Modal Constraints on Temporal Reference

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This paper seeks to explain the role of modal expressions in constraining the temporal reference of their prejacents, motivated by two pieces of yet unobserved, seemingly unrelated data. The first is a novel exception to the so-called Upper Limit Constraint (ULC). The ULC says that the reference time of an embedded clause has an upper bound of the event time of the embedding clause (Abusch, 1993, Kratzer, 1998, Schlenker, 2004, Anand & Hacquard, 2008, a.o.). However, as seen below, the ULC holds only for some embedding predicates.

(1) a. Martina thought$_i$ Carissa got$_j$ pregnant. $j < i$
     b. Martina thought$_i$ Carissa was$_j$ pregnant. $j \leq i$
     c. Martina hoped$_i$ Carissa got$_j$ pregnant. $j > i$ or $j < i$

Non-modalized clauses embedded under *think* cannot have a reference time later than the embedding event time, i.e., the time at which Martina has her belief in (1a-b).[2] This case has been taken to exemplify all attitude verbs that embed finite clauses. But (1c) is a counterexample, showing that clauses embedded under *hope* may have a reference time later than matrix event time.

The second observation concerns the range of the temporal comparatives *earlier* and *later*. When these comparatives relate the event time of the modified clause to an implicit, anaphorically determined time argument, the two times must be on the same side of speech time, at least in unembedded contexts. If two times are not on the same side of speech time, they are incommensurable.

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[2]There is an additional, irrelevant constraint here, which is that only stative predicates can have their event time be equal to reference time (rather than overlapping reference time), thus the difference in possible temporal reference between (1a-b).

(2)   *Temporal incommensurability with* later
    a. Alexa left$_i$ 12 months ago. She got$_j$ back 9 months later$_i$.
$$i < j < n$$
    b. Alexa will$_i$ leave in 12 months . She'll$_j$ get back 9 months later$_i$.
$$n < i < j$$
    c. Alexa left$_i$ 3 months ago. #She's gonna$_j$ get back 9 months later$_i$.
$$\#i < n < j$$

(3)   *Temporal incommensurability with* earlier
    a. Alexa got$_j$ back 3 months ago. She left$_i$ 9 months earlier$_j$.
$$i < j < n$$
    b. Alexa will$_j$ get back in 12 months. She'll$_i$ leave 9 months earlier$_j$.
$$n < i < j$$
    c. Alexa will$_j$ get back in 6 months. #She left$_i$ 9 months earlier$_j$.
$$\#i < n < j$$

I propose that both of these phenomena can be accounted for by enriching the typical Lewis-Kratzer model of modality (Lewis, 1973, Kratzer, 1981, 2012) to include partial histories, slices of worlds which include only certain intervals of time. As quantifiers over these partial histories, modals impart constraints on the range of possible values for temporal pronouns in their prejacents. Since modals may vary in terms of what kind of partial histories they quantify over, they may also vary in terms of how they temporally constrain their prejacents. As I show below, and as Condoravdi (2002) and Werner (2006) have shown for modal auxiliaries, it is possible to make generalizations about what temporal constraints come with what kinds of modal base. The theory I present elegantly captures this fact without reducing variation in temporal orientation among modals to lexical idiosyncrasy.

The analysis in brief is thus as follows. While *think* takes a strictly doxastic modal base, *hope* may have either a circumstantial or doxastic modal base. Doxastic or epistemic modal bases, like those associated with *think* or the silent epistemic necessity operator (Kratzer, 2012) in (3c), only support present or past temporal reference. I argue that these modal bases consist of worlds or histories which extend only up to evaluation time, and that the orientation of *think* in (1a), and the infelicity of (3c), follow from this. Conversely circumstantial/metaphysical modal bases like used in *will* and *might* only support future temporal orientation (Condoravdi, 2002); I argue that these modal bases consist of histories which extend forward from evaluation time, and thus support only future reference. Since *hope* may take circumstantial or doxastic modal bases, it may have any kind of temporal orientation, modulo other constraints.

In Section 1 I establish some terminological and theoretical preliminaries. In Section 2 I discuss modal-temporal correspondences in addition to

the ones above and show that they have not been adequately accounted for. In Section 3 I provide the formal details for the theory sketched above and in Section 4 show how it can derive modal-temporal correspondences. In Section 5 I show how this handles the issues relating to Sequence of Tense, allowing for a simpler theory with no stipulated Upper Limit Constraint. In Section 6 I show how this handles the Ban on Temporal Crossover. In Section 7 I conclude.

1 Preliminaries

Although I will propose some alterations, the formal framework I will adopt largely follows the Lewis-Kratzer tradition of modality (Lewis, 1973, Kratzer, 1981, 2012), including the notion that modals quantify over worlds. The modifications to the classic picture I will pursue simply involve treating worlds as *histories* as in the Branching Times framework.

Modals come in many varieties, determined by their various parameters. Quantificational force is one parameter. Another is the 'flavor' of the conversational backgrounds, contextual parameters that determine their quantificational domains. Two conversational background-types are usually cited: modal bases, sets of propositions which determine the basic domain of the modal; and ordering sources, sets of propositions which determine an ordering according to which the highest ordered worlds in the modal base may be selected. I will refer to the set of worlds over which a given modal quantifies, determined together by a modal base and an ordering source, as the modal domain.

I assume two basic kinds of modal bases: doxastic, a set of propositions believed by some agent(s); and circumstantial, a set of propositions objectively true of the evaluation world. I assume the metaphysical modal base is a special case of the circumstantial modal base (the set of all true facts up to a given time), while an epistemic is a special case of a doxastic one (a set of beliefs that happen to be true). Additionally, ordering sources may give modals flavors like deontic, teleological, or bouletic, and can make the difference between weak and strong necessity modals (Kratzer, 1981).

I assume that the conversational backgrounds are represented as 'hidden indexicals' in the tree and are syntactically selected by the modal. Thus the lexicon of modality is as below. For the purposes of this paper I suppress the role of context in determining the ordering source; in reality there should be an ordering source pronoun as well, but in order to simplify things somewhat I assume that the ordering source is lexically determined. In (4), f is a variable over modal bases.

(4)   *Modal Denotation*
       $[\![modal]\!]^g = \lambda p[\lambda f[\lambda w[Qw' \in \text{BEST}(f(w))[p(w')]]]]$

(5) *Modal Base Pronoun*
$$[\![mbro_6]\!]^g = \lambda w\{w' \mid w' \in \cap(g(6)(w))\}$$

Like gendered nominal pronouns in English, these modal base pronouns may carry presuppositions, e.g., *defined only if g(6) is a set of known propositions* etc; see below. Thus the lexicon may contain multiple such pronouns corresponding to the different varieties of modality seen in the language, with individual modal lexical items syntactically selecting for various of them.

Finally, what this paper is concerned with is the interaction of modality with temporal properties. Crucially we must distinguish between the temporal anchoring of the modal itself and the temporal anchoring of its prejacent. Condoravdi (2002) coins the terms *temporal orientation* and *temporal perspective* to maintain just this distinction. The temporal perspective of a modal refers to the time argument that that modal is *itself* relativized to. The temporal orientation of a modal is the temporal reference of its prejacent. Thus *must* in (6a) has a present perspective and orientation, while *(were) supposed to* in (6b) has a past perspective and future orientation.

(6)   a.   Given at all the hateful things in his journal, John must be the killer.
      b.   (Mom said last week that) you were supposed to help me yesterday.

In (6a), the time of the evidence from which the epistemic modal *must* determines its domain is the present. So is the the time of the prejacent. In (6b), the time of the rule or obligation was last week, while the obliged behavior was in the future with respect to that obligation (even though it is in the past relative to speech time).

The basic terminological and theoretical assumptions having been established, I can now restate the the central explanandum of this paper more succinctly. It is the relationship between a modal's *modal base* and its *temporal orientation*.

2   Modal-Temporal Correspondences

The correspondence between temporal orientation and modal base type seen in the data above is only a sample of a robust generalization. First, modals with circumstantial modal bases cannot have embedded past orientation. Condoravdi (2002) argued this point for metaphysical modals like *might*.

(7)   John might be at the store.

While (7) can have an epistemic/present reading, as well as a metaphysical/future reading, a metaphysical/present reading is predicted to be synonymous with (8).[3] But no such reading exists.

(8)   John is at the store.

So metaphysical modals don't ever have past or present orientation. This is is true for deontics like *have to* and *must* as well.

(9)   a.   You know the rules; # you {have to/must} have done the dishes last Tuesday.
        b.   You know the rules; # you {have to/must} be doing the dishes right now.
        c.   You know the rules; you {have to/must} do the dishes next Tuesday.

This is not be too surprising if we assume that deontic and teleological modals have circumstantial modal bases as well.

Second, doxastic modals cannot have future orientation; (10c) can only have a deontic or teleological reading.[4]

(10)   a.   He's a smart guy. He {has got to/must/has to} have aced his test yesterday.
        b.   He's a smart guy. He {has got to/must/has to} be acing his test right now.

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[3] The set of worlds identical to the evaluation world up to speech time are necessarily identical with respect to any proposition indexed at speech time or prior. John is therefore at the store in all or none of them. Thus if we say that John is at the store in one such world, we are really saying he is at the store at all of them, or put more simply, that he is at the store at the evaluation world.

[4] It is worth noting that Condoravdi (2002) claims that possibility modals are compatible with future-epistemic readings. Condoravdi provides an example like the following.

(i)   a.   John is either going to meet the provost or the dean.
        b.   It has been decided who he will meet, but I don't know who it is.
        c.   He may meet the dean, and he may meet the provost.

However, my judgment is that (ic) is infelicitous in the context of (ia-b);it either sounds contradictory with regard to whether or not who John will meet is settled, or, if an epistemic reading is forced, simply ill-formed, on par with (iia); (iib) is a much better continuation..

(ii)   a.   #Maybe he meets the dean, maybe he meets the provost.
        b.   Maybe he's going to meet the dean, maybe he's going to meet the provost.

Confusion about whether there is an future-epistemic reading for possibility modals is unsurprising since these possibility modals are all compatible with future-metaphysical readings, and the distinction between the two is very fine. However, neither *have to*, nor *must*, nor *got to* has a future-metaphysical readings, and for these the lack of future-epistemic readings is very clear. I do not think this is a coincidence.

c. He's a smart guy. # He {has got to/must/has to} ace his test tomorrow.

Condoravdi proposes the present and past orientations for metaphysical modals are ruled out by the Diversity Condition, a presupposition which *might* lexically carries. The Diversity Condition says the modal domain of *might* must be 'diverse' with respect to the prejacent; i.e., there must be p and not-p worlds in the domain. Thus given that all worlds metaphysically accessible from a given evaluation world are identical to that evaluation world up to evaluation time, diversity is guaranteed not to hold for all non-future times.

However, this does not derive the temporal orientation of necessity modals, since necessity modals universally quantify over their domain. If a necessity modal had this presupposition, they would always either be contradictory or trivially true. Werner's (2006) proposal is that this condition, what he calls the Disparity Principle, applies to the modal base, not the whole modal domain. In cases where there is an ordering source, the modal base may be diverse with respect to the prejacent, while the modal domain is not. Thus necessity modals may satisfy Diversity/Disparity while still being true.

However, this does not extend to temporal constraints on epistemic modals, like those seen in (10). In order to account for this, Werner proposes a Non-Disparity Principle, which he claims is a violable constraint on all modal expressions which says: "A proposition must make no distinction between speech-time branching worlds" (Werner, 2006, p. 248). When it conflicts with the Disparity Principle, the Non-Disparity Principle does not hold. However, in the case of epistemics, this constraint can hold and has the effect of restricting to a present or past interpretation only.

It's not clear what the motivation for the Non-Disparity Principle is, however, or how to formalize it. Moreover, Werner's proposal requires all necessity modals to have a non-empty ordering source, lest they be filtered out by the Disparity Principle. This seems unlikely, especially in the case of logical modals, like (11).

(11)   It logically must be the case that $1 + 1 = 2$.

Thus, while the Diversity/Disparity approach captures some modal constraints on temporal reference, it fails to get them all. I propose a different approach, in which modals quantify over partial histories, with different kinds of modals quantifying over different kinds of histories. In order to flesh out this proposal, I introduce the Branching Times framework.

3 Branching Times Framework

To implement the theory sketched above I use a Branching Times (BT) model, developed by Prior (1967) and Thomason (1970) and also used by Bonomi & del Prete (ms.). In this model, the basic index type is the *moment*, and the more familiar types of *world* and *time* are derived from this more basic type. Moments are the analogues to world-time pairs in the more familiar $T \times W$ model developed by Thomason (1984) and used in Condoravdi (2002), Kaufmann (2005), and elsewhere.

> **Def. 1: Ontology** There are two basic types; moments, M, and truth values.

Simple propositions are sets of moments (or characteristic functions of such sets). I use m, n, o for variables over moments.

> **Def. 2: Timeline** A timeline $w \in W$ is a pair $\langle S, <_w \rangle$ where $S \subset M$ and $<_w$ is a transitive ordering on S such that:
>
> 1. $\forall m \forall n \forall o [(n <_w m \;\&\; o <_w m) \rightarrow \exists R \in \{<_w, >_w, =\}[nRo]]$
> 2. $\forall m \forall n [m <_w n \rightarrow \exists o [m <_w o <_w n]]$

Definition 2 says the following: What I call timelines here are dense, partially ordered sets of moments; the equivalent of what Thomason (1970) calls "treelike structures". They may branch going forward, but not backward; i.e., a given moment may have many successors which are not ordered among themselves, but all moments ordered prior to a given moment are indeed ordered among themselves. I use w, w', etc. for timelines.

> **Def. 3: Histories** A history $h \in \mathcal{H}$ is a pair $\langle S, <_h \rangle$ where $S \subset M$ and $<_h$ is a transitive ordering on S such that
>
> 1. $h \in W$
> 2. $\forall m \forall n \in S \exists R \in \{<_h, >_h, =\}[mRn]$

> **Def. 4: Branching** $\forall w \forall w' \in W, w' \sqsubset w := \forall m \forall n [m <_w n \rightarrow m <_{w'} n]$

Definition 3 says that histories are timelines which do not branch, i.e., are fully ordered. Histories are thus essentially the counterpart of "worlds" in a more traditional modal analysis. Note, however, that histories (and timelines generally) may or may not have maximally or minimally ordered elements; thus they can "begin" and/or "end". Definition 4 says that a timeline w is a branch of another timeline w' if every pair of moments ordered by w receives the same order in w'.

Def. 5: Moments are Unique $\forall m \in M[\exists! w \in W[m \in w \ \& \ \neg \exists w' \in W[w \sqsubset w']]]$

Definition 5 says that every moment exists in only one 'maximal' timeline, i.e., the same moment cannot appear in two non-overlapping timelines.

Def. 6: Temporal Equivalence Let the relation $\approx$ establish equivalence classes on moments in different histories, such that

$$\forall m \forall n[m \approx n \rightarrow$$
$$\exists h \exists k \forall m' \forall n'[(m' \approx n' \ \& \ m' <_h m \ \& \ n' \in k) \rightarrow [n' <_k n]]]$$

Def. 7: Times T is the set of times $t \in T$ iff $\exists n[t = \{m \mid m \approx n\}]$

Def. 8: Bar $\forall t \forall h[t|h := \iota m[m \in h \ \& \ m \in t]]$

Def. 9: Temporal Ordering $\forall w \forall t \forall t'[t <_w t' := w|t <_w w|t']$

Definition 6 defines the temporal equivalence relation, which says that if $m \approx n$ and $m' \approx n'$ and m is prior to m' in h, then n is prior to n' in k, unless k does not include n'. By Definition 7, times are then just equivalence classes over the temporal equivalence relation, i.e., sets of moments which are temporally equivalent. I use t, u, v for times. Definition 8 defines the relation $\mid$ which gives the unique moment at the "intersection" of a stated history and time; for any t, h, note that for any time t and history h, there is exactly one such moment, or there is none (in which case $t|h$ is undefined). Definition 9 says that the ordering relation $<$ can be used with times as a shorthand for the ordering of the moments those times represent.

Def. 10: Glomming Histories If $h = \langle S_h, <_h \rangle$ and $i = \langle S_i, <_i \rangle$ are histories, $h \sqcup i = \langle S_h \cup S_i, <_j \rangle$ such that

1. $\forall m \forall n[m <_h n \rightarrow m <_j n]$
2. $\forall m \forall n[m <_i n \rightarrow m <_j n]$
3. $\forall m[m \in i \ \& \ m \notin h \rightarrow [\forall n \in h[n <_j m]]]$

The glom operator $\sqcup$ is defined in Definition 10 as taking two histories and putting them together so that the ordering in each of the original histories is preserved, and so that one history comes entirely after the other. This operator will be useful in talking about continuations of the evaluation world; the circumstantially/metaphysically accessible worlds will be the ones that, when glommed with the evaluation world, form a history in M (i.e., forms a coherent history). Before defining these notions of accessibility precisely, I define the kinds of histories which will be crucial.

Def. 11: Three Kinds of Histories

1. $\mathcal{M}$ is the set of maximal histories,
   $\mathcal{M} = \{h \in \mathcal{H} \mid \forall m \in h \exists o, n \in h[o <_h m <_h n]\}$;

2. $\mathcal{A}$ is the set of actual histories,
   $\mathcal{A} = \{i \in \mathcal{H} \mid \forall m \in i \exists n \in i[n <_i m\ \&\ \exists o \in i[\neg \exists o' \in i[o <_i o']]]\}$;

3. $\mathcal{F}$ is the set of future histories,
   $\mathcal{F} = \{j \in \mathcal{H} \mid \exists i \in \mathcal{A}[i \sqcup j \in \mathcal{M}]\}$;

Def. 12: Histories of Moments, Times, Etc.,

1. $m!$ is the (unique) actual history of m (iff $m \in M$),
   $m! = \iota i \in \mathcal{A}[m \in i\ \&\ \neg \exists n[m <_i n]]$;

2. $\mathcal{F}_m$ is the set of future histories of m (iff $m \in M$),
   $\mathcal{F}_m = \{j \in \mathcal{F} \mid m! \sqcup j \in \mathcal{M}\}$;

3. $\mathcal{A}_t$ is the set of actual histories of t (iff $t \in T$),
   $\mathcal{A}_t = \bigcup_{m \in t}\{m!\}$.

4. $\mathcal{F}_t$ is the set of future histories of t (iff $t \in T$),
   $\mathcal{F}_t = \{j \in \mathcal{F} \mid \exists i \in \mathcal{A}_t[i \sqcup j \in \mathcal{M}]\}$;

5. $j!$ is the unique actual history of j (iff $j \in \mathcal{F}$),
   $j! = \iota i \in \mathcal{A}[i \sqcup j \in \mathcal{M}]$

6. $\mathcal{F}_i$ is the set of future histories of i (iff $i \in \mathcal{A}$),
   $\mathcal{F}_i = \{j \in \mathcal{F} \mid i \sqcup j \in \mathcal{M}\}$;

Def. 13: Maximal Branch $\forall h \in \mathcal{H}, \omega(h) := \iota w \in W[\forall k \in \mathcal{M}[h \sqsubset k \rightarrow k \sqsubset w]]$

Maximal histories are the kind which are best analogues to worlds in a standard $T \times W$ model; they go off infinitely in both directions. Actual histories are partial histories which do not have a first element (i.e., extend infinitely far into the past) but do have a last element (i.e., they end at some point). Future histories are the inverse, extending infinitely into the future. Actual and future histories can be defined by the moment or time at which they begin/end, as shown in Definition 12 above. Finally, Definition 13 allows for reference to a maximal branching timeline of which a given history is a branch.

With these formalisms, capturing the modal-temporal correspondences discussed above becomes very straightforward. I assume that the lexicon includes two modal base pronouns; a doxastic one which restricts only to actual histories, and a circumstantial one, which restricts only to future histories. I use the symbol ∂ to indicate presuppositions.

(12)   a. $[\![\text{DOX}_6]\!]^g = \lambda t \lambda h \{i \in \mathcal{A}_t \mid i \in \cap(g(6)(h|t))\}$
$$\partial g(6)(h|t) \subseteq \{p \mid \text{thinks}(x, p, h|t)\}$$
       b. $[\![\text{CIR}_6]\!]^g = \lambda t \lambda h \{j \in \mathcal{F}_t \mid j! \in \cap(g(6)(h|t))\}$
$$\partial g(6)(h|t) \subseteq \{p \mid p(h|t!)\}$$

(12a) takes time and history arguments and returns the set of actual histories compatible with what a given individual believes at the moment determined by that time and history.[5] (12b) takes the same arguments and returns the set of future histories whose 'root' is compatible with a given set of facts, which are true of the actual history of the moment determined by its arguments.

The notion that the epistemic modal base should always determine a set of actual histories, and that the circumstantial modal base should always determine a set of future histories is well-motivated. First of all, we can only truly know things about the present or past, since the future is inherently unknowable – this is a point frequently made by proponents of the theory that predictive expressions like *will* are modals rather than simple temporal operators (e.g., Kaufmann, 2005). Thus restricting epistemic claims to the present and past is motivated by the Maxim of Quality (Grice, 1989).[6] Second, since the circumstances in a given world are fully settled up to evaluation time, it makes sense that circumstantial-modal expressions would be restricted to the future, i.e., the only contingent part of a set of circumstantially accessible worlds. This is motivated by the Maxim of Manner, since embedding a past/present-time prejacent under a circumstantial modal would be equivalent to the prejacent simpliciter. This is essentially the same motivation Condoravdi (2002) and Werner (2006) provide for their constraints against metaphysical modals with past or present orientation, but couching the constraint differently. Sensibly, deontic and teleological modals take circumstantial modal bases, since they concern rules and goals for future behavior.

Thus, a single modal lexical item may impose different temporal constraints depending on what modal base it takes. But this is not arbitrary, lexical idiosyncrasy – there is a deep motivation for the temporal constraints introduced by each kind of modal. This lays the groundwork for explaining the phenomena introduced above.

4   Modal-Temporal Correspondences Redux

Katz (2001) makes the important point that among non-finite-embedding attitude verbs, there is variation in the temporal possibilities of the em-

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[5]I leave it intentionally vague how the believer-argument is determined.

[6]I.e., there is a pragmatic motivation for the lexical item having the denotation that it does. I am not arguing that the synchronic constraint against using epistemics with the future is a pragmatic one.

bedded clause. But it has not been observed that this variation extends to finite-embedding attitude verbs, implicating sequence of tense. Returning to the data in (1), we see that in embedded contexts, most finite-embedding attitude verbs only allow relative-present or relative-past temporal reference, while *hope* is an important exception.

(13) a. Martina thought$_i$ Carissa got$_j$ pregnant. $j < i$
     b. Martina knew$_i$ Carissa got$_j$ pregnant. $j < i$
     c. Martina said$_i$ Carissa got$_j$ pregnant. $j < i$
     d. Martina hoped$_i$ Carissa got$_j$ pregnant. $j > i$ or $j < i$

There is a clear pattern among the attitude verbs that embed finite complements; epistemic or doxastic ones embed only relative-present or -past temporal reference, while the root modal verb *hope* does not restrict its complement at all. By positing that the verbs in (13a-c) take only epistemic or doxastic modal bases, and that *hope* may take either a doxastic or an epistemic modal base, these temporal properties fall out naturally.

Other verbs of desire are future-oriented, however all but *hope*[7] take non-finite complements (14). In fact, the generalization that temporal properties of the embedded clause can be predicted from modal base type holds up for non-finite embedding attitude verbs across the board; doxastic verbs like *believe* cannot have future reference, while the deontic reading of *tell* cannot have past reference.

(14) a. Martina wanted$_i$ Carissa to get$_j$ pregnant. $j > i$
     b. Martina prefered$_i$ (for) Carissa to get$_j$ pregnant. $j > i$

(15) a. #Itamar believed his daughter to go to bed.
     b. Itamar believed his daughter to {be in, have gone to} bed.

(16) a. Itamar told his daughter to go to bed.
     b. #Itamar told his daughter to {be in, have gone to} bed.

Moreover, the phenomenon is not limited to the case of embedding under a matrix past tense attitude verb. In fact, the patterns may be clearer without the morphological obfuscation of sequence of tense.

(17) a. Martina thinks Carissa {got, #gets} pregnant.
     b. Martina knows Carissa {got, #gets} pregnant.
     c. Martina says Carissa {got, #gets} pregnant.
     d. Martina hopes Carissa {got, gets} pregnant.

As in (13), epistemic/doxastic attitude verbs cannot take an embedded future reference time, but *hope* can. Importantly the embedded complement can only have a relative-future reading if it is morphologically present

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[7]Except the verb of counterfactual desire, *wish*. I leave a discussion of the temporal properties of counterfactuals for future research.

tense. I argue that this shows that the so-called present tense is actually semantically non-past. Kaufmann (2005) also argues for treating the present as non-past.

This assumption requires another, to explain the infelicity of (18).

(18)   #It rains tomorrow.

If the present is really non-past, why is (18) bad? Kaufmann (2005) uses (18) to motivate a constraint against future temporal reference in the real world, due to the unknowability of the future. This argument is usually part of the story that predictive expressions like *will* are modals rather than purely temporal operators. Given our system we can handily explain (18), by assuming the presence of a ubiquitous, covert epistemic modal, following Kaufmann (2005), Kratzer (2012) and others. Given what has already been said about epistemic modals, this would have the effect of limiting 'matrix' reference time to present or past in all contexts, except in the presence of future-modals.

The analysis is thus as follows: Modals, including attitude verbs, introduce temporal constraints on their prejacents depending on the kinds of history they quantify over. The English inventory of tenses includes two lexical items: a morphologically invariant relative-past tense, and a morphologically variant relative-non-past tense, which agrees with an embedding past tense. The 'upper limit constraint' is really just an effect of the embedding attitude verbs which depends on the modal base they take. In the next two sections I show formally how this accounts for the data presented above.

5   The Upper Limit Constraint in Embedded Contexts

In my compositional framework, vPs denote propositional radicals, functions from a history and a time to a truth value (19). Reference time is denoted by a temporal pronoun (Partee, 1973) which I call *tro* (20). Tense is an operator which takes a propositional radical, a reference time argument, and an evaluation time argument, and returns a simple proposition, a function from histories to truth values. It has the effect of imposing a temporal restriction on the range of possible values for reference time. For this specification the maximal branch $\omega(h)$ is used, as defined in Definition 13.

(19)   *Propositional Radicals*
        $\llbracket v\mathrm{P} \rrbracket = \lambda t[\lambda h[v\mathrm{P}(h|t)]]$

(20)   *Temporal Pronouns*
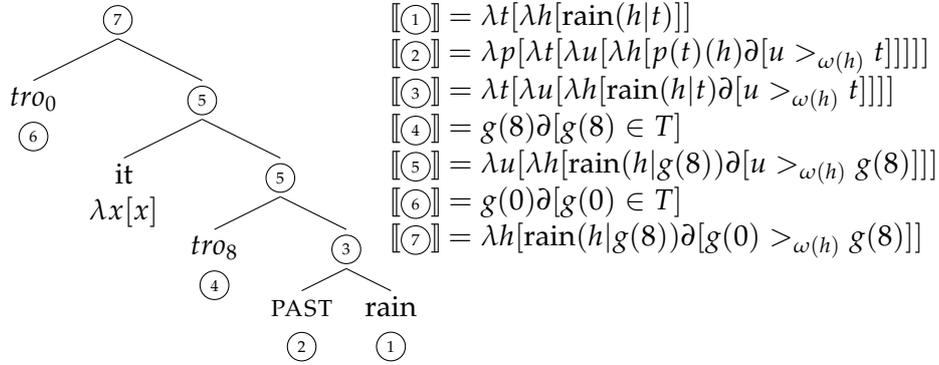 $\llbracket tro_8 \rrbracket = g(8)\partial[g(8) \in T]$

(21)   *Tenses* (T^0)

a. $\llbracket \text{PAST} \rrbracket = \lambda p \lambda t \lambda u \lambda h[p(t)(h)\partial[u >_{\omega(h)} t]]$
b. $\llbracket \text{NPST} \rrbracket = \lambda p \lambda t \lambda u \lambda h[p(t)(h)\partial[u \not>_{\omega(h)} t]]$

Finally I assume that speech time is represented in the tree, as an instance of *tro*. It bears the special designated index 0, as in Heim (1994). (Alternatively, following Hacquard's (2006) proposal, the speech event could be represented in the tree, with Tense taking the temporal trace of that event.) A simple derivation for (22) is given in (23); for this tree and those just below, the covert epistemic necessity modal is suppressed.

(22)   It rained.

(23)

$\llbracket \text{①} \rrbracket = \lambda t[\lambda h[\text{rain}(h|t)]]$
$\llbracket \text{②} \rrbracket = \lambda p[\lambda t[\lambda u[\lambda h[p(t)(h)\partial[u >_{\omega(h)} t]]]]]$
$\llbracket \text{③} \rrbracket = \lambda t[\lambda u[\lambda h[\text{rain}(h|t)\partial[u >_{\omega(h)} t]]]]$
$\llbracket \text{④} \rrbracket = g(8)\partial[g(8) \in T]$
$\llbracket \text{⑤} \rrbracket = \lambda u[\lambda h[\text{rain}(h|g(8))\partial[u >_{\omega(h)} g(8)]]]$
$\llbracket \text{⑥} \rrbracket = g(0)\partial[g(0) \in T]$
$\llbracket \text{⑦} \rrbracket = \lambda h[\text{rain}(h|g(8))\partial[g(0) >_{\omega(h)} g(8)]]$

Now consider the case of an attitude verb, *hope*, like in (24). Supposing that it takes the subtree in (23) starting at node ⑤ as a complement. It first takes its external argument, as well as its modal base argument, in (26);[8] I represent the presupposition of the modal base pronoun (ensuring that it is epistemic) in ⑩ but suppress it thereafter. Tense, reference time, and evaluation time combine in (27).
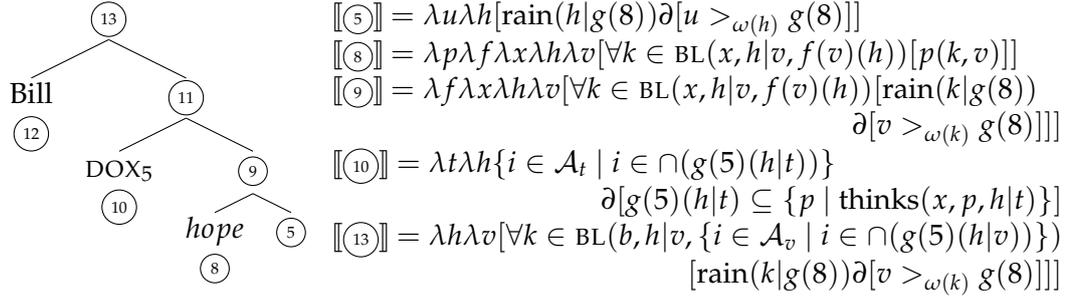
(24)   Bill hoped it rained.

The final denotation is in ⑲, in full in (25). The modal domain is determined by taking the set of histories in the modal base (the set of actual histories epistemically accessible from the evaluation history at reference time $g(7)$), and selecting from them the histories which best match the desires of Bill at the evaluation history at reference time. The sentence is true iff it rains in every history in said modal domain, at embedded reference time $g(8)$, and if the presuppositions are satisfied.

(25) $\lambda h[\forall k \in \text{BL}(b, h|g(7), \{i \in \mathcal{A}_{g(7)} \mid i \in \cap(g(5)(h|g(7)))\})[\text{rain}(k|g(8))$
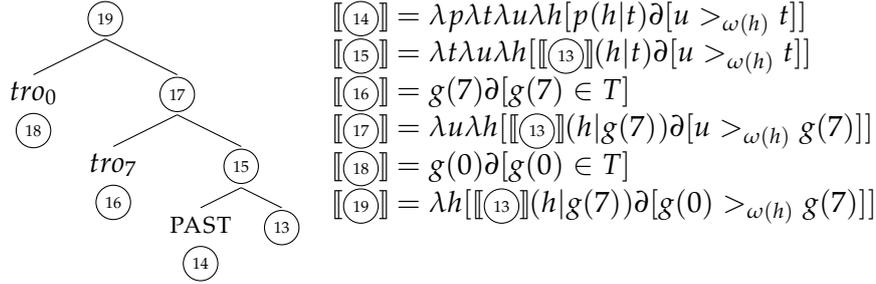$\partial[g(7) >_{\omega(k)} g(8)]]]\partial[g(0) >_{\omega(h)} g(7)]]$

_____

[8]Since *hope* is invariably bouletic, I assume its ordering source (BL) is lexically specified, but nothing hinges on this.

Besides the suppressed presupposition ensuring that the modal base is doxastic, there are two presuppositions, shown in the second line of (25). The outer presupposition says that the evaluation time $g(0)$ is after the matrix reference time $g(7)$; i.e., $g(7)$ is in the past. The inner presupposition then says that the matrix reference time $g(7)$ is after the embedded reference time $g(8)$. This is the effect of past embedded under past.

(26)

$\llbracket \text{⑤} \rrbracket = \lambda u \lambda h [\text{rain}(h|g(8)) \partial [u >_{\omega(h)} g(8)]]$

$\llbracket \text{⑧} \rrbracket = \lambda p \lambda f \lambda x \lambda h \lambda v [\forall k \in \text{BL}(x, h|v, f(v)(h))[p(k, v)]]$

$\llbracket \text{⑨} \rrbracket = \lambda f \lambda x \lambda h \lambda v [\forall k \in \text{BL}(x, h|v, f(v)(h))[\text{rain}(k|g(8))$
$\partial [v >_{\omega(k)} g(8)]]]$

$\llbracket \text{⑩} \rrbracket = \lambda t \lambda h \{i \in \mathcal{A}_t \mid i \in \cap(g(5)(h|t))\}$
$\partial [g(5)(h|t) \subseteq \{p \mid \text{thinks}(x, p, h|t)\}]$

$\llbracket \text{⑬} \rrbracket = \lambda h \lambda v [\forall k \in \text{BL}(b, h|v, \{i \in \mathcal{A}_v \mid i \in \cap(g(5)(h|v))\})$
$[\text{rain}(k|g(8)) \partial [v >_{\omega(k)} g(8)]]]$

(27)

$\llbracket \text{⑭} \rrbracket = \lambda p \lambda t \lambda u \lambda h [p(h|t) \partial [u >_{\omega(h)} t]]$

$\llbracket \text{⑮} \rrbracket = \lambda t \lambda u \lambda h [\llbracket \text{⑬} \rrbracket(h|t) \partial [u >_{\omega(h)} t]]$

$\llbracket \text{⑯} \rrbracket = g(7) \partial [g(7) \in T]$

$\llbracket \text{⑰} \rrbracket = \lambda u \lambda h [\llbracket \text{⑬} \rrbracket(h|g(7)) \partial [u >_{\omega(h)} g(7)]]$

$\llbracket \text{⑱} \rrbracket = g(0) \partial [g(0) \in T]$

$\llbracket \text{⑲} \rrbracket = \lambda h [\llbracket \text{⑬} \rrbracket(h|g(7)) \partial [g(0) >_{\omega(h)} g(7)]]$

But (24) is ambiguous, due to two homophonous alternations: The circumstantial modal base could be used lieu of a doxastic one, and the non-past tense could replace the past, since the non-past undergoes agreement when embedded under past. With both changes, *hope* quantifies over future histories, and the embedded non-past gives future orientation.

Suppose, however, that we swapped *hope* for *think*, which selects syntactically only for a doxastic modal base. Since this modal base is a set of actual histories, embedding non-past under *think* would give rise to infelicity in the case of a non-stative verb.[9]

(28) $\llbracket tro_7 \text{ PAST bill DOX}_5 \text{ thought it } tro_8 \text{ NPST rained } \rrbracket =$
$\lambda h [\forall k \in \text{ST}(b, h|g(7), \{i \in \mathcal{A}_{g(7)} \mid i \in \cap(g(5)(h|g(7)))\})[\text{rain}(k|g(8))$
$\partial [g(7) \not>_{\omega(k)} g(8)]]] \partial [g(0) >_{\omega(h)} g(7)]]$

Since the histories quantified over by *think* extend only up to reference time $g(7)$, and $g(8)$ is after $g(7)$, for every k in the domain of the attitude verb,

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[9]I assume *think* differs from hope in having a stereotypical rather than bouletic ordering source.

$k|g(8)$ will be undefined. Thus (28) is infelicitous on relative-future reading. The upper limit constraint is derived for epistemic and doxastic based attitude verbs, but not circumstantial ones.

6 Temporal Incommensurability

Temporal incommensurability effects, seen in (2c) and (3c), are repeated below.

(29)   Alexa left$_i$ 3 months ago. #She's gonna$_j$ get back 9 months later$_i$.

$$\#i < n < j$$

(30)   Alexa will$_j$ get back in 6 months. #She left$_i$ 9 months earlier$_j$.

$$\#i < n < j$$

These can be easily accounted for if the temporal comparatives *earlier* and *later* are sensitive to the evaluation history when comparing times. Below, μ is a variable over measures of time, to which the ordering is relativized.[10]

(31)   *Temporal Comparatives*
    a. $[\![\text{later}_3]\!] = \lambda\mu\lambda p\lambda t\lambda h[p(h|t) \ \& \ t >_h^\mu g(3)]$
    b. $[\![\text{earlier}_3]\!] = \lambda\mu\lambda p\lambda t\lambda h[p(h|t) \ \& \ g(3) >_h^\mu t]$

As discussed above, matrix sentences obey a kind of 'upper limit constraint' due to a ubiquitous, covert epistemic modal. Additionally I assume predictive expressions like *will* and *gonna* quantify over future histories. Consider then derivation of these two discourses; the covert epistemic which was suppressed in derivations above is now included.

(32)   a. $[\![\text{alexa left}_2]\!] = \lambda h[\forall i \in [\![\text{EPI}_4]\!][\text{leave}(a, i|g(2))\partial[g(0) >_{\omega(i)} g(2)]]]$
    b. $[\![\text{she's gonna}_3 \text{ get back 9 months later}]\!] =$
        $\lambda h[\forall j \in [\![\text{CIR}_1]\!][\text{back}(a, j|g(3)) \ \& \ g(3) >_j^{9mos} g(2)\partial[g(0) \not>_{\omega(i)} g(3)]]]$

(33)   a. $[\![\text{a. is gonna}_3 \text{ get back}]\!] =$
        $\lambda h[\forall j \in [\![\text{CIR}_1]\!][\text{back}(a, j|g(3))\partial[g(0) \not>_{\omega(i)} g(3)]]]$
    b. $[\![\text{she left}_2 \text{ 9 months earlier}]\!] =$
        $\lambda h[\forall i \in [\![\text{EPI}_4]\!][\text{leave}(a, i|g(2)) \ \& \ g(3) >_i^{9mos} g(2)\partial[g(0) >_{\omega(i)} g(2)]]]$

In (32b), the formula $g(3) >_j^{9mos} g(2)$ is undefined since $g(2)$ is presupposed to be in the past in (32a), and therefore $j|g(2)$ is (for each future j) undefined. Likewise in (33b), the formula $g(3) >_i^{9mos} g(2)$ is undefined since $g(3)$ is presupposed to be future in (33a) and therefore $i|g(3)$ is (for each actual history i) undefined.

There are reasons to suspect this is not the whole story, however. Spelling out the standard of comparison as a full clause seems to alleviate the effect.

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[10]For reasons of space I elide the details of how time measurement works.

(34)   Carissa got pregnant three months ago.
          She's gonna give birth 9 months after {#∅, #that, ^{OK}she conceived.}

This is to be addressed in future work.

7   Conclusion

This paper raises two empirical points which cannot be accounted for under present theories of tense. To account for these points I propose that modals quantify over temporally restricted parts of worlds, called partial histories, and therefore impose temporal constraints on their prejacents. Besides accounting for the data at hand, this proposal helps to capture modal-temporal correspondences in modal auxiliaries, as well as the apparent matrix constraint against future times, which is due to a covert modal operator. Additionally, this move can simplify the theory of sequence of tense phenomena in English, eliminating the need for a stipulated upper limit constraint, and instead showing that constraints on embedded temporal reference are due entirely to the embedding modal.

References

Abusch, Dorit. 1993. Two theories of tense in intensional contexts. *Proceedings of the 9th Amsterdam Colloquium*.

Anand, Pranav, & Hacquard, Valentine. 2008. When the Present is all in the Past. *In:* L. de Saussure, J. Moeschler, & Pusk, G. (eds), *Recent Advances in the Syntax and Semantics of Tense, Mood and Aspect*. Mouton de Gruyter.

Bonomi, Andrea, & del Prete, Fabio. ms.. *Evaluating future-tensed sentences in changing contexts*. http://filosofia.dipafilo.unimi.it/bonomi/future.pdf.

Condoravdi, Cleo. 2002. Temporal Interpretation of Modals: Modals for the Present and for the Past. *Pages 59–88 of:* Beaver, D., Kaufmann, S., Clark, B., & Casillas, L. (eds), *The Construction of Meaning*. CSLI Publications.

Grice, H. Paul. 1989. Logic and conversation. *Pages 22–40 of: Studies in the Ways of Words*. Harvard University Press: Cambridge, Massachusetts.

Hacquard, Valentine. 2006. *Aspects of Modality*. Ph.D. thesis, MIT.

Heim, Irene. 1994. Comments on Abusch's theory of tense. *Pages 143–170 of:* Kamp, Hans (ed), *Ellipsis, Tense, and Questions*. Amsterdam: University of Amsterdam.

Katz, Graham. 2001. Tense selection and the temporal interpretation of complement clauses. *Proceedings of Sinn und Bedeutung 6*, 169–184.

Kaufmann, Stefan. 2005. Conditional Truth and Future Reference. *Journal of Semantics*, **22**, 119–128.

Kratzer, Angelika. 1981. The notional category of modality. *Pages 38–74 of:* Eikmeyer, H.-J., & Rieser, H. (eds), *Words, Worlds, and Context*. de Gruyter.

Kratzer, Angelika. 1998. More structural analogies between pronouns and tenses. *Proceedings of SALT*, **7**.

Kratzer, Angelika. 2012. *Modality and Conditionals*. Oxford University Press.

Lewis, David. 1973. *Counterfactuals*. Harvard University Press: Cambridge, Massachusetts.

Partee, Barbara. 1973. Some structural analogies between tenses and pronouns in English. *Journal of Philosophy*, **70**(18), 601–609.

Prior, Arthur N. 1967. *Past, Present, and Future*. Oxford University Press.

Schlenker, Phillippe. 2004. Sequence phenomena and double access readings generalized. *In:* Lecarme, & Guéron (eds), *The Syntax of Time*. MIT Press.

Thomason, Richmond. 1970. Indeterminist time and truth-value gaps. *Theoria*, **36**, 264–281.

Thomason, Richmond. 1984. Combinations of tense and modality. *Pages 135–165 of:* Gabbay, D., & Guenther, F. (eds), *Handbook of Philosophical Logic, Vol. II*. D. Reidel Publishing Company.

Werner, Tom. 2006. Future and non-future modal sentences. *Natural Language Semantics*, **14**, 235–255.