Word Order and Incremental Update

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The central claim of this paper is that surface-faithful word-by-word update is feasible and desirable, even in languages where word order is supposedly free.

As a first step, in sections 1 and 2, I review an argument from Bittner 2001a that semantic composition is not a static process, as in PTQ, but rather a species of anaphoric bridging. But in that case the context-setting role of word order should extend from cross-sentential discourse anaphora to sentence-internal anaphoric composition. This can be spelled out as a two-part hypothesis. First, in all languages anaphoric composition derives incremental updates based on the topological order rather than the syntactic hierarchy. And secondly, rigid vs. free word order is simply rigid vs. free mapping from syntax to topology.

To formalize this hypothesis, I first present, in section 3, *Seven-sorted Logic of Change with Centering*. This makes it possible, in section 4, to articulate a system of constraints on basic meanings in Kalaallisut — a polysynthetic language with free word order, ideally suited to test the hypothesis of incremental update. The key assumptions about topology as the input to anaphoric composition are spelled out in section 5, which concludes the development of a general formal framework.

This formal framework then serves, in sections 6 through 8, to explicate topologically based incremental updates for increasingly more complex samples of an actual Kalaallisut text. This reveals ubiquitous patterns of prominence-guided anaphora, in all semantic domains, to increasingly more complex types of discourse referents. These anaphoric patterns show that the context-setting role of word order indeed does extend from discourse to word-to-word anaphora. And this, in turn, strongly supports the hypothesis of topologically based anaphoric composition.

Finally, in section 9 I adduce evidence from English that this hypothesis also holds for languages with rigid word order, albeit the fixed mapping keeps the topology close to the syntax.

I conclude that both free and rigid word orders receive a natural account if semantic composition is viewed as topologically based anaphoric bridging. This view sheds crosslinguistic light on centering, prominence-guided anaphora, and the universal context-setting role of word order, in every language and at every level.

1 Montagovian update based on syntactic hierarchy

Since Montague's PTQ research on semantic composition has been dominated by what I will term the *Montagovian view* (M). In

Montagovian theories of semantic composition the primary burden rests on static mechanisms — function application, variable binding and, possibly, static type shifting. Dynamics is essentially irrelevant for sentence-internal composition.

(*M*) *Composition à la PTQ* (static)

- Primary burden: function application
  static variable binding
  (static type shifting)
- Irrelevant / marginal: dynamic anaphora.

This is true of the original PTQ system, for good reasons — dynamic semantics had not yet been invented in 1973. But the same continues to hold for dynamic descendants of PTQ — say, *Dynamic Montague Grammar* of Groenendijk and Stokhof 1990, or *Compositional DRT* of Muskens 1996.

For instance, in Compositional DRT the words that constitute (1) would be assigned the neo-Montagovian meanings in (2), ignoring tense and modality.

(1) He bought a big house.

(2) *Neo-Montagovian basic meanings* (cf. Muskens 1996) Type

he_n	$\rightsquigarrow$	$\lambda P_{[se]}\,(P(u_n))$	$[[se]]$
buy	$\rightsquigarrow$	$\lambda Q_{[[se]]}\,\lambda v_{se}\;Q(\lambda v_{se}'\;[\mid v\ \text{BUY}\ v'])$	$[[se]][se]$
house	$\rightsquigarrow$	$\lambda v_{se}\,[\mid \text{HOUSE}\ v]$	$[se]$
big	$\rightsquigarrow$	$\lambda P_{[se]}\,\lambda v_{se}\,(P(v);\,[\mid \text{BIG}\ v])$	$[se][se]$
a^n	$\rightsquigarrow$	$\lambda P_{[se]}'\,\lambda P_{[se]}\,([u_n\mid\,];\,P'(u_n);\,P(u_n))$	$[se][[se]]$

These are essentially as in PTQ, except that the basic types are replaced with dynamic counterparts. The entity type *e* is replaced with *se* — the type of a dynamic concept, mapping information states (type *s*) to entities. Similarly, the truth value type *t* is replaced with *sst*, abbreviated as a box, [ ]. This is the type of a context change potential, relating input states of information to potential outputs.

Because of these type correspondences, the static compositional rules of PTQ continue to work in this dynamic descendant. Thus, given the basic meanings in (2), the meaning of sentence (1) can be composed just as in PTQ — by function application — as shown in (3). The result is a box that includes a discourse referent for a house, ready to participate in dynamic anaphora. But in Compositional DRT and other Montagovian theories such anaphoric potential plays no role in sentence-internal composition.

(3) he$_1$ [buy [a^2 [big house]]]
$\rightsquigarrow$ $\lambda P\ (P(u_1))(\lambda Q\ \lambda v\ Q(\lambda v'[\ |\ v\ \text{BUY}\ v']))$
$(\lambda P'\ \lambda P\ ([u_2|\ ];\ P'(u_2);\ P(u_2))$
$(\lambda P\ \lambda v\ (P(v);\ [\ |\ \text{BIG}\ v])(\lambda v\ [\ |\ \text{HOUSE}\ v])))))$
$=\ [u_2|\ u_1\ \text{BUY}\ u_2,\ \text{HOUSE}\ u_2,\ \text{BIG}\ u_2]$

In general, any theory that conforms to the Montagovian assumptions in (*M*) is static at the sentence-internal level. But from (*M*) we can infer ($\mathbf{W}_M$):

($\mathbf{W}_M$) Word order plays no role in semantic composition.

This is because the static compositional operations in (*M*) rely only on the syntactic dominance hierarchy and are entirely independent of the linear left-to-right order. Accordingly, Montagovian semantic theories are usually set up so that word order need not even be represented in the structural input to semantic composition, at least not in languages whose word order is supposedly free. This order-independent classical architecture is what I wish to challenge in this paper.

2 Incremental update based on topological order

In fact, I have already challenged the Montagovian view in Bittner 2001a. My complaint was that it fails to generalize across typologically distant languages in a manner that would reconcile two important desiderata for a theory of natural language semantics — universality and surface-faithfulness. The PTQ view of semantic composition is too parochial. Its basic meaning assignment and static semantic rules crucially rely on English bracketing. But the bracketing can be quite different in typologically distant languages — e.g. in *Kalaallisut* (Eskimo-Aleut: Greenland) the proposition of English (1) can be expressed as (4): [1]

(4) *Angisuu-mik illu-si-vu-q.*
big-sg.MOD house-buy-IND.IV-3sg
'He bought a big house.'

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[1] Kalaallisut examples are transcribed in the standard orthography, minus the allophonic lowering of *i* and *u* (to *e* and *o*) before uvulars, and the devoicing of *v* (to *f*) in consonant clusters. The glosses include the following abbreviations. *Agr*: sg = singular, pl = plural, 1 = 1st, 2 = 2nd, $3_\perp$ = background 3rd, $3_\top$ = topical 3rd. *Case*: ABL = ablative (source), DAT = dative (goal), EQU = equalis (standard of comparison), ERG = ergative, LOC = locative, MOD = modalis (modifier), VIA = vialis (path). *Mood*: $\text{ELA}_\top$ = elaboration of $\top$-subject, $\text{ELA}_\perp$.IV = IV-elaboration of $\perp$-subject, $\text{ELA}_\perp$.TV = TV-elaboration of $\perp$-subject, $\text{FCT}_\top$ = old fact about $\top$-subject, $\text{FCT}_\perp$ = old fact about $\perp$-subject, IND.IV = indicative IV, IND.TV = indicative TV.

Because of the different bracketing, PTQ style analyses such as (2) and (3) of English (1) fail to generalize to Kalaallisut (4). One must posit either Kalaallisut-specific basic meanings (as van Geenhoven 1998) or else more English-like input to semantic composition (as Bittner 1994). Neither solution is satisfactory. If the basic meaning assignment is language-specific, then it cannot capture intuitions about crosslinguistic morpheme-by-morpheme equivalences — for example, the intuition that the English verb *buy* is equivalent to the Kalaallisut verbal suffix *-si*. On the other hand, abandoning surface-faithfulness amounts to saying that only English structures are interpretable, whereas Kalaallisut structures must first be assimilated to English — hardly what we mean when we claim, or hope, that natural language semantics is universal.

To resolve this dilemma, I proposed in Bittner 2001a that composition is better thought of as a dynamic process. Its main role is to build anaphoric bridges, by filling in missing but predictable bits of meaning — a form of accommodation similar to definite antecedent bridging in discourses like (5).

(5) He bought [a house]. [The roof] is leaking.
⤳ He bought [a house]. *It has a roof.* [The roof] is leaking.

In discourse anaphoric bridging is based on prominent discourse referents and common knowledge — for instance, in (5), the well-known part-whole relation between roofs and houses. Compositional bridging likewise involves prominence-guided anaphora. But it does not rely on defeasible inferences from common knowledge. Instead, compositional bridges are built by non-defeasible type-driven rules of an order-sensitive compositional system employing dynamic type-lifting operators — a form of grammaticized accommodation (defined in Bittner 2001a).

Thus, reversing the Montagovian view (*M*), the anaphoric view (*A*) puts the main burden of semantic composition on dynamic prominence-guided anaphora, relegating static operations to a marginal role, if any.

(*A*) *Composition as anaphora* (dynamic)

• Primary burden:	prominence-guided anaphoric bridging (by dynamic type-lifting)
• Irrelevant / marginal:	function application, static variable binding.

The key notion of prominence-guided anaphora can be formalized by combining the typed *Logic of Change* of Muskens 1995 with the prominence-guided first order *Predicate Logic with Anaphora* of Dekker 1994. The result is a typed *Logic of Change with Centering* presented in Bittner 2001a. In this system discourse referents (aka *drefs*) are not variables, but prominence-ranked semantic objects — entities, events, etc, depending on the ontology ($A1$) — forming two stacks, as set forth in ($A2$).

($A1$) *Ontology*:
entities e, eventualities o, … (other basic types)
kinds $\kappa := oe$, … (other functional types)

($A2$) *Fore-* | *Back-ground*: i. a-drefs added to $\top$- | $\bot$-stack by $\mathbf{v}_a$ | v_a
ii. top a-dref retrieved by $(\mathbf{d}a)_{sa}$ | $(da)_{sa}$

The two dref stacks are denoted by lattice-theoretic symbols for top ($\top$) and bottom ($\bot$). Intuitively, they represent foregrounded and backgrounded drefs. A dref object can be added to the foreground stack or background stack by a bold or italicized variable of the appropriate type. For any type a, the topmost dref can then be retrieved by a demonstrative of the form $\mathbf{d}a$ or da (with 'd' mnemonic for 'that'). Demonstratives are not variables, but dynamic a-concepts (type sa), mapping the current information state to the appropriate type a dref object.

Given this representation language and the universal system of bridge-building type-lifting operators of Bittner 2001a, it is no longer a dilemma that languages may converge on the same meaning across different bracketing, as in (1) and (4). The convergence can be traced to crosslinguistic agreement on two key points. First, the two languages agree on the bridgeable basic meanings — in this case, on (6). And secondly, they agree on the prominence-guided anaphoric bridges to be built by the dynamic type-lifting of this grammaticized bridging system.

(6) *Bridgeable basic meanings* (à la Bittner 2001a)

				Type
he,	-3sg	⇝	$[\,\vert\,$ 3SG $\mathbf{d}e]$	[ ]
buy,	-buy	⇝	$\lambda z_e\,[\,\vert\,\mathbf{d}e$ BUY $z]$	$[e]$
house,	house-	⇝	$\lambda z_e\,[k_\kappa\vert$ HOUSE $k, z \leq k]$	$[e]$
big,	big-	⇝	$\lambda z_e\,[\,\vert\,z$ BIG $d\kappa]$	$[e]$
a,	---	⇝	$\lambda P_{[e]}\,P$	$[e][e]$

With this much agreed on, anaphoric composition tolerates dissent on every other point, including radically different bracketing. All this means is that some anaphoric bridges are built in a different order or at a different level — say, syntax in one language, morphology in another. Thus, for example, English (1) and Kalaallisut (4) can be composed as in (1′) and (4′), respectively.

(1′) he [buy [a [big house]]]

$$\rightsquigarrow \; [|\ 3\text{SG}\ \mathbf{d}e];$$
$$([y_e|\ ];\ \lambda z_e([\ |\ \mathbf{d}e\ \text{BUY}\ z];$$
$$\lambda P_{[e]}\ P\ (\lambda z_e([k_\kappa|\ \text{HOUSE}\ k,\ z \leq k];\ [|\ z\ \text{BIG}\ d\kappa]))(z))\{de\})$$

(4′) big [[house-buy]-3sg]

$$\rightsquigarrow \; ((([y_e|\ ];\ \lambda z_e([k_\kappa|\ \text{HOUSE}\ k,\ z \leq k];\ [\ |\ \mathbf{d}e\ \text{BUY}\ z])\{de\}));\ [|\ 3\text{SG}\ \mathbf{d}e])$$
$$\lambda z_e[\ |\ z\ \text{BIG}\ d\kappa]\{de\}$$

Both compositional paths respect surface bracketing, letting English be English and Kalaallisut, Kalaallisut. And in both languages any bits of meaning that are missing from the lexical entries in (6) are predictably filled in, by the universal type-lifting system, which resolves type mismatch by building an anaphoric bridge.

At the end of the day, once the prominence-guided anaphoric links are resolved, both compositional paths converge on the same bottom line, to wit (7).

(7) $[\ |\ 3\text{SG}\ \mathbf{d}e];\ [k_\kappa\ y_e|\ \mathbf{d}e\ \text{BUY}\ y,\ \text{HOUSE}\ k,\ y \leq k,\ y\ \text{BIG}\ k\,]$

This representation presupposes an input state with a foregrounded — i.e., topical — individual ($\mathbf{d}e$), which is atomic and is neither the speaker nor the addressee. The background stack of the input is updated as follows. First, y_e adds an entity, and then k_κ tops it up with a kind. In the ontology of (A1) a kind is a function that maps any event where the kind is instantiated to the instantiating entity. In (7) the background kind is instantiated by houses, while the background entity is a big instance of that kind bought by the currently topical individual.

Semantic convergence across structural diversity provides dramatic support for the anaphoric view of semantic composition. But if composition is prominence-guided anaphora, then the context-setting role of word order should extend from discourse anaphora to compositional anaphoric bridging. More precisely, I propose to replace the static view of worder order ($\mathbf{W}_M$) with the dynamic hypothesis ($\mathbf{W}_A$).

($\mathbf{W}_A$)
- *All languages*: Anaphoric composition derives word-by-word updates based on surface topological trees.
- *'Free' order*: Free map: GF → TopoF.
  Words ordered for optimal anaphora (*Ideal*: short links).

This comprises two claims. First, in all languages anaphoric composition derives incremental updates based on surface trees representing ordered topological fields. And secondly, languages with free word order freely map any grammatical function to any topological field.

Words are ordered for optimal anaphora — intuitively, so that anaphoric links, ranked by importance, are as short as possible.

For rigid word order, the hypothesis that the input to semantic composition is the topological order rather than the syntactic hierarchy is less revolutionary than it sounds. With fixed mapping from syntax to topology, topological trees are like syntactic trees of theories such as HPSG, modulo topological field assignments to dependent nodes. This reassuring point will be illustrated for English in section 9.

But first we develop a suitable formal framework (sections 3–5) and motivate the universal hypothesis ($\mathbf{W}_A$) with evidence from Kalaallisut, whose word order is free. With free mapping from syntax to topology, the hypothesis that it is topology, not syntax, that serves as the input to semantic composition is indeed radical. A claim of this magnitude cannot be persuasively argued without extensive, and therefore complex, evidence. So we will proceed gently, from simple episodic discourse to more complex varieties. Throughout, topological order will be shown to play a key role, because ubiquitous prominence-guided anaphora in all semantic domains crucially relies on this order to determine the local context (sections 6–8).

3 Seven-sorted Logic of Change with Centering (LCC_7)

The *Logic of Change* of Muskens 1995 distinguished four basic sorts: entities e, eventualities o, times τ, and worlds $\mathbf{w}$. To incorporate the insights of Grosz *et al* 1995, the *Logic of Change with Centering* developed by Bittner 2001a, b replaced classical index-based anaphora with anaphora based on current prominence. Also, following Partee 1984, eventualities were sorted into events ε and states σ. In addition, Kalaallisut texts further motivate parallel sorting of entities, into active α and passive β, as well as supplementing the temporal sort τ with a spatial sort π. The resulting *Seven-sorted Logic of Change with Centering* (LCC_7, see Appendix) will then suffice to define all of the commonly occurring dref types, as in (*A*1). By the standards of constructed examples, considered by Muskens 1995 and other pioneers, this seven-sorted ontology may seem unduly complex. But with all due respect to the pioneers, it is time, I think, to move on to real texts. And to interpret those, by topologically based incremental update, no leaner ontology will do because all of the dref types in table (*A*1) are in constant demand.

(A1) Seven-sorted ontology of LCC_7 (• marks dref types)

Type	Abbr.	Name of objects	$^{\top}V$	$^{\bot}V$	$^{\top}D$	$^{\bot}D$
t		truth values				
$\mathbf{w}$		worlds		w		
ε		•events	$\mathbf{e}$	e		
σ		•states	$\mathbf{s}$	s		
α		•active entities	$\mathbf{a}$	a		
β		•passive entities	$\mathbf{b}$	b		
τ		•times	$\mathbf{t}$	t		
π		•places	$\mathbf{l}$	l		
$\mathbf{w}t$	ω	•possibilities	$\mathbf{p}$	p		
$\mathbf{ww}t$	Ω	•ω-concepts (accessibility relations)	$\mathbf{q}$	q		
$\mathbf{w}\tau t$	θ	•τt-concepts (τ-domain concepts)	$\underline{\mathbf{T}}$	$\underline{T}$		
$\mathbf{w}\varepsilon$		•ε-concepts	$\underline{\mathbf{e}}$	$\underline{e}$		
:		:	:	:		
εt		•ε-sets	$\mathbf{E}$	E		
:		:	:	:		
$\varepsilon\varepsilon$		•ε-dependencies (processes)	$\mathbf{e\,e}$	ee		
:		:	:	:		
$\varepsilon\vee\varepsilon\varepsilon\vee\sigma$	o	•eventualities (*o*ccur)	$\mathbf{ev}$	ev		
$\alpha\vee\beta$	e	•entities (*e*xist)	$\mathbf{x}$	x		
$\mathbf{w}\tau\mathsf{v}$	η^{v}	•v-habits ($\mathsf{v} \in \{o, \varepsilon, \varepsilon\varepsilon, \sigma\}$)	$\mathbf{h}^{\mathsf{v}}$	h^{v}		
$\mathbf{w}o\mathsf{n}$	κ^{n}	•n-kinds ($\mathsf{n} \in \{e, \alpha, \beta, \tau, \pi\}$)	$\mathbf{k}^{\mathsf{n}}$	k^{n}		
$\eta^{\mathsf{v}}\eta^{\mathsf{v}}$	$\eta\eta^{\mathsf{v}}$	•v-scales	$\mathbf{h\,h}^{\mathsf{v}}$	hh^{v}		
$\kappa^{\mathsf{n}}\kappa^{\mathsf{n}}$	$\kappa\kappa^{\mathsf{n}}$	•n-scales	$\mathbf{k\,k}^{\mathsf{n}}$	kk^{n}		
ab		•ab-dependencies (a, b, any •-types)	$\boldsymbol{f}_{\mathsf{ab}}$	f_{ab}		
$\mathbf{s}$		stacks (of •-typed dref objects)				
$\mathbf{w}\times\mathbf{s}\times\mathbf{s}$	s	information states		i, j		
$s\mathsf{a}$		dynamic a-concepts (a, any •-type)			$\mathbf{d}\mathsf{a}_n$	$d\mathsf{a}_n$
sst		updates		J		

Thus, even simple episodic passages (such as (8)–(9) in section 6) involve reference to all of the seven basic types — possibilities (type $\omega := \mathbf{w}t$), events (ε), states (σ), active entities (α), passive entities (β), as well as times (τ) and places (π). Process drefs — for chains of events — are also common. Formally, these are ε-dependencies, mapping each stage of the process, except the last, to the next stage.

Drefs for concepts are required for intensional contexts. Set-level drefs are needed for distributive plurals (e.g., the first NP in (8)). Drefs for a-dependencies, with assorted types a, are evoked not only by process verbs but also, for instance, reflexives (à la bound pronouns of Jacobson

1996), reciprocals (à la Schwarzschild 1996), and some functional nouns (e.g., 'morning.of' in (11)). Distributivity and functional nouns may also refer to more complex a-to-b dependencies. And so may comparatives and ellipsis (e.g., in (12)), to name just a few sources of such drefs.

Habituals refer to habits (e.g., in (10)–(11) in section 7). We model a habit as a function that maps any world and time when the habit is instantiated to the instantiating eventuality (type $\eta^{v} := \mathbf{w}\tau v$, for some sort of eventuality v). This extends to habituals the encapsulation strategy that Stone 1997 first proposed for modality. On this view, neither phenomenon involves a quantifier, be it generic or modal. Instead, both evoke drefs — for habits or possibilities — that encapsulate entire dependencies and are then suitably related by habitual or modal predicates. In particular, temporal anaphora relates habits to τ-domain concepts (type $\theta := \mathbf{w}\tau t$).

Kind-level nominals refer to kinds of entities (e.g., seals in (8)), or kinds of times (e.g., durations in (12)), or kinds of places. To model these, we again extend Stone's encapsulation strategy. That is, a kind is a function that maps any world and eventuality where the kind is instantiated to that particular instance (type $\kappa^{n} := \mathbf{w}on$, for a nominal type n). For entities, this theory of kinds is similar to Chierchia 1998, but without maximality. There are many kinds of seals, durations, etc.

This has implications for comparison, which ranks habits or kinds on a scale. Adapting Kamp 1975 and Cresswell 1976, we model a scale as a chain of successively more restricted degrees. For example, to be long to a degree *k* is to instantiate that degree on a scale for length (e.g., ⟨≥ *1 min*, ≥ *2 min*, …⟩ in section 8). A degree is simply a ranked habit or kind on a scale. Typewise, a scale is a η- or κ-dependency, mapping each degree, except the top, to the next degree up the scale.

All of these general points will be illustrated with samples of a Kalaallisut text in sections 6 through 8. But first we must constrain the key basic meanings. So as a first application of LCC_7, we spell out a system of constraints on basic meanings in Kalaallisut, which will play a crucial role in topologically based incremental update.

4 Constraints on basic meanings in Kalaallisut

Basic meanings in Kalaallisut conform to a system of six constraints — (B1)–(B3) for roots and derivational morphemes, and (B4)–(B6) for inflectional morphemes.

By (B1), a noun root or noun-forming suffix contributes a predicate whose primary argument is (a) backgrounded and (b) of a n-type. That is, depending on the noun and its context, the primary argument may be a basic n-object (entity, time or place), a set of n-objects, an intensional concept of a n-object, a n-dependency, a n-kind, a n-scale for ranking kinds, or some other function with n-values.

(B1) The primary argument of (X\)N is backgrounded and is of n-*type*, where
i. e, α, β, τ, π are n-types,
ii. if n is an n-type, then so is nt, and an for all a.

Mutatis mutandis, (B2) is similar. The primary argument of a verb root or verb-forming suffix is (a) backgrounded and (b) of a v-type. That is, depending on the verb and its context, the primary argument may be a basic v-object (event or state), a set of v-objects, an intensional concept of a v-object, a v-dependency (e.g., a process), a v-habit, a v-scale for ranking habits, or some other function with v-values.

(B2) The primary argument of (X\)V is backgrounded and is of v-*type*, where
i. o, ε, σ, are v-types,
ii. if v is a v-type, then so is vt, and av for all a.

(B3) constrains secondary arguments of verbs, i.e., their nominal subjects and objects. By default, the subject is topical (e.g. $\text{WAKE.UP}_{\mathbf{d}\omega}\langle e, \mathbf{d}\alpha\rangle$), and any direct object, backgrounded (e.g. $\text{USE}_{\mathrm{d}\omega}\langle ee, \mathbf{d}\alpha, d\beta\rangle$). These defaults may be defeated by agreement, which in Kalaallisut explicitly contrasts topical third person vs. backgrounded third (glossed '-3sg$_{\top}$' vs. '-3sg$_{\perp}$').

(B3) The subject of (X\)V is topical and any direct object backgrounded, unless subject or object agreement defeats these defaults.

Turning now to the inflectional system, (B4) says that the verbal inflection locates the last — i.e., most prominent — eventuality of the stem in relation to the current topic time in every world of the current modal topic. Just what this relation is depends on the aspectual sort of the eventuality — e.g., the current topic time is included in a state, but it frames an event, and at least the first stage of a process.

(B4) V\V relates the last v-argument of the stem V to the temporal topic in every world of the modal topic in aspect-guided manner (e.g., $\mathbf{d}\tau \subseteq_{\mathbf{d}\omega} d\sigma$ for *states*, $d\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau$ for *events*, $d\varepsilon\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau$ or $\mathbf{beg}\ d\varepsilon\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau$ for *processes.*)

In addition, by (B5), the mood inflection of the main verb updates the modal topic (e.g., indicative mood typically reintroduces the modal topic, $[\mathbf{p}|\ \mathbf{p} = \mathbf{d}\omega]$). In contrast, dependent moods update the temporal topic. The details again depend on the aspectual sort of the most prominent eventuality of the stem. If this eventuality is a state, then the new topic time is its duration; for a process, it is part of the duration; and for an event, it is the duration of the result state, which I dub the *aftertime*.

(B5) *MAIN.mood*-V\V updates modal topic. *DEP.mood*-V\V updates temporal topic in aspect-guided manner (e.g., [**t**| **t** $=_{\mathbf{d}\omega}$ **tm** *d*σ] for *states*, [**t**| **t** $=_{\mathbf{d}\omega}$ **aft** *d*ε] for *events*, [**t**| **t** $\subseteq_{\mathbf{d}\omega}$ **tm** *d*εε] for *processes*.)

Finally, by (B6), an overt subject updates the n-topic while an overt direct object updates the top n-dref in the background, unless possessor agreement defeats these defaults. Oblique cases contribute characteristic relations (e.g. the contribution of the dative case on a place-denoting noun is 'includes the end of the path').

(B6) *SUB.case* updates the n-topic and *DIROBJ.case*, the backgrounded n-dref,unless possessor agrement defeats these defaults. Each *OBL.case* contributes a relation (e.g. *shore*-DAT ⇝ [| SHORE$_{\mathbf{d}\omega}$ **d**π]; [h^{ε}| **end**⟨**path** h^{ε}⟩ ⊆ **d**π]).

5 Topological input to incremental update

Supported by lexical constraints such as (B1)–(B6), the topology of Kalaallisut freely assigns anaphorically optimal topological orders to unordered syntactic dependency structures. In addition, Kalaallisut syntax freely licenses *pro*-drop. Prominent nominal referents are normally expressed only by pronominal agreement, unless recentering requires a full subject or object NP (recall (B6)).

In general, following Pollard and Sag 1987, I assume that syntax generates unordered dependency structures that are ordered by the topology. This assigns the head and each of the dependents to one of five *topological fields* (extrapolating from Abraham and de Meij 1986, Kathol 2000, etc), ordered left to right as follows:

(*T*1) *Linear order* (<)
initial field (*if*) < initial boundary (*ib*) < middle field (*mf*)
< final boundary (*fb*) < final field (*ff*)

The ordered topological tree is the input to anaphoric composition. This derives incremental updates by proceeding left to right, except for one field — *mf* in Kalaallisut, *ib* in English — designated to elaborate background drefs set up by the head (*T*2). This anaphoric dependence defeats the default left-to-right order of update, forcing the head to be interpreted first (*T*3). And since the designated update deferring field may be embedded within any complex phrase, incremental update must be based on the topological order, not the defeasible left-to-right default.

(*T*2) *Head-elaborating field*
mf_H: Kalaallisut, …
ib_H: English, …

(*T*3) *Topological order* ($\angle$)
unmarked left sister $\angle$ right sister $\angle$ head-elaborating left sister

This completes the development of a formal framework for anaphoric composition — i.e., topologically based incremental update. We now turn to the crucial evidence that favors order-sensitive anaphoric composition over order-independent Montagovian theories. Systematic support comes from Kalaallisut, where free word order together with massive *pro*-drop and polysynthesis provide a formidable challenge for surface-faithful incremental update. Nevertheless, a pilot study of an actual text — an Eskimo myth, entitled "The Kid Son of Aataarsuaq", narrated for 4th graders [2] — showed that topologically based incremental update is not only feasible but also revealing. What it reveals are systematic patterns of prominence-guided anaphora, in all semantic domains, that crucially depend on the topological order for the local context. In sections 6–8 I present samples of this ubiquitous order-sensitive anaphora, to increasingly more complex types of drefs.

6 Episodic passage: Anaphora to drefs of simple types

We begin with a sample of simple episodic discourse. In general, simple episodic discourse involves only simple types of drefs — the seven basic sorts (possibilities $\omega := \mathbf{w}t$, agentive entities α, non-agentive entities β, events ε, states σ, times τ, and places π) or else simple functions (mostly processes $\varepsilon\varepsilon$, or kinds $\kappa^n := \mathbf{w}o\mathsf{n}$). A paradigm example is the passage (8)–(9). In the local context of the aforementioned myth, "The Kid Son of Aataarsuaq", the modal topic ($\mathbf{d}\omega$) are the story worlds, the topic time ($\mathbf{d}\tau$) is during the boy's childhood, and the topical α-entity ($\mathbf{d}\alpha$) is the boy.

(8) *Ilaanni* *if*
part.of-$3pl_{\perp}$.sg-LOC
'One day (*lit.* one of them),

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[2] Sommer, David. 1972. Aataarsuup Irnikasia. *Kalaallisut Ilinniutit*, ed. by David Sommer, Erling Holm and Chr. Berthelsen, 27–32. Copenhagen: Ministry for Greenland. (The full text, with topologically based incremental updates, is posted at *http://www.rci.rutgers.edu/~mbittner*).

	anguta-a	*qajar-tur-lu-ni*	*ib*
	[father-$3sg_{\perp}$.sg	kayak-make.typical.use-ELA$_{\top}$-$3sg_{\top}$]	
	while his father was out in his kayak,		
	qasigissa-mik	*pi-sa-qar-pu-q*	mf_H V
	spotted.seal-sg.MOD	get-tv\rn-have-IND.IV-3sg	
	he caught a spotted seal.'		
(9)	*Tikik-ka-mi*		*if*
	come.back-FCT$_{\top}$-$3sg_{\top}$		
	'When he came back,		
	nuli-i	*uqar-vig-a-a*: "…"	*ib* V *ff*
	wife-$3sg_{\top}$.sg	say-iv\tv-IND.TV-3sg.3sg: "…"	
	he said to his wife: "…" '		

The topological fields indicated on the right of (8)–(9) induce updates that set up the following drefs for times, events, states and processes:

	input **dτ**	…|||||||||||t_0 ||||||||||||…	
(D_8)	*if*	|||t_1|||	(part of t_0)
	ib	••ee_1••	(man a_0 out in kayak)
		|||t_2|||	(during ee_1)
	mf_H V	•e_1	(a_0 gets sth, a seal b_1)
		—s_1———	(result state of e_1)
(D_9)	*if*	• e_2	(end of ee_1, a_0 returns)
		|||t_3|||	(aftertime of e_2)
	ib V *ff*	• e_3	(a_0 says p_3 to wmn a_1)

Recall from (B4) that the mood inflection in Kalaallisut locates the most prominent eventuality of the stem in relation to the current topic time in every world of the current modal topic. Just what this temporal relation is depends on the aspectual sort of the eventuality — event, state, or process — as stated in (B4) and illustrated in (8) and (9). In addition, the main verb mood updates the modal topic, whereas dependent verb moods update the temporal topic. The details of the new topic time also predictably vary with the aspectual sort. This variation is spelled out in (B5) and is also illustrated in (8) and (9). Suppose now that the input topic time is t_0 — the period of the boy's childhood discussed in the last sentence. Then, in intuitive terms, the passage (8)–(9) gives rise to the following incremental updates.

The *if* of (8) contains a temporal locative. This updates the input topic time t_0 to a subinterval, call it t_1. Next, in the *ib* of (8), we have a dependent clause. In keeping with (B6), the *ib*-subject updates the α-topic to the boy's father, the man Aataarsuaq.[3] Then the *ib*-verb, inflectionally marked as an elaboration of the α-topic (by this point, the man), introduces two temporal drefs. The stem introduces a process, call it ee_1, in which the current α-topic makes typical use of a kayak. That is, the man goes out in his kayak, hunts, and returns. The elaboration mood locates this process — throughout the modal topic, i.e., in every story world — within the current topic time, t_1, and updates the topic time to a subinterval, t_2, of the kayak use process. Next, the main verb adds two more eventuality drefs. The root adds an event, e_1, in which the current α-topic (still the man) gets something, and then the stative suffix '-have' adds the result state, s_1. The indicative mood locates the last mentioned eventuality (the result state s_1) in a wrap-around relation around the current topic time, t_2, in every world of the current modal topic. It also reintroduces this topic (still the story worlds) into the foreground. This is the local context for the final update in (8), with the head-elaborating middle field, mf_{H}. In Kalaallisut the left edge of mf_{H} is always a modalis NP, which shuns *ib* and *if*.[4] In (8) the head-elaborating modalis NP adds that the man's catch is a spotted seal.

Moving on to (9), *if* contains a dependent verb that is inflectionally marked as a fact about the current α-topic. Factive verbs in Kalaallisut typically refer to familiar eventualities, participating in similar bridging relations as definite NPs in English. Thus, in (9) the factive stem 'come.back-' introduces the final stage, e_2, of the currently prominent kayak use process, ee_1. This is analogous to the nominal part-whole bridging, from the indefinite *a house* to the definite *the roof*, in English (5). The factive mood locates this home coming event in the current topic time, t_2, in every world of the modal topic. It also updates the topic time to t_3, the aftertime of this home coming, i.e., the duration of the result state. This is as long as the man remains home on this occasion or perhaps only until he takes off his outdoors clothes and settles down for the evening. In *ib* of (9), again in keeping with (B6), the overt object updates the background stack, by depositing the woman on top.[5] Moving

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[3] The background possessor agreement (*-a* '$3sg_{\perp}$.sg') on 'father-' presupposes that the boy is the top α in the background ($d\alpha$). This should hold in the input state, or at the latest in the output. In the input to (8) the boy is the α-topic ($\mathbf{d}\alpha$), so the requirement must be met by the output. It is, after a recentering update demotes the boy and promotes his father (second line in (8′a), *pace* (B6)). Example (12) below is another instance of agreement-guided topic+background recentering.

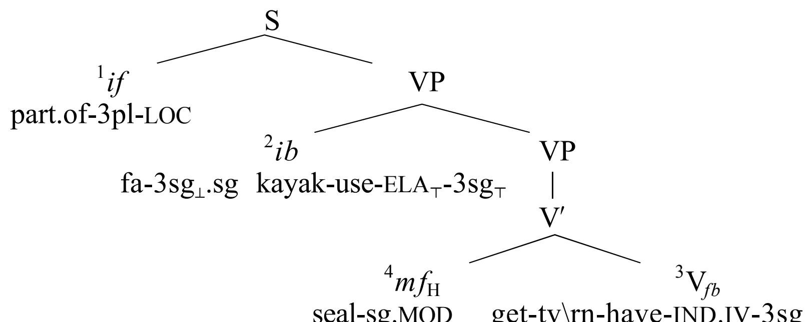
[4] Topological fields can be multiply instantiated or not instantiated at all.

[5] This time the topical possessor agreement (*-i* '$3sg_{\top}$.sg') on 'wife-' requires that the man be the α-topic ($\mathbf{d}\alpha$) — ideally already in the input, at the latest in the output. In (9) this requirement is met is the input, so the recentering update only adds the woman to the background (third line in (9′a)), *pace* (B6). Example (11) below is another instance of agreement-guided background update.

on to the main verb, the stem adds a speech event e_3 and an accessibility relation q_1 such that in every world w of the modal topic (i.e., in every story world) the current α-topic (the man) says q_1w to the background α-dref (the woman). The indicative mood locates the speech event e_3 within the current topic time, t_3, in every story world (current modal topic). It also reintroduces the story worlds as the modal topic. Finally, in *ff* the direct quote adds further conditions on the accessibility relation q_1, specifying the content of what was said in e_3.

More formally, anaphoric composition applies to the topological trees (T_8) and (T_9) and derives the updates in (8′) and (9′) (ignoring presuppositions). For both sentences the incremental updates are spelled out in (a), which reduce to the overall update in (b) (by the definitions in Bittner 2001b and the Appendix below).

(T_8)



(8′) a. $^1([T_{\tau t}|\ T = \{t\text{: } t \subseteq \mathbf{d}\tau\}];\ [\mathbf{t}_\tau|\ \mathbf{t} \in d(\tau t)]);$

$^2((([\ |\ d\alpha =_{\mathbf{d}\omega} \text{FA } \mathbf{d}\alpha];\ [\mathbf{a}_\alpha\ a_\alpha|\ \mathbf{a} = d\alpha,\ a = \mathbf{d}\alpha]);$

$([k_\kappa|\ \text{KAYAK } k];\ [ee_{\varepsilon\varepsilon}|\ \text{MAKE.TYPICAL.USE}_{\mathbf{d}\omega}\langle ee,\ \mathbf{d}\alpha,\ d\kappa\rangle];$

$[\mathbf{t}_\tau'|\ d\varepsilon\varepsilon \subseteq_{\mathrm{d}\omega} \mathbf{d}\tau,\ \mathbf{t}' \subseteq_{\mathbf{d}\omega} \mathbf{tm}\ d\varepsilon\varepsilon]));$

$^3([e_\varepsilon|\ \text{GET}_{\mathbf{d}\omega}\langle e,\ \mathbf{d}\alpha,\ \mathbf{th}\ e\rangle];\ [b_\beta|\ b =_{\mathbf{d}\omega} \mathbf{th}\ d\varepsilon];\ [s_\sigma|\ s =_{\mathbf{d}\omega} \mathbf{rs}\ d\varepsilon];$

$[\mathbf{p}_\omega|\ \mathbf{d}\tau \subseteq_{\mathbf{d}\omega} d\sigma,\ \mathbf{p} = \mathbf{d}\omega]);$

$^4([k_\kappa'|\ \text{SEAL } k_\kappa'];\ [\ |\ d\beta =_{\mathbf{d}\omega} d\kappa\langle d\varepsilon\rangle])$

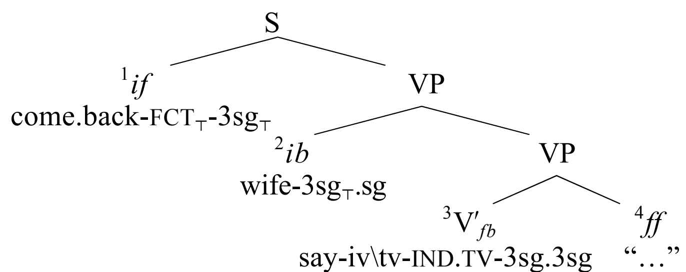
b. $[\mathbf{p}_\omega\ \mathbf{t}_\tau'\ \mathbf{a}_\alpha\ \mathbf{t}_\tau\ k_\kappa'\ s_\sigma\ b_\beta\ e_\varepsilon\ ee_{\varepsilon\varepsilon}\ k_\kappa\ a_\alpha\ T_{\tau t}|$

$\mathbf{p} = \mathbf{d}\omega,\ \mathbf{t}' \subseteq_{\mathbf{p}} (\mathbf{tm}\ ee \cap \mathbf{tm}\ s) \subseteq_{\mathbf{p}} \mathbf{t} \subseteq \mathbf{d}\tau,\ \mathbf{a} =_{\mathbf{p}} \text{FA }\ a,\ a = \mathbf{d}\alpha,$

$T_{\tau t} = \{t\text{: } t \subseteq \mathbf{d}\tau\},\ \text{KAYAK } k,\ \text{MAKE.TYPICAL.USE}_{\mathbf{p}}\langle ee,\ \mathbf{a},\ k\rangle,$

$\text{GET}_{\mathbf{p}}\langle e,\ \mathbf{a},\ b\rangle,\ s =_{\mathbf{p}} \mathbf{rs}\ e,\ b =_{\mathbf{p}} k'\langle e\rangle,\ \text{SEAL } k']$

(T_9)



(9′) a. $^{1}([e_\tau |\ e = \mathbf{end}\ d\varepsilon\varepsilon,\ \text{COME.TO}_{\mathbf{d}\omega}\langle e,\ \mathbf{d}\alpha,\ \mathbf{loc}\langle \mathbf{beg}\ d\varepsilon\varepsilon\rangle\rangle];$
$[\mathbf{t}_\tau |\ d\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau,\ \mathbf{t} =_{\mathbf{d}\omega} \mathbf{aft}\ d\varepsilon]);$
$^{2}([\ |\ d\alpha_2 =_{\mathbf{d}\omega} \text{WF}\ \mathbf{d}\alpha];\ [a_\alpha |\ a = d\alpha_2]);$
$^{3}([e_\varepsilon{}'\ q_\Omega |\ \text{SAY}_{\mathbf{d}\omega}\langle e',\ \mathbf{d}\alpha,\ q\rangle];\ [\ |\ \mathbf{dat}\ d\varepsilon =_{\mathbf{d}\omega} d\alpha];$
$[\mathbf{p}_\omega |\ d\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau,\ \mathbf{p} = \mathbf{d}\omega]);$
$^{4}(\ldots)$

b. $[\mathbf{p}_\omega\ \mathbf{t}_\tau\ e_\varepsilon{}'\ q_\Omega\ a_\alpha\ e_\varepsilon |$
$\mathbf{p} = \mathbf{d}\omega,\ e' \subseteq_{\mathbf{p}} \mathbf{t} =_{\mathbf{p}} \mathbf{aft}\ e,\ e \subseteq_{\mathbf{p}} \mathbf{d}\tau,$
$e = \mathbf{end}\ d\varepsilon\varepsilon,\ \text{COME.TO}_{\mathbf{p}}\langle e,\ \mathbf{d}\alpha, \mathbf{loc}\langle \mathbf{beg}\ d\varepsilon\varepsilon\rangle\rangle,$
$\text{SAY}_{\mathbf{p}}\langle e',\ \mathbf{d}\alpha,\ q\rangle,\ a =_{\mathbf{p}} (\text{WF}\ \mathbf{d}\alpha) =_{\mathbf{p}} (\mathbf{dat}\ e')];\ ^{4}(\ldots)$

The incremental updates in (8′a) and (9′a) give some sense of the ubiquity of prominence-guided anaphora. Each update involves at least one anaphoric link to a dref of some type. Note that each word-to-word link favors order-sensitive incremental update over order-independent Montagovian update. So anaphoric composition is favored as soon as we interpret simple episodic texts like (8)–(9). But prominence-guided anaphora — and hence sensitivity to order — is by no means limited to drefs of simple types. We now show that it is just as ubiquitous for drefs of higher types, predictably evoked by certain other expressions.

7 Habitual passage: Anaphora to habits and τ-domain concepts

Our story is about a man with many enemies who, before they got him, trained his boy to be a mighty diver, so that he would avenge him. Here is how it all began:

(*) 'As soon as his son was born, the father *took*^{e1} him out and *ran*^{e2} with him down **to**^{l1} the shore. There he *dipped*^{e3} his head in a hole in the ice for a long time. Then he *carried*^{e4} him back up *home*^{l2}, on the run.'

The passage (*) introduces a chain of events diagrammed in (D_*). They include e_1, where the man takes the boy outside; e_2, where he runs with him to the shore, l_1; and e_3, where he dips his head in a hole in the ice. Also, the topic time is updated to t_1, the aftertime of e_1. This is as long as the man stays outside with the baby. The current α-topic is the man, while the baby boy is the top background α.

(D*) • • • e_1: man a_0 takes boy a_2 out.
$e_1 \ldots e_3$ e_2: a_0 runs with a_2 to l_1-shore.
e_3: a_0 dips a_2's head in the sea for a long time
|||||| t_1 = **aft** e_1 (i.e., as long as man stays outside)

(D*) is the local context for the next sentence:

(10) *Taama=iliur-tuar-pa-a.*
thus=act.on-keep.on -IND.TV-3sg.3sg
'He kept on doing this to him.'

This sentence has minimal topology (T_{10}),

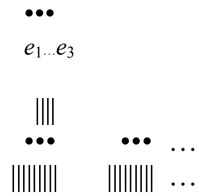
(T_{10}) S
|
[a]thus=[b]act.on-[c]keep.on-[d]IND.TV-**3SG**.3SG

which gives rise to the incremental updates spelled out in (10′):

(10′) $^a[h^{\varepsilon\varepsilon}|\ \mathbf{mnr}\ h^{\varepsilon\varepsilon} = \mathbf{mnr}\ \langle d\varepsilon_3, d\varepsilon_2, d\varepsilon_1\rangle]$;
$^b[\ |\ \text{ACT.ON}\langle d\eta^{\varepsilon\varepsilon}, \mathbf{d}\alpha, d\alpha\rangle]$;
$^c[\underline{T}|\ \mathbf{beg}\ d\eta^{\varepsilon\varepsilon} \subseteq \mathbf{beg}\ \underline{T}, \underline{T} \subseteq d\eta^{\varepsilon\varepsilon}]$;
$^d[\mathbf{p}|\ \mathbf{d}\tau \subseteq_{\mathbf{d}\omega} d\eta^{\varepsilon\varepsilon}, \mathbf{p} = \mathbf{d}\omega]$

That is, the demonstrative clitic 'thus' retrieves the aforementioned chain of events $\langle e_1, e_2, e_3\rangle$. Also, to satisfy the presupposition of the upcoming continuative suffix '-keep.on', it introduces a habit, say h_1, instantiated by such event chains. The verbal root 'act.on-' confirms that any instance of h_1 is a chain of actions by the man on the boy. Let's call h_1 a training habit. The continuative suffix then sets up a background temporal domain concept, $\underline{T}_1$, such that (a) the first h_1-training session falls within the first $\underline{T}_1$-time, and (b) every $\underline{T}_1$-time includes an h_1-training session. The temporal structure is thus extended to (D_{10}). Finally, the indicative mood locates the period of h_1-training around the current topic time, t_1, in every story world — for (B4), habits are stative — and reintroduces the story worlds as the modal topic.

(D_{10})



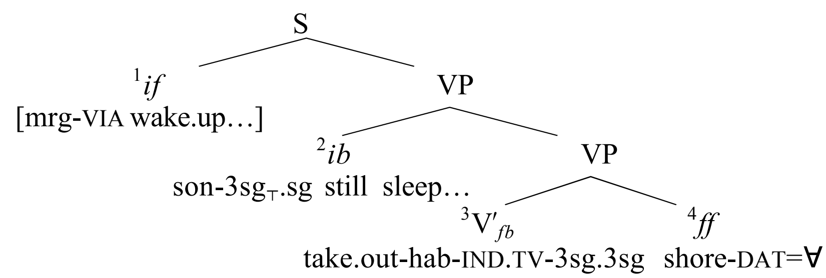
e_1: man a_0 takes boy a_2 out
e_2: a_0 runs with a_2 to l_1-shore
e_3: a_0 dips a_2's head in the sea for a long time
t_1 = **aft** e_1 (i.e., as long as man stays outside)
h_1: a_0 trains a_2 in the manner of $\langle e_1, e_2, e_3\rangle$
$\underline{T}_1$: 1st h_1-session included in 1st $\underline{T}_2$-time, every $\underline{T}_1$-time includes an h_1-session

(D_{10}) is the local context for the next sentence, (11):

(11) *Ullaa-kkut* *itir-lu-ni=lu*
[morning-sg.VIA wake.up-ELA$_{\top}$-3sg$_{\top}$=and]$_{if}$
'Every morning when he woke up,
irn-i *suli* *sinit-tu-q*
[son-3sg$_{\top}$.sg still sleep-ELA$_{\perp}$.IV-3sg$_{\perp}$]$_{ib}$
while his son was still asleep,
annit-tar-pa-a *sissa-mu=innaq.*
[take.out-habit-IND.TV-3sg.3sg]$_V$ [shore-sg.DAT=∀]$_{ff}$
he would take him out, always to the shore. '

This sentence has the same basic topology as (9),

(T_{11})



and hence the same basic order of incremental update:

(11′) $^1(([tt|\ tt =_{d\theta} \text{MORNING.OF}]; [\underline{\mathbf{T}}|\ \underline{\mathbf{T}} = d\tau\tau\langle d\theta\rangle]);$
$([h^{\varepsilon}|\ \text{WAKE.UP}\langle h^{\varepsilon}, \mathbf{d}\alpha\rangle]; [\underline{\mathbf{T}}|\ \mathbf{d}\theta \subseteq_{\mathbf{d}\omega} d\eta^{\varepsilon}, \underline{\mathbf{T}} = \mathbf{aft}\ \langle d\eta^{\varepsilon}|\mathbf{d}\theta\rangle]);$
$^2(([\ |\ \text{SON.OF}_{\mathbf{d}\omega}\langle d\alpha, \mathbf{d}\alpha\rangle]; [a|\ a = d\alpha]); [\underline{\mathbf{T}}|\ \underline{\mathbf{T}} \bullet\!\subseteq \mathbf{d}\theta];$
$([h^{\sigma}|\ \text{SLEEP}\langle h^{\sigma}, d\alpha\rangle]; [\underline{\mathbf{T}}|\ \mathbf{d}\theta \subseteq_{\mathbf{d}\omega} d\eta^{\sigma}, \underline{\mathbf{T}} = \mathbf{tm}\ \langle d\eta^{\sigma}|\mathbf{d}\theta\rangle]);$
$^3([h^{\varepsilon}|\ \text{TAKE.OUT}\langle h^{\varepsilon}, \mathbf{d}\alpha, d\alpha\rangle]; [\mathbf{p}|\ \mathbf{d}\theta \subseteq_{\mathbf{d}\omega} d\eta^{\varepsilon}, \mathbf{p} = \mathbf{d}\omega]);$
$^4([\ |\ \text{SHORE}_{\mathbf{d}\omega}\ \mathbf{d}\pi]; [\ |\ \mathbf{end}\langle\mathbf{path}\ d\eta^{\varepsilon}\rangle \subseteq_{\mathbf{d}\omega} \mathbf{d}\pi]; [\ |\ d\eta^{\varepsilon} \subseteq_{\mathbf{d}\omega} \mathbf{d}\theta])$

The details, of course, are different, as diagrammed in (D_{11}). First, in *if* of (11), the temporal oblique introduces the mornings of $\underline{T}_1$-times as the new temporal topic, $\underline{T}_2$. The topic elaborating *if*-verb then adds a habit, h_2, instantiated by the man waking up on $\underline{T}_2$-mornings. It also updates the topical temporal domain concept to the aftertimes of h_2-awakenings. The aftertime concept, $\underline{T}_3$, is then further refined in *ib*. Here the temporal particle 'still' first updates it to $\underline{T}_4$ — initial subintervals of $\underline{T}_3$-times. The background elaborating *ib*-verb then adds a habit, h_3, instantiated by the boy still sleeping at $\underline{T}_4$-times — i.e., on $\underline{T}_2$-mornings during the initial $\underline{T}_4$-period after the man's h_2-awakening.[6] It also, in effect, reintroduces $\underline{T}_4$ as the topical temporal domain concept. Next, the main verb adds a yet another habit, h_4, instantiated by the man taking the boy outside. The indicative mood locates this habit so that in every story world every $\underline{T}_4$-time (current temporal topic) includes an h_4-taking out event. As usual, the story worlds are reintroduced as the modal topic. Finally, in *ff*, the universally quantified dative adds that every h_4-taking out event terminates on the topical l_1-shore, at every $\underline{T}_4$-time in every story world.

(D_{11})
••• e_1: man a_0 takes boy a_2 out
$e_1 ... e_3$ e_2: a_0 runs with a_2 to l_1-shore
e_3: a_0 dips a_2's head in the sea for a long time
|||| t_1 = **aft** e_1 (i.e., as long as man stays outside)
••• ••• … h_1: a_0 trains a_2 in the manner of $\langle e_1, e_2, e_3 \rangle$
|||||||| |||||||| … $\underline{T}_1$: 1st h_1-session included in 1st $\underline{T}_2$-time,
every $\underline{T}_1$-time includes an h_1-session
||||| ||||| … $\underline{T}_2$: mornings of $\underline{T}_1$-times
• • … h_2: man a_0 wakes up on $\underline{T}_2$-morning
|||| ||| … $\underline{T}_3$: aftertimes of h_2-awakenings on $\underline{T}_2$-mornings
|| || … $\underline{T}_4$: initial subintervals of $\underline{T}_3$-aftertimes
—— —— … h_3: boy a_2 still asleep at $\underline{T}_4$-initial subintervals
• • … h_4: a_0 takes a_2 out to l_1-shore at $\underline{T}_4$-times

(D_{11}) is the local context for the next sentence, which concerns the result of a long period of h_1-training. It also illustrates prominence-guided anaphora to yet more abstract types of drefs, predictably evoked by scalar comparison and ellipsis.

8 Comparison and ellipsis: Scales and other dependencies

After (11), the next sentence is (12):

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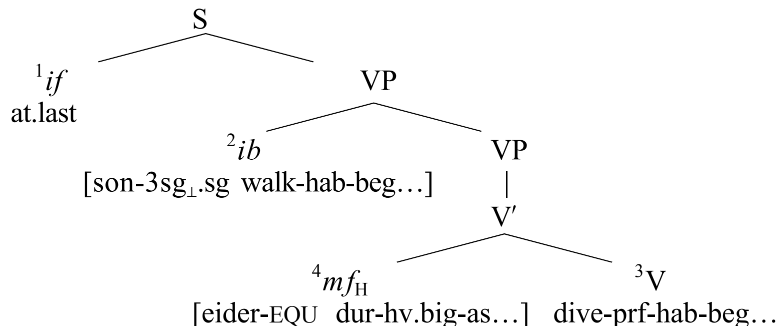
[6] In (11) the topical possessor agreement (*-i* '**3**sg$_{\top}$.sg') on the *ib*-subject 'son-' defeats the default of (B6), that an overt subject updates the α-topic. The current α-topic (the man) satisfies the presupposition of the topical possessor agreement, so the referent of this *ib*-subject (the boy) is added to the background, not the foreground (third line of (11′)), *pace* the exception clause of (B6).

(12) *Kiisa*
[at.last]$_{if}$
'In the end,
irnir-a *pisut-ta-lir-a-mi*
[son-3sg$_{\perp}$.sg walk-habit-begin-FCT$_{\top}$-3sg$_{\top}$]$_{ib}$
when his son began to walk,
mitir-tut *sivi-su-tigi-su-mik*
[eider-sg.EQU duration-have.big-as…as-iv\cn-sg.MOD]$_{mf}$
aqqa-ama-sa-lir-pu-q.
dive-prf-habit-begin-IND.IV-3sg
he began to dive and stay under water as long as an eider.'

This sentence has the same basic topology as (8), and hence the same basic order of incremental update, explicated in (12′).

(T_{12})



(12′)

$$^{1}([\mathbf{t}|\ \mathbf{t} \subseteq_{\mathbf{d}\omega} \cup\mathbf{d}\theta,\ \mathbf{beg}\ \mathbf{d}\theta <<_{\mathbf{d}\omega} \mathbf{t}];$$
$$^{2}(([\ |\ \mathrm{SON}_{\mathbf{d}\omega}\langle d\alpha, \mathbf{d}\alpha\rangle];\ [\mathbf{a}\ a|\ \mathbf{a} = d\alpha,\ a = \mathbf{d}\alpha]);$$
$$([h^{\varepsilon}|\ \mathrm{WALK}\langle h^{\varepsilon}, \mathbf{d}\alpha\rangle];\ [e|\ e =_{\mathbf{d}\omega} \mathbf{beg}\ d\eta^{\varepsilon}];$$
$$[\mathbf{t}|\ d\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau,\ \mathbf{t} =_{\mathbf{d}\omega} \mathbf{aft}\ d\varepsilon]));$$
$$^{3}([f_{\alpha\eta}|\ \mathrm{DIVE}\langle f_{\alpha\eta}, \alpha\rangle];\ [f_{\alpha\eta}|\ f_{\alpha\eta} = \mathbf{rs}\ d\alpha\eta^{\varepsilon}];\ [e|\ e =_{\mathbf{d}\omega} \mathbf{beg}\ d\alpha\eta^{\sigma}\langle\mathbf{d}\alpha\rangle];$$
$$[\mathbf{p}|\ d\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau,\ \mathbf{p} = \mathbf{d}\omega]);$$
$$^{4}((([k^{\alpha}|\ \mathrm{EIDER}\ k^{\alpha}];\ [kk^{\tau}\ |\ d\alpha\eta^{\sigma}\langle d\kappa^{\alpha}\rangle \sim_{kk} d\alpha\eta^{\sigma}(\mathbf{d}\alpha)]);$$
$$([f_{\sigma\tau}]\ f_{\sigma\tau} =_{\mathbf{d}\kappa\kappa} \mathbf{tm},\ \mathbf{scale}(\mathbf{d}\kappa\kappa^{\tau}, |f_{\sigma\tau}|)];$$
$$[h^{\sigma}|\ h^{\sigma} = d\alpha\eta^{\sigma}\langle d\kappa^{\alpha}\rangle,\ \ d\sigma\tau\langle h^{\sigma}\rangle \subseteq \mathbf{end}\ \mathbf{d}\kappa\kappa^{\tau}];$$
$$[h^{\sigma}|\ h^{\sigma} = d\alpha\eta^{\sigma}(\mathbf{d}\alpha),\ d\sigma\tau\langle h^{\sigma}\rangle \sim_{d\kappa\kappa} d\sigma\tau\langle d\eta^{\sigma}\rangle];$$
$$[k^{\tau}|\ k^{\tau} = d\sigma\tau\langle d\eta^{\sigma}\rangle];\ [\ |\ d\kappa^{\tau} = ((\mathbf{end}\ \mathbf{d}\kappa\kappa^{\tau})|d\eta^{\sigma})]))$$

To begin with, in *if* of (12), the temporal particle 'at last' signals the shift back to episodic discourse. Specifically, it introduces a new topic time — a late subinterval of the period covered by the $\underline{T}_4$-training times. So the new topic time, call it t_2, is after a long period of h_1-training. Next, in *ib* we have a topic-oriented factive clause. Guided by the possessor agreement ((B6) and ftn. 3), the *ib*-subject demotes the old

α-topic (the man) and sets up the boy as the new α-topic. The topic-oriented factive *ib*-verb then adds three drefs. First, the root adds a habit, h_5, instantiated by events in which the baby boy walks. This satisfies the presupposition of the habitual suffix, which comes next. The inceptive suffix then adds the boy's first h_5-walk, e_5. Finally, the factive mood locates this first walk in the current topic time, t_2, and updates the topic time to the aftertime, t_3 — i.e., the boy has just become a toddler.

The next batch of drefs comes from the main verb. The root 'dive' must satisfy both the presupposition of the following habitual suffix and of the upcoming ellipsis in mf_{H}. To do that, it introduces a habit-valued function, $f_{\alpha\eta,\,1}$, from α-entities to their diving habits. The resultative suffix then sets up the related result state function $f_{\alpha\eta,\,2}$, from α-entities to habits instantiated by the results of their $f_{\alpha\eta,\,1}$-dives. This will derive the apparent copying by ellipsis, as anaphora to a dependency dref.[7] Next, the inceptive suffix adds the start, e_6, of the first $f_{\alpha\eta,\,2}$-diving result of the boy — i.e., e_6 is the start of the result state of the boy's first $f_{\alpha\eta,\,1}$-dive. The indicative mood locates this start, e_6, in the current topic time, t_3 (the boy has just become a toddler), in every story world, with concomitant reintroduction of the story worlds as the modal topic.

(D_{12})	… |||	t_2: late subinterval of $\cup \underline{T}_4$
	• • • …	$h^{\varepsilon}{}_5$: boy a_2 walks
	•	e_5: 1st h_5-walk
	|||	t_3: aftertime of e_5 (a_2 has bcm a toddler)
		$f_{\alpha\eta,\,1}$: $a \rightarrow a$'s diving habit
		$f_{\alpha\eta,\,2}$: $a \rightarrow$ result states of $f_{\alpha\eta,\,1}(a)$-dives
	•	e_6: 1st $f_{\alpha\eta,\,2}(a_2)$ (= result state of a_2's 1st $f_{\alpha\eta,\,1}$-dive) begins
		$k^{\alpha}{}_1$: eider
		$kk^{\tau}{}_1$: τ-scale, tm $f_{\alpha\eta,\,2}\langle k_1\rangle \sim$ tm $f_{\alpha\eta,\,2}(a_2) \sim$ top $kk^{\tau}{}_1$
		$h^{\sigma}{}_6 = f_{\alpha\eta,\,2}\langle k^{\alpha}{}_1\rangle$
	—— —— …	$h^{\sigma}{}_7 = f_{\alpha\eta,\,2}(a_2)$
	|||||| |||||| …	$k^{\tau}{}_2$ = time $f_{\alpha\eta,\,2}(a_2)$

This is the local context for the head-elaborating update with mf_{H}. In (12) mf_{H} contains a complex modalis NP, consisting of a dependent noun in the equalis case and a modalis-marked head noun. The update proceeds left to right, since there is no embedded mf_{H} (no embedded modalis NP).

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[7] This analysis of ellipsis as anaphora is inspired by, but ontologically more conservative than, Stone and Hardt 1999.

The initial dependent noun introduces a kind, k_1, instantiated by eiders. Even though the boy is mythical, k_1-eiders, which provide a diving standard, need not be. More likely, k_1-eiders are real, as well as adult and healthy. In addition, the equalis case (first half of 'as…as') sets up a temporal scale, kk_1, which ranks $f_{\alpha\eta,\,2}$-diving result times of k_1-eiders on a par with $f_{\alpha\eta,\,2}$-diving result times of the boy. This derives the apparent copying by ellipsis as repeated reference to a dependency dref.

Last but not least we come to the modalis noun, the head of mf_{H}. Here, the nominal root 'duration-' introduces a function from states to run times and says that the aforementioned temporal scale kk_1 ranks kinds of run times by their duration. Next, the suffix '-have big' adds a habit, $h^{\sigma}{}_6$, instantiated by $f_{\alpha\eta,\,2}$-diving results of k_1-eiders and says that these diving results have big run times, at the top of this duration scale. For instance, suppose that the duration scale kk_1 ranks the following kinds of run times: $\langle \geq$ *1 min*, …, $\geq$ *5 min*$\rangle$. Then, for top kk_1-rank, the run times of diving k_1-eiders would have to be at least 5 minutes long. Next comes the suffix of comparative similarity (second half of 'as…as'). This adds a habit, $h^{\sigma}{}_7$, instantiated by the boy's $f_{\alpha\eta,\,2}$-diving results, and says that their run times rank just as high. The nominalizing suffix '-IV\CN' adds a temporal dref, $k^{\tau}{}_2$, for this kind of run time. Finally, the modalis case identifies this kind of run time as the top kk_1-degree of duration restricted to the boy's $h^{\sigma}{}_7$-diving results. (Two sentences later, after more h_1-training, the boy's new diving results far surpass the $k^{\tau}{}_2$-duration.)

The incremental updates exemplified in the last three sections illustrate the ubiquity of prominence-guided anaphora. Word by word, there are usually several anaphoric links to topical and backgrounded drefs of various types. Ubiquitous word-to-word anaphora provides compelling evidence for anaphoric composition based on the topological order — the first half of hypothesis ($\mathbf{W}_A$). We now turn to the second half, which concerns the dichotomy between free and rigid word order.

9 Universal context-setting role of word order

As stated in section 5, I assume crosslinguistic agreement on three basic points. The input to anaphoric composition are tree representations of five topological fields ordered as in (*T*1). Based on this input, anaphoric composition derives incremental updates, by proceeding left to right except for a designated topological field — mf_{H} in Kalaallisut, ib_{H} in English (*T*2). This field is designated to elaborate background drefs set up by the head — an anaphoric dependence which forces the head to be interpreted first, defeating the left-to-right default (*T*3).

(*T*1) *Linear order* (<)
initial field (*if*) < initial boundary (*ib*) < middle field (*mf*)
< final boundary (*fb*) < final field (*ff*)

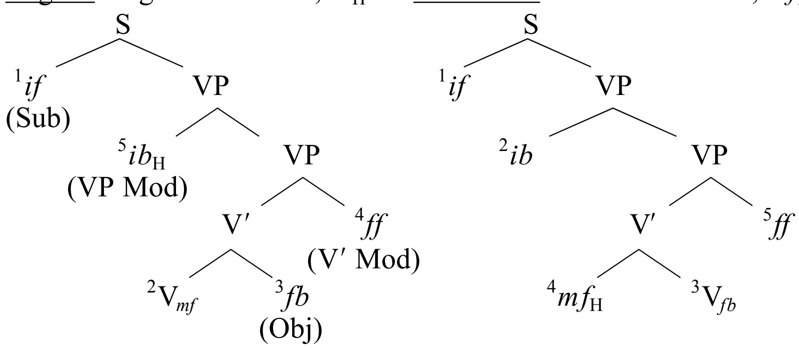
($T2$) *Head-elaborating field*
mf_H: Kalaallisut, …
ib_H: English, …

($T3$) *Topological order* (∠)
unmarked left sister ∠ right sister ∠ head-elaborating left sister

Both Kalaallisut and English designate the field immediately before the head for the head-elaborating, update-deferring, function. If this generalization turns out to hold also in other languages, then the stipulation ($T2$) may be dispensed with.

Be it as it may, crosslinguistic uniformity stops at the mapping from syntax to topology. In rigid word order languages, represented by English, grammatical functions are mapped to fixed topological fields.[8] In contrast, free word order languages, such as Kalaallisut, freely map any grammatical function to any topological field. The consequences for the relation between grammatical functions and topologically-based incremental update are schematically shown in ($T4$):

($T4$) English: Rigid word order, ib_H Kalaallisut: Free word order, mf_H



For example, consider the English sentence (14):

(14) He quickly bought a house for Ole.

The input to anaphoric composition is the topological tree (T_{14}). This looks just like a syntactic tree, modulo topological field labels.

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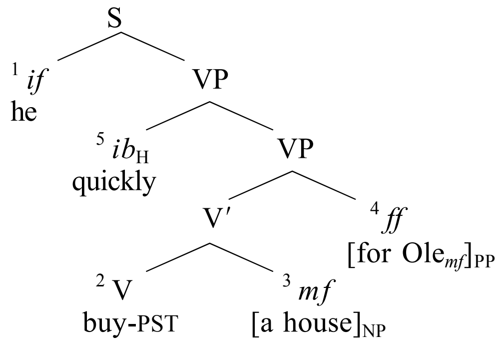
[8] More precisely, since topological fields may be multiply instantiated, the indicated GFs occupy designated edges (left or right). For example, the subject occupies the right edge of *if* in sentences such as [[a][*when John returned*], [b][*he*]]$_{if}$ *quickly*$_{ib}$ *bought*$_{mf}$ [*a house*]$_{fb}$ [*for Ole*]$_{ff}$. In a multiply instantiated field the update must proceed left to right. Since a topological *n*-tuple has no syntactic head, it cannot contain any embedded head-elaborating field to defeat the left-to-right default.

(T_{14})



The immediate output of incremental update is given in (14′a) (including the presuppositions of *he* and *PST*), which reduces to the overall update in (14′b).

(14′) a. $^{1}[\,|\ \text{3SG}\ \mathbf{d}\alpha];$
$([b|\ ];\ ^{2}([e|\ \text{BUY}_{\mathbf{d}\omega}\langle e, \mathbf{d}\alpha, d\beta\rangle];\ [\ |\ \text{PST}\ \mathbf{d}\tau];\ [\mathbf{t}|\ d\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{t}, \mathbf{t} = \mathbf{d}\tau]);$
$^{3}([k|\ ];\ [\ |\ d\beta =_{\mathbf{d}\omega} d\kappa\langle d\varepsilon\rangle];\ [\ |\ \text{HOUSE}\ d\kappa]));$
$^{4}([a|\ ];\ [\ |\ \text{FOR}_{\mathbf{d}\omega}\langle d\varepsilon, d\alpha\rangle];\ [\ |\ d\alpha = ole]);$
$^{5}[\ |\ \text{QUICK}_{\mathbf{d}\omega}\ d\varepsilon]$

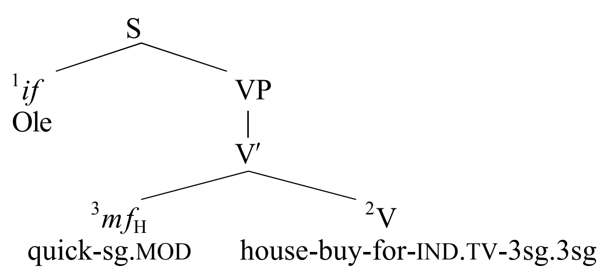
b. $[|\ \text{3SG}\ \mathbf{d}\alpha];\ [\ |\ \text{PST}\ \mathbf{d}\tau];$
$[\mathbf{t}\ a\ k\ e\ b|\ \ \mathbf{t} = \mathbf{d}\tau,\ e \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau,\ \text{BUY}_{\mathbf{d}\omega}\langle e, \mathbf{d}\alpha, b\rangle,\ b =_{\mathbf{d}\omega} k\langle e\rangle,\ \text{HOUSE}\ k,$
$\text{FOR}_{\mathbf{d}\omega}\langle e, a\rangle,\ a = ole,\ \text{QUICK}_{\mathbf{d}\omega}\ e]$

In Kalaallisut, essentially the same meaning is expressed by (15):

(15) *Ole sukkasuu-mik illu-si-up-pa-a*
Ole quick-sg.MOD house-buy-for-IND.TV-3sg.3sg
'He quickly built a house for Ole.'

The topological tree that serves as the input to anaphoric composition looks quite different, as depicted in (T_{15}).

(T_{15})



Therefore, there are corresponding changes in the incremental updates, spelled out in (15′a) (including presuppositions). But at the end of the day, the overall update for Kalaallisut is virtually the same as for English (compare (15′b) to (14′b)).

(15′) a. $^{1}[a|\ a = ole]$;
$^{2}(([k|\ ];\ [\ |\ {*}\mathrm{HOUSE}\ d\kappa];\ [e|\ \mathrm{BUY}_{\mathbf{d}\omega}\langle e,\ \mathbf{d}\alpha,\ d\kappa\langle e\rangle\rangle]);$
$[\ |\ \mathrm{FOR}_{\mathbf{d}\omega}\langle d\varepsilon,\ d\alpha\rangle];\ [\ |\ \mathrm{REAL}\ \mathbf{d}\omega];\ [\mathbf{p}_{\omega}|\ d\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau,\ \mathbf{p} = \mathbf{d}\omega];$
$[|\ 3\mathrm{SG}\ \mathbf{d}\alpha,\ 3\mathrm{SG}\ d\alpha]);$
$^{3}[\ |\ \mathrm{QUICK}_{\mathbf{d}\omega}\ d\varepsilon]$

b. $[\ |\ 3\mathrm{SG}\ \mathbf{d}\alpha];\ [\ |\ \mathrm{REAL}\ \mathbf{d}\omega];$
$[\mathbf{p}\ k\ e\ a|\ \mathbf{p} = \mathbf{d}\omega,\ e \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau,\ \mathrm{BUY}_{\mathbf{d}\omega}\langle e,\ \mathbf{d}\alpha,\ k\langle e\rangle\rangle,\ {*}\mathrm{HOUSE}\ k,$
$\mathrm{FOR}_{\mathbf{d}\omega}\langle e,\ a\rangle,\ a = ole,\ 3\mathrm{SG}\ a,\ \mathrm{QUICK}_{\mathbf{d}\omega}\ e]$

This captures the intuitive equivalence, since the truth conditions are similar. There is an event in which the current α-topic buys an instance of a house-valued kind for the benefit of Ole, the new background α In English the number inflection on the object NP restricts the number of houses per instance to one, whereas in Kalaallisut the uninflected incorporated noun leaves the number open. In both languages the house-buying event is located within the current topic time in every world of the current modal topic. Depending on the verbal inflection — tense in English, mood in Kalaallisut — it is either explicitly presupposed or reasonably inferred that we are talking about the currently topical past of the topical reality.

10 Conclusion

Based on Kalaallisut and English, two typologically distant languages, I have argued for a two-part hypothesis. Universally, anaphoric composition derives incremental updates based on the topological order — left-to-right, except for a designated head-elaborating field. Crucially, the input cannot be an unordered syntactic hierachy. Rigid vs. free word order is simply rigid vs. free mapping from syntax to topology.

This unorthodox view receives systematic support from an actual text in Kalaallisut, a language with supposedly free word order. To explicate this point, I presented *Seven-sorted Logic of Change with Centering* (LCC_7) and used it to spell out incremental updates, for increasingly more complex sample passages, by proceeding left to right except for mf_{H}, whose head-elaborating function forces the head to be interpreted first. This exercise reveals that any attempt to 'unscramble' the words of a Kalaallisut sentence would lose crucial anaphoric information — just like scrambling the sentences of a text. For text-level anaphora this, of course, is a truism. But within each Kalaallisut sentence there is ubiquitous word-to-word anaphora, which likewise depends on the surface word order for the local context.

More generally, anaphoric composition presupposes strictly surface-faithful input. It is crucial that the input respect not only the word order, but also *pro*-drop and word-internal structure. For instance, by default, agreement contributes only presuppositions (as in (4)). In contrast, overt NPs construed with agreement always give rise to recentering updates, with far-reaching consequences for subsequent prominence-guided anaphora (ftn. 3, 5, 6). Likewise, word-internal structure must be respected because prominence-guided anaphora persists at the morphological level.

If these word-to-word and morph-to-morph anaphoric patterns are confirmed by further research, then they have fundamental implications for the semantic theory. Not least, they strongly favor anaphoric composition, based on the surface topological order, over PTQ style theories, based on an indexed syntactic hierarchy (e.g., PTQ analysis tree, or LF). For only uniform surface dynamics can explain the universal context-setting role of order, in every language and at every level.

Appendix: ***Seven-sorted Logic of Change with Centering*** **($\mathbf{LCC_7}$)**

LCC_7 extends the two-sorted system of Bittner 2001b, which distinguished only worlds and entities. In LCC_7 there are seven basic sorts: worlds $\mathbf{w}$, agentive entities α, non-agentive entities β, events ε, states σ, times τ, and places π.

Some sorts are related by partial world-dependent mappings: $\mathbf{tm}_w$ (*run time*, *o* to τ), $\mathbf{loc}_w$ (*location*, *o* to π), $\mathbf{path}_w$ (*path*, ε to $\pi\pi$), $\mathbf{rs}_w$ (*result state*, ε to σ), $\mathbf{agt}_w$ (*agent*, ε to α), $\mathbf{dat}_w$ (*goal*, ε to *e*), $\mathbf{th}_w$ (*theme*, *o* to *e*), $\mathbf{mnr}_w$ (*manner*, *o* to $(\mathbf{w}ot)t$).

LCC_7 also includes the conditions defined in (8′)–(12′). (For convenience, I freely import set-theoretic symbols into LCC_7, including image-building abstracts of the form $\{fx\colon x \in \text{Dom } f\}$, and function-building abstracts of the form $\langle fx\colon x \in \text{Dom } f\rangle$.)

(8′). Conditions on *basic dref types* ($\omega := \mathbf{w}t, \alpha, \beta, \varepsilon, \sigma, \tau, \pi$), *processes* ($\varepsilon\varepsilon$), and *kinds* ($\kappa^n := \mathbf{w}o\mathsf{n}$):

- $T = \{t\colon t \subseteq \mathbf{d}\tau\}$ abbreviates
  $\lambda i.T = \{t\colon t \subseteq \mathbf{d}\tau i\}$
- $\mathbf{t} \in d(\tau t)$ abbreviates
  $\lambda i.\ \mathbf{t} \in d(\tau t)i$
- $d\alpha =_{\mathbf{d}\omega} \text{FA } \mathbf{d}\alpha$ abbreviates
  $\lambda i.\forall w \in \mathbf{d}\omega i\colon d\alpha i = \text{FA}_w\ (\mathbf{d}\alpha i)$
- $\text{KAYAK}\ k$ abbreviates
  $\lambda i.\forall w \in \text{Dom } k\ \forall ev \in \text{Dom } kw\colon \text{KAYAK}_w\ (kw\ ev)$

- $e \in ee$ abbreviates
  $e \in (\text{Dom } ee \cup \text{Ran } ee)$
- $\text{MAKE.TYPICAL.USE}_{\mathbf{d}\omega}\langle ee, \mathbf{d}\alpha, d\kappa^{\beta}\rangle$ abbreviates
  $\lambda i.\forall w \in \mathbf{d}\omega i$: $\text{TYPICAL.FOR}_w(\mathbf{mnr}_w\, ee, d\kappa^{\beta} i)$
  $\wedge\ \forall e \in ee$: $\text{USE}_w(e, \mathbf{d}\alpha i, d\kappa^{\beta} iwe)$
- $d\varepsilon\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau$ abbreviates
  $\lambda i.\forall w \in \mathbf{d}\omega i \forall e \in ee$: $\mathbf{tm}_w\, e \subseteq \mathbf{d}\tau i$
- $\mathbf{beg}\ ee$ abbreviates
  $\iota e.\ e \in (\text{Dom } ee — \text{Ran } ee)$
- $\mathbf{end}\ ee$ abbreviates
  $\iota e.\ e \in (\text{Ran } ee — \text{Dom } ee)$
- $\mathbf{t} \subseteq_{\mathbf{d}\omega} \mathbf{tm}\ d\varepsilon\varepsilon$ abbreviates
  $\lambda i.\forall w \in \mathbf{d}\omega i$: $\mathbf{t} \subseteq [\mathbf{tm}_w\,(\mathbf{beg}\ d\varepsilon\varepsilon i), \mathbf{tm}_w(\mathbf{end}\ d\varepsilon\varepsilon i)]$
- $\text{GET}_{\mathbf{d}\omega}\langle e, \mathbf{d}\alpha, \mathbf{th}\ e\rangle$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\text{GET}_w(e, \mathbf{d}\alpha i, \mathbf{th}_w\ e)$
- $b =_{\mathbf{d}\omega} \mathbf{th}\ d\varepsilon$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $b = \mathbf{th}_w\ e$
- $s =_{\mathbf{d}\omega} \mathbf{rs}\ d\varepsilon$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $s = \mathbf{rs}_w\ e$
- $\mathbf{d}\tau \subseteq_{\mathbf{d}\omega} d\sigma$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\mathbf{d}\tau i \subseteq \mathbf{tm}_w\,(d\sigma i)$
- $\text{SEAL}\ k$ abbreviates
  $\lambda i.\ \forall w \in \text{Dom } k\ \forall ev \in \text{Dom } kw$: $\text{SEAL}_w\,(kw\ ev)$
- $d\beta =_{\mathbf{d}\omega} d\kappa^{\beta}\langle d\varepsilon\rangle$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $d\beta i = d\kappa^{\beta} iw(d\varepsilon i)$

(9′). More on *basic dref types.* Enter *accessibility relations* ($\Omega := \mathbf{w}\omega$):

- $\text{COME.TO}_{\mathbf{d}\omega}\langle e, \mathbf{d}\alpha, \mathbf{loc}\langle\mathbf{beg}\ d\varepsilon\varepsilon\rangle\rangle$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\text{COME.TO}_w(e, \mathbf{d}\alpha i, \mathbf{loc}_w(\mathbf{beg}\ d\varepsilon\varepsilon i))$
- $d\varepsilon \subseteq_{\mathbf{d}\omega} \mathbf{d}\tau$
  abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\mathbf{tm}_w\, d\varepsilon i \subseteq \mathbf{d}\tau i$
- $\mathbf{t} =_{\mathbf{d}\omega} \mathbf{aft}_w\ e$ abbreviates
  $\lambda i.\forall w \in \mathbf{d}\omega i$: $\mathbf{t} = \mathbf{tm}_w(\mathbf{rs}_w\ e)$
- $\text{SAY}_{\mathbf{d}\omega}\langle e, \mathbf{d}\alpha, q\rangle$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\text{SAY}_w(e, \mathbf{d}\alpha i, qw)$
- $\mathbf{dat}\ d\varepsilon =_{\mathbf{d}\omega} d\alpha$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\mathbf{dat}_w\ d\varepsilon i = d\alpha i$

(10′). Conditions on *habits* ($\eta^{\varepsilon\varepsilon} := \mathbf{w}\tau(\varepsilon\varepsilon)$) and **τ**-*dom concepts* ($\theta := \mathbf{w}\tau t$)

- $\mathbf{mnr}\ h = \mathbf{mnr}\ \langle d\varepsilon_3, d\varepsilon_2, d\varepsilon_1\rangle$ abbreviates
  $\lambda i.\ \forall w \in \text{Dom } h\ \forall t \in \text{Dom } hw$:
  $\mathbf{mnr}_w hwt = \mathbf{mnr}_w\langle d\varepsilon_3 i, d\varepsilon_2 i, d\varepsilon_1 i\rangle$

- $\text{ACT.ON}\langle d\eta^{\varepsilon\varepsilon}, \mathbf{d}\alpha, d\alpha\rangle$ abbreviates

  $\lambda i.\ \forall w \in \text{Dom}\ d\eta^{\varepsilon\varepsilon}i\ \forall t \in \text{Dom}\ d\eta^{\varepsilon\varepsilon}iw$:

  $\quad \mathbf{tm}_w\ d\eta^{\varepsilon\varepsilon}iwt \subseteq t$

  $\quad \wedge\ \forall e \in d\eta^{\varepsilon\varepsilon}iwt(\mathbf{agt}_w\ e = \mathbf{d}\alpha i \wedge \mathbf{th}_w\ e = d\alpha i)$,

  where $\mathbf{tm}_w\ d\eta^{\varepsilon\varepsilon}iwt := [\mathbf{tm}_w(\mathbf{beg}\ d\eta^{\varepsilon\varepsilon}iwt), \mathbf{tm}_w(\mathbf{end}\ d\eta^{\varepsilon\varepsilon}iwt)]$
- $\mathbf{beg}\ d\eta^{\varepsilon\varepsilon} \subseteq \mathbf{beg}\ \underline{T}$ abbreviates

  $\lambda i.\ \forall w \in \text{Dom}\ d\eta^{\varepsilon\varepsilon}i$: $\mathbf{min}_<(\text{Dom}\ d\eta^{\varepsilon\varepsilon}iw) \subseteq \mathbf{min}_<(\underline{T}w)$
- $\underline{T} \subseteq d\eta^{\varepsilon\varepsilon}$ abbreviates

  $\lambda i.\ \forall w \in \text{Dom}\ \underline{T}$: $\underline{T}w \subseteq \text{Dom}\ d\eta^{\varepsilon\varepsilon}iw$
- $\mathbf{d}\tau \subseteq_{\mathbf{d}\omega} d\eta^{\varepsilon\varepsilon}$ abbreviates

  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\mathbf{d}\tau i \subseteq \mathbf{tm}_w\ d\eta^{\varepsilon\varepsilon}iw$,

  where $\mathbf{tm}_w\ d\eta^{\varepsilon\varepsilon}iw := [\mathbf{min}_<(\text{Dom}\ d\eta^{\varepsilon\varepsilon}iw), \mathbf{max}_<(\text{Dom}\ d\eta^{\varepsilon\varepsilon}iw)]$

(11′). More on *habits* ($\eta^{\varepsilon} := \mathbf{w}\tau\varepsilon$, $\eta^{\sigma} := \mathbf{w}\tau\sigma$) and τ-*domain concepts*:

- $tt =_{d\theta} \text{MORNING.OF}$ abbreviates

  $\lambda i.\ \forall w \in \text{Dom}\ d\theta i\ \forall t \in \text{Dom}\ tt$: $tt(t) = \text{MORNING.OF}_w\ t$
- $\underline{\mathbf{T}} = d\tau\tau\langle d\theta\rangle$ abbreviates

  $\lambda i.\ \text{Dom}\ \underline{\mathbf{T}} = \text{Dom}\ d\theta i$

  $\quad \wedge\ \forall w \in \text{Dom}\ \underline{\mathbf{T}}$: $\underline{\mathbf{T}}w = \{d\tau\tau it: t \in d\theta iw\}$
- $\text{WAKE.UP}\langle h^{\varepsilon}, \mathbf{d}\alpha\rangle$ abbreviates

  $\lambda i.\ \forall w \in \text{Dom}\ h^{\varepsilon}\ \forall t \in \text{Dom}\ h^{\varepsilon}$:

  $\quad \mathbf{tm}_w\ h^{\varepsilon}wt \subseteq t \wedge \text{WAKE.UP}_w(h^{\varepsilon}wt, \mathbf{d}\alpha i)$
- $\mathbf{d}\theta \subseteq_{\mathbf{d}\omega} d\eta^{\varepsilon}$ abbreviates

  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\mathbf{d}\theta iw \subseteq \text{Dom}\ d\eta^{\varepsilon}iw$
- $\underline{\mathbf{T}} = \mathbf{aft}\langle d\eta^{\varepsilon} |\ \mathbf{d}\theta\rangle$ abbreviates

  $\lambda i.\ \text{Dom}\ \underline{\mathbf{T}} = \text{Dom}\ \mathbf{d}\theta i$

  $\quad \wedge\ \forall w \in \text{Dom}\ \underline{\mathbf{T}}$: $\underline{\mathbf{T}}w = \{t \cap \mathbf{aft}_w\ d\eta^{\varepsilon}iwt: t \in \mathbf{d}\theta iw\}$
- $\underline{\mathbf{T}} \bullet\!\subseteq \mathbf{d}\theta$ abbreviates

  $\lambda i.\ \text{Dom}\ \underline{\mathbf{T}} = \text{Dom}\ \mathbf{d}\theta i$

  $\quad \wedge\ \forall w \in \text{Dom}\ \underline{\mathbf{T}}\ \exists tt \forall t \in \text{Dom}\ tt$:

  $\qquad tt(t) \subseteq t \wedge \mathbf{beg}\ tt(t) = \mathbf{beg}\ t$

  $\qquad \wedge\ \underline{\mathbf{T}}w = \{t \cap tt(t): t \in \mathbf{d}\theta iw\}$
- $\text{SLEEP}\langle h^{\sigma}, d\alpha\rangle$ abbreviates

  $\lambda i.\ \forall w \in \text{Dom}\ h^{\sigma}\ \forall t \in \text{Dom}\ h^{\sigma}w$:

  $\quad t \subseteq \mathbf{tm}_w\ h^{\sigma}wt \wedge \text{SLEEP}_w(h^{\sigma}wt, d\alpha i)$
- $\mathbf{d}\theta \subseteq_{\mathbf{d}\omega} d\eta^{\sigma}$ abbreviates

  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\mathbf{d}\theta iw \subseteq \text{Dom}\ d\eta^{\sigma}iw$
- $\underline{\mathbf{T}} = \mathbf{tm}\langle d\eta^{\sigma} |\ \mathbf{d}\theta\rangle$ abbreviates

  $\lambda i.\ \text{Dom}\ \underline{\mathbf{T}} = \text{Dom}\ \mathbf{d}\theta i$

  $\quad \wedge\ \forall w \in \text{Dom}\ \underline{\mathbf{T}}$: $\underline{\mathbf{T}}w = \{t \cap \mathbf{tm}_w\ d\eta^{\sigma}iwt: t \in \mathbf{d}\theta iw\}$
- $\text{SHORE}_{\mathbf{d}\omega}\ \mathbf{d}\pi$ abbreviates

  $\lambda i.\ \forall w \in \mathbf{d}\omega i$: $\text{SHORE}_w\ \mathbf{d}\pi i$

- $\mathbf{end}\langle\mathbf{path}\ d\eta^{\varepsilon}\rangle \subseteq_{\mathbf{d}\omega} \mathbf{d}\pi$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i\ \forall t \in \text{Dom}\ d\eta^{\varepsilon}w\text{: } \mathbf{end}(\mathbf{path}_w\ d\eta^{\varepsilon}wt) \subseteq \mathbf{d}\pi i$
- $d\eta^{\varepsilon} \subseteq_{\mathbf{d}\omega} \mathbf{d}\theta$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i\text{: Dom}\ d\eta^{\varepsilon}iw \subseteq \mathbf{d}\theta iw$
- $\mathbf{t} \subseteq_{\mathbf{d}\omega} \cup\mathbf{d}\theta$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i\text{: } \mathbf{t} \subseteq [\mathbf{min}_{<}(\mathbf{d}\theta iw), \mathbf{max}_{<}(\mathbf{d}\theta iw)]$
- $\mathbf{beg}\ \mathbf{d}\theta <<_{\mathbf{d}\omega} \mathbf{t}$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i\text{: } \mathbf{min}_{<}(\mathbf{d}\theta iw) << \mathbf{t}$
- $e =_{\mathbf{d}\omega} \mathbf{beg}\ d\eta^{\varepsilon}$ abbreviates
  $\lambda i.\ \forall w \in \mathbf{d}\omega i\text{: } e = d\eta^{\varepsilon}iw(\mathbf{min}_{<}(\text{Dom}\ d\eta^{\varepsilon}iw))$

(12′). Conditions on *scales* and *other dependencies*:

- $\text{DIVE}\langle f_{\alpha\eta}, \alpha\rangle$ abbreviates
  $\lambda i.\ \forall a \in \text{Dom}\ f_{\alpha\eta}\ \forall w \in \text{Dom}\ f_{\alpha\eta}a\ \forall t \in \text{Dom}\ f_{\alpha\eta}aw\text{:}$
  $\quad \mathbf{tm}_w\ f_{\alpha\eta}awt \subseteq t \wedge \text{DIVE}_w(f_{\alpha\eta}awt, a)$
- $f_{\alpha\eta} = \mathbf{rs}\ d\alpha\eta^{\varepsilon}$ abbreviates
  $\lambda i.\ \text{Dom}\ f_{\alpha\eta} = \text{Dom}\ d\alpha\eta^{\varepsilon}i$
  $\quad \wedge\ \forall a \in \text{Dom}\ f_{\alpha\eta}\text{: Dom}\ f_{\alpha\eta}a = \text{Dom}\ d\alpha\eta^{\varepsilon}ia$
  $\quad \wedge\ \forall a \in \text{Dom}\ f_{\alpha\eta} \forall w \in \text{Dom}\ f_{\alpha\eta}a\text{:}$
  $\quad f_{\alpha\eta}aw = \langle \mathbf{rs}_w(d\alpha\eta^{\varepsilon}iawt)\text{: } t \in \{\mathbf{aft}_w\ e\text{: } e \in \text{Ran}\ d\alpha\eta^{\varepsilon}iaw\}\rangle)$
- $d\alpha\eta^{\sigma}\langle d\kappa^{\alpha}\rangle \sim_{kk.\tau} d\alpha\eta^{\sigma}(\mathbf{d}\alpha)$ abbreviates
  $\lambda i.\mathbf{max}_{<kk.\tau}\{k^{\tau} \in kk^{\tau}\text{:}$
  $\qquad \forall w \in \text{Dom}\ d\kappa^{\alpha}i\ \forall s \in \text{Ran}\ d\alpha\eta^{\sigma}i(d\kappa^{\alpha}iws)w\text{:}$
  $\qquad \mathbf{tm}_w\ s = k^{\tau}ws\}$
  $\ = \mathbf{max}_{<kk.\tau}\{k^{\tau} \in kk^{\tau}\text{:}$
  $\qquad \forall w \in \text{Dom}\ d\alpha\eta^{\sigma}i(\mathbf{d}\alpha i)\forall s \in \text{Ran}\ d\alpha\eta^{\sigma}i(\mathbf{d}\alpha i)w\text{:}$
  $\qquad \mathbf{tm}_w\ s = k^{\tau}ws\}$
  where $k <_{kk} k'$ iff $k' \in \{kk(k), kk(kk(k)), \ldots\}$
- $f_{\sigma\tau} =_{d\kappa\kappa} \mathbf{tm}$ abbreviates
  $\lambda i.\ \forall k^{\tau} \in d\kappa\kappa^{\tau}i\ \forall w \in \text{Dom}\ k^{\tau}\ \forall s \in \text{Dom}\ k^{\tau}w\text{: } f_{\sigma\tau}s = \mathbf{tm}_w\ s$
- $\mathbf{scale}(d\kappa\kappa^{\tau}, |f_{\sigma\tau}|)$ abbreviates
  $\lambda i.\ \exists k^{\tau}{}_1, \ldots, k^{\tau}{}_n\text{: } d\kappa\kappa^{\tau}i = \chi\langle k^{\tau}{}_1, \ldots, k^{\tau}{}_n\rangle \wedge k^{\tau}{}_n \subset \ldots \subset k^{\tau}{}_1$
  $\quad \wedge\ \forall k^{\tau} \in \text{Dom}\ d\kappa\kappa^{\tau}i\text{:}$
  $\quad \mathbf{min}\{|f_{\sigma\tau}s|\text{: } w \in \text{Dom}\ k^{\tau}, s \in \text{Dom}\ k^{\tau}w\}$
  $\quad < \mathbf{min}\{|f_{\sigma\tau}s|\text{: } w \in \text{Dom}\ d\kappa\kappa^{\tau}ik, s \in \text{Dom}\ d\kappa\kappa^{\tau}ikw\}$
  where $\chi\langle k_1, \ldots, k_n\rangle := \langle k_{m+1}\text{: } k_m \in \{k_1, \ldots k_{n-1}\}\rangle$
  and $k \subset k'$ iff $\forall w \in \text{Dom}\ k\text{: Ran}\ kw \subset \text{Ran}\ k'w$
- $h^{\sigma} = d\alpha\eta^{\sigma}\langle d\kappa^{\alpha}\rangle$ abbreviates
  $\lambda i.\ \text{Dom}\ h^{\sigma} = \{w \in \text{Dom}\ d\kappa^{\alpha}i\text{: Ran}\ d\kappa^{\alpha}iw \cap \text{Dom}\ d\alpha\eta^{\sigma}i \neq \varnothing\}$
  $\quad \wedge\ \forall w \in \text{Dom}\ h^{\sigma}\text{:}$
  $\quad \text{Dom}\ h^{\sigma}w = \{t \in \text{Dom}\ d\alpha\eta^{\sigma}iaw\text{: } a \in \text{Ran}\ d\kappa^{\alpha}iw\}$
  $\quad \wedge\ \forall w \in \text{Dom}\ h^{\sigma}\ \forall t \in \text{Dom}\ h^{\sigma}w\text{: } h^{\sigma}wt = d\alpha\eta^{\sigma}i(d\kappa^{\alpha}iw(h^{\sigma}wt))wt$

- $d\sigma\tau\langle h^\sigma\rangle \subseteq \textbf{end}\ d\kappa\kappa^\tau$ abbreviates
  $\lambda i.\ \forall w \in \text{Dom}\ h^\sigma$:
  $\{d\sigma\tau i(h^\sigma wt): t \in \text{Dom}\ h^\sigma w\} \subseteq \text{Ran}\ (\textbf{end}\ d\kappa\kappa^\tau i)w$
- $d\sigma\tau\langle h^\sigma\rangle \sim_{d\kappa\kappa} d\sigma\tau\langle d\eta^\sigma\rangle$ abbreviates
  $\lambda i.\ \textbf{max}_{<kk}\{k^\tau \in d\kappa\kappa^\tau i: \forall w \in \text{Dom}\ h^\sigma \forall s \in \text{Ran}\ h^\sigma w:$
  $d\sigma\tau is = k^\tau ws\}$
  $= \textbf{max}_{<kk}\{k^\tau \in d\kappa\kappa^\tau i: \forall w \in \text{Dom}\ d\eta^\sigma i \forall s \in \text{Ran}\ d\eta^\sigma iw:$
  $d\sigma\tau is = k^\tau ws\}$
- $k^\tau = d\sigma\tau\langle d\eta^\sigma\rangle$ abbreviates
  $\lambda i.\ \text{Dom}\ k^\tau = \text{Dom}\ d\eta^\sigma i$
  $\wedge\ \forall w \in \text{Dom}\ k^\tau: \text{Dom}\ k^\tau w = \text{Ran}\ d\eta^\sigma iw$
  $\wedge\ \forall w \in \text{Dom}\ k^\tau\ \forall s \in \text{Dom}\ k^\tau w: k^\tau ws = d\sigma\tau is$
- $d\kappa^\tau = ((\textbf{end}\ d\kappa\kappa^\tau)|d\eta^\sigma)$ abbreviates
  $\lambda i.\ \text{Dom}\ d\kappa^\tau i = \{w: \text{Ran}\ d\eta^\sigma iw \subseteq \text{Dom}\ (\textbf{end}\ d\kappa\kappa^\tau i)w\}$
  $\wedge\ \forall w \in \text{Dom}\ d\kappa^\tau i: \text{Dom}\ d\kappa^\tau iw = \text{Ran}\ d\eta^\sigma iw$
  $\wedge\ \forall w \in \text{Dom}\ d\kappa^\tau i\ \forall s \in \text{Dom}\ d\kappa^\tau iw: d\kappa^\tau iws = (\textbf{end}\ d\kappa\kappa^\tau i)ws$

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