The Modal Future Hypothesis Debugged.

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Abstract This note identifies and corrects some problems in developments of the thesis that predictive expressions, such as English *will*, are modals. I contribute a new argument supporting Cariani and Santorio's recent claim that predictive expressions are non-quantificational modals. At the same time, I improve on their selectional semantics by fixing an important bug. Finally, I show that there are benefits to be reaped by integrating the selection semantics framework with standard ideas about the future orientation of modals.

This note identifies and corrects some problems in developments of the "modal future hypothesis" — the thesis that predictive expressions, such as English *will*, are modals.

The modal future hypothesis is assumed here without argument (for arguments, see Klecha 2014). But it is important to make its content clearer. Start with some rough definitions. The "predictive expressions" of language $\mathcal{L}$ form a subset of the devices of future reference in $\mathcal{L}$, identified by two additional properties. First, predictive expressions refer to the future independently of one's location in time (ruling out phrases like *in the year 2222*). Second, they do not introduce restriction to a specific interval within the future (ruling out frame adverbials like *tomorrow*). Paradigmatic examples of predictive expressions in English are *will* and *gonna*.

The *modals* of $\mathcal{L}$ are those expressions whose evaluation rules manipulate a possible world of evaluation. Modals are often characterized as those expressions that denote concepts of possibility and necessity. However, this characterization fails to include some *bona fide* modals under respectable theories. For some examples: Stalnaker's account of conditionals Stalnaker (1968); scalar theories of probability operators in the style of Yalcin (2010) and Lassiter (2011, 2017); the analysis of ability modals in Mandelkern et al. (2017); and the kind of theory *will* explored in this article.

The modal future hypothesis is the claim that predictive expressions are modals. The "provincial" version of the hypothesis is restricted to English. Ac-

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cording to the "universal" version, the claim holds in every language. The version of the hypothesis that I assume here is in between these: I take the modality of predictive expressions to be a non-accidental feature of a diverse variety of languages. Indeed, though I will carry out this investigation with English as the primary target, there is evidence that the modal future hypothesis holds in a variety of languages besides English (see the cross-linguistic findings discussed in Giannakidou & Mari 2017, Bochnak 2019).

My limited goal is to sharpen our perspective on which semantic implementation of the modal future hypothesis is correct. I do so in three steps: §1 reproduces and extends arguments to the effect that the correct modal semantics uses selection functions. This idea is along the lines of recent proposals by Cariani & Santorio (2018) and, independently, Kratzer (forthcoming). I contribute a new argument in its favor. §2 identifies and corrects a technical bug in Cariani and Santorio's semantics. Their theory projects the wrong modal profile for *will*-sentences. §3 takes up a piece of unfinished business for defenders of selection semantics. In particular, none of the existing formulations of selection semantics addresses the future-orientation of sentences involving predictive expressions. I show how to integrate the theory with an off-the-shelf framework for future-orientation (Condoravdi 2002). This integration is virtuous—leading to benefits that neither selection semantics nor Condoravdi's theory have on their own.

1 The Indispensability of Selection

Here is the theory of Cariani & Santorio (2018) in a nutshell. Suppose that context provides a selection function σ. σ inputs a world and a set of worlds, returning a world under these constraints:

success: if $p \neq \emptyset$, $\sigma(w,p) \in p$

centering: if $w \in p$, $\sigma(w,p) = w$

Letting D be a variable provided as argument to *will* and ranging over modal domains (sets of worlds). Say that the "historical possibilities" in context c are those worlds that agree with the settled facts up to the time of c. That agreement could come about because those worlds share an initial segment of their history or because they are more duplicates (without sharing parts). This way of characterizating historical possibilities is resolutely neutral between a metaphysical conception according to which worlds overlap and branch (this view is sometimes—inappropriately, in my view—called "indeterminist") and a conception on which worlds may at best "look alike" for segments of their histories, but never share parts (in the inappropriate terminology: "determinist"). Cariani

and Santorio propose the semantic entry in (1) together with the metasemantic thesis in (2):

(1) $[\![will_D]\!] = \lambda p.\lambda w.p(\sigma(w,D))$

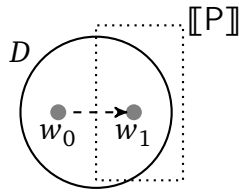
(2) in context c, D is initially assigned to the historical possibilities in c.

We speak of initial assignment because the value of D might be shifted away by various operators (and perhaps even by some discourse-level operations).

Register five critical features of the theory in (1)-(2).

(i) Say that a "bare forecast" is an unembedded *will* sentence with no adjuncts, like *it will rain*. Suppose the world of utterance is w_0. Then $will_D$(*it rains*) is true at w_0 if and only if *it rains* is true at w_0.[1] In this sense, *will* makes a trivial contribution to the truth-conditions of bare forecasts.

(ii) the semantics invites the additional assumption that conditional antecedents restrict D. It follows that the use of selection functions is not trivial in conditionals of the form *if* P, *will* Q. In particular, in such conditionals, restricting D with the antecedent proposition $[\![\mathsf{P}]\!]$ might slice off the actual world, leaving the selection function to do non-trivial work. Diagrammatically:



Here, the selection function must select out of $[\![\mathsf{P}]\!]$ from w_0's perspective.

In selection semantics, the modal nature of *will* is disguised until something like this sort of domain restriction happens.

(iii) The modal domain D may also be intervened on by means of modal subordination (Roberts 1989, Klecha 2014, Cariani & Santorio 2018). Analogously to the case of conditional restriction, restriction-by-subordination can leave the selection function with non-trivial work to do.

(iv) The theory does not even attempt to account for the future-orientation of sentences like *It will rain*. All temporal structure is idealized away.

1 Explanation: if w_0 is the actual world of c, then $w_0 \in D$ because w_0 must be a duplicate of itself up to the time of c. By centering, w_0 must be selected.

(v) Though the theory evaluates *will*-sentences relative to a single world, it makes no assumptions about the underlying metaphysical structure of the future. In particular, the theory is available to defenders of branching metaphysics as much as it is available to defenders of "divergence" metaphysics. This neutrality an be achieved by applying the supervaluation techniques of Thomason (1970).[2]

Cariani & Santorio (2018) give two kinds of arguments favoring the selectional account over a quantificational alternative.[3] Let us consider a baseline quantificational account. Let f be a historical modal base, returning for each world w and context c the set of its historical duplicates of w up to the time of c.

(3) $[\![will_f]\!] = \lambda p.\lambda w.\forall v \in f(w), p(v)$

According to this, bare forecasts express necessity restricted to the historical possibilities. (This is, in essence, the "Peircean future tense" of Prior 1967: ch. VII.) Contemporary defenders of quantificational theories typically endorse modified versions of (3).[4] The typical move is to inject a second dimension of modal relativity *via* an ordering source in the style of Kratzer's semantics for modals.[5] That said, (3) will suffice to highlight the shortcomings of all quantificational accounts.

The first argument against (3) is that it incorrectly predicts that *will* enters in non-trivial scope relations with negation.[6] If it did, we should be able to detect truth-conditional differences between *will*>*not* scope configurations and *not*>*will*. But we do not. It is tempting to file this under the more general category of idiosyncratic interaction between English modals and negation. But there is more to the case of *will*. We can sidestep the peculiar scope demands of English modals by using quantificational determiners that bundle in negation. Note that (4a) and (4b) are equivalent, while (4c) and (4d) are not (Higginbotham 1986, 2003).

2 Thomason's thesis is sometimes confused with a quantificational theory of *will* in the linguistics literature—e.g. in (Copley 2009: p.12), and Bochnak (2019). This is a misinterpretation of Thomason's formalism. The universal quantification introduced by the supervaluationist technique is not attached to any lexical item. Instead, it is a device to resolve indeterminacies (such as for example the indeterminacy concerning which world is actual in a branching setting).

3 Some of these arguments are anticipated by those who reject the modal future hypothesis, e.g. Kissine (2008). However, even when the insights are related, they are often developed differently. I will be agnostic on the status of those antecedents.

4 I ignore existential accounts, which are convincingly refuted in Kissine (2008).

5 The ordering source is normality-based in Copley (2009), probabilistic in Kaufmann (2005); and knowledge-based in Giannakidou & Mari (2017).

6 MacFarlane (2014), Schoubye & Rabern (2017), Cariani & Santorio (2018).

(4) a. Everyone will fail, if they goof off
b. No one will pass, if they goof off
c. Everyone has to fail, if they goof off
d. No one has to pass, if they goof off

Any satisfactory account of predictive expressions must explain why they appear to be "semantically scopeless" in such occurrences.[7]

Relatedly, Thomason (1970) notes that *It will rain or it will not rain* sounds like a logical truth. However, it is predicted false by the theory in (3) whenever there are historical possibilities in which it rains and ones in which it doesn't.

These arguments strike against most, but not all, quantificational theories. In particular, they are effectively defused by analyses of *will* that appeal to the phenomenon of homogeneity. This appeal is a core tenet of Copley's (2009, 2014) account (see also Kaufmann 2002: on the "presumption of settledness"). While Copley's theory is more complicated, amending (3) to (5) illustrates the essential idea.

(5) $[\![will_D]\!] = \lambda p.\lambda w : D$ is homogeneous w.r.t $p.\forall v \in D, p(v)$
where D is homogeneous w.r.t p iff either $D \subseteq p$ or $D \subseteq \overline{p}$

With some work (which I won't repeat here), this approach can capture the apparent equivalence of (4a) and (4b), and the validity of disjunctions of the form: *will* P *or will not* P.

Against this, Cariani and Santorio advance a second argument—one that involves judgments about credence.[8] Suppose that a genuinely indeterministic coin is tossed in a fair setup. The state of the world up to the present doesn't settle whether the coin will land heads or tails. Suppose also that you know all this. The key observation is that it is permissible — maybe even required — to have an intermediate credence, plausibly .5, in the proposition expressed by *the coin will land heads*. That is not predicted by the quantificational semantics in (3) nor by its homogeneity-enriched sibling (5). The information in the scenario, together with the semantics in (3), guarantees that $will_D$*(heads)* is false. After all, one can conclude only by reasoning with the given information that $will_D$*(heads)* expresses the empty proposition. One's credence in that proposition should

7 Some authors (Giannakidou & Mari 2017, Todd forthcoming) maintain that the behavior of *will* with respect to negation is sufficiently well explained by assuming that it always takes wide scope over negation. Unfortunately, these authors do not engage with data like the ones in (7).

8 The argument follows in a long tradition of leveraging credence judgments in semantics, though one that is limited to the philosophical literature. See Prior (1976), Belnap et al. (2001) in the future contingents literature; See also Edgington (2008), Santorio (2017, ms.), Mandelkern (forthcomingb) for similar credence-based arguments concerning conditionals.

be zero. The homogeneity semantics in (5) is minimally, but not substantially different: one's credence in $will_D$*(heads)* should be whatever is appropriate when one knows that a presupposition fails. Such a credence should arguably be zero (one knows something incompatible with the sentence's truth-condition) or undefined.

I find this argument convincing, but it sometimes generates the worry that it relies on judgments about rational credence that are not canonized in semantics. Behind this concern might be the reasonable further worry that the argument, embedded as it is in a more general theory of information and inquiry, involves unspoken assumptions that demand, at the very least, caution.

So, let me emphasize some related, but more conventional, problems. Probability operators, (e.g. *it is likely*) can turn judgments about credence into judgments about acceptability of a more standard sort. Suppose that the coin is 80% biased towards heads, while still keeping the setup indeterministic. In such a case, quantificational theories fail to predict the acceptability of

(6) it is likely that the coin will land heads

Retrospective evaluations dramatize this remark, as was noticed already in Prior (1976). Imagine that you have organized a parade for Tuesday. On Monday, your friend Nara says *it will rain tomorrow*. Tuesday arrives and it rains. This story is enough to put you in a position (on Tuesday) to recognize the truth of what Nara asserted. No quantificational view predicts this, however. After all, the conclusive evidence you obtained on Tuesday only settles how things went in *one* of Monday's historical possibilities. By contrast, if on Tuesday it didn't rain, you would be in a position to evaluate Nara's assertion as false. The upshot is that the truth-value of *it will rain* is entirely settled by the actual profile of its prejacent. Instead, quantificational theories must demand that other elements of the modal profile of the prejacent of *it will rain* matter to its evaluation.[9]

9 There is a non-standard relativist view that avoids this last argument. One might treat *will* as a quantificational modal with a historical modal base that is set by the context of assessment. This version of relativism shares with MacFarlane's the idea that bare forecasts are assessment sensitive (MacFarlane 2003, 2014). However, it diverges from his treatment in a crucial respect: MacFarlane doesn't think that *will* is a modal. He thinks instead that future-directed sentences are assessment sensitive at the post-compositional level that he calls the "post-semantics". In fact, no relativists accept the form of relativism I just sketched, and conversely, no modal theorists accept semantic relativism.

Of course, being non-standard doesn't make such a proposal wrong. But note also that it is still vulnerable to all the other arguments against quantificational theories.

2 Modal Bases in Selection Semantics

I take it that these considerations establish selection semantics as the correct framework for a modal analysis of *will*. But which selection-based theory is best?

Not the one in Cariani & Santorio (2018). That theory turns out to have a bug in a big place. It assigns the wrong modal profile to *will* sentences. While I illustrate the problem by considering the interaction between *will* and *might*, the issue is rather general. The same bug shows up in interactions between predictive expressions and epistemic attitude verbs, like *believe*, and probability operators. To illustrate the bug, let us consider a scenario: suppose that all of the historical possibilities — all of the worlds that duplicate the settled facts up to the time of the context — agree that it will rain tomorrow. However, due to my fallibility as an epistemic agent, my information state lets in some possibilities that are not historical possibilities. Let $\Diamond$ be an operator that tracks compatibility with one's information. Let f range over modal bases for this modal, once again represented here as an argument of the modal.

(7) $[\![\Diamond_f]\!] = \lambda p.\lambda w.\exists v \in f(w), p(v)$

Composing $\Diamond$ with Cariani and Santorio's *will* yields some bad predictions: true-sounding claims about possibility of future events come out false. Before unpacking this, let me highlight that it is not essential to my argument that the semantics in (7) be taken as a good analysis of epistemic *might* in English. Follow along in the argument by filling in your judgments about English *might* claims, but, if necessary, replace (7) with your favorite semantics for *might*.

Onto to the case. Recall that my information in w_0 is compatible with no rain tomorrow, even though rain is, in fact, historically settled (that is, even though it rains at all of the possible worlds that agree with the settled facts). In this setup, consider the sentence:

(8) It is possible that it will rain tomorrow

The expected prediction about this sentence in the given scenario is that it is true. So let w_0 be one of the worlds that agree with the settled historical facts. We expect:

(9) $[\![\Diamond_f(will_D(\text{it is sunny tomorrow}))]\!](w_0) = 1$

After all, it is possible, in the relevant epistemic sense, that it will be sunny tomorrow. Unfortunately, the theory does not deliver this. Let v be an epistemically but not historically possible world in which it is sunny. We expect v to witness the truth of the prejacent of $\Diamond_f$ in (9). That is:

(10) $[\![will_D(\text{it is sunny tomorrow})]\!](v) = 1$

However, this expectation is frustrated. The selected world must come from D and D is the set of historical possibilities *in the utterance context*. This requires $\sigma(v, D)$ to be a rain-world, since the historical possibilities in the utterance context were stipulated to all be rain worlds.

One of the most immediate reflections of the bug is that, contrary to what Cariani & Santorio (2018) say, the selection semantics framework lacks an explanation for the apparent inconsistency of sentences like:

(11) a. * It will rain but it might not
b. * It will rain but it is possible that it will not rain

I take these to differ in that only (11b) involves an embedding of *will* under epistemic possibility. But both are defective in a way that the package of semantics and pragmatics ought to explain.

Cariani & Santorio (2018: fn.4) lean on a suggestion by (Portner 2009: pp.239-240) to the effect that the badness of (11a) might be explained in whatever way we explain the badness of "epistemic contradictions" (Yalcin 2007) like:

(12) It is raining but it might not be

Yalcin's account of (12)—which I focus on for definiteness—is that (12) sounds inconsistent because no information state (modeled as a set of worlds) accepts it. Unfortunately, the analogous move does not work in the context of the bug-affected semantics. Consider an information state s consisting of two worlds w_1 (rainy) and w_2 (sunny) that are not historical duplicates. Suppose Sarah utters (11a) at w_1. By design, s accepts that it might not rain (in Yalcin's system a state accepts a *might*-claim iff some world in the state verifies the prejacent). The problem concerns the evaluation of the first conjunct. Under the present specifications, the domain D for *will* is $\{w_1\}$. For this reason, $\sigma(w_1, D) = \sigma(w_2, D) = w_1$. As a consequence, *it will rain* is accepted throughout s. for the critical reason that, even from the perspective of w_2, we must select w_1. Since both conjuncts are accepted in s, (11a) is accepted. The problem arises because of the bug: a bug free semantics should avoid the consequence that if *it will rain* is uttered in w_1, then it must be true at w_2. As for (11b), I have already noted that the bug-affected semantics does not handle embeddings of *will* under possibility operators.

The bug is easy enough to fix. Instead of requiring D to be a domain fixed once and for all by context, let it be more similar to a Kratzerian modal base — a function f that maps worlds to modal domains. The revised analysis is in (13), with its associated metasemantics in (14)

(13) $[\![will_f]\!] = \lambda p.\lambda w.p(\sigma(w, f(w)))$

(14) in context c, $f(w)$ is initially assigned to the function that maps each world w to the historical possibilities in w relative to context c

Recall that the idea of historical possibility in w relative to c is cashed out, on the present account in terms of duplication up to the time of c. If we assume, as seems plausible, that duplication is an equivalence relation, then f is a function that maps each world to the cell including all and only its duplicates (up to a certain point in time).

It is easy to see that this revised analysis delivers the prediction in (9):

(15) $[\![\Diamond_f(will_{f'}(\text{it is sunny tomorrow}))]\!](w_0) = 1$

To see why this works, return to the problem posed by the epistemically but not historically possible world v. When evaluating from v's perspective, our selection term is not $\sigma(v, D)$ but $\sigma(v, f'(v))$, which by centering returns v (the epistemically but not historically possible sunny world).

3 Selection Semantics and Future Orientation

None of this speaks to the future orientation of typical *will* sentences. Obviously, the eventuality that is described in a bare forecast must be located in the future for the sentence to be true.

(16) a. # I eat tomorrow
b. I will eat tomorrow

In English, bare present tense sentences like *I eat* cannot have future reference times.[10] Hence, (16a) is only acceptable on a "scheduled" reading, unlike its bare forecast counterpart in (16b). An adequate account of the semantic contribution of predictive expressions must capture their ability shift the evaluation of a sentence towards the future.

The selectionist theories I have considered punt on this task by declining to supply worlds with temporal structure. It is time to tackle this unfinished bit of the agenda. Start by enriching worlds with a series of times ordered by a temporal precedence relation $<$. Cariani & Santorio (2018) float an analysis of *will* that makes it *both* a selectional modal and a quantifier over times. To develop this idea, assume that sentences denote functions from world/time pairs to truth-value. Let **p** range over such functions. Next, extend the selection

10 There are, of course, present-directed, and epistemic-sounding, interpretations of *will*, given the appropriate frame adverbials and stative prejacents. See, Palmer (1987), Copley (2009), Klecha (2014), Giannakidou & Mari (2017), Ramchand (2017), Cariani & Santorio (2018), Bochnak (2019). Nothing I say here is incompatible with that, though I am not presently trying to *account* for those interpretations.

semantics insight so as to predict the (typical but not universal) future-orientation of *will*-sentences.

(17) $[\![will_f]\!] = \lambda \mathbf{p}.\lambda w.\lambda t.\exists t' > t, \mathbf{p}(\sigma(w, f(w)), t')$

The problem is that (17) undermines a key element of the motivation for selection semantics. It predicts non-trivial scope interactions between *will* and negation, because the existential quantifier in the denotation of *will* combines differently with negations scoping over or under it.

Before reaching for an alternative framework, it is valuable to consider a second elementary design principle that might appear problematic in the selectionist setting. Our assumption that *will* is scopeless, and the consequent rejection of (17), points towards a semantics that does away with existential quantification over times altogether. The problem is that that existential quantification did seem to be doing some explanatory work. Consider:

(18) a. I will eat tomorrow
b. I will not eat tomorrow

The bare forecast in (18a) shows *will* imposing an *existential* constraint on a relevant future interval: its truth only requires eating to happen at *some* time tomorrow. By contrast, (18b) imposes a *universal* constraint on that interval: (18b) does not say that some part of tomorrow will feature some not-eating; instead, it says that eating will not happen at *any point* tomorrow. This is puzzling for the defender of selection semantics, since I emphasized that the semantics must deny that *will* carries any quantificational structure. Where does this structure come from? Standard ideas from event semantics provide the answer: this quantification is over events and comes from the semantics of the prejacent—more specifically, from the contribution of perfective aspect (Klein 1994: ch.5, von Stechow & Beck 2015: §2.2).

The technical task I set for this section is to integrate this standard idea with the selectionist approach so as to predict the future orientation of *will* sentences. That integration is facilitated by the fact that there already are several unified frameworks involving events, worlds and times, such as Condoravdi (2002), Hacquard (2006), von Stechow & Beck (2015). Here, I integrate selection semantics with a modified version of Condoravdi's system, because it is the minimal basis on which to satisfy the design principles outlined above.[11]

11 With that said, Condoravdi (2002) is probably not the state of the art among those frameworks, and I do not intend to signal commitment to many of the key thesis of her framework. In addition to the alternatives noted above, see also Matthewson (2012), Klecha (2016) and Ramchand (2017).

For Condoravdi, *will* is future-oriented partly because it is a core lexical feature of modals that they can extend intervals of evaluation into the future.[12] Condoravdi appeals to the quantificational analysis of *will* I rejected above (Condoravdi 2002: p.13): *will* quantifies over historical possibilities and extends an interval of evaluation. Instead, I propose that *will* performs world selection and interval extension. This intervention will showcase the fruitful effects of integrating selection semantics with Condoravdi's system.

Moving on to the formalism, consider a toy language built out of "sentence radicals". These are tenseless descriptions of events or states (and accordingly further classified as *eventive* or *stative*). In addition, the toy language contains the following pronounced expressions: *not*, *and*, *will*. Following consensus among defenders of the modal future hypothesis, and in particular Abusch (1997), decompose *will* and *would* in terms of tense, and the modal morpheme WOLL. In particular, we decompose *will* as PRES+WOLL. (We will refrain from having past tense as well, but if we did, we'd also decompose *would* as PAST+WOLL.) The system allows composite tenses *via* a perfect operator PERF. Finally, in the next setion, we will consider an expansion of the language with modal operators such as *might*.

3.1 Models

I interpret this language against $W \times T$ structures (Thomason 1984), extended so as to include events and states. Specifically, define a model $\mathcal{M}$ as a 7-tuple $\langle \mathcal{W}, \mathcal{T}, \mathcal{E}, \approx_t, <, \tau, v \rangle$ where:

- $\mathcal{W}$, $\mathcal{T}$, and $\mathcal{E}$ are respectively non-empty sets of worlds, times and eventualities (events or states).
- $\approx_t$ is a relation between worlds indexed to a time. ($\mathcal{T} \mapsto \mathcal{W} \times \mathcal{W}$). Intuitively $w \approx_t v$ iff w and v are duplicates up to time t.
- $<$ is a irreflexive, transitive and linear relation on times ($\mathcal{T} \times \mathcal{T}$). Interpret this as the temporal precedence relation. I occasionally abuse notation and use $<$ to relate *intervals* i.e. convex sets of times, so that $\mathcal{I}_1 < \mathcal{I}_2$ iff every point in $\mathcal{I}_1$ precedes every point in $\mathcal{I}_2$.
- τ is a function from event/world pairs to intervals ($\mathcal{E} \times \mathcal{W} \mapsto \mathcal{P}(\mathcal{T})$). Intuitively, $\tau(e, w)$ is the temporal trace of e in w.

12 This is not to say that all modal sentences end up being future oriented. In Condoravdi's system, modals scoping under perfect can get non-future oriented interpretations.

- v is a valuation function that inputs a sentence radical P, an event e and a world w. It outputs 1 if e is an eventuality in w and P describes e; 0 otherwise.

For a guiding example of what it is for a radical to describe an event, think about the relationship between *They win* and events of winning by the referenced group.

It is convenient to state the semantics with the help of the following abbreviations.

- if $\mathcal{I}$ is any interval, $\textsc{ext}(\mathcal{I})$ is the extension of $\mathcal{I}$ towards the future.

  $$\textsc{ext}(\mathcal{I}) = \mathcal{I} \cup \{x \in \mathcal{T} \mid \text{for all } t \in \mathcal{I}, x > t\}$$

- *now*: the present moment, given a context. (not an interval)
- σ: a selection function (provided by context), satisfying:

  success: for $w \in \mathcal{W}$, $p \subseteq \mathcal{W}$ with $p \neq \emptyset$, $\sigma(w,p) \in p$

  centering: for $w \in \mathcal{W}$, $p \subseteq \mathcal{W}$ with $w \in p$, $\sigma(w,p) = w$

- f: a modal base (provided as an argument to WOLL)
- $\circ$: the overlap relation between intervals

3.2 Semantics

Onto the semantic theory. Start with the evaluation of radicals. Reserve Q for eventive sentence radicals and R for stative sentence radicals.

$$[\![\mathsf{Q}]\!] = \lambda w.\lambda \mathcal{I}.\exists e(v(\mathsf{Q},e,w) = 1 \ \& \ \tau(e,w) \subseteq \mathcal{I})$$

$$[\![\mathsf{R}]\!] = \lambda w.\lambda \mathcal{I}.\exists e(v(\mathsf{R},e,w) = 1 \ \& \ \tau(e,w) \circ \mathcal{I})$$

An eventive radical, such as *I go home* is true at w and $\mathcal{I}$ iff the temporal trace of my going home in w is wholly included in $\mathcal{I}$. A stative radical, such as *I be home* is true at w and $\mathcal{I}$ iff the temporal trace of my staying home overlaps $\mathcal{I}$.[13]

In Condoravdi's system, sentences denote functions from worlds to truth values. However, much of the semantic computation manipulates functions from world-interval pairs to truth values. Call such functions *interval intensions* and reserve upper-case bold variables like **P** to range over them. (Note that

13 Condoravdi also considers "temporal properties", but have slightly modified her setup to make them unnecessary while still retrieving the same truth-conditions for clauses.

the denotations of sentence radicals are interval intensions.) In this system, an important job of tense is to input interval intensions and output propositions (i.e. sets of worlds). Indeed, tenses head clauses and part of their semantic role is to saturate temporal interval arguments. In particular, the semantic entry for PRES is:

$$[\![\text{PRES}]\!] = \lambda \mathbf{P}.\lambda w.\mathbf{P}(w,\{now\})$$

This analysis makes PRES an indexical: PRES(I be home) is true at a world w just in case there is a state corresponding to me being home that occurs in w and overlaps the time of context of utterance. Several well-known anaphoric effects involving tense cannot be captured under this indexical analysis (Grønn & von Stechow 2016). Such effects may be captured by an alternative analysis—for instance by letting the interval of evaluation for PRES be the reference of a covert variable. While it seems plausible to me that tenses might be ambiguous between anaphoric and indexical, I won't expand this line of thought here.

Though I won't make much use of it, it is important to note that Condoravdi provides an analysis for perfect:

$$[\![\text{PERF}]\!] = \lambda \mathbf{P}.\lambda w.\lambda \mathcal{I}.\exists \mathcal{I}^* < \mathcal{I}, \mathbf{P}(w,\mathcal{I}^*)$$

Note that unlike tenses, PERF outputs an interval intension. Only simple tenses saturate the interval argument in the system, and in this system the perfect is not a simple tense but a device to create composite tenses. Though Condoravdi does not discuss past tense operators, the natural entry within her framework would make PAST$(\cdot)$ equivalent to PRES(PERF$(\cdot)$).

We can now implement the selection semantics for WOLL. In accordance with our design specifications, WOLL makes two contributions. It selects a world out of the historical modal base and it extends the interval of evaluation into the future.

$$[\![\text{WOLL}]\!] = \lambda f.\lambda \mathbf{P}.\lambda w.\lambda \mathcal{I}.\mathbf{P}(\sigma(w,f(w)),\text{EXT}(\mathcal{I}))$$

Neither effect involves quantification and, as we will see shortly, the resulting theory happily predicts that *will* and *not* commute.

Negation needs to operate at two different types. Clausal negation operates on propositions.

$$[\![not]\!] = \lambda p_{\langle s,t\rangle}.\lambda w.p(w) = 0$$

However, structures like PRES(*might*(*not*(*he be sad*))) must be allowed too. Such structures require negation to operate at the sub-clausal level and thus to apply to objects of the appropriate type—in this case, interval intensions.

$$[\![not]\!] = \lambda \mathbf{P}.\lambda w.\lambda \mathcal{I}.\mathbf{P}(w,\mathcal{I}) = 0$$

I will be neutral here on how this behavior is derived—whether by type-shifting, polymorphism, or ambiguity. As for conjunction, we will only need clause-level conjunction, endowed with standard Boolean semantics.

Here is an illustration of the truth-conditions that this system projects on bare forecasts with eventive prejacents, like *I will eat*:

Truth conditions for *will* P (for P eventive)

i. $[\![will_f(\mathsf{P})]\!] = [\![\textsc{pres}(\textsc{woll}(f, \mathsf{P}))]\!] = [\![\textsc{pres}]\!][\![(\textsc{woll}(f, \mathsf{P}))]\!]$

ii. $[\![\textsc{woll}(f, \mathsf{P})]\!] =$

$= \lambda w.\lambda \mathcal{I}.\exists e(\nu(\mathsf{P}, e, \sigma(w, f(w))) = 1 \ \& \ \tau(e, \sigma(w, f(w))) \subseteq \textsc{ext}(\mathcal{I}))$

Putting i. and ii. together and saturating the interval argument with PRES:

iii. $[\![will_f(\mathsf{P})]\!] =$

$= \lambda w.\exists e(\nu(\mathsf{P}, e, \sigma(w, f(w))) = 1 \ \& \ \tau(e, \sigma(w, f(w))) \subseteq \textsc{ext}(\{now\}))$

4 Applications

In this section I identify and prove four general facts that show that the semantics satisfies the design constraints that motivated it. To start, note by inspecting the result of the derivation above that the semantics does have bare forecasts shift the evaluation of their prejacents towards the future. The mission to give selection semantics an account of future orientation is accomplished. The question is: have we accomplished this in a way that is consistent with the remainder of our motivation?

4.1 On the *will* - *not* interaction

The basic desideratum, inherited from Cariani & Santorio (2018), was to have the system be such that *not* and *will* commute. This is where the proposal in (17) failed.

Fact 1 *will* P *and* will not *P have complementary truth conditions*

Consider the case of eventive prejacents and recall the truth conditions for *will* P we just derived, namely:

$$\lambda w.\exists e(\nu(\mathsf{P}, e, \sigma(w, f(w))) = 1 \ \& \ \tau(e, \sigma(w, f(w))) \subseteq \textsc{ext}(\{now\}))$$

Truth-conditions for *will*(*not* P) (for P eventive)

i. $[\![will_f\,(not\ \mathsf{P})]\!] = [\![\textsc{pres}(\textsc{woll}(f,\ not\ \mathsf{P}))]\!] = [\![\textsc{pres}]\!][\![(\textsc{woll}(f,\ not\ \mathsf{P}))]\!]$

ii. $[\![not]\!]([\![\mathsf{P}]\!]) = \lambda w.\lambda\mathcal{I}.\neg\exists e(v(\mathsf{P},e,w) = 1\ \&\ \tau(e,w) \subseteq \mathcal{I})$

iii. $[\![\textsc{woll}(f,\ not\ \ \mathsf{P})]\!] =$

$= \lambda w.\lambda\mathcal{I}.\neg\exists e(v(\mathsf{P},e,\sigma(w,f(w))) = 1\ \&\ \tau(e,\sigma(w,f(w))) \subseteq \mathcal{I})$

iv. $[\![will_f\,(\text{not}\ \mathsf{P})]\!] =$

$= \lambda w.\neg\exists e(v(\mathsf{P},e,\sigma(w,f(w))) = 1\ \&\ \tau(e,\sigma(w,f(w))) \subseteq \textsc{ext}(\{now\}))$

Incidentally, these derivations highlight a second fact.

Fact 2 *Bare forecasts quantify existentially over events while sentences of the form* will not *P quantify universally over events.*

It is the quantification over events we baked into our account of sentence radicals—and not quantification over times—that accounts for why bare forecasts have existential force.

4.2 Future *might* contradictions

Finally, let us investigate the relationship between selectional *will* and possibility operators. Focus on sentences like:

(19) a. It will rain but it might not
b. It will rain but it is possible that it will not rain

Call these *future might contradictions*, FMCs for short. I claim that the inconsistency of FMCs can be explained by the same moves that explain the inconsistency of epistemic contradictions (like *It is raining but it might not be*). In making this argument, I won't consider every possible explanation of the infelicity of epistemic contradictions. Instead, I show how Yalcin's (2007) account might be adapted to the present context.[14]

Yalcin argues *it's raining but it might not be* is *informationally* inconsistent, in the sense that no information state can accept it. To replicate his reasoning, we must characterize this notion of informational inconsistency and distinguish it from the classical notion. *Classical entailment* is corresponds, in the present context, to preservation of truth at a world. A sentence P is *classically inconsistent*

14 This need not count as an endorsement of Yalcin's solution. For alternatives, see Dorr & Hawthorne (2013), Mandelkern (forthcominga), Stojnić (forthcoming)

iff P is true at no worlds. Under *informational entailment*, premises $P_1, ..., P_x$ entail a conclusion Q iff there is no state accepts all of the P_i's but rejects Q. Formally, say that an information state s is a set of worlds. Say that s accepts a sentence P iff for every world $w \in s$, $P(w) = 1$. Then say that $P_1, ..., P_x$ *informationally entail* Q iff there is no information state that accepts each of the premises but does not accept the conclusion. A sentence is informationally inconsistent iff no state accepts it.

What we must verify then is that (19a) is informationally inconsistent in this sense. Start by assuming that (19a) and (19b) have these logical forms:

(20) a. $will_f(P)$ & $\textsc{pres}(might_{f'}\ not\ P)$
b. $will_f(P)$ & $\textsc{pres}(might_{f'}\ will_f\ not\ P)$

Since the same facts are true of both of these forms, I collapse the presentation and focus only on (20a).

The key choice point for our purposes is whether the *might* in (19a) is historical or epistemic. I consider both possibilities below.[15] Under the *historical option*, *might* and *will* have the same modal base: the function that assigns to each world w the set of historical possibilities in w. If this option is adopted we follow Condoravdi in giving *might* has a semantics that combines existential quantification over a modal base and interval extension.

$$[\![might]\!] = \lambda f.\lambda \mathbf{P}.\lambda w.\lambda \mathcal{I}.\exists v \in f(w).\mathbf{P}(v, \textsc{ext}(\mathcal{I}))$$

Under the *epistemic option*, since we aim to replicate Yalcin's reasoning, *might* needs a denotation that is as close as possible to the one in Yalcin (2007). In that system, *might* constrains states of information and does not constrain worlds. Accordingly, I use s in the formulation below to range over functions from worlds to truth-values—i.e., sets of worlds.

$$[\![might]\!] = \lambda \mathbf{P}.\lambda s.\lambda w.\lambda \mathcal{I}.\exists v \in s.\mathbf{P}(v, \textsc{ext}(\mathcal{I}))$$

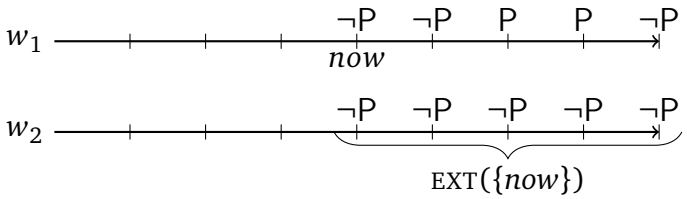
To simulate Yalcin's system all the types of the other expressions must be raised with (possibly vacuous) abstractions over states

We can now state and prove the last couple of facts:

Fact 3 *Under the epistemic assumption, the schemas in* (20a) *and* (20b) *are pointwise consistent, but informationally inconsistent.*

15 Condoravdi (2002) suggests that *might* can either have (i) a future-oriented historical interpretation or (ii) a present-oriented epistemic one—while allowing that there could be (iii) future-oriented epistemic examples. Klecha (2016) gives several interesting arguments against this third possibility in the case of *might*. But even so we must consider both options, since *may* seems to have future-oriented epistemic interpretations and to give rise to analogues of FMCs.

Proof of pointwise consistency: let $s = \{w_1, w_2\}$ such that w_1 verifies P during EXT($\{now\}$); w_2 verifies *not* P during that same interval. For example:



Consider applying $[\![might]\!]$ and $[\![will_f]\!]$ to the appropriate inputs

$$[\![\textit{might not P}]\!](s, w_1, \text{EXT}(\{now\})) = \exists v \in s.[\![P]\!](v, \text{EXT}(\{now\}))$$
$$[\![\text{will}_f \text{ P}]\!](s, w_1, \text{EXT}(\{now\})) = [\![P]\!](\sigma(v, f(w_1)), \text{EXT}(\{now\})) = [\![P]\!](w_1, \text{EXT}(\{now\}))$$

These are evidently both true in our current setting.

Proof of informational inconsistency: suppose by *reductio* that information state s accepts a FMC. In particular, s must accept PRES(*might not* P). Hence, there is a world $z \in s$ such that

$$(*) \quad [\![\textit{not P}]\!](z, \text{EXT}(\{now\})) = 1$$

However, since $z \in s$ and s accepts $will_f(\mathsf{P})$, $[\![will_f(\mathsf{P})]\!](z) = 1$; this requires

$$(**) \quad 1 = [\![\mathsf{P}]\!](\sigma(z, f(z), \text{EXT}(\{now\})) = [\![\mathsf{P}]\!](z, \text{EXT}(\{now\}))$$

The second equality is justified by centering. Evidently the chain of equalities in (**) contradicts (*), concluding our proof of informational inconsistency.

Under the historical assumption—the assumption that the *might* in FMCs is historical—there is an additional difficulty. We need to prove that (20a) is informationally inconsistent. As it turns out, this requires an additional stipulation. The assumption we need is that information states cannot distinguish between worlds that are historical duplicates. In other words, if two worlds share the exact same history, then no information state can distinguish them.[16] We implement

16 The philosophical interpretation of this condition is of great interest, as it appears to be a moderate version of skepticism about the future. In the present context, we set those matters aside and focus on exploring the consequences of the assumption for the interpretation of FMC's.

that assumption as a restriction on the set of admissible states in context c. We say that s is admissible in c iff $f_c(w) \subseteq s$ where f is the historical modal base in c defined above. Then we claim that the definition of informational inconsistency ranges only over admissible states.

Fact 4 *Under the historical assumption and the epistemic openness of historical possibilities, sentences of the form* (20a) *are point-wise consistent, but informationally inconsistent.*

> *Proof of pointwise consistency:* this is the same as the proof of Fact 3, with one small change. Instead of supposing that $\{w_1, w_2\}$ represents an information state, assume that $\{w_1, w_2\}$ is the historical modal base. The same reasoning goes through *mutatis mutandis*.
>
> *Proof of informational inconsistency:* suppose by *reductio* that a state s that is admissible in c accepts a FMC. So, s must accept $\textsc{pres}(\textit{might}_{f'}\ \textit{not}\ \mathsf{P})$—where f' is the historical modal base in c. This must mean that for every world $v \in s$ there is a world $z \in f'(v)$ that verifies *not* P relative to $\textsc{ext}(\{now\})$. Since s is an admissible information state, $f'(v) \subseteq s$. By this and $z \in f'(v)$, we must have $z \in s$. This means that there is a world z in state s that verifies *not* P. However, this is incompatible with s accepting $will_f(\mathsf{P})$, since it would demand that z verify $will_f(\mathsf{P})$.[17]

Taking stock, the present strategy was to assimilate future might contradictions (FMCs) to epistemic contradictions. To execute this strategy, we implemented a close analogue to Yalcin's account in terms of informational inconsistency. We noted that FMCs are indeed informationally inconsistent.

This is dialectically significant: Kissine (2008, 2014) leverages such sentences to challenge modal theories of *will*. According to him, to account for the incompatibility of FMCs,[18] modal theories must collapse $will_f(\mathsf{P})$, on the one hand, and $\textsc{pres}(might(will_f\,\mathsf{P})$, on the other. Kissine gets to his collapse result because he has a particular kind of account of FMCs in mind: he thinks that modal theorists must derive the inconsistency of FMCs by imposing constraints on the accessibility relation of *will*. It is those constraints that cause the collapse. However, the

17 This argument might appear marred by the fact that we had to appeal to the Epistemic Openness assumption. For what it's worth, I believe that this assumption is indispensable even for *non-modal* analyses of *will* (as long as one is attempting to replicate the informational inconsistency account and one assumes that the *might* in FMCs is historical).

18 Kissine considers separately the case of $\neg will_f(\mathsf{P})$ & $\textsc{pres}(might_{f'}\mathsf{P})$ because he is targeting quantificational analyses

account I provided here avoids both this path and the collapse result. (I state, while omitting the obvious proof, that in the present system $will_f(\mathsf{P})$ is pointwise stronger than $\textsc{pres}(might_{f'}\mathsf{P})$.) Indeed, the truth-conditions that selection semantics bestows onto bare forecasts are equivalent to the truth-conditions that a non-modal theory would bestow on such predictions. The modal nature of predictive expressions is not detectable in bare forecasts. In light of that, our default expectation should be that, whatever path a non-modal theorist might choose to account for the incompatibility of FMCs can be replicated in the selectionist setting.

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