e.g.

naparsima- | s\np: $\lambda_{\Sigma_{se}}[sick\langle x \rangle]$ (intransitive verb)
nuannari- | s\np\np: $\lambda_{\Sigma_{se}}\lambda_{\Sigma_{se}}[like\langle x, y \rangle]$ (transitive verb)

– **inflectional centering** by MOOD + pn-arguments, e.g.

-DEC _{τ} -3S | s/(s\np): $\lambda P(P \tau)$ (ctr fact about τ)
-DEC _{τ} -3S.3S | s/(s\np\np): $\lambda R([\tau \neq \perp]; R \tau \perp)$ (ctr fact about $\langle \tau, \perp \rangle$)
-FCT _{τ} -3S _{τ} | (s/s)/(s\np): $\lambda P\lambda K(P \tau; K)$ (bck fact abt input τ)
(s/s)/(s\np): $\lambda P\lambda K(\tau[x] x = \perp]; P \tau; K)$ (... output τ)
-FCT _{\perp} -3S _{\perp} | (s/s)/(s\np): $\lambda P\lambda K(P \perp; K; [\tau \neq \perp])$ (bck fact abt input \perp)
(s/s)/(s\np): $\lambda P\lambda K([x] x = \tau]; P \perp; K; [\tau \neq \perp])$ (... output \perp)

4 ENGLISH IN UPDATE WITH CENTERING

• APPROACHES TO PRONOUN INTERPRETATION

– **coherence**-driven (Hobbs 1979)

- (8) *The city council denied the demonstrators a permit because ...*
 a. ... *they* feared violence. (*they* = the city council)
 b. ... *they* advocated violence. (*they* = the demonstrators)

– **parallelism**-driven (Sidner 1983). Kehler's (9) shows the strength of this effect.

- (9) *Margaret Thatcher admires Hilary Clinton,*
and George W. Bush absolutely worships her. (*her* = Hilary Clinton)

– **attention**-driven (Sidner '83, Kameyama '86, Brennan *et al* '87, Grosz *et al* '95)

- (10) a. *John* hit *Bill*. *Mary* told *him* to go home. (*him* = John)
 b. *Bill* was hit by *John*. *Mary* told *him* to go home. (*him* = Bill)

– **attention+coherence**-driven (Kehler 2002: Ch. 6)

"My analysis of pronoun interpretation [is] based on the interaction of two aspects of interpretation:

- (i) the linguistic properties of the linguistic form in question, and
 (ii) the properties of the process of establishing coherence for my three types of relations [*causal*, e.g. (8); *resemblance*, e.g. (9); *contiguity*, e.g. (10)]
 ... [re (i)] pronouns [are] linguistic devices ... that encode signals to the hearer about the degree of salience the referent holds within the current discourse state ... [i.e. signals] that this level of salience is high." (Kehler 2002:156)

• ATTENTION + COHERENCE IN UC₀:**Causal relation** (*Explanation*): signaled by the complementizer *because*

- (8') *The city council^T denied the demonstrators[⊥] a permit because ...*
^T[*x* | *city.council*(*x*), *x* ∈ ⊥[⊖]]; [*x* | *demonstrators*(*x*), *x* ∈ ⊥[⊖]]; [*deny*(^T, ⊥)];
 a. ... *they_T* feared violence.
 [*fear.violence*(^T)] (^T: the city council)
 b. ... *they_⊥* advocated violence.
 [*advocate.violence*(⊥)] (⊥: the demonstrators)

Resemblance rel. (*Parallel*): signaled by *and* & near synonyms *admire...worship*

- (9') *Margaret Thatcher^T admires Hilary Clinton[⊥], and ...*
^T[*x* | *margaret*(*x*), *x* ∈ ⊥[⊖]]; [*x* | *hilary*(*x*), *x* ∈ ⊥[⊖]]; [*admire*(^T, ⊥)];
 ... *George W. Bush^T absolutely worships her_⊥.*
^T[*x* | *george*(*x*), *x* ∈ ⊥[⊖]]; [^T ≠ ⊥]; [*worship*(^T, ⊥)] (⊥: Hilary Clinton)

Contiguity relation (*Occasion*): default in story tellingKehler's (11), problem for *static* centering theory ([BFP], [GJW]), but not UC:

- ⟨⟨⟩, ⟨..., ⊙, ●⟩⟩ (initial input: ⊙ = Terry, ● = Tony)
- (11) i. *Terry^T set out for an outdoor excursion on Monday.*
^T[*x* | *terry*(*x*), *x* ∈ ⊥[⊖]]; ^T[*t_d* | *set.out*(^T, *t*), *monday*(*t*), ...];
 ⟨⟨⊙⟩, ⟨..., ⊙, ●⟩⟩ ⟨⟨*t₁*, ⊙⟩, ⟨..., ⊙, ●⟩⟩ (*t₁*: topic time)
- ii. *It_T was a beautiful day, hovering around 83 degrees.*
 [*beautiful.day*(^T *τ*), ...];
- iii. *He_T was excited about trying out his_T new sailboat[⊥].*
 [*x* | *new.sailboat.of*(*x*, ^T)]; [*excited.about.trying.out*(^T, ⊥)]
 ⟨⟨⊙⟩, ⟨*τ*, ..., ⊙, ●⟩⟩ (entity dref's only)
- iv. *He_T wanted Tony[⊥] to join him_T on a sailing expedition.*
 [*x* | *tony*(*x*), *x* ∈ ⊥[⊖]]; [^T ≠ ⊥]; [*want.to.join.on.sailing.exp*(^T, ⊥)];
 ⟨⟨⊙⟩, ⟨*τ*, ..., ⊙, ●⟩⟩
- v. *The_T marina[⊥] ...*
^T[*x* | *marina*(*x*), *use*(^T, *x*)];
 ⟨⟨□, ⊙⟩, ⟨*τ*, ..., ⊙, ●⟩⟩
 ... *is actually very close to Tony's house.*
 [*tony*(⊥), ⊥ ∈ ⊥[⊖]]; [*x* | *house.of*(*x*, ⊥)]; [*very.close.to*(^T, ⊥)]
 ⟨⟨□, ⊙⟩, ⟨*τ*, ..., ⊙, ●⟩⟩
- vi. *He_T called him_⊥ at 6 AM.*
^T[*x* | *x* = ^T']; [*x* | *x* = ⊥']; [^T ≠ ⊥]; [*call.at.6AM*(^T, ⊥)];
 ⟨⟨⊙, □, ⊙⟩⟩, ⟨*τ*, ..., ⊙, ●⟩⟩
- vii. *He_T was sick and furious with him_⊥ for waking him_T up so early. ???*
 [*sick*(^T)]; [^T ≠ ⊥]; [*furious.with*(^T, ⊥), *wake.up*(⊥, ^T)] **garden path!**

5 CONCLUSION

- NL anaphors refer to *perspective*-dependent entities (e.g. ⊥ for 'top-ranked entity in the background'), where the *curr. discourse perspective* is an empirical notion.
- The clearest and most direct evidence comes from *centering systems*, which grammatically track the current discourse perspective and make use of *top-level anaphors* (e.g. Mandarin 'like_T', Kalaallisut 'like-FCT_⊥-3S_⊥-3S_T')
 • *English pronouns* can refer to any of the top four drefs (i.e. ^T, ^{T'}, ⊥, ⊥'). Still, coherence relations and/or gender presuppositions usu. successfully disambiguate
- All languages use *full np*'s for *descriptive anaphora* (to ^T-set or ⊥[⊖]-set). In UC only this form of anaphora is available for lower-ranked drefs (below ^{T'}, ⊥').

APPENDIX: *Update with Nominal Centering* (UC₀)D1 (UC₀ types Θ).

- i. $t, e, s \in \Theta$ (truth values, entities, perspectives)
 ii. $(ab) \in \Theta$, if $a, b \in \Theta$

D2 A UC₀-frame is a set $\{\mathcal{D}_a \mid a \in \Theta\}$ of non-empty a -domains \mathcal{D}_a such that:

- i. $\mathcal{D}_t = \{1, 0\}$ and \mathcal{D}_e are non-empty disjoint sets
 $\mathcal{D}_s = \cup_{n \geq 0, m \geq 0} \{\langle \langle a_1, \dots, a_n \rangle, \langle b_1, \dots, b_m \rangle \rangle : a_i, b_j \in \mathcal{D}_e\}$
 ii. $\mathcal{D}_{(ab)} = \{f \mid \text{Dom } f \subseteq \mathcal{D}_a \ \& \ \text{Ran } f \subseteq \mathcal{D}_b\}$

D3 A UC₀-model is a pair, $\mathcal{M} = \langle \mathcal{D}, \llbracket \cdot \rrbracket \rangle$ such that $\mathcal{D} = \{\mathcal{D}_a : a \in \Theta\}$ is a UC₀-frame and $\llbracket \cdot \rrbracket$ maps any $A \in \text{Con}_a$ to $\llbracket A \rrbracket \in \mathcal{D}_a$. Moreover, for all $i = \langle i_1, i_2 \rangle \in \mathcal{D}_s$:

- $\llbracket \top \rrbracket(i) \doteq (i_1)_1$ $\llbracket \perp \rrbracket(i) \doteq (i_2)_1$ (\doteq for \doteq , if defined)
 $\llbracket \top \uparrow \rrbracket(i) \doteq (i_1)_2$ $\llbracket \perp \uparrow \rrbracket(i) \doteq (i_2)_2$
 $\llbracket \top^\circ \rrbracket(i) = \lambda \{(i_1)_n : n \geq 1\}$ $\llbracket \perp^\circ \rrbracket(i) = \lambda \{(i_2)_n : n \geq 1\}$ (λ for char. function)

D4.1 (UC₀ syntax) For any type $a \in \Theta$, we define the set of a -terms, Trm_a :

- b.** $A \in \text{Trm}_a$ if $A \in \text{Con}_a \cup \text{Var}_a$
a. $BA \in \text{Trm}_b$ if $B \in \text{Trm}_{(ab)}$ & $A \in \text{Trm}_a$
 λ . $\lambda u_a(B) \in \text{Trm}_{(ab)}$ if $u_a \in \text{Var}_a$ & $B \in \text{Trm}_b$
 $=$. $(A = B) \in \text{Trm}_t$ if $A, B \in \text{Trm}_a$
 \neg . $\neg A \in \text{Trm}_t$ if $A \in \text{Trm}_t$
 \wedge . $(A \wedge B) \in \text{Trm}_t$ if $A, B \in \text{Trm}_t$
 \bullet . $(A \top B), (A \bullet B) \in \text{Trm}_s$ if $A \in \text{Trm}_e$ & $B \in \text{Trm}_s$

D4.2 (UC₀-semantics). For any model $\mathcal{M} = \langle \mathcal{D}, \llbracket \cdot \rrbracket \rangle$ and \mathcal{M} -assignment g , define:

- b.** $\llbracket A \rrbracket^g = \llbracket A \rrbracket$ if $A \in \text{Con}_a$
 $= g(A)$ if $A \in \text{Var}_a$
a. $\llbracket BA \rrbracket^g \doteq \llbracket B \rrbracket^g(\llbracket A \rrbracket^g)$
 λ . $\llbracket \lambda u_a(B) \rrbracket^g(d) \doteq \llbracket B \rrbracket^{g[u/d]}$ for any $d \in \mathcal{D}_a$
 $=$. $\llbracket (A = B) \rrbracket^g = 1$ if $\llbracket A \rrbracket^g = \llbracket B \rrbracket^g$; $= 0$, otherwise
 \neg . $\llbracket \neg A \rrbracket^g = 1$ if $\llbracket A \rrbracket^g = 0$; $= 0$, otherwise
 \wedge . $\llbracket (A \wedge B) \rrbracket^g = 1$ if $\llbracket A \rrbracket^g = 1$ & $\llbracket B \rrbracket^g = 1$; $= 0$, otherwise
 \bullet . $\llbracket (A \top B) \rrbracket^g \doteq \langle \langle \llbracket A \rrbracket^g \cdot i_1 \rangle, i_2 \rangle$ where $\langle i_1, i_2 \rangle = \llbracket B \rrbracket^g$
 $\llbracket (A \bullet B) \rrbracket^g \doteq \langle i_1, (\llbracket A \rrbracket^g \cdot i_2) \rangle$ & $(d \cdot \langle d_1, \dots, d_n \rangle) := \langle d, d_1, \dots, d_n \rangle$

D5 (Truth). For any $(st)st$ -term K , model \mathcal{M} , and info-state $c \in \mathcal{D}_{st, \mathcal{M}}$: K is true in \mathcal{M} given c , iff $\forall g: \llbracket K \rrbracket^g(c) \neq \lambda \emptyset$

ABBREVIATIONS

A1 (implication & quantifiers)

- i. $(\varphi_t \rightarrow \psi_t) := \neg(\varphi \wedge \neg\psi)$
 ii. $\forall u_a \varphi_t := (\lambda u_a(\varphi) = \lambda u_a(u = u))$
 $\exists u_a \varphi_t := \neg \forall u \neg \varphi$

A2 (DRT-notation).

i. perspectival concepts (type se)

- $A_e^\circ := \lambda i_s(A)$ $x_e^\circ := \lambda i_s(x)$
 $A_{se}^\circ := \lambda i_s(Ai)$ $\top^\circ := \lambda i_s(\top i) = \top$

ii. conditions (type st)

- $B \langle A_1, \dots, A_n \rangle := \lambda i_s(B A_1^\circ i, \dots, A_n^\circ i)$ $car \langle \perp \rangle := \lambda i_s(car \perp i)$
 $(A =_i B) := \lambda i_s(A^\circ i = B^\circ i)$ $(\top =_i x) := \lambda i_s(\top i = x)$

iii. updates (type $(st)st$)

- $[C_{st}] := \lambda i_{st} \lambda j_s (Ij \wedge Cj)$ (test)
 $[x_e] C_{st} := \lambda i_{st} \lambda j_s (\exists x_e \exists i_i (Ii \wedge Ci \wedge j = x \bullet i))$ (\perp -update with test)
 $\top [x_e] C_{st} := \lambda i_{st} \lambda j_s (\exists x_e \exists i_i (Ii \wedge Ci \wedge j = x \top \bullet i))$ (\top -update with test)
 $(K_{(st)st}; K'_{(st)st}) := \lambda i_{st} \lambda j_s (K' KI j)$ (sequencing)

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