Maximal Informativity Accounts for the Distribution of Temporal *in*-Adverbials*

Vincent Rouillard
vrouillard@fas.harvard.edu
https://orcid.org/0000-0003-0982-1596

Harvard University
Cambridge, United States of America

Abstract

Temporal *in*-adverbials lead a double life. Under one guise, they specify the durations of events; under another, they specify the durations of stretches of time throughout which certain events do *not* take place. Each variety comes with its own seemingly idiosyncratic distributional restrictions. The distribution of the first class of expressions is restricted by the lexical aspect of VPs (Vendler, 1967; Dowty, 1979; Krifka, 1989, i.a.). The distribution of the second class is restricted by the polarity of the sentences in which they occur (Gajewski, 2005, 2007; Hoeksema, 2006; Iatridou & Zeijlstra, 2017, 2021). I argue for a unified semantic analysis of both classes, which derives from one semantic principle their eclectic distribution: it must be possible for temporal *in*-adverbials to provide a maximally informative measure.

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1 Introduction

Among the list of its temporal modifiers, the English language includes the class of *temporal in-adverbials* (TIAs). The focus of this article will be on the distribution of one subclass of TIAs, viz. those whose measure phrase consists of a numeral and a measure word (e.g. *in three days*). I exclude from my presentation any discussion of TIAs whose measure phrases consist of either a definite description (e.g. *in the last three days*) or a bare measure word (e.g. *in days*). However narrow this focus may seem, it will allow us to dampen much noise and to hone in on an intriguing property of TIAs: these expressions lead a double life. Under one guise, they tell us about the durations of events.[1] For example, the TIA in (1-a) is most naturally interpreted as telling us how long it took Mary to write an entire paper. I will refer to TIAs of this sort as *event TIAs* (E-TIAs). The contrast in (1) illustrates how the acceptability of E-TIAs hinges on the lexical properties of the VPs they appear with.

(1) a. Mary wrote up a paper in three days.
b. *Mary was sick in three days.

The sentences in (1) differ in terms of the lexical aspect of their VPs: the VP in (1-a) is *telic* but is *atelic* in (1-b). The distinction is originally Garey's (1957) and, although it bears some similarity to the difference between *accomplishment terms* and *activity terms* in Vendler (1957, 1967), it is quite a bit more broad. Telic VPs describe events that reach some necessary end; atelic VPs describe events that may or may not reach such an end. Thus an event can only be described by *write up a paper* if it ends with a paper beeing written, whereas the events described by *be sick* include any portion of some protracted illness as well as any bout of illness that ends in (for example) a full recovery. The telic/atelic distinction has long been understood to be a determining factor in the distribution of E-TIAs: they are acceptable with telic but not atelic VPs (Vendler, 1967; Dowty, 1979; Krifka, 1989, i.a.). Yet, as revealed by (2-a), some TIAs are perfectly fine with atelic VPs.

(2) a. Mary hasn't been sick in three days.
b. *Mary has been sick in three days.

Here, *in three days* isn't an E-TIA: it does not specify the duration of a sickness event, but instead that of a stretch of time throughout which Mary wasn't sick. On its most natural interpretation, (2-a) states that a three-day gap stands between Mary's last period of illness and the present moment. I refer to such expressions as *gap TIAs* (G-TIAs). As the contrast in (2) makes plain, G-TIAs are *negative polarity items* (NPIs).

Semantic explanations have been offered for both why E-TIAs reject atelic predicates (Dowty, 1979; Krifka, 1989, 1998, i.a.) and why G-TIAs are NPIs (Gajewski, 2005, 2007; Hoeksema, 2006; Iatridou & Zeijlstra, 2017, 2021). Yet, hardly anything has been said about how the two types of expressions relate. In this article, I propose a semantic unification of E- and G-TIAs and go on to show that a single principle accounts for their distributional properties. The theoretical underpinnings of this principle rest on the notion of *maximal informativity* (Beck & Rullmann, 1999; Fox & Hackl, 2006; von Fintel et al., 2014, i.a.): in very rough terms, a TIA is only acceptable when it can measure with absolute precision.

In the course of this paper, it will become apparent that the perfect tense is a crucial element in the E-/U-perfect ambiguity. Some time will be spent motivating amendments

[1] I use the term *event* as a catch-all for things in the extension of a VP, be they events, states, or processes (cf. *eventualities* in Bach (1986)).

that I bring to the semantics of the perfect, which I argue denotes a quantificational expression restricted to *open intervals*. This assumption will turn out to be a key ingredient in deriving the polairty sensitivity of G-TIAs.

Much ground will be covered in the pages to follow. In §2, I lay down the formal apparatus upon which I rely throughout the course of the paper. In §3, I flesh out the details of my unified analysis of TIAs. In §4, I show how maximal informativity can account for both the distributions of E- and G-TIAs. In §5, I provide extensive motivation for the claim that the perfect must be a quantifier restricted to open intervals. In §6, I compare my analysis to prior accounts of the polarity sensitivity of G-TIAs. Finally, §7 concludes.

2 Technical Background

2.1 Formal Conventions

I assume the existence of a domain of entities $\mathtt{D_e}$, of truth-values $\mathtt{D_t}$, of events $\mathtt{D_v}$, of times $\mathtt{D_i}$, and of numbers $\mathtt{D_n}$. Each of these comprises the elements that belong to a basic semantic type. I employ a bivalent semantics where $\mathtt{D_t} = \{\top, \bot\}$; $\mathtt{D_i}$ includes a set of time-atoms (i.e. moments); $\mathtt{D_n}$ includes the set of real numbers.

For any two semantic types σ and τ, I write $(\sigma\tau)$ as the type of functions from objects of type σ to those of type τ (Winter, 2016). For any type σ, we also have the type $(\mathtt{s}\sigma)$ of functions from possible worlds to objects of type σ. Type construction is right-associative and parentheses are spared as much as possible. For example, $((\mathtt{s}(\mathtt{et}))((\mathtt{s}(\mathtt{et}))\mathtt{t}))$ can be simplified to $(\mathtt{set})(\mathtt{set})\mathtt{t}$. The same principle is employed to minimize the number of brackets in the syntactic representations of natural language sentences, where sisterhood is right-associative.

When unspecified for type, variables are represented as $\mathtt{x}, \mathtt{y}, \mathtt{z}, \mathtt{z}^1, \mathtt{z}^2, \ldots$; variables of type $\mathtt{v}$ are represented as $\mathtt{e}, \mathtt{e}^1, \mathtt{e}^2, \ldots$; variables of type $\mathtt{i}$ as $\mathtt{t}, \mathtt{t}^1, \mathtt{t}^2, \ldots$; as a special case, variables of type $\mathtt{i}$ assigned to moments are represented as $\mathtt{m}, \mathtt{m}^1, \mathtt{m}^2, \ldots$; variables of type $\mathtt{n}$ as $\mathtt{n}, \mathtt{n}^1, \mathtt{n}^2, \ldots$; variables ranging over worlds are represented as $\mathtt{w}, \mathtt{w}^1, \mathtt{w}^2, \ldots$

The interpretation function $[\![\cdot]\!]^{\mathtt{u},\mathtt{s},\mathtt{g}}$ is parameterized by a world of evaluation $\mathtt{u}$, a time of evaluation $\mathtt{s}$, and an assignment function $\mathtt{g}$. For any sentence being interpreted, $\mathtt{s}$ is assigned the time of its utterance. I assume that a sentence's utterance time is always momentaneous. Parameters are omitted when inconsequential to the interpretation of an expression. Semantic composition proceeds according to the familiar rules from Heim & Kratzer (1998).

2.2 Structures and Maps

The majority of this section is taken straight out of Krifka's (1989) seminal work, which lays down the foundations for structure preserving mappings between structured individual domains. While I remain quite faithful to his account, I will be flagging significant points of departure as they arise.

The topics discussed here are presented semi-formally; a more in depth discussion of some of them is given in the Appendix. The goal here is to provide the reader with an understanding of how structures on the domains of events and times are related to the strict ordering of the real numbers used for measurement. The tools discussed here will prove useful for understanding how expressions like *in three days* can go about measuring either the durations of events (E-TIAs) or those of simple timespans (G-TIAs). We will see that, ultimately, the measurement of events is done through the measurement of times onto which they are mapped.

2.2.1 Part Structures on Events and Times

Like Krifka (1989, 1991, 1998), I assume that both the domain of events $\mathtt{D_v}$ and the domain of times $\mathtt{D_i}$ are structured by the kinds of lattices first developed in Link (1983), which have come to be known as *part structures*.

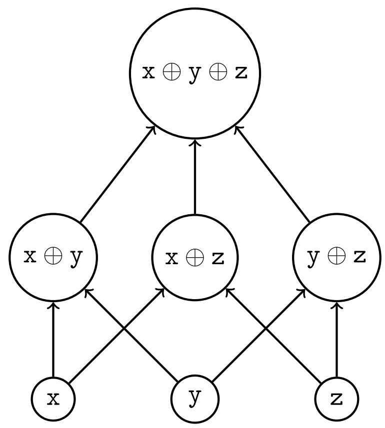

Figure 1: Example part structure.

For a given domain $\mathtt{D}_\sigma$, a part structure is a kind of partial order induced by a *part-whole relation* $\sqsubseteq_\sigma$; $\sqsubseteq_\sigma$ and the *sum operation* $\oplus_\sigma$ are interdefinable; the *proper part-whole relation* $\sqsubset_\sigma$ is the strict counterpart of $\sqsubseteq_\sigma$; the *overlap relation* $\otimes_\sigma$ holds of any two individuals that share a part in common.

(3) a. $\mathtt{x} \sqsubseteq_\sigma \mathtt{y} :\leftrightarrow \mathtt{x} \oplus_\sigma \mathtt{y} = \mathtt{y}$
    b. $\mathtt{x} \sqsubset_\sigma \mathtt{y} :\leftrightarrow \mathtt{x} \sqsubseteq_\sigma \mathtt{y} \wedge \mathtt{x} \neq \mathtt{y}$
    c. $\mathtt{x} \otimes_\sigma \mathtt{y} :\leftrightarrow \exists \mathtt{z} \in \mathtt{D}_\sigma(\mathtt{z} \sqsubseteq_\sigma \mathtt{x} \wedge \mathtt{z} \sqsubseteq_\sigma \mathtt{y})$

$\mathtt{D}_\sigma$ may or may not include *atoms* (i.e. individuals belonging to $\mathtt{D}_\sigma$ without proper parts that are also in $\mathtt{D}_\sigma$). I leave open whether or not there are atoms in $\mathtt{D_v}$. Like Krifka (1989, 1991), however, I assume that members $\mathtt{D_i}$ are all composed of time-atoms, i.e. *moments* (but *cf.* Krifka, 1998).

2.2.2 From Events to Times and from Times to Numbers

Events occur at times and those times have durations. What relationship is there between the parts of an event and the parts of the time at which it takes place, and what is the relationship between the duration of a time and the durations of its parts? Both questions can be answered once we have in hand the right structure preserving maps from domain to domain. One such map is the *runtime* (or *temporal trace*) function τ, which is a function from events onto their runtimes, i.e. the times at which they take place. It is a homomorphism that preserves the part structure of events in that of times (Krifka, 1989): the runtime of a sum of events is always the sum of their runtimes.

(4) $\forall \mathtt{e}^1, \mathtt{e}^2(\tau(\mathtt{e}^1 \oplus_{\mathtt{v}} \mathtt{e}^2) = \tau(\mathtt{e}^1) \oplus_{\mathtt{i}} \tau(\mathtt{e}^2))$

A measure function μ is another example of a (possibly partial) structure preserving map, this one onto the set real numbers $\mathbb{R}$. To define a measure function for times, we require a means of comparing their magnitudes. Clearly, the part relation on times must play a part in this: we want the magnitude of a sum of times to exceed that of each of the parts being summed. But μ cannot rely on the part-whole relation alone since we find times which are incomparable relative to parthood. In Figure 1, for instance, it is neither the case that $\mathtt{x}$ is part of $\mathtt{y}$ nor that $\mathtt{y}$ is part of $\mathtt{x}$. Our measure function must therefore rely upon a relation within which all times are comparable (or at least all times to which the measure function can be reasonably applied). To this end, it must refer back to a *total preorder* $\lesssim_\mu$ which specifies, for all times that stand in the relation, what their relative magnitudes are.

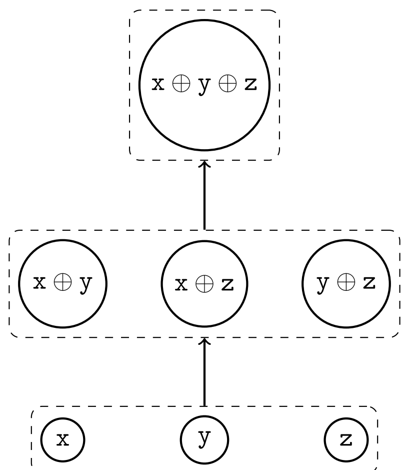

Figure 2: Example Total Preorder.

We want the preorder to be a continuation of (a possibly restricted portion of) the part-whole relation: for any pair of times that stand in the $\lesssim_\mu$ relation, it should be the case that $\mathtt{t}^1 \sqsubseteq_{\mathtt{i}} \mathtt{t}^2$ implies that $\mathtt{t}^1 \lesssim_\mu \mathtt{t}^2$. Moreover, as already mentioned, we want the magnitudes of a time's proper parts to be strictly less than its own. To achieve these desiderata, we must first assume that μ maps times onto real numbers such that the structure of the total preorder is preserved in that of the total order that $\leq$ imposes on the reals.

(5) $\forall \mathtt{t}^1, \mathtt{t}^2 \in \mathtt{dom}(\mu) : \mathtt{t}^1 \lesssim_\mu \mathtt{t}^2 \leftrightarrow \mu(\mathtt{t}^1) \leq \mu(\mathtt{t}^2)$

We can already think of a total preorder in terms of a total order between equivalence classes, where each class groups together times that share the same magnitude (i.e. times $\mathtt{t}^1$ and $\mathtt{t}^2$ such that $\mathtt{t}^1 \lesssim_\mu \mathtt{t}^2$ and $\mathtt{t}^2 \lesssim_\mu \mathtt{t}^1$). We can think of the measure function as collapsing each equivalence class into a numerical value that reflects the magnitude of its members.

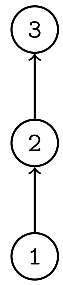

Figure 3: Example Total Order.

We now need to map our part structure onto our preorder to make sure the magnitude of a time grows as we add new parts to it. The first step is to make μ additive: the measure of a sum of two times is always the same as the sum of their measures. As Krifka (1989, 1998) points out, however, we must exert caution when handling the measures of overlapping times. If the measure of a sum of overlapping times $\mathtt{t}^1$ and $\mathtt{t}^2$ were the sum of the measures of $\mathtt{t}^1$ and $\mathtt{t}^2$, we would end up counting their overlap twice. To avoid this, Krifka restricts his definition of additivity to only non-overlapping individuals.

(6) $\forall \mathtt{t}^1, \mathtt{t}^2 \in \mathtt{dom}(\mu) : \neg \mathtt{t}^1 \otimes_{\mathtt{i}} \mathtt{t}^2 \rightarrow \mu(\mathtt{t}^1 \oplus_{\mathtt{i}} \mathtt{t}^2) = \mu(\mathtt{t}^1) + \mu(\mathtt{t}^2)$

This doesn't actually prevent us from measuring the sums of overlapping times. With the right axiomatization of part structure, we can ensure that a sum of overlapping times is always describable in terms of non-overlapping times; the measure of any sum of times can thus always be rendered as the sum of non-overlapping times (see Appendix).

Together, (5) and (6) make μ an *extensive measure function* (e.g. Krantz et al., 1971). As things stand, we don't yet guarantee that adding parts to a time increases its magnitude. This is because nothing stops us from assigning negative values to times. Turning once more to Figure 1, it could be that $\mu(\mathtt{x}) = \mu(\mathtt{y}) = -\mathtt{1}$, in which case $\mu(\mathtt{x} \oplus_\sigma \mathtt{y}) = -\mathtt{2}$. This satisfies additivity, but the increase in parts results in a decrease in measure. We can avoid this by assuming that μ is *positive*: the measure of a sum of non-overlapping times is always strictly greater than that of any of its parts.

(7) $\forall \mathtt{t}^1, \mathtt{t}^2 \in \mathtt{dom}(\mu) : \neg \mathtt{t}^1 \otimes_{\mathtt{i}} \mathtt{t}^2 \rightarrow \mu(\mathtt{t}^1) < \mu(\mathtt{t}^1 \oplus_{\mathtt{i}} \mathtt{t}^2)$

I leave to the reader the task of verifying that our desiderata are met. As a final comment, note that positivity entails that the measure of any of the times that stands in the preorder relation $\lesssim_\mu$ (i.e. any time for which μ is defined) must be greater than $\mathtt{0}$. The range of μ is therefore the set of positive real numbers $\mathbb{R}^+$.

2.2.3 The Domain of Temporal Measurement

I've hinted at the fact that the set of times that stand in the $\lesssim_\mu$-relation may be more restricted than those that stand in the $\sqsubseteq_{\mathtt{i}}$-relation. I will take a moment here to say something about what kinds of times it is reasonable for us to be measuring. Although Krifka (1989) is not explicit on the matter, intuitions are fairly clear: the sorts of times that it makes any sense to measure are almost exclusively timespans, i.e. *intervals* of time. I say *almost* because we can also sensibly add up the measures disjoint intervals. For example, if yesterday Mary wrote half of a paper in two hours and today she wrote the other half in three hours, it is appropriate to say that she wrote the paper in five hours. What we can measure are therefore times comprised of at least one interval.

In order to define what intervals are, we will refer to a temporal *precedence relation* $\preceq_{\mathtt{i}}$. When restricted to moments, both $\preceq_{\mathtt{i}}$ and the corresponding strict counterpart $\prec_{\mathtt{i}}$ are total orders. For any pair of moments, one of them must precede the other. Moments are therefore organized in what can naturally be understood as a *timeline*. Note that, contrary to colloquial usage, precedence is here reflexive: a time always precedes itself. The colloquial usage is captured in terms of *strict* precedence, such that no time ever strictly precedes itself. I depart from Krifka (1989) in assuming that the ordering is *dense*: between any two distinct moments we always find a third moment.

(8) $\forall \mathtt{m}^1, \mathtt{m}^2(\mathtt{m}^1 \prec_{\mathtt{i}} \mathtt{m}^2 \rightarrow \exists \mathtt{m}^3(\mathtt{m}^1 \prec_{\mathtt{i}} \mathtt{m}^3 \prec_{\mathtt{i}} \mathtt{m}^2))$

When extended to the whole of the temporal domain, precedence forms a partial order. A time $\mathtt{t}^1$ precedes $\mathtt{t}^2$ iff every moment in $\mathtt{t}^1$ precedes every moments in $\mathtt{t}^2$; $\mathtt{t}^1$ strictly precedes $\mathtt{t}^2$ iff every moment in $\mathtt{t}^1$ strictly precedes every moment in $\mathtt{t}^2$.

(9) a. $\mathtt{t}^1 \preceq_{\mathtt{i}} \mathtt{t}^2 :\leftrightarrow \forall \mathtt{m}^1, \mathtt{m}^2((\mathtt{m}^1 \sqsubseteq_{\mathtt{i}} \mathtt{t}^1 \wedge \mathtt{m}^2 \sqsubseteq_{\mathtt{i}} \mathtt{t}^2) \rightarrow \mathtt{m}^1 \preceq_{\mathtt{i}} \mathtt{m}^2)$
b. $\mathtt{t}^1 \prec_{\mathtt{i}} \mathtt{t}^2 :\leftrightarrow \mathtt{t}^1 \preceq_{\mathtt{i}} \mathtt{t}^2 \wedge \neg \mathtt{t}^1 \otimes_{\mathtt{i}} \mathtt{t}^2$

The members of the set of time intervals $\mathtt{T}$ have two properties that distinguish them from other times. First, we will assume, unlike Krifka, that intervals always have a greatest lower bound and a least upper bound. These are the latest time that precedes every moment in the interval and the earliest times that is preceded by every moment in it. When defined, the functions $\mathtt{min}^{\preceq_{\mathtt{i}}}$ and $\mathtt{max}^{\preceq_{\mathtt{i}}}$ pick out these respective bounds.[2]

(10) a. $\mathtt{min}^{\preceq_{\mathtt{i}}}(\mathtt{t}) := \mathtt{the}(\lambda \mathtt{m}^1.\mathtt{m}^1 \preceq_{\mathtt{i}} \mathtt{t} \wedge \forall \mathtt{m}^2(\mathtt{m}^2 \preceq_{\mathtt{i}} \mathtt{t} \rightarrow \mathtt{m}^2 \preceq_{\mathtt{i}} \mathtt{m}^1))$
b. $\mathtt{max}^{\preceq_{\mathtt{i}}}(\mathtt{t}) := \mathtt{the}(\lambda \mathtt{m}^1.\mathtt{t} \preceq_{\mathtt{i}} \mathtt{m}^1 \wedge \forall \mathtt{m}^2(\mathtt{t} \preceq_{\mathtt{i}} \mathtt{m}^2 \rightarrow \mathtt{m}^1 \preceq_{\mathtt{i}} \mathtt{m}^2))$

We will call a time's greatest lower bound its *left boundary* (LB) and its least upper bound its *right boundary* (RB). An interval thus always has both an LB and an RB.

(11) $\forall \mathtt{t} \in \mathtt{T} : \exists \mathtt{m}^1(\mathtt{min}^{\preceq_{\mathtt{i}}}(\mathtt{t}) = \mathtt{m}^1) \wedge \exists \mathtt{m}^2(\mathtt{max}^{\preceq_{\mathtt{i}}}(\mathtt{t}) = \mathtt{m}^2)$

The second characteristic of intervals is the fact that they are always *convex*: if two moments are a part of an interval, any moment between the two also is. The attentive reader will have noticed that this means that an interval is a stretch of time that includes every moment between its LB and RB, although this leaves open whether or not the interval's boundaries are also part of it. When this is the case, we have a closed interval; when it isn't, we have an open interval. This distinction will play a crucial role in §4.

(12) $\forall \mathtt{m}^1, \mathtt{m}^2, \mathtt{m}^3\ \forall \mathtt{t} \in \mathtt{T} : (\mathtt{m}^1, \mathtt{m}^2 \sqsubseteq_{\mathtt{i}} \mathtt{t} \wedge \mathtt{m}^1 \preceq_{\mathtt{i}} \mathtt{m}^3 \preceq_{\mathtt{i}} \mathtt{m}^2) \rightarrow \mathtt{m}^3 \sqsubseteq_{\mathtt{i}} \mathtt{t}$

If intervals are defined as convex times with an LB and RB, this makes moments (degenerate) intervals: a moment is trivially convex and is always its own greatest lower bound and least upper bound. Should we then assume that we can measure moments? We will place moments squarely outside of the domain of measurement. This will follow from our assuming that, if we can measure a time, then any smaller duration measures one of its proper parts.

[2]The metalanguage expression $\mathtt{the}(\mathtt{f})$ is defined only if $\exists \mathtt{x}(\mathtt{f}(\mathtt{x}) \wedge \forall \mathtt{y}(\mathtt{f}(\mathtt{y}) \rightarrow \mathtt{x} = \mathtt{y}))$. When defined, it picks out the unique $\mathtt{x}$ such that $\mathtt{f}(\mathtt{x})$.

(13) $\forall \mathtt{t}^1 \in \mathtt{dom}(\mu)\ \forall \mathtt{n}^1, \mathtt{n}^2 \in \mathbb{R}^+ : (\mu(\mathtt{t}^1) = \mathtt{n}^1 \wedge \mathtt{n}^2 < \mathtt{n}^1) \rightarrow \exists \mathtt{t}^2 \sqsubseteq_{\mathtt{i}} \mathtt{t}^1 : \mu(\mathtt{t}^2) = \mathtt{n}^2$

Since the measure of time is positive, and there is no smallest positive real number, it follows that any time that can be measured is made up of shorter times. Because moments have no proper parts, they cannot have parts with a smaller measure. The domain of our measure function μ is therefore restricted to non-atomic intervals and their sums, which avoids having to assign arbitrary durations to time-atoms. A measure function μ over times is thus a surjection onto the positive real numbers (*cf.* Fox & Hackl, 2006) .

2.2.4 Summing Up

We now have a system of structure preserving maps that take us from $\mathtt{D_v}$ to $\mathtt{D_i}$, and from (part of) $\mathtt{D_i}$ to (part of) $\mathtt{D_n}$. As Figure 4 demonstrates, our system of maps allows us to measure any event $\mathtt{e}$ directly using the composed function $\mu \circ \tau$, provided that $\tau(\mathtt{e})$ is in our domain of measurement.

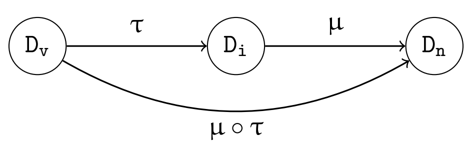

Figure 4: Mapping domains onto domains.

For the rest of this paper, runtime functions will always be relativized to a world while measure functions will be relativized to a unit of measurement. For any world $\mathtt{w}$, $\tau_{\mathtt{w}}$ returns the runtime of events at world $\mathtt{w}$; for any unit ϕ, the function μ_ϕ returns the duration of interval pluralites in unit ϕ.

2.3 Tense, Aspect, and the Perfect

The meanings of the *simple past* and *present perfect simple* sentences in (14-a) and (14-b) appear to be quite similar. Each conveys that, prior to the moment of its utterance, an event of Mary writing up a paper took place.

(14) a. Mary wrote up a paper.
b. Mary has written up a paper.

However, the meanings of their *past progressive* and *present perfect progressive* counterparts in (15-a) and (15-b) come apart sharply. While the former only indicates that Mary was in the process of writing up a paper *prior* to its moment of utterance, the latter clearly signifies that Mary is still engaged in this process *at* the moment of utterance.

(15) a. Mary was writing up a paper.
b. Mary has been writing up a paper.

English tense, aspect, and its perfect all play an important role in shaping the meanings of these sentences. Since all three ingredients will feature prominently in our discussion of TIAs, this section reviews what are for us their most important semantic contributions.

2.3.1 Tense and Aspect

The sentence in (14-a) is in the past tense and perfective aspect (not to be confused with the perfect). I assume its *logical form* (LF) to be (16). Throughout the paper I assume VP-internal subjects (Zagona, 1982; Kitagawa, 1986; Koopman & Sportiche, 1991, i.a.).

(16) $\textsc{past}_1$ PFV [Mary write up a paper]

I won't be providing any of the compositional details for VPs. Here, I simply take the VP's extension to be (the characteristic function of) the set of events of Mary writing up a paper; for any world $\mathtt{w}$, the metalanguage predicate $\mathtt{mwp_w}$ characterizes the set of events of Mary writing up a paper ($\mathtt{mwp}$-events) at $\mathtt{w}$.

(17) $[\![\text{Mary write up a paper}]\!]^{\mathtt{u}} \coloneqq \mathtt{mwp_u}$

The VP is sister to PFV, an operator meant to encode the semantic contributions of the perfective aspect. This operator plays a dual role. On the one hand, it quantifies over events in the extension of the VP. On the other, it relates those events to times.

(18) $[\![\textsc{pfv}]\!]^{\mathtt{u}} \coloneqq \lambda \mathtt{V_{vt}} \lambda \mathtt{t}.\exists \mathtt{e}(\mathtt{V}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t})$

In the spirit of Klein (1994) and many others, our operator combines with a set of events $\mathtt{V}$ and returns the set of times which (at the world of evaluation) include (the runtime of) a $\mathtt{V}$-event (i.e. have this runtime as a part). Tenses can then be fed into this output which, following Partee (1973), I treat as pronouns: the past carries a referential index to which $\mathtt{g}$ assigns a specific time. Nothing in the paper hinges on this particular assumption.

(19) For any $\mathtt{j}$, $[\![\textsc{past}_{\mathtt{j}}]\!]^{\mathtt{s,g}}$ is defined only if $\mathtt{g}(\mathtt{j}) \prec_{\mathtt{i}} \mathtt{s}$.
When defined, $[\![\textsc{past}_{\mathtt{j}}]\!]^{\mathtt{s,g}} \coloneqq \mathtt{g}(\mathtt{j})$.

The semantic composition of our LF proceeds as in (20).[3]

(20)
$$[\![\textsc{pfv}]\!]^{\mathtt{u}}(\mathtt{mwp_u})(\mathtt{g}(1))$$
$$= (\lambda \mathtt{t}.\exists \mathtt{e}(\mathtt{mwp_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))(\mathtt{g}(1))$$
$$= \exists \mathtt{e}(\mathtt{mwp_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{g}(1))$$

The composition of PFV and the VP results in the set of times that include an $\mathtt{mwp}$-event (at $\mathtt{u}$). Provided $\mathtt{g}(1)$ strictly precedes $\mathtt{s}$, the aspectual phrase (AspP) can combine with tense. The result is true (i.e. denotes $\top$) iff $\mathtt{g}(1)$ includes some $\mathtt{mwp}$-event.

The main difference between (14-a) and its past progressive counterpart in (15-a) can be understood in terms of grammatical aspect: the former is in the perfective while the latter is in the imperfective. The LF I assume for (15-a) is thus (21).

(21) $\textsc{past}_1$ IMPV [Mary write up a paper]

It will be sufficient for us to treat the aspectual operator IMPV as differing from PFV only in the direction of inclusion (Klein, 1994, i.a.): rather than include an event in a time, it includes that time in the event.[4]

(22) $[\![\textsc{impv}]\!]^{\mathtt{u}} \coloneqq \lambda \mathtt{V_{vt}} \lambda \mathtt{t_i}.\exists \mathtt{e}(\mathtt{V}(\mathtt{e}) \wedge \mathtt{t} \sqsubseteq_{\mathtt{i}} \tau_{\mathtt{u}}(\mathtt{e}))$

[3] I write "$(\lambda x.\phi)(y) = \psi$" as shorthand for "$(\lambda x.\phi)(y) = \top$ iff ψ".
[4] This abstracts away a great deal of complexity surrounding the imperfective, most especially its modal characteristics. For more details on the English progressive, see Dowty (1979).

The LF in (21) is true iff, as stated in (23), $\mathtt{g(1)}$ is included in some $\mathtt{mwp}$-event. We can understand this to mean that, at $\mathtt{g(1)}$, Mary was in the process of writing a paper.

(23) $[\![\text{IMPV}]\!]^{\mathtt{u}}(\mathtt{mwp_u})(\mathtt{g(1)}) = \exists\mathtt{e}(\mathtt{mwp_u(e)} \wedge \mathtt{g(1)} \sqsubseteq_{\mathtt{i}} \tau_{\mathtt{u}}(\mathtt{e}))$

2.3.2 The Perfect

We turn now to the present perfect simple counterpart of (14-a) in (14-b). The LF I assume for this sentence is (24).

(24) PRES PERF PFV [Mary write up a paper]

The perfect is sometimes described as either an aspect or a tense, but it fits neither rubric particularly well (e.g. Comrie, 1976). It is better thought of as an element that interacts with tense and aspect. It is common to think of it as referencing an interval called either the *extended now interval* (XN; McCoard, 1978; Heny, 1982; Richards, 1982; Mittwoch, 1988) or the *perfect time span* (PTS; Iatridou et al., 2003). I employ the latter terminology, although I will be qualifying my use of it shortly.

What relationship is there between tense and aspect on the one hand and the perfect on the other? In the simple past, aspect establishes an inclusion relation between a set of events and the time referenced by tense. In the perfect, the inclusion relation is between the set of events and the PTS; tense is now relegated to the role of fixing the PTS's RB (Heny, 1982; Mittwoch, 1988; Iatridou et al., 2003). Tense *right-bounds* the PTS, by which I mean that its LB is the PTS's RB. We can define right-bounding in terms of $\mathtt{min}^{\preceq_{\mathtt{i}}}$ and $\mathtt{max}^{\preceq_{\mathtt{i}}}$.

(25) $\mathtt{rb}(\mathtt{t}^1, \mathtt{t}^2) :\leftrightarrow \mathtt{max}^{\preceq_{\mathtt{i}}}(\mathtt{t}^2) = \mathtt{min}^{\preceq_{\mathtt{i}}}(\mathtt{t}^1)$

Unlike the authors above, I don't assume that there is such a thing as *the* PTS of a sentence. I instead follow von Fintel & Iatridou (2019) in treating PERF as an existential quantifier over intervals; there is thus not one PTS but a class of PTSs that can witness the existential statement. When it makes sense to do so, however, I will allow myself to speak as if there were such a thing as *the* PTS of a sentence. I defer my arguments for a quantificational analysis of the perfect until §5.

(26) $[\![\text{PERF}]\!] := \lambda\mathtt{I_{it}}\lambda\mathtt{t}^1.\exists\mathtt{t}^2 \in \mathtt{T}(\mathtt{rb}(\mathtt{t}^1, \mathtt{t}^2) \wedge \mathtt{I}(\mathtt{t}^2))$ (*To be revised*)

The perfect combines with a set of times $\mathtt{I}$ and returns the set of times that right-bound some *interval* in $\mathtt{I}$. In (24), this set of times is given by the AspP. The perfect then combines with the tense, which in (24) is the present. PRES is interpreted relative to the time of evaluation $\mathtt{s}$ and simply denotes that time.

(27) $[\![\text{PRES}]\!]^{\mathtt{s}} := \mathtt{s}$

Compositionally, PERF thus intervenes between the AspP and tense. The interpretation of (24) is given below.

(28) $[\![\text{PERF}]\!]([\![\text{PFV}]\!]^{\mathtt{u}}(\mathtt{mwp_u}))(\mathtt{s})$
$= (\lambda\mathtt{t}^1.\exists\mathtt{t}^2 \in \mathtt{T}(\mathtt{rb}(\mathtt{t}^1, \mathtt{t}^2) \wedge \exists\mathtt{e}(\mathtt{mwp_u(e)} \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}^2)))(\mathtt{s})$
$= \exists\mathtt{t} \in \mathtt{T}(\mathtt{rb}(\mathtt{s}, \mathtt{t}) \wedge \exists\mathtt{e}(\mathtt{mwp_u(e)} \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))$

The result of composition is a true statement iff $\mathtt{s}$ right-bounds an interval that includes some $\mathtt{mwp}$-event. Since $\mathtt{s}$ is momentaneous, its right-bounding an interval simply makes $\mathtt{s}$

that interval's RB. A scenario verifying our statement is represented in Figure 5.

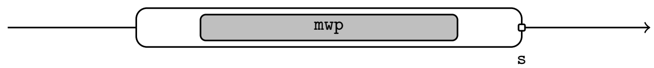

Figure 5: Scenario verifying (28).

The meaning we predict is reasonably close to that of the simple past. However, some readers may have realized that (28) is true in scenarios where the mwp-event ends *at* s (or even when it is *coextensive* with a PTS). This appears to be incorrect: the intuition is that (14-b) implies that the mwp-event ended *prior* to s. For the time being, we ignore this issue; we return to it in §5 with a revised semantics for the perfect.[5] For now, let's note that the general approach we are following finds support in the perfect's interaction with other tenses. Take for example the past perfect simple sentence in (29-a) and its LF in (29-b).

(29) a. Mary had written up a paper.
b. PAST_1 PERF PFV [Mary write up a paper]

Whereas its present perfect counterpart relates Mary's paper writing to the utterance time, (29-a) intuitively relates it to a time prior to that. This is what is predicted.

(30) $[\![\text{PERF}]\!]([\![\text{PFV}]\!]^{\mathtt{u}}(\mathtt{mwp_u}))(\mathtt{g(1)}) = \exists \mathtt{t} \in \mathtt{T}(\mathtt{rb}(\mathtt{g(1)},\mathtt{t}) \wedge \exists \mathtt{e}(\mathtt{mwp_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))$

The statement in (30) is true iff an interval right-bounded by g(1), which is prior to the utterance time, includes some mwp-event. This is verified by scenarios such as Figure 6, where for simplicity g(1) is momentaneous.

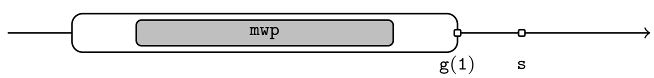

Figure 6: Scenario verifying (30).

The reader can verify that this semantics makes sensible predictions for the future perfect as well. Having looked at the perfect's interaction with tense, let's turn to its interaction with aspect. The LF for the present perfect progressive sentence in (15-b) is given in (31), where the aspectual operator is IMPV.

(31) PRES PERF IMPV [Mary write up a paper]

We first saturate the meaning of the perfect with the AspP headed by the imperfective, followed by the present.

[5] It won't do to simply assume that the perfect requires the event to be *non-finally* included in a PTS, as in (i) (*cf.* Heny, 1982).

(i) $\exists \mathtt{t} \in \mathtt{T}(\mathtt{rb}(\mathtt{s},\mathtt{t}) \wedge \exists \mathtt{e}(\mathtt{mwp_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t} \wedge \mathtt{max}^{\preceq_{\mathtt{i}}}(\tau_{\mathtt{u}}(\mathtt{e})) \prec_{\mathtt{i}} \mathtt{max}^{\preceq_{\mathtt{i}}}(\mathtt{t})))$

If this were our solution, then (ii) would now be true in scenarios where an mwp-event ends at s. The problem is only pushed onto the negative case.

(ii) Mary hasn't written up a paper.

(32) $[\![\text{PERF}]\!]([\![\text{IMPV}]\!]^{\mathtt{u}}(\mathtt{mwp_u}))(\mathtt{s}) = \exists \mathtt{t} \in \mathtt{T}(\mathtt{rb}(\mathtt{s},\mathtt{t}) \wedge \exists \mathtt{e}(\mathtt{mwp_u}(\mathtt{e}) \wedge \mathtt{t} \sqsubseteq_{\mathtt{i}} \tau_{\mathtt{u}}(\mathtt{e})))$

We get a statement that is true iff some interval right-bounded by $\mathtt{s}$ is included in an $\mathtt{mwp}$-event. Figure 7 depicts a scenario verifying (32). We can understand the scenario as one where Mary is in the process of writing up a paper at $\mathtt{s}$, which gets at the intuition that (15-b) implies that Mary's paper writing is ongoing.

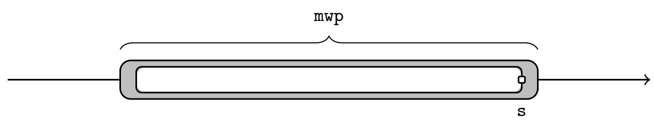

Figure 7: Scenario verifying (32).

2.3.3 Existential and Universal Perfects

Heny (1982) observes that sentences like (33) can be used to mean either that Mary was sick for a period of time that falls *somewhere* between Monday and now or that her sickness extends *throughout* that span of time. For convenience, I will refer to the interval ranging from the end of Monday up to the moment of utterance as *the* PTS of this sentence.[6]

(33) Mary has been sick since Monday.

Since the latter interpretation strictly entails the former, we must address a question typically raised by privative oppositions (i.e. a pair of readings where one strictly entails the other): are we dealing with a *bona fide* ambiguity or is the stronger interpretation simply the limiting case of the weaker? Although Heny ultimately settles for the second option, Mittwoch (1988) uses examples like (34) to argue for the first.

(34) Mary hasn't been sick since Monday.

If (33) were to unambiguously mean that Mary was sick *somewhere* in the PTS, its negation should unambiguously mean that Mary wasn't sick *anywhere* in it. This is not what we observe: (34) can indeed take on this interpretation, but it can also make the weaker claim that her sickness did not extend throughout the PTS. This interpretation would be true, for example, if her sickness began on Tuesday. She concludes that (33) and its negation are both true ambiguities. She observes that the two senses seem to correspond to what McCawley (1971, 1981) calls an *existential perfect* (E-perfect) and a *universal perfect* (U-perfect). As the name suggests, (33)'s E-perfect reading is the one where Mary's sickness occurs somewhere in the PTS; its U-perfect reading is the one where she is sick throughout the PTS. (34)'s E-perfect reading is the one where she isn't sick anywhere in the PTS; its U-perfect reading is the one where she is not sick throughout the PTS. We will follow Mittwoch in treating these sentences as ambiguous.[7]

[6]Since intervals may or may not include their boundaries, there isn't actually a single interval ranging from the end of Monday to the moment of utterance; there are in fact four. For now, we can assume that the PTS referred to here includes both its LB and RB.

[7]Michael White (p.c.) suggests a way of treating (33) as unambiguously E-perfect while deriving (34)'s ambiguity in terms of the scope of negation. When the negation outscopes *since Monday*, we get the "E-perfect" reading; when *since Monday* outscopes the negation, we get the "U-perfect reading". I find the idea of scopal ambiguity a highly plausible mechanism for deriving (34)'s two readings, but it cannot be the only mechanism. Consider the sentence in (i), where (33) is essentially embedded in a universal quantifier's

I follow von Fintel & Iatridou (2019) in their implementation of (33)'s ambiguity in terms of grammatical aspect: the E-perfect is in the perfective while the U-perfect is in the imperfective. The roots of this idea draw from Iatridou et al. (2003), who first established the connection between E-perfects and the perfective aspect. Treating (33)'s ambiguity as one of aspect is interesting given the inability of *be sick* to take on progressive morphology.

(35) *Mary has been being sick since Monday.

The claim is then that, although it is not marked morphologically, we still find echoes of the distinction between a present perfect simple and a present perfect progressive in (33)'s E-/U-perfect ambiguity. The LF for the E-perfect reading is given in (36).

(36) PRES PERF [PFV Mary be sick] since Monday

Similar to the VP *Mary write up a paper*, I treat *Mary be sick* as denoting the predicate of events of Mary being sick (mbs-events).

(37) $[\![\text{Mary be sick}]\!]^{\mathtt{u}} := \mathtt{mbs_u}$

The *since*-adverbial in (36) modifies the AspP. Ultimately, its contribution will be to have Monday *left-bound* the PTS; $\mathtt{t}^1$ left-bounds $\mathtt{t}^2$ iff $\mathtt{t}^2$ right-bounds $\mathtt{t}^1$.

(38) $\mathtt{lb}(\mathtt{t}^1, \mathtt{t}^2) :\leftrightarrow \mathtt{rb}(\mathtt{t}^2, \mathtt{t}^1)$

Assuming that, in the metalanguage, mday corresponds to the most recent Monday, we can have the adverbial denote the set of times left-bounded by mday.

(39) $[\![\text{since Monday}]\!] := \lambda\mathtt{t}.\mathtt{lb}(\mathtt{mday}, \mathtt{t})$

In the course of semantic composition, we first have the AspP and the adverbial combine via (generalized) predicate modification. The perfect then combines with the resulting predicate of times and afterwards with tense.

(40)
$$\begin{aligned}&[\![\text{PERF}]\!]([\![[\text{ PFV Mary be sick }] \text{ since Monday}]\!]^{\mathtt{u}})(\mathtt{s})\\ &= [\![\text{PERF}]\!](\lambda\mathtt{t}.\mathtt{lb}(\mathtt{mday},\mathtt{t}) \wedge \exists\mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))(\mathtt{s})\\ &= \exists\mathtt{t} \in \mathtt{T}(\mathtt{rb}(\mathtt{s},\mathtt{t}) \wedge \mathtt{lb}(\mathtt{mday},\mathtt{t}) \wedge \exists\mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))\end{aligned}$$

The formula in (40) is true iff there exists an interval that is left-bounded by mday, right-bounded by s, and which includes an mbs-event. This is verified by scenarios like Figure 8, which captures well the essence of (33)'s E-perfect reading.

restrictor.

(i) Everyone who has been sick since Monday stayed home.
  a. Everyone who was sick at some point between Monday and now stayed home.
  b. Everyone who was sick at every point between Monday and now stayed home.

The sentence is ambiguous between a weaker E-perfect reading in (i-a) and a stronger U-perfect reading in (i-b). If (33) were unambiguously E-perfect, we would not expect a U-perfect interpretation for (i). Indeed, the reader can verify that adjusting the scope of *since Monday* relative to the universal quantifier will never derive (i-b) as the sentence's reading.

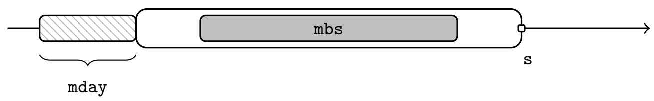

Figure 8: Scenario verifying (40).

The U-perfect interpretation for (33) has the LF in (41). The only difference between this LF and the one in (36) is in the choice of aspectual operator.

(41) PRES PERF [IMPV Mary be sick] since Monday

The compositional steps we had in the case of the perfective are the same we have here.

(42) $[\![\text{PERF}]\!]([\![[\text{ IMPV Mary be sick }] \text{ since Monday}]\!]^{\mathtt{u}})(\mathtt{s})$
$= [\![\text{PERF}]\!](\lambda \mathtt{t}.\mathtt{lb}(\mathtt{t}, \mathtt{mday}) \wedge \exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \mathtt{t} \sqsubseteq_{\mathtt{i}} \tau_{\mathtt{u}}(\mathtt{e})))(\mathtt{s})$
$= \exists \mathtt{t} \in \mathtt{T}(\mathtt{rb}(\mathtt{s}, \mathtt{t}) \wedge \mathtt{lb}(\mathtt{mday}, \mathtt{t}) \wedge \exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))$

The statement in (42) is true iff some interval is left-bound by mday, right-bounded by s, and is included in an mbs-event. This is verified by Figure 9, where we see that Mary is sick throughout the PTS. This gets nicely at the meaning of the U-perfect.

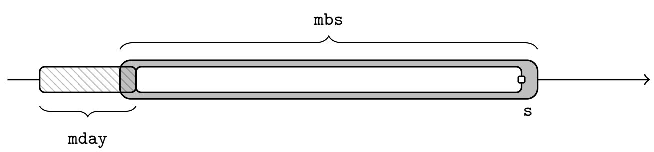

Figure 9: Scenario verifying (42).

3 A Unified Analysis of TIAs

3.1 Desiderata

Before we develop a unified semantics for E- and G-TIAs, we must have accurate descriptions of their meanings. In §1, the sentences in (1) were used to exemplify some of the constraints on the distribution of E-TIAs. I defer to §4 any explanation of the role played by lexical aspect in determining whether or not we accept E-TIAs. For the time being, we will focus on (1-a)'s meaning.

(1) a. Mary wrote up a paper in three days.
b. *Mary was sick in three days.

We might expect the sentence to mean something along the lines of: there exists a three-day mwp-event whose runtime is included in some salient past time. This is too strong. It has been recognized since at least Dowty (1979) that (1-a)'s literal meaning is best understood as stating that the event lasted three days *or less*. As evidence for this, consider following up (1-a) with either of the sentences in (43).

(43) a. What's more, she wrote it up in two days!
b. #What's more, she wrote it up in four days!

If (1-a) were to mean that it took *exactly* three days for Mary to write up her paper, it would be inconsistent with either (43-a) or (43-b). This is not what we observe. The follow-up in (43-a) adds consistent information to the initial utterance, which is precisely what we expect if (1-a) means that it took three days or less for Mary to do her writing; writing a paper in two days or less strictly entails doing so in three days or less. This weaker meaning also explains the oddness of the follow up in (43-b): since writing a paper in three days or less entails doing so in four days or less, (43-b) is redundant.

Although we normally infer from (1-a) that Mary's paper writing lasted three days, the defeasibility of the inference suggests that it is a *scalar implicature*. This is further supported by the fact that the implicature disappears when we embed (1-a) in a entailment reversing environment, another hallmark of scalar implicatures.

(44) Every postdoc who wrote up a paper in three days earned additional funding.

What (44) states is not just that every postdoc who took a full three days to write a paper had it published. On its most natural interpretation, the sentence entails that the postdocs who wrote their papers in less than three days also received more funding. This is only expected if *in three days* is interpreted as *in three days or less*.

To be sure, (44) can take on the weaker reading where it is only the postdocs who wrote papers in *exactly* three days who got more funding, but this doesn't weaken our point. It is a well known fact that scalar implicatures can be derived local to the scope of downward monotone functions (Horn, 1985, 1989; Levinson, 2000; Chierchia et al., 2012). The weaker reading should be understood as one where the meaning of the quantifier's restrictor has been enriched by a local implicature. With the tools presented in §2, we can state the basic meaning of (1-a) as (45), where $\mathtt{g(1)}$ is our salient past time and $\mathtt{d}$ is the unit for days.

(45) $\exists \mathtt{e}(\mathtt{mwp_u}(\mathtt{e}) \wedge (\mu_\mathtt{d} \circ \tau_\mathtt{u})(\mathtt{e}) \leq 3 \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{g}(1))$

We now turn to G-TIAs, whose distributional constraints we exemplified using the sentences in (2). Once again, these constraint will not be our focus here.

(2) a. Mary hasn't been sick in three days.
b. *Mary has been sick in three days.

There is, however, another constraint on their distribution which will be of interest to us here. Notice from (46) that G-TIAs are unacceptable without the perfect.

(46) *Mary wasn't sick in three days.

This makes sense if we follow Iatridou & Zeijlstra (2017, 2021) in assuming that the role of G-TIAs is to fix the LB of PTSs, which it cannot do if a sentence lacks the perfect. We can state (2-a)'s meaning as follows: there are no $\mathtt{mbs}$-events included in a PTS that is right-bounded by $\mathtt{s}$ and whose LB is the moment three days prior to $\mathtt{s}$. In order to facilitate discussing G-TIAs, it will be convenient for us to formalize a way of picking out PTSs of this sort. To this end, let us define the function $\mathtt{max}^{\sqsubseteq_\mathtt{i}}$ which, when defined, picks out from a set of times $\mathtt{I}$ the $\mathtt{I}$-time that has every $\mathtt{I}$-time as a part.

(47) $\mathtt{max}^{\sqsubseteq_\mathtt{i}}(\mathtt{I_{it}}) \coloneqq \mathtt{the}(\lambda \mathtt{t}^1.\mathtt{I}(\mathtt{t}^1) \wedge \forall \mathtt{t}^2(\mathtt{I}(\mathtt{t}^2) \rightarrow \mathtt{t}^2 \sqsubseteq_\mathtt{i} \mathtt{t}^1))$

The function $\mathtt{pts}$ can then be defined in terms of $\mathtt{max}^{\sqsubseteq_\mathtt{i}}$. For a number $\mathtt{n}$, a unit of measurement ϕ, and a time $\mathtt{t}$, it returns the largest interval that is both right-bounded by $\mathtt{t}$

and included in a time whose measure in unit ϕ is $\mathtt{n}$. This may seem like a roundabout way of defining an interval whose RB is $\mathtt{t}$ and whose LB is $\mathtt{n}$ ϕ's prior to $\mathtt{t}$, but this particular formulation will prove useful in establishing certain semantic equivalences later on.

(48) $\mathtt{pts}(\mathtt{n}, \phi, \mathtt{t}^1) := \mathtt{max}^{\sqsubseteq_i}(\lambda \mathtt{t}^2.\exists \mathtt{t}^3(\mu_\phi(\mathtt{t}^3) = \mathtt{n} \wedge \mathtt{t}^2 \in \mathtt{T} \wedge \mathtt{rb}(\mathtt{t}^1, \mathtt{t}^2) \wedge \mathtt{t}^2 \sqsubseteq_i \mathtt{t}^3))$

What $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ returns is the interval consisting of every moment ordered inclusively between $\mathtt{s}$ and the moment three days prior to $\mathtt{s}$. Notice that, on the definition in (48), this is a closed interval: both $\mathtt{s}$ and the moment three days prior to it are part of $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$. We can now state the meaning of (2-a) as follows: there are no $\mathtt{mbs}$-events included in $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$.

(49) $\neg\exists \mathtt{e}(\mathtt{mbs}_\mathtt{u}(\mathtt{e}) \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_i \mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$

While it is natural to interpret (2-a) as conveying that Mary used to be sick and that her sickness ended three days ago, this appears to be a scalar implicature. This is evidenced by the fact that both of the sentences in (50) can be used to follow up (2-a) (*cf.* Iatridou & Zeijlstra, 2017, 2021).

(50) a. What's more, she hasn't been sick in four days!
b. What's more, she has never been sick in her life!

The consistency of (2-a) with (50-a) demonstrates that the former does not entail that Mary has been sick and that her sickness ended three days ago; its consistency with (50-b) shows that (2-a) doesn't even entail that Mary has been sick at all. (49) is consistent with either possibility.

Before moving on, I want to address a possible worry concerning the statement of (2-a)'s meaning in (49): since we aren't assuming that there is such a thing as *the* PTS of a sentence, how can (49) be consistent with our conception of the perfect? As we will soon see, our choice of a quantification analysis makes no difference; we can derive (49) while still treating the perfect as a quantifier.

3.2 The Syntax of TIAs

E-TIAs are acceptable with telic VPs but not atelic VPs; G-TIAs are acceptable in negative sentences in the perfect but not their positive counterparts. Unsurprisingly, negative sentences in the perfect in which the VP is telic, such as (51), are ambiguous between an E- and a G-TIA interpretation.

(51) Mary hasn't written up a paper in three days.

On its E-TIA reading, the sentence means that there are no three-day $\mathtt{mwp}$-events in any PTS right-bounded by $\mathtt{s}$. On its G-TIA reading, it means that there are no $\mathtt{mwp}$-events in $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$. What kind of ambiguity are we dealing with here? To better answer the question, we can draw a comparison between (51)'s ambiguity and that of (52), which also admits two readings.

(52) Mary has been sick for three days.

On the first reading, the sentence means that a three-day $\mathtt{mbs}$-event is included in a PTS right-bounded by $\mathtt{s}$. On the second, it asserts that Mary was sick throughout $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$.

(52) is another example of a privative opposition, where the second reading entails the first. How can we be sure that (52)'s second reading isn't simply the limiting case of the first? A classic argument for this being a true ambiguity comes from Dowty (1979) who, following a suggestion by Bennett & Partee (1972), presents examples like (53) as evidence of this.

(53) For three days, Mary has been sick.

When we front the *for*-adverbial, only the second reading survives. The argument demonstrates that the second reading can be independently derived in some configurations, but it is only convincing insofar as we are committing ourselves to a view where (53)'s meaning must be available to (52). If we allow adverbial fronting to unlock otherwise unavailable readings, the argument loses its bite. I propose instead what I take to be a better argument: we can show (52)'s ambiguity if we embed it in an entailment reversing environment. This is an obvious extension of Mittwoch's (1988) argument for a genuine E-/U-perfect ambiguity.

(54) Everyone who has been sick for three days must stay home.

In (54), we've (essentially) embedded (52) in the restrictor of a universal quantifier. If (52) only had the first reading, (54) should unambiguously mean that all the people who were sick for three days within a PTS right-bounded by `s` must stay home. However, the sentence clearly has the weaker reading where only those who were sick throughout the last three days must stay home. This is expected only if the second reading is available for (52).

The ambiguity in (52) can be understood in terms of what is being modified by the *for*-adverbial (Vlach, 1993; Iatridou et al., 2003, i.a.). When it measures an event it modifies the VP; this is the position of an *event-level adverbial*. When it measures a PTS, it modifies the whole of the AspP; this is where von Fintel & Iatridou (2019) place *perfect-level adverbials*. The schemata in (55) illustrate the relative positions of event- and perfect-level adverbials.[8]

(55) a. TENSE (PERF) ASP [VP ADV]
b. TENSE *(PERF) [ASP VP] ADV

Following Iatridou & Zeijlstra (2017, 2021), I suggest that the E-/G-TIA distinction should also be understood in terms of the distinction between event-/perfect-level adverbials. First, observe the parallel between (53) and (56).

(56) In three days, Mary hasn't written up a paper.

Just like the event-level reading of (52) disappears when we front the *for*-adverbial, (51)'s E-TIA reading disappears when we front the TIA.[9] We can uncover additional parallels between syntactic manipulations of (51) and (52). Following a suggestion by Filipe Hisao Kobayashi (p.c.), we can use VP-fronting to isolate both the event-level reading of a *for*-adverbial and the E-TIA reading of a TIA.

[8] Interestingly, event-level *for*-adverbials force an E-perfect reading, while perfect-level ones force a U-perfect reading (e.g. Dowty, 1979; Mittwoch, 1988).

[9] We shouldn't conclude that sentence-initial *for*- and *in*-adverbials are always perfect-level. The adverbial in (i) is clearly event-level, which is unsurprising given the absence of the perfect.

(i) For three days, Mary was sick.

The correct conclusion to draw is that, when an adverbial is ambiguous between an event- and perfect-level reading in its base position, only the latter reading survives fronting (*cf.* Iatridou et al., 2003).

(57) a. Mary hasn't done much lately, but be sick for three days she has.
b. Mary's done much lately, but write up a paper in three days she hasn't.

By front a VP with a *for*-adverbial, we force an event-level reading; by fronting a VP with a TIA, we force an E-TIA reading. This is quite natural on the assumption that event-level adverbials, among which E-TIAs should be counted, modify VPs.

The effect of syntactic manipulations on what readings are available for *for*-adverbials and TIAs argue in favor of a structural ambiguity in both cases. To add support for this view in the case of TIAs, I present a new observation that comes from stacking them.

(58) a. Mary hasn't written up a paper in three days in two weeks.
b. #Mary hasn't written up a paper in two weeks in three days.

In (58-a), *in three days* is closer to the VP than *in two weeks*. We see that proximity to the VP correlates with interpretation: the adverbial closest to the VP can only be interpreted as an E-TIA, whereas the one furthest away must be a G-TIA. The rigidity of this correspondence is evidenced by the oddness of (58-b), which is analytical: it asserts that within the PTS coextensive with the last three days, there are no two-week `mwp`-events. We should assume that proximity to the VP lines up with the syntactic position of event- and perfect-level adverbials relative to VPs.

3.3 The Semantics of TIAs

I've argued that E-TIAs are event-level adverbials while G-TIAs are perfect-level adverbial. The schemata in (59) reflect this: E-TIAs modify VPs and G-TIAs AspPs.

(59) a. ASP [VP E-TIA]
b. [ASP VP] G-TIA

This leads to a compositional challenge: the semantic type of VPs differs from that of AspPs. How can TIAs compose with both? The simplest solution to the problem is to have *in* instantiate a relation that is underspecified as to the type of its relata.

(60) $[\![\text{in}]\!] := \lambda \mathtt{M}_{\sigma \mathtt{i}} \lambda \mathtt{t} \lambda \mathtt{x}_{\sigma}.\mathtt{M}(\mathtt{x}) \sqsubseteq_{\mathtt{i}} \mathtt{t}$

My treatment of E-TIAs is in the spirit of Dowty's (1979). Roughly put, *in* establishes an inclusion relation between two times. In more precise terms, we can think of *in* as denoting a three-way relation between a mapping onto times $\mathtt{M}$, a time $\mathtt{t}$, and an individual $\mathtt{x}$: the relation holds iff $\mathtt{M}(\mathtt{x})$ is temporally included in $\mathtt{t}$ (*cf.* Champollion, 2017).

As is always the case, the easiest way to understand this definition of *in* is with an example. The LF I assume for (61-a) is (61-b). In contrast to Dowty, I don't assume that TIAs combine directly with their measure phrases. Instead, I assume that the measure phrase is extracted from the adverbial.

(61) a. Mary wrote up a paper in three days.
b. [three days] 2 PAST_1 PFV [Mary write up a paper] [in RT] $\mathtt{t}_2$

When a TIA modifies a VP, it must able to semantically combine with a predicate of events. This is where our choice of mapping comes in. In the case of E-TIAs, this mapping is done through the runtime function, which the covert expression RT denotes.

(62) $[\![\text{RT}]\!]^{u} := \tau_u$

After it is fed both the runtime function and the time assigned to the index of the measure phrase's trace, the TIA denotes the predicate of events in (63).

(63) $[\![\text{in}]\!](\tau_u)(g(2)) = \lambda e.\tau_u(e) \sqsubseteq_i g(2)$

This then combines with *Mary write up a paper* through predicate modification.

(64) $[\![$[Mary write up a paper] [in RT] $t_2]\!]^{u,g} = \lambda e.\text{mwp}_u(e) \wedge \tau_u(e) \sqsubseteq_i g(2)$

I treat the measure word *days* as a *parameterized quantifier*, in a sense close the one used in Hackl (2001). After it combines with a number n, it denotes the existential generalized quantifier restricted to n-day times.

(65) a. $[\![\text{three}]\!] := 3$
b. $[\![\text{days}]\!] := \lambda n \lambda I_{it}.\exists t[\mu_d(t) = n \wedge I(t)]$
c. $[\![\text{three days}]\!] = \lambda I_{it}.\exists t[\mu_d(t) = 3 \wedge I(t)]$

When we put all of our ingredients together, we finally arrive at the meaning in (66).

(66) $[\![$[three days] 2 PAST$_1$ PFV [Mary write up a paper] [in RT] $t_2]\!]^{u,s,g}$
$= [\![\text{three days}]\!](\lambda t.[\![\text{PFV}]\!]^{u}(\lambda e.\text{mwp}_u(e) \wedge \tau_u(e) \sqsubseteq_i t)(g(1)))$
$= [\![\text{three days}]\!](\lambda t.\exists e(\text{mwp}_u(e) \wedge \tau_u(e) \sqsubseteq_i t \wedge \tau_u(e) \sqsubseteq_i g(1)))$
$= \exists t(\mu_d(t) = 3 \wedge \exists e(\text{mwp}_u(e) \wedge \tau_u(e) \sqsubseteq_i t \wedge \tau_u(e) \sqsubseteq_i g(1)))$

This states that an mwp-event is both included in a three-day time and in $g(1)$. To say that an event is included in a three-day time is to place an upper bound its duration: it boils down to saying that the event lasted three days or less. As long as we discount the possibility of there being momentaneous mwp-events, (66) is equivalent to (45), i.e. what we argued to be the meaning of (61-a).[10]

(45) $\exists e(\text{mwp}_u(e) \wedge (\mu_d \circ \tau_u)(e) \leq 3 \wedge \tau_u(e) \sqsubseteq_i g(1))$

Let's now turn to the sentence in (67-a), for which I assume the LF in (67-b). This is the LF for the sentence's E-perfect interpretation. The sentence could in principle also have a U-perfect interpretation, but I leave all discussion of this interpretation to §5.

(67) a. Mary hasn't been sick in three days.
b. not [three days] 1 PRES PERF [PFV Mary be sick] [in ID] t_1

Since AspPs are predicates of times, a G-TIA requires a mapping from times onto times. There is really no harm in assuming a trivial mapping: I take *in*'s map argument to be the identity function, denoted by the covert element ID.

(68) $[\![\text{ID}]\!] := \text{id}$

The meaning we get for the TIA is the predicate of times that are included in $g(1)$.

(69) $[\![\text{in}]\!](\text{id})(g(1)) = \lambda t.t \sqsubseteq_i g(1)$

[10]The equivalence is lost if we allow for momentary mwp-events because measure functions are undefined for time atoms. While (66) could be true given a momentaneous event as the witness for the existential, (45) would be undefined. It strikes me as perfectly reasonable to assume that mwp-events are never momentaneous.

It is now with the AspP that the TIA combines through predicate modification.

(70) $[\![[$ PFV Mary be sick $]$ $[$ in ID $]$ $t_1]\!]^{u,g} = \lambda \mathtt{t}.\exists \mathtt{e}(\mathtt{mbs_u(e)} \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{t} \sqsubseteq_\mathtt{i} \mathtt{g(1)})$

In (70), we encounter temporal Russian dolls: we have the predicate of times which include an mbs-event and which are themselves included in $\mathtt{g(1)}$. We now have the necessary ingredients to derive the meaning for (67-b) straightforwardly. Before we do so, however, let's derive the meaning the portion of this LF that is in the scope of the negation.

(71) $[\![[$ three days $]$ 1 PRES PERF $[$ PFV Mary be sick $]$ $[$ in ID $]$ $t_1]\!]^{u,s}$
$= [\![\text{three days}]\!](\lambda \mathtt{t}^1.[\![\text{PERF}]\!](\lambda \mathtt{t}^2.\exists \mathtt{e}(\mathtt{mbs_u(e)} \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{t}^2 \sqsubseteq_\mathtt{i} \mathtt{t}^1))(\mathtt{s}))$
$= [\![\text{three days}]\!](\lambda \mathtt{t}^1.\exists \mathtt{t}^2 \in \mathtt{T}(\mathtt{rb}(\mathtt{s},\mathtt{t}^2) \wedge \exists \mathtt{e}(\mathtt{mbs_u(e)} \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{t}^2 \sqsubseteq_\mathtt{i} \mathtt{t}^1)))$
$= \exists \mathtt{t}^1(\mu_\mathtt{d}(\mathtt{t}^1) = 3 \wedge \exists \mathtt{t}^2 \in \mathtt{T}(\mathtt{rb}(\mathtt{s},\mathtt{t}^2) \wedge \exists \mathtt{e}(\mathtt{mbs_u(e)} \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{t}^2 \sqsubseteq_\mathtt{i} \mathtt{t}^1)))$

Our meaning is stated in terms of a long and complicated formula. What we have is the statement that there exists an mbs-event e, that its runtime $\tau_\mathtt{u}(\mathtt{e})$ is included in an interval $\mathtt{t}^2$ that is right-bounded by s, and that $\mathtt{t}^2$ is included in a three-day time $\mathtt{t}^1$. We can substitute for this complicated statement the equivalent yet much simpler formula in (72). This states that an mbs-event is included in the interval $\mathtt{pts(3,d,s)}$. The equivalence of both formulas is easily demonstrates.

(72) $\exists \mathtt{e}(\mathtt{mbs_u(e)} \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{pts(3,d,s)})$

We can first sketch a proof that (71) entails (72). Let e be an mbs-event, let $\mathtt{t}^2$ be an interval that is right-bounded by s and that includes $\tau_\mathtt{u}(\mathtt{e})$, and let $\mathtt{t}^1$ be a three-day time that includes $\mathtt{t}^2$. Since, by definition, $\mathtt{pts(3,d,s)}$ includes every interval that is both right-bounded by s and included in a three day time, it includes $\mathtt{t}^2$. By the transitivity of the part-whole relation, it follows that $\tau_\mathtt{u}(\mathtt{e})$ is included in $\mathtt{pts(3,d,s)}$.

Let's now sketch a proof that (72) entails (71). Let e be an mbs-event such that $\tau_\mathtt{u}(\mathtt{e})$ is included in $\mathtt{pts(3,d,s)}$. Again by definition, we know that $\mathtt{pts(3,d,s)}$ is largest interval that is right-bounded by s and included in a three-day time. Thus, $\mathtt{pts(3,d,s)}$ is an interval $\mathtt{t}^2$ that is right-bounded by s, that is included in a three-day long time $\mathtt{t}^1$ (i.e. itself), and that includes $\tau_\mathtt{u}(\mathtt{e})$.

At this point, it is easy to see that the meaning we derive for (67-b) is the negation of (72) in (49). This is, once again, precisely the meaning we argued for.

(49) $\neg\exists \mathtt{e}(\mathtt{mbs_u(e)} \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{pts(3,d,s)})$

Before moving on, I want to make two final comments. Firstly, (67-a) is predicted to have a possible LF where negation scopes below *three days*. The meaning for this LF, however, is trivial: it asserts the existence of a three-day time in which we don't have a time right-bounded by the moment of utterance in which Mary was sick. This is no doubt true of most three-day times, and should be ruled out as a possible reading due to its general uninformativity. Secondly, when discussing a sentence like (67-a), I will from hereon refer to $\mathtt{pts(3,d,s)}$ as *the* PTS of that sentence.

4 A Unified Constraint on the Distribution of TIAs

4.1 Maximal Informativity and E-TIAs

4.1.1 Maximal Informativity and the Subinterval Property

To my knowledge, Krifka (1989, 1998) is the first to propose that *maximal informativity* (Beck & Rullmann, 1999; von Fintel et al., 2014; Fox & Hackl, 2006, i.a.) is central to determining whether or not E-TIAs are acceptable. My presentation of the matter departs significantly from his and I'm unclear on how much of it he would actually sign off on. Nevertheless, I think that the majority of it remains true to the spirit, if not the details, of his proposal. Let me begin by defining what it means for something to be maximally informative in a property.

(73) For any $\mathtt{P}_{\sigma st}$, and $\mathtt{w}$,
$\mathtt{max}^{\models}(\mathtt{w},\mathtt{P}) := \mathtt{the}(\lambda \mathtt{x}.\mathtt{P}(\mathtt{x},\mathtt{w}) \wedge \forall \mathtt{y}(\mathtt{P}(\mathtt{y},\mathtt{w}) \rightarrow (\mathtt{P}(\mathtt{x}) \models \mathtt{P}(\mathtt{y}))))$

At a given world, $\mathtt{x}$ is maximally informative in $\mathtt{P}$ iff (a) $\mathtt{P}$ holds of $\mathtt{x}$ and (b) if $\mathtt{P}$ holds of anything else, this follows from the fact that it holds of $\mathtt{x}$. As we are about to see, E-TIAs are unacceptable when the measure they provide cannot be maximally informative. To make the point, let's take a look at properties that are defined according to the schema in (74).

(74) $\lambda \mathtt{n}\lambda \mathtt{w}.\exists \mathtt{t}(\mu(\mathtt{t}) = \mathtt{n} \wedge \exists \mathtt{e}(\mathtt{P}(\mathtt{e},\mathtt{w}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))$

Given a measure function μ and a property of events $\mathtt{P}$, our schema derives properties that characterize a set of number-world pairs $\langle \mathtt{n},\mathtt{w}\rangle$ such that, at $\mathtt{w}$, μ returns $\mathtt{n}$ as the duration of some time that includes a $\mathtt{P}$-event. Properties that satisfy the schema can be derived using the LFs of sentences containing E-TIAs. Whether or not a maximally informative number is defined in these properties depends on our choice of $\mathtt{P}$; generally, a maximally informative number is defined when $\mathtt{P}$ derives from a telic, but not an atelic, VP. Let's first look at (61-a) again, where an E-TIA is acceptable, and its LF in (61-b).

(61) a. Mary wrote up a paper in three days.
b. [three days] 2 $\textsc{past}_1$ PFV [Mary write up a paper] [in RT] t_2

In order to derive from our LF the sort of property we want, we can substitute a pronoun for *three* and abstract over both its index and the world of evaluation.

(75) $\lambda \mathtt{n}\lambda \mathtt{w}.[\![$[pro_3 days] 2 $\textsc{past}_1$ PFV [Mary write up a paper] [in RT] $t_2]\!]^{\mathtt{w},\mathtt{s},\mathtt{g}[3\mapsto \mathtt{n}]}$
$= \lambda \mathtt{n}\lambda \mathtt{w}.\exists \mathtt{t}(\mu_{\mathtt{d}}(\mathtt{t}) = \mathtt{n} \wedge \exists \mathtt{e}(\mathtt{mwp}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{g}(1) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))$

In (75), the property of events that corresponds to our $\mathtt{P}$ in (74) is the property of $\mathtt{mwp}$-events that are included in $\mathtt{g}(1)$.

(76) $\lambda \mathtt{e}\lambda \mathtt{w}.\mathtt{mwp}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{g}(1)$

What about a property of events $\mathtt{P}$ makes it possible for a number to be maximally informative in (74)? *Pace* Krifka, what is relevant isn't that $\mathtt{P}$-events are made up of $\mathtt{P}$-atoms (i.e. $\mathtt{P}$-events with no proper parts that are themselves $\mathtt{P}$-events). That's neither sufficient nor necessary. What is crucial is whether or not the durations of shortest $\mathtt{P}$-events, be they $\mathtt{P}$-atoms or not, are constant across worlds.[11]

[11] $\mathtt{P}$ may include no $\mathtt{P}$-atoms even if $\mathtt{P}$-event are all minimal insofar as they have the same duration. For

Intuitively, we think that it's possible for exactly one $\mathtt{mwp}$-event to be included in $\mathtt{g(1)}$. Part of this has to do with the fact that we conceive of $\mathtt{mwp}$-events as always starting with Mary initiating a writing process and culminating in a paper having been written: no proper part of this process is itself an $\mathtt{mwp}$-event.[12] We also think that worlds differ in terms of this event's duration. At one world, it lasts exactly one day; at another exactly two days; at another exactly three days; *etc.* Because the duration of the $\mathtt{mwp}$-event varies across worlds, it is informative to talk about the durations of times that include an $\mathtt{mwp}$-event. At the first world, times of one or more days include an $\mathtt{mwp}$-event in $\mathtt{g(1)}$; at the second, only times of two or more days do; at the third, only times of three or more days do; *etc.*

Now suppose that, at our world of evaluation $\mathtt{u}$, there is exactly one $\mathtt{mwp}$-event in $\mathtt{g(1)}$ and it lasts exactly three days. Is there a maximally informative number in (75)? Figure 10 highlights, for every numerical input, which of the property's outputs are true at $\mathtt{u}$.

$$\vdots$$
$$\mathtt{u}\quad \lambda w.\exists t(\mu_d(t) = \boxed{4} \wedge \exists e(\mathtt{mwp}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1) \wedge \tau_w(e) \sqsubseteq_i t))$$
$$\vdots$$
$$\mathtt{max}\quad \lambda w.\exists t(\mu_d(t) = \boxed{3} \wedge \exists e(\mathtt{mwp}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1) \wedge \tau_w(e) \sqsubseteq_i t))$$
$$\vdots$$
$$\lambda w.\exists t(\mu_d(t) = \boxed{2} \wedge \exists e(\mathtt{mwp}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1) \wedge \tau_w(e) \sqsubseteq_i t))\quad \Uparrow$$
$$\vdots$$

Figure 10: Output of (75) true at $\mathtt{u}$.

For every $n \geq 3$, it is true at $\mathtt{u}$ that an $\mathtt{n}$-day time includes an $\mathtt{mwp}$-event; for every $n < 3$ this is false. Observe that the outputs of (76) are totally ordered by entailment: propositions derived from smaller values strictly entail those derived from greater ones. This makes (75) *upward scalar* (Beck & Rullmann, 1999). The maximally informative number in (75) is thus the smallest value that returns a true proposition, i.e. 3.

Let's now compare (61-a) with the sentence in (77-a), where the E-TIA is unacceptable. The only difference between the two LFs is in the choice of VP.

(77) a. *Mary was sick in three days.
b. [three days] 2 $\textsc{past}_1$ PFV [Mary be sick] [in RT] t_2

Through the same process we applied to (61-a), we derive from (77-b) the property in (78).

(78) $\lambda n \lambda w.\exists t(\mu_d(t) = n \wedge \exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1) \wedge \tau_w(e) \sqsubseteq_i t))$

The property of events corresponding to our $\mathtt{P}$ in (74) is that of $\mathtt{mbs}$-events included in $\mathtt{g(1)}$.

example, it could be that there aren't any atoms in the predicate of events that range from 1pm to 2pm; this set might include an hour long event of an orchestra playing, part of which is an hour long event of a violin being played, part of which is an hour long event of strings vibrating, and so on infinitely.

[12] This makes the property of $\mathtt{mwp}$-events *quantized* in the sense of Krifka (1989, 1991, 1998).

(i) A property P_{svt} is quantized, $\mathtt{QUA(P)}$, iff
$\forall e^1, e^2\ \forall w(P(e^1, w) \wedge P(e^2, w) \wedge e^1 \sqsubseteq_v e^2 \rightarrow e^1 = e^2)$

(79) $\lambda e \lambda w.\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1)$

What is different between this property of events and the one in (76)? When Mary undergoes a period of sickness, we think that she is sick throughout that period; she is sick at *any* point in it. (79) has the *subinterval property* (Bennett & Partee, 1972; Dowty, 1979), which I render as (80) in the framework of event semantics.[13]

(80) A property P_{vst} has the subinterval property, $\mathtt{SUB}(P)$, iff
$\forall e^1\ \forall t\ \forall w(P(e^1, w) \wedge t \sqsubseteq_i \tau_w(e^1) \rightarrow \exists e^2(P(e^2, w) \wedge t = \tau_w(e^2)))$

The subinterval property makes the durations of the smallest mbs-events invariant across worlds: all such events are momentaneous. This produces semantic entailments that we don't see in the previous case. For any n, it obviously follows from there being an mbs-event included in an n-day time that there exists an mbs-event. What is less obvious is that the converse also holds. If there exists an mbs-event, then there exists a momentaneous mbs-event; if there exists a momentaneous mbs-event, then it is included in an n-day time. In other words, it is redundant to say that an mbs-event is included in a time of *any* duration: an n-day time includes an mbs-event iff there exists an mbs-event. The property in (78) turns out to be equivalent to the constant in (81).

(81) $\lambda n \lambda w.\exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1))$

Suppose that, at u, there is an mbs-event included in g(1). No matter the input we feed into (78), we get a true proposition. In fact, we always get the *same* true proposition: each of the outputs in Figure 11 just consists of the worlds at which there was an mbs-event included in g(1).

$$u \left\{ \begin{array}{c} \vdots \\ \lambda w.\exists t(\mu_d(t) = \boxed{4} \wedge \exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1) \wedge \tau_w(e) \sqsubseteq_i t)) \\ \vdots \\ \lambda w.\exists t(\mu_d(t) = \boxed{3} \wedge \exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1) \wedge \tau_w(e) \sqsubseteq_i t)) \\ \vdots \\ \lambda w.\exists t(\mu_d(t) = \boxed{2} \wedge \exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i g(1) \wedge \tau_w(e) \sqsubseteq_i t)) \\ \vdots \end{array} \right. \quad \Updownarrow$$

Figure 11: Outputs of (78) true at u.

The property in (78) is both upward scalar and *downward scalar* (Beck & Rullmann, 1999): the outputs of greater values entail those of smaller values. Unlike in (75), there can never be a maximally informative number in (75): if the output of a number is true, then it both entails and is entailed by the outputs of all other numbers. Any number returns for (78) a proposition that is as informative as what any other number returns. The interaction of the subinterval property with E-TIAs results in information collapse: the TIAs contribute no information!

[13]The subinterval property is probably overly conservative: any part of an mbs-event e's runtime is the runtime of an mbs-event *that is part of* e. However, the weaker subinterval property suffices for our purposes.

As mentioned earlier, Krifka is the first to tie the licensing of TIAs to whether it's possible for the numerals in their measure phrases to be maximally informative.[14] I say *possible* here because we've already seen that this number need not *actually* be maximally informative. Although we normally infer from (61-a) that it took Mary *no less* than three days to write up her paper (i.e. that 3 is maximally informative in (75)), this is a cancellable scalar implicature.

Perhaps it seems odd for the availability of an *optional* scalar to be necessary for E-TIAs to be acceptable. Nevertheless, if not through its appeal to common sense, the idea that pathological scalar implicatures lead to unacceptability finds support in its successful applications. One striking example of this is in how it can account for the polarity sensitivity of many NPIs (e.g. Krifka, 1995; Chierchia, 2013). Since ours is unified treatment of TIAs, which exhibit polarity sensitivity when they are perfect-level adverbials, there is a great deal of appeal in extending this idea to our cases.

A corollary of the proposal that I haven't seen discussed is that E-TIAs are predicted to be unacceptable with telic VPs like *the climber reach the summit*, assuming that events in the extensions of achievement verbs are momentaneous. Being momentaneous, they are included in times of every duration and an E-TIA ends up being uninformative. Yet, we see in (82) that our VP is happy to combine with an E-TIA.

(82) The climber reached the summit in three days.

Far from arguing against the role of maximal informaitivity in the licensing of E-TIAs, (82) is the exception that proves the rule. It's easy to overlook the powerful coercion mechanisms that we employ to salvage otherwise pathological statements; in (82), the VP is forced to take on an inchoative interpretation where the events are processes that lead to the summit being reached, i.e. climbing events. In this case, the process is understood to begin at the start of the climb (or a contextually salient point during the climb) and end at the summit being reached. By ensuring that there is a beginning and end to the processes, it becomes informative to discuss the durations of times that include them.

4.1.2 Minimal Parts

We just saw how the subinterval property makes it impossible for E-TIAs to provide a maximally informative measure. However, the subinterval property is not necessary for this. Let me illustrate this fact by considering the sentence in (83).

(83) *The dancers waltzed in one hour.

While the E-TIA is unacceptable with the atelic VP *the dancers waltz*, we may resist the idea that the property of events of the dancers waltzing has the subinterval property. Indeed, we might think that moments are too short to be the runtimes of anything we would call a waltzing event; a waltz may need to be conceptualized as comprising a minimum of three steps. This is the *minimal parts problem* for atelic VPs (Taylor, 1977; Dowty, 1979, i.a.).

For Krifka (1989, 1998), what is crucial to the unacceptability of E-TIAs with atelic predicates is not the subinterval property but instead a general conversational constraint on

[14] Krifka's (1989) discussion is somewhat more involved. It appeals both to a principle of informativity as well as a principle of brevity which serves to exclude redundant material. Since maximal informativity subsumes redundancy insofar as uninformative material cannot be maximally informative, I only appeal to the first kind of principle.

the use of *cumulative reference*. He assumes that atelic VPs are (strictly) cumulative: the sum of two waltzing events is also a waltzing event.

(84) A property $\mathtt{P}_{\mathtt{v\sigma t}}$ is cumulative, $\mathtt{CUM(P)}$, iff
$$\forall \mathtt{w}(\exists \mathtt{e}^1, \mathtt{e}^2(\mathtt{P}(\mathtt{e}^1, \mathtt{w}) \wedge \mathtt{P}(\mathtt{e}^2, \mathtt{w}) \wedge \mathtt{e}^1 \neq \mathtt{e}^2) \wedge \forall \mathtt{e}^1, \mathtt{e}^2(\mathtt{P}(\mathtt{e}^1, \mathtt{w}) \wedge \mathtt{P}(\mathtt{e}^2, \mathtt{w}) \rightarrow \mathtt{P}(\mathtt{e}^1 \oplus_{\mathtt{v}} \mathtt{e}^2, \mathtt{w})))$$

The claim is that, in normal conversation, we simply avoid reference to the minimal elements in a cumulative property. This holds not just for atelic VP, but for mass nouns and bare plurals. However, as Krifka points out, not only is it possible to coerce atelic predicates into referencing minimal events, but doing so allows them to combine with E-TIAs.

(85) The dancers waltzed in 3 seconds.

If we imagine a strange competition where the goal is for contestants to dance the shortest waltz, here imagined as a succession of three steps, (85) is quite alright. He concludes that (83)'s unacceptability stems from the fact that one hour is too long to be maximally informative: to be maximally informative with a property $\mathtt{P}$, the measure provided by a TIA must correspond the duration of a minimal $\mathtt{P}$-event.

Reasonable though Krifka's conclusion may seem, it is too weak. Even if the measure provided by an E-TIA corresponds to the duration of a minimal $\mathtt{P}$-event, it cannot be maximally informative unless minimal $\mathtt{P}$-events differ in terms of their durations. Suppose, for example, that all waltzing events were comprised of 3-second waltzing subevent; nothing shorter can be considered a waltz.[15] Now consider the property in (86) where $\mathtt{s}$ is the unit for seconds and, for any $\mathtt{w}$, $\mathtt{tdw}_{\mathtt{w}}$ is the set of events of the dancers waltzing at $\mathtt{w}$.

(86) $\lambda \mathtt{n} \lambda \mathtt{w}.\exists \mathtt{t}(\mu_{\mathtt{s}}(\mathtt{t}) = \mathtt{n} \wedge \exists \mathtt{e}(\mathtt{tdw}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{u}} \sqsubseteq_{\mathtt{i}} \mathtt{g}(1) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))$

Suppose that at $\mathtt{u}$, there exists at least one $\mathtt{tdw}$-event included in $\mathtt{g}(1)$. Figure 12 highlights the true outputs of (86) true at $\mathtt{u}$ and their logical relations to one another.

$$\mathtt{u}\left\{\begin{array}{c} \vdots \\ \lambda \mathtt{w}.\exists \mathtt{t}(\mu_{\mathtt{s}}(\mathtt{t}) = \boxed{4} \wedge \exists \mathtt{e}(\mathtt{tdw}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{g}(1) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t})) \\ \vdots \\ \lambda \mathtt{w}.\exists \mathtt{t}(\mu_{\mathtt{s}}(\mathtt{t}) = \boxed{3} \wedge \exists \mathtt{e}(\mathtt{tdw}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{g}(1) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t})) \end{array}\right. \Updownarrow$$
$$\begin{array}{c} \vdots \\ \lambda \mathtt{w}.\exists \mathtt{t}(\mu_{\mathtt{s}}(\mathtt{t}) = \boxed{2} \wedge \exists \mathtt{e}(\mathtt{tdw}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{g}(1) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t})) \\ \vdots \end{array}$$

Figure 12: Output of (86) true at $\mathtt{u}$.

For any $\mathtt{n} < 3$, the output of $\mathtt{n}$ cannot be maximally informative given that it is contradictory to the assumption that minimal $\mathtt{tdw}$-events all last three seconds. Moreover, all other outputs turn out to be equivalent. For any $\mathtt{n} \geq 3$, saying that an $\mathtt{n}$-second time includes a $\mathtt{tdw}$-event is just the same as asserting the existence of a $\mathtt{tdw}$-event. If there exists

[15] This is similar the view in (Link, 1998, p.203), where the solution to the minimal parts is to assume that atelic predicates have the subinterval property *down to some degree of granularity*. For a convincing critique of this view, which concludes that it is too strong, see Champollion (2017).

any $\texttt{tdw}$-event at all, then part of it is a minimal three-second $\texttt{tdw}$-event; for any $\texttt{n} \geq 3$, that minimal event is a $\texttt{tdw}$-event included in an $\texttt{n}$-second time. It therefore follows that all outputs resulting from some $\texttt{n} \geq 3$ are just the worlds where the dancers waltzed in $\texttt{g}(1)$. We have a *partial* informational collapse here: the E-TIA is either redundant or contradictory. Thus, no number could possibly be maximally informative in (86) if minimal $\texttt{tdw}$-events all shared the same duration.

The cause of (85)'s acceptability is therefore that we can imagine minimal waltzes as having different durations. Because of this, the existence of a $\texttt{tdw}$-event does not entail the existence of a $\texttt{tdw}$-event included in a three-second time; it is informative to give the duration of times that include minimal $\texttt{tdw}$-events.

4.1.3 Licensing E-TIAs Locally

We have almost everything we need for an accurate description of a restriction on the distribution of E-TIAs. We linked the acceptability of E-TIAs to the availability of maximal informativity implicatures. In §3, we mentioned that scalar implicatures are sometimes drawn in the scope of a logical operator. We may wonder whether E-TIAs can be licensed if their maximal informativity requirement is satisfied locally. It seems that indeed they can. Referencing an observation found in both Mittwoch (1982) and White & Zucchi (1996), White (1994) observes that an E-TIA is licensed in (87).

(87) Mary wrote something in three days.

If I write a paper in three days, part of that is the writing of a section; part of writing a section is writing a paragraph; part of writing a paragraph is writing a line; part of writing a line is writing a word; part of writing a word is writing a letter. These are all shorter and shorter events of writing *something*. The maximally informative number of days in which someone writes something is the smallest amount of time it took in days for that person to write *anything at all*. But it doesn't make much sense for Mary to have taken three days to write anything, and we might expect the E-TIA in (87) to be just as bad here as it is with a VP like *the dancers waltz*. This can be remedied if the maximal informativity requirement can be satisfied low, which is consistent with the scalar implicature we actually draw from the sentence; (87) is best understood as stating that there exists a thing such that it took Mary three days to write that thing. This can be derived if we treat the object in *Mary write something* as a quantifier which undergoes raising, as in (88).

(88) something 3 [three days] 2 $\textsc{past}_1$ [Mary write t_3] [in $\textsc{rt}$] t_2

As Krifka (1998) notes, maximal informativity can now be satisfied within the scope of *something*. The property with respect to which it is satisfied is given in (89).

(89) $\lambda n \lambda w. [\![[\ \mathit{pro}_4 \text{ days }]\ 2\ \textsc{past}_1\ [\text{ Mary write } t_3\ ]\ [\text{ in } \textsc{rt}\ ]\ t_2]\!]^{w,s,g[4 \mapsto n]}$
$= \lambda n \lambda w. \exists t(\mu_d(t) = n \wedge \exists e(\texttt{write}(e, m, g(3)) \wedge \tau_w(e) \sqsubseteq g(1) \wedge \tau_w(e) \sqsubseteq_i t))$

The *maximal informativity principle* (MIP) defined in (90) is a descriptive generalization that sums up everything we have said about the acceptability conditions of E-TIAs. Notice that, because I am assuming a unified analysis of TIAs, the MIP is formulated as a requirement for both E- and G-TIAs. The principle requires that, for some constituent of the LF in which it appears, it must be possible for the number in a TIA's measure phrase to be maximally informative.

(90) **Maximal Informativity Principle:**
Given a numeral **N**, a measure word **M**, an index $\mathtt{j}$, and a map function **f**, an LF of the form [[**N M**] $\mathtt{j}$ ... [in **f**] $\mathtt{t_j}$ ...] is licensed only if it is contained in an LF γ such that, for some $\mathtt{w}^1$, $\mathtt{max}^{\vDash}(\mathtt{w}^1, \lambda \mathtt{n} \lambda \mathtt{w}^2.[\![\gamma[\mathbf{N} \mapsto pro_{\mathtt{k}}]]\!]^{\mathtt{w}^2,\mathtt{s},\mathtt{g}[\mathtt{k}\mapsto\mathtt{n}]}) = [\![\mathbf{N}]\!]$.

The reader may wonder if maximal informativity isn't stronger than what we actually need. After all, when it doesn't lead to a contradiction, an E-TIA with an atelic VP is simply uninformative. Rather than a maximal informativity principle, we may only need an informativity principle. But E-TIAs with atelic predicates turn out to be informative in precisely those environments where they could be maximally informative (excluding cases where they would provide a measure that is smaller than that of a minimal event, in which case they are contradictory and thus overly informative). Moreover, the MIP's strength will pay off in the long run: we can account for the unacceptability of G-TIAs in terms of maximal informativity, but not in terms of informativity alone.

4.2 Maximal Informativity and G-TIAs

4.2.1 Current Predictions

On a unified treatment of TIAs, the MIP applies to both E- and G-TIAs. Ideally, the principle not only prevents E-TIAs from modifying atelic VPs, but doubles as an account of the polarity sensitivity of G-TIAs. This would dispense the need for any additional stipulations about the distribution of TIAs. But things are never as simple as we would like them to be. We will eventually succeed in deriving the polarity sensitivity of G-TIAs from the MIP, but this will require revising our lexical entry for the perfect.

Understanding the issues ahead requires understanding that times are distinguished not just in terms of whether or not they have a greatest lower bound and a least upper bound, but also based on whether or not they include their bounds. As I mentioned in §3, our definition of the metalanguage function $\mathtt{pts}$, repeated in (48), always picks out an interval that includes both of its bounds. For example, $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ is the interval that includes all and only the moment that are *inclusively* ordered between $\mathtt{s}$ and the moment exactly three days prior to it.

(48) $\mathtt{pts}(\mathtt{n}, \phi, \mathtt{t}^1) := \mathtt{the}(\lambda \mathtt{t}^2.\exists \mathtt{t}^3(\mu_\phi(\mathtt{t}^3) = \mathtt{n} \wedge \mathtt{t}^2 \in \mathtt{T} \wedge \mathtt{rb}(\mathtt{t}^1, \mathtt{t}^2) \wedge \mathtt{t}^2 \sqsubseteq_{\mathtt{i}} \mathtt{t}^3))$

A time is *closed* when it includes both its LB and RB; it is *open* when it excludes them both. While a time can in principle include only one of its bounds, we will restrict our attention to the set of closed times $\mathtt{C}$ and the set of open times $\mathtt{O}$. Note that moments are closed intervals and that an open moment is a contradiction in terms.

(91) a. $\mathtt{C} := \{\mathtt{t} \mid \mathtt{min}^{\preceq_\mathtt{i}}(\mathtt{t}) \sqsubseteq_\mathtt{i} \mathtt{t} \wedge \mathtt{max}^{\preceq_\mathtt{i}}(\mathtt{t}) \sqsubseteq_\mathtt{i} \mathtt{t}\}$
b. $\mathtt{O} := \{\mathtt{t} \mid \mathtt{min}^{\preceq_\mathtt{i}}(\mathtt{t}) \not\sqsubseteq_\mathtt{i} \mathtt{t} \wedge \mathtt{max}^{\preceq_\mathtt{i}}(\mathtt{t}) \not\sqsubseteq_\mathtt{i} \mathtt{t}\}$

Among closed and open times are the special cases of closed and open intervals. Being bounded and convex, intervals can always be identified by their endpoints. It is therefore common to represent intervals as two bracketed moments: the first is its LB, the second its RB. Whether the interval is closed or open is indicated by the orientation of the brackets. Brackets face each other for closed intervals, and face away from each other for open ones.

(92) For any $\mathtt{m}^1, \mathtt{m}^2, \mathtt{m}^3$ such that $\mathtt{m}^1 \preceq_{\mathtt{i}} \mathtt{m}^2$,

a. $\mathtt{m}^3 \sqsubseteq_{\mathtt{i}} [\mathtt{m}^1, \mathtt{m}^2] \leftrightarrow \mathtt{m}^1 \preceq_{\mathtt{i}} \mathtt{m}^3 \preceq_{\mathtt{i}} \mathtt{m}^2$

b. $\mathtt{m}^3 \sqsubseteq_{\mathtt{i}}]\mathtt{m}^1, \mathtt{m}^2[\leftrightarrow \mathtt{m}^1 \prec_{\mathtt{i}} \mathtt{m}^3 \prec_{\mathtt{i}} \mathtt{m}^2$

We can now show that, on current assumptions, it is far from clear that the MIP accounts for G-TIAs being NPIs. We begin by looking at the unacceptable sentence in (93-a), whose meaning we derived as (93-b).

(93) a. *Mary has been sick in three days.

b. $\exists \mathtt{e}(\mathtt{mbs}_{\mathtt{u}}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$

To check whether or not the MIP rules out (93-a), we first derive (94) from its LF. This property characterizes the set of number-world pairs $\langle \mathtt{n}, \mathtt{w} \rangle$ such that, at $\mathtt{w}$, an $\mathtt{mbs}$-event is included in $\mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s})$.

(94) $\lambda \mathtt{n} \lambda \mathtt{w}. \exists \mathtt{e}(\mathtt{mbs}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s}))$

Our property is upward scalar: an event included in $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ is necessarily in $\mathtt{pts}(4, \mathtt{d}, \mathtt{s})$, but $\mathtt{pts}(4, \mathtt{d}, \mathtt{s})$ can include events that $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ doesn't. For a maximally informative number to be defined in (94), it must be possible for there to be a smallest $\mathtt{n}$ such that $\mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s})$ includes an $\mathtt{mbs}$-event. In a callous act of terminological abuse, we will say that 3 is maximally informative in (94) when $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ is the *smallest* PTS to include an $\mathtt{mbs}$-event. Here, the class of PTSs I have in mind are the closed intervals whose RB is $\mathtt{s}$. Figure 13 shows that it is quite easy to come up with scenarios where this is satisfied.

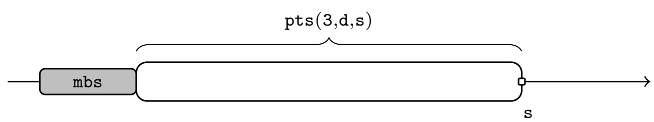

Figure 13: A smallest closed PTS that includes an $\mathtt{mbs}$-event.

In this scenario, Mary undergoes a period of sickness whose final moment is exactly three days prior to $\mathtt{s}$; this final moment coincides with the LB of $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$. The subinterval property holds of the property of $\mathtt{mbs}$-events, which means that this final moment is the runtime of an $\mathtt{mbs}$-event. Because $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ is closed, it includes its LB and therefore includes this momentaneous event. However, smaller PTSs include no such event: Mary was sick exactly three days ago, but no later than that. Since $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ can be the smallest PTS to include such an event, the MIP doesn't rule out (93-a).

In an effort remedy the situation, we might try and make stipulations about atelic VPs that would make scenarios like Figure 13 impossible. For example, we could reject the subinterval property here and assume that there aren't any momentaneous $\mathtt{mbs}$-events. Another approach might be to assume that the span of Mary's sickness is open. If the sickness stretched up to $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$'s LB but excluded it, $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ wouldn't actually include any sickness. With enough stipulations about the lexical properties of the VP, we can perhaps manage to have the MIP rule out (93-a). Valiant though such efforts are, they are left dead in the water the moment we realize that the problem extends to sentences with telic VPs. Take the example of (95) which, although acceptable under an E-TIA reading, does not admit a G-TIA interpretation.

(95) Mary has written up a paper in three days.

If it were available, this reading would assert the existence of an mwp-event in $\texttt{pts}(3, \texttt{d}, \texttt{s})$. Here again, 3 is maximally informative in the relevant property when $\texttt{pts}(3, \texttt{d}, \texttt{s})$ is the smallest PTS to include an mwp-event. Scenarios like Figure 14 show that such scenarios are also easy to come by.

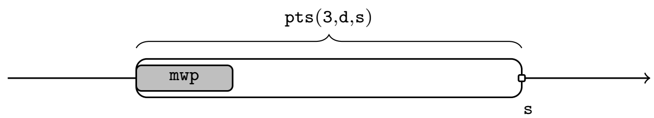

Figure 14: A smallest closed PTS that includes and mwp-event.

Here, $\texttt{pts}(3, \texttt{d}, \texttt{s})$ includes an mwp-event with which it shares its LB. We already discussed the fact that an mwp-event must begin with Mary initiating a writing process and end in its culmination. As such, no proper part of this span of writing is itself the runtime of another mwp-event; any portion of this process contained in smaller PTSs is too small to qualify as an mwp-event. The smallest PTS to include an mwp-event is therefore $\texttt{pts}(3, \texttt{d}, \texttt{s})$.[16]

Things wouldn't be so bad if the only issue that our analysis faced were the MIP's failure to predict that G-TIAs are NPIs. After all, constraints are cheap and we can always come up with another one. However, the theory in its current state makes jarring predictions about negative sentences like (96-a), whose meaning we expect to be (96-b).

(96) a. Mary hasn't been sick in three days.
b. $\neg\exists \texttt{e}(\texttt{mbs}_\texttt{u}(\texttt{e}) \wedge \tau_\texttt{u}(\texttt{e}) \sqsubseteq_\texttt{i} \texttt{pts}(3, \texttt{d}, \texttt{s}))$

This states that the interval $\texttt{pts}(3, \texttt{d}, \texttt{s})$ includes no mbs-events. We saw already that a scalar implicature typically enriches this meaning so as to convey that Mary stopped being sick three days ago. This enrichment doesn't require the last moment of Mary's sickness to be three days prior to s *on the dot*; when we draw scalar implicatures from numerals, we allow ourselves some degree of imprecision. But if we were to demand absolute precision here, we would plausibly land on the reading where the last bit of sickness was exactly three days ago. On current assumptions, however, a maximally informative reading doesn't look like it's even possible. Consider what it would mean for 3 to be maximally informative in (97).

(97) $\lambda \texttt{n} \lambda \texttt{w}.\neg\exists \texttt{e}(\texttt{mbs}_\texttt{w}(\texttt{e}) \wedge \tau_\texttt{w}(\texttt{e}) \sqsubseteq_\texttt{i} \texttt{pts}(\texttt{n}, \texttt{d}, \texttt{s}))$

The property is downward scalar. If $\texttt{pts}(3, \texttt{d}, \texttt{s})$ includes no mbs-event, then neither can $\texttt{pts}(2, \texttt{d}, \texttt{s})$. The converse implication does not hold. For 3 to be maximally informative in (97), $\texttt{pts}(3, \texttt{d}, \texttt{s})$ must be the *largest* PTS to include no mbs-event. We just saw that, if we allow there to be a final moment of sickness for Mary, then $\texttt{pts}(3, \texttt{d}, \texttt{s})$ includes that moment as soon as the former's LB abuts the latter's RB, as in Figure 13. For (96-b) to be true, there needs to be a gap between $\texttt{pts}(3, \texttt{d}, \texttt{s})$'s LB and the final moment of her sickness, as depicted in Figure 15.[17]

[16] This remains true even if we assume that the event runtime is open. The LB of this open time is shared with that of $\texttt{pts}(3, \texttt{d}, \texttt{s})$, while the LB of smaller PTSs is always strictly after that of our event. As such, those smaller PTSs do not include the event.

[17] (96-a) can also be true if Mary was never sick at all. Since I assume that logical time has no beginning,

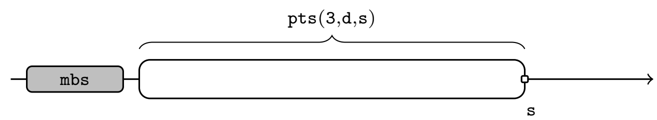

Figure 15: No greatest closed PTS can exclude an `mbs`-event.

Given the dense ordering on moments, there must be some moment between the event's RB and the interval's LB. Because we are also assuming that all intervals have measure and that their measures are additive, we are forced to conclude that there is some $\mathtt{n} > \mathtt{3}$ such that $\mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s})$ includes no `mbs`-event. If we assume that there can be a final moment of sickness, `3` cannot be maximally informative in (97). In fact, a stronger point can be made: the theory predicts that what intuitively feels like the strongest interpretation we can assign to (96-a) actually describes a scenario that falsifies it!

A point of caution: our intuitions may not be sharp enough to properly assess whether or not a sentence is true in scenarios where this hinges on a single moment of overlap. But it is nevertheless striking how the demands of the MIP and the polarity sensitivity of G-TIAs seem to be at odds with one another. Why can a G-TIA's numeral be maximally informative in the absence of negation, where it is unacceptable, but not with negation, where it is fine? To be sure, this doesn't entail that negative sentences like (96-a) are ruled out, as the MIP is satisfied below the scope of the negation. However, it is probably fair to say that there is disharmony between these two aspects of the analysis.

We could once again try tweaking our assumptions about atelic VPs, for example by assuming that they denote sets of events which span open times. This would once more allow the `mbs`-event to share its RB with the LB of $\mathtt{pts}(\mathtt{3}, \mathtt{d}, \mathtt{s})$ without the latter including any sickness event. But as before, telic VPs are a problem. Take the G-TIA reading of (98), which should mean that no `mwp`-event is included in $\mathtt{pts}(\mathtt{3}, \mathtt{d}, \mathtt{s})$. If we were to push our interpretation of the sentence to the limits of precision, it seems to convey that Mary's paper writing reached its point of culmination exactly three days ago.

(98) Mary hasn't written up a paper in three days.

As soon as $\mathtt{pts}(\mathtt{3}, \mathtt{d}, \mathtt{s})$'s LB is as early as that of an `mwp`-event, as in for example Figure 14, $\mathtt{pts}(\mathtt{3}, \mathtt{d}, \mathtt{s})$ will include it. Only if the event's LB strictly precedes that of $\mathtt{pts}(\mathtt{3}, \mathtt{d}, \mathtt{s})$ can (98) be true. But now, this means that (98) can only be true if a gap exists between that event's LB and the PTS's LB, as in Figure 16.

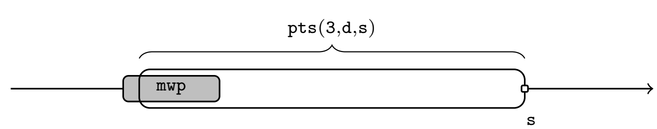

Figure 16: No greatest closed PTS can exclude an `mwp`-event.

If we have a gap between the two LBs, then we necessarily have a bigger PTS that doesn't include the event.[18] There is no way for `3` to be maximally informative in the relevant property.

there cannot be a largest PTS to include no `mbs`-event in those scenarios.

[18]Here too, this remains true if the event runtime is open. A closed PTS will include an open runtime as

Interestingly, it isn't even clear that a scenario like Figure 16 verifies (98), contrary to what the theory predicts. There is a feeling that, for (98) to be true, $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$ can't include any portion of an mwp-event. This looks like temporal homogeneity: either a PTS fully includes an mwp-event or it excludes all of its parts. We might wonder if temporal homogeneity might solve the problem here. It does not; if (98) states that no part of an mwp-event is in $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$, we just end up with a scenario analogous to the one in Figure 15. A gap still needs to exist between the event's RB and the interval's LB.

We are left in an awkward position. It seems like a G-TIA's numeral can be maximally informative in positive sentences, but not negative one. We saw that even if we toy around with the boundaries of event runtimes, the requirements of the MIP can't seem to line up with when G-TIAs are acceptable. But it turns out that I have been misleading you. In focusing on the boundaries of runtimes, I have obscured the most straightforward solution to the problem. In what follows, I suggest that the polarity sensitivity of G-TIAs is best captured in terms of closed runtimes interacting with open PTSs.

4.2.2 Open Intervals and Maximal In/Exclusions of Closed Times

The polarity sensitivity of G-TIAs finds a natural explanation in the fact that, while there cannot be a smallest open interval to *include* a closed time, there can be a largest open interval to *exclude* one. In preparation for the discussion ahead, it will be convenient to introduce some tools that will allow us to either remove a time's boundaries (if it is closed) or add them to it (if it is open). These are the respective roles of the o and c functions below.[19]

(99) a. $\mathtt{o}(\mathtt{t}^1) := \mathtt{the}(\lambda \mathtt{t}^2.\forall \mathtt{m}(\mathtt{m} \sqsubseteq_\mathtt{i} \mathtt{t}^2 \leftrightarrow (\mathtt{m} \sqsubseteq_\mathtt{i} \mathtt{t}^1 \wedge \mathtt{m} \neq \mathtt{min}^{\preceq_\mathtt{i}}(\mathtt{t}^1) \wedge \mathtt{m} \neq \mathtt{max}^{\preceq_\mathtt{i}}(\mathtt{t}^1))))$

b. $\mathtt{c}(\mathtt{t}^1) := \mathtt{the}(\lambda \mathtt{t}^2.\forall \mathtt{m}(\mathtt{m} \sqsubseteq_\mathtt{i} \mathtt{t}^2 \leftrightarrow (\mathtt{m} \sqsubseteq_\mathtt{i} \mathtt{t}^1 \vee \mathtt{m} = \mathtt{min}^{\preceq_\mathtt{i}}(\mathtt{t}^1) \vee \mathtt{m} = \mathtt{max}^{\preceq_\mathtt{i}}(\mathtt{t}^1))))$

Let's revise the meaning we assigned to the unacceptable sentence in (100-a): it now asserts that an mbs-event is included in the *open* counterpart of $\mathtt{pts}(3, \mathtt{d}, \mathtt{s})$. Let's furthermore stipulate that, for any w, only closed times belong to the range of $\tau_\mathtt{w}$.

(100) a. *Mary has been sick in three days.

b. $\exists \mathtt{e}(\mathtt{mbs}_\mathtt{u}(\mathtt{e}) \wedge \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s})))$

Making our interval open does not change the scalarity of the properties we are interested in; like its earlier counterpart, (101) is upward scalar. Accordingly, for the MIP to now rule out (100-a), it must be impossible for $\mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$ to be the smallest *open* PTS to include an mbs-event.

(101) $\lambda \mathtt{n} \lambda \mathtt{w}.\exists \mathtt{e}(\mathtt{mbs}_\mathtt{w}(\mathtt{e}) \wedge \tau_\mathtt{w}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{o}(\mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s})))$

On our new set of assumptions, it is *logically* impossible for there to be a maximally informative number in (101). Suppose that we have an open interval $]\mathtt{m}^1, \mathtt{m}^2[$ and a close time t; an open time like $]\mathtt{m}^1, \mathtt{m}^2[$ can only include a closed time like t if $\mathtt{m}^1$ strictly precedes t's LB while $\mathtt{m}^2$ is strictly preceded by t's RB. There is thus always a gap between the boundaries of a PTS and those of an event that it includes. This guarantees that there will never fail

soon as the former's LB is at least as early as the latter's. There still needs to be a gap between the two LBs for (98) to be true, and as a consequence a larger PTS that doesn't include the event.

[19] If a time t is open, o(t) simply returns t. If t is closed, the same is true of c(t).

to be a smaller PTS to include the event. A concrete visualization of this is provided in Figure 17.

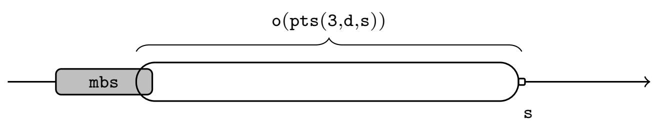

Figure 17: No smallest open PTS can include an mbs-event.

In order for $\texttt{o}(\texttt{pts}(\texttt{3}, \texttt{d}, \texttt{s}))$ to include an mbs-event, it must include at least one moment of Mary's sickness. In Figure 17, for example, the PTS includes her final moment of sickness. However, this inclusion is only possible if a gap exists between this moment and the PTS's LB; if the two coincide, then the moment of sickness is not included in the PTS. Given the dense ordering of moments, there will always be another moment in the gap between the two times. It follows that, for some $\texttt{n} < \texttt{3}$, the open interval $\texttt{o}(\texttt{pts}(\texttt{n}, \texttt{d}, \texttt{s}))$ includes Mary's final moment of sickness; 3, therefore, cannot be maximally informative in (101). The MIP now predicts (100-a)'s unacceptability.

Our new assumptions predict the unacceptability of G-TIAs in simple positive environments, and this no matter the lexical properties of the VP. Let's give another look at (102-a), which we saw lacked the G-TIA reading in (102-b).

(102) a. Mary has written up a paper in three days.
b. $\exists \texttt{e}(\texttt{mwp}_\texttt{u}(\texttt{e}) \wedge \tau_\texttt{u}(\texttt{e}) \sqsubseteq_\texttt{i} \texttt{o}(\texttt{pts}(\texttt{3}, \texttt{d}, \texttt{s})))$

The open interval $\texttt{o}(\texttt{pts}(\texttt{3}, \texttt{d}, \texttt{s}))$ only includes an mwp-event in scenarios like Figure 18, where the interval's LB strictly precedes that of the event's runtime.

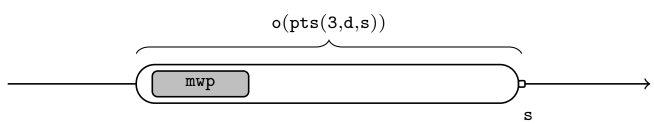

Figure 18: No smallest open PTS can include an mwp-event.

As with the previous scenario, $\texttt{o}(\texttt{pts}(\texttt{3}, \texttt{d}, \texttt{s}))$ cannot be the smallest PTS to include the event. Since there is a gap between its LB and that of the runtime, there is necessarily some $\texttt{n} < \texttt{3}$ such that $\texttt{o}(\texttt{pts}(\texttt{n}, \texttt{d}, \texttt{s}))$ includes the event. The MIP rules out the G-TIA reading for (102-a), leaving us only with its E-TIA interpretation. No matter the lexical properties of our VP, there is no escaping the logic of how open intervals include closed times.

So far, so good. Now we must show that the MIP doesn't rule out G-TIAs in negative environments. Consider (103-a), for which we now assume the meaning in (103-b).

(103) a. Mary hasn't been sick in three days.
b. $\neg\exists \texttt{e}(\texttt{mbs}_\texttt{u}(\texttt{e}) \wedge \tau_\texttt{u}(\texttt{e}) \sqsubseteq_\texttt{i} \texttt{o}(\texttt{pts}(\texttt{3}, \texttt{d}, \texttt{s})))$

As before, the PTS being open doesn't affect the scalarity of our property: (104) is downward scalar. 3 is therefore maximally informative in it when $\texttt{o}(\texttt{pts}(\texttt{3}, \texttt{d}, \texttt{s}))$ is the largest open PTS to exclude any mbs-event.

(104) $\lambda n \lambda w . \neg \exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i \mathtt{o}(\mathtt{pts}(n, d, s)))$

In Figure 19, we have a scenario where the final moment at which Mary was sick coincides with the PTS's LB.

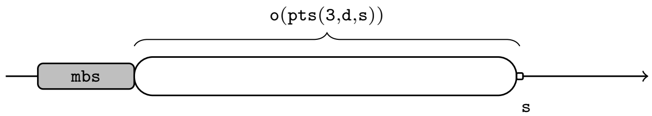

Figure 19: A largest open PTS to include no mbs-event.

Sentence (103-b) is true in this scenario: since $\mathtt{o}(\mathtt{pts}(3, d, s))$ excludes its own LB, it doesn't include any part of the mbs-event. But as soon as we move the PTS's LB further back in time, it will precede Mary's final moment of sickness and thus include an mbs-event. It follows that, for any $n > 3$, $\mathtt{o}(\mathtt{pts}(n, d, s))$ includes an mbs-event. We have a scenario where $\mathtt{o}(\mathtt{pts}(3, d, s))$ is the largest PTS that doesn't include any mbs-event! The MIP therefore doesn't block (103-a).

Once again, the lexical properties of our VP do not affect our result. Let's now turn to the sentence in (105-a), whose meaning is now (105-b).

(105) a. Mary hasn't written up a paper in three days.
b. $\neg \exists e(\mathtt{mwp}_u(e) \wedge \tau_u(e) \sqsubseteq_i \mathtt{o}(\mathtt{pts}(3, d, s)))$

Is it possible for $\mathtt{o}(\mathtt{pts}(3, d, s))$ to be the largest PTS that doesn't include an mwp-event? Consider a scenario like Figure 20, where the PTS shares its LB with that of an mwp-event's runtime.

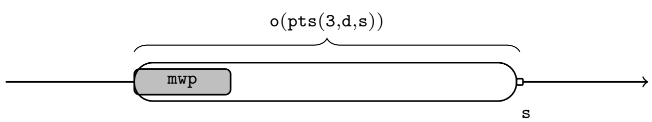

Figure 20: A largest open PTS to include no mwp-events.

Here, our PTS doesn't include the mwp-event because it excludes one moment from it. However, for any $n > 3$, the interval $\mathtt{o}(\mathtt{pts}(n, d, s))$ does include this moment and thus includes an mwp-event. We thus have a largest PTS that includes no mbs-events!

There may be a worry here: we already discussed the fact that scenarios like Figure 20 don't really seem to verify the sentence in (105-a) because of temporal homogeneity. The meaning we probably want for the sentence is stronger than (105-b): we want there to be no mwp-events that *overlaps* with the PTS.

(106) $\neg \exists e(\mathtt{mwp}_u(e) \wedge \tau_u(e) \otimes_i \mathtt{o}(\mathtt{pts}(3, d, s)))$

But this semantic amendment makes no difference for us. If (106) were the meaning we chose to assign (105-a), we would still be able to find a largest PTS that doesn't overlap with any mwp-event. This will be a scenario analogous to Figure 19, where the RB of an mwp-event abuts $\mathtt{o}(\mathtt{pts}(3, d, s))$. Since our choice of meaning for (105-a) turns out to be immaterial to whether or not MIP rules out the sentence, I will ignore the issue of temporal homogeneity altogether.

We now have a set of assumptions that predict the polarity sensitivity of G-TIAs. These are that PTSs are open intervals and that event runtimes are closed times. Our final task in this section will be to implement this change compositionally.

4.2.3 Revising our Semantics for the Perfect

The assumption that event runtimes are closed can be hardwired into the definition of the runtime function. This doesn't require revising the meanings of any of our lexical entries. To account for PTSs being open intervals, all that we need is a minor revision of our lexical entry for PERF. We initially took this to denote a relation between a predicate of times $\mathtt{I}$ and a time $\mathtt{t}$, such that there exists, in the domain of intervals, an $\mathtt{I}$-time which is right-bounded by $\mathtt{t}$. The only change we need to make is to further restrict the domain of the existential: its restrictor needs to be the domain of *open* intervals $\mathtt{T} \cap \mathtt{O}$.

(107) $[\![\text{PERF}]\!] \coloneqq \lambda \mathtt{I}_{\mathtt{it}} \lambda \mathtt{t}^1.\exists \mathtt{t}^2 \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{t}^1, \mathtt{t}^2) \wedge \mathtt{I}(\mathtt{t}^2))$ (*Revised*)

We don't need to change anything about the syntax for (67-a), whose G-TIA reading is still derived from the LF in (67-b).

(67) a. Mary hasn't been sick in three days.
b. not [three days] 1 PRES PERF [PFV Mary be sick] [in ID] t_1

As we did previously, we will derive (107-b)'s meaning in three steps. First, we derive the meaning of the material that is below the scope of the negation.

(108)
$$
\begin{aligned}
&[\![\text{[three days] 1 PRES PERF [PFV Mary be sick] [in ID] } t_1]\!]^{u,s}\\
&= [\![\text{three days}]\!](\lambda \mathtt{t}^1.[\![\text{PERF}]\!](\lambda \mathtt{t}^2.\exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}^2 \sqsubseteq_{\mathtt{i}} \mathtt{t}^1))(\mathtt{s}))\\
&= [\![\text{three days}]\!](\lambda \mathtt{t}^1.\exists \mathtt{t}^2 \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s}, \mathtt{t}^2) \wedge \exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}^2 \sqsubseteq_{\mathtt{i}} \mathtt{t}^1)))\\
&= \exists \mathtt{t}^1(\mu_{\mathtt{d}}(\mathtt{t}^1) = 3 \wedge \exists \mathtt{t}^2 \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s}, \mathtt{t}^2) \wedge \exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}^2 \sqsubseteq_{\mathtt{i}} \mathtt{t}^1)))
\end{aligned}
$$

As before, we end up with temporal Russian dolls: we get a formula that states that there exists an $\mathtt{mbs}$-event $\mathtt{e}$, that its runtime $\tau_{\mathtt{u}}(\mathtt{e})$ is included in an *open* interval $\mathtt{t}^2$ that is right-bounded by $\mathtt{s}$, and finally that $\mathtt{t}^2$ is included in a three-day time $\mathtt{t}^1$. Now we can move on to the second step in our derivation, whereby we show that this rather clunky formula is equivalent to the much simpler one in (109).

(109) $\exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s})))$

First, let's show that the formula in (108) entails (109). The largest open interval that is both right-bounded by $\mathtt{s}$ and included in a three day long time is $\mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$. If an open interval $\mathtt{t}^2$ is right-bounded by $\mathtt{s}$ and is included in a three-day time $\mathtt{t}^1$, then $\mathtt{t}^2$ is included in $\mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$. Any event included in $\mathtt{t}^2$ must therefore be included in $\mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$. Now we show that (109) entails (108). The time $\mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$ is an open interval $\mathtt{t}^2$ that is right-bounded by $\mathtt{s}$ and included in a three-day time $\mathtt{t}^3$. If this $\mathtt{t}^2$ includes an $\mathtt{mbs}$-event, then we have our Russian dolls. Our third and last step is simply to negate (109), which gives us (110). (110) and (109) are precisely the meanings we wanted for (67-a) and its negation.

(110) $\neg\exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s})))$

4.3 Section Summary

In §3, I argued for a unified semantic analysis of E- and G-TIAs. I showed that a single lexical entry for *in* was sufficient to derive both readings. The major difference between an E-TIA and a G-TIA is in the syntactic position of the adverbial. In and of itself, this unified semantics falls short of explaining why the acceptability of E-TIAs is contingent on the lexical aspect of the VP, and why that of G-TIAs is contingent on the polarity of the sentence. I began this section with what Krifka (1989) observed: the licensing of E-TIAs is tied to maximal informativity. I then showed how to stretch this observation to the licensing of G-TIAs.

I wouldn't blame the reader who finds the stipulations that were made in this section rather *ad hoc*. I am reminded of a quote from Bennett (1981) in which he comments on Glen Helman's proposal to distinguish between certain events in terms of whether or not they are open intervals: "Almost everyone finds the analysis to be mysterious – a 'logician's trick'." I understand that we are in want of an explanation for why some times are open while others are closed, but frankly I haven't the slightest clue what such an explanation is supposed to look like. In lieu of one, I will defend my assumptions empirically: I will spend the next section providing independent motivation for them. I hope that, by the end of that section, the reader will be as convinced as I am that they are correct.

Before moving on to the next section, I need to say a few words about how our new assumptions affect the subinterval property. As we have it, the subinterval property holds of a property of events $\mathtt{P}$ iff any proper part of a $\mathtt{P}$-event's runtime is itself the runtime of a $\mathtt{P}$-event. But this definition can never be satisfied if event runtimes must be closed: the runtime of any (non-momentaneous) event has a part that is open, which by assumption cannot be the runtime of an event. To avoid this problem, we need a different higher-order property. The *closed subinterval property*, which I will assume holds of the property of $\mathtt{mbs}$-events, is defined in (111).

(111) A property of events $\mathtt{P_{svt}}$ has the closed subinterval property, $\mathtt{CSUB(P)}$, iff
$\forall \mathtt{e}^1 \forall \mathtt{t} \forall \mathtt{w}(\mathtt{P}(\mathtt{e}^1, \mathtt{w}) \wedge \mathtt{t} \sqsubseteq_{\mathtt{i}} \tau_{\mathtt{w}}(\mathtt{e}^1) \rightarrow \exists \mathtt{e}^2(\mathtt{P}(\mathtt{e}^2, \mathtt{w}) \wedge \mathtt{c}(\mathtt{t}) = \tau_{\mathtt{w}}(\mathtt{e}^2)))$

The closed subinterval property holds of $\mathtt{P}$ iff, whenever we look at a portion $\mathtt{t}$ of a $\mathtt{P}$-event's runtime, the *closed counterpart* of $\mathtt{t}$ (if $\mathtt{t}$ isn't closed already) is the runtime of a $\mathtt{P}$ event. This definition has certain consequences that will become important in the next section. It ensures that the runtime of an $\mathtt{mbs}$-event cannot have parts throughout which Mary was sick, but which are not themselves the spans of $\mathtt{mbs}$-events. For example, this avoids ever encountering scenarios like Figure 21.

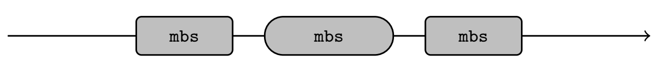

Figure 21: Impossible scenario for the closed subinterval property.

What this represents is a cumulation of three disjoint times throughout which Mary was sick. If we take the property of $\mathtt{mbs}$-events to be cumulative, the cumulation of all three times is itself the runtime of an $\mathtt{mbs}$-event. This is not a problem, since this cumulative time is closed. However, the middle segment is open and therefore cannot be the runtime of an $\mathtt{mbs}$-event. This is in spite of the fact that it cumulates moments of sickness. This is counter-intuitive: it implies that it is false to say that Mary was sick for the duration of this period. Our definition of the closed subinterval property guarantees that the closed counterpart of this middle segment spans an mbs-event.

5 The Perfect Quantifies over Open Intervals

In this section, I offer independent motivation for two of the assumptions I've made about the meaning of the perfect. In §5.1, I give arguments for a quantificational treatment of the perfect; in §5.2, I argue for the perfect's domain of quantification being restricted to open intervals and for runtimes to be closed.

My arguments will all be drawn from looking at the behavior of E- and U-perfects. Recall that we follow von Fintel & Iatridou (2019) in accounting for this ambiguity in terms of grammatical aspect: an E-perfect boils down to a perfect of the perfective and a U-perfect to a perfect of the imperfective.

5.1 The Perfect is Quantificational

5.1.1 The MIP and Sentence Ambiguities

There is no question that (112) is an unacceptable sentence. But it's worth emphasizing that the sentence's unacceptability *simpliciter* implies the unacceptability of the sentence on any possible reading.

(112) *Mary has been sick in three days.

There are in principle four readings to (112). These are conditioned by whether we have an E-TIA or a G-TIA and whether we have an E-perfect or a U-perfect. If the MIP is to completely rule out (112), it needs to do so on all possible interpretations. Happily, not only is this the case, but it affords us an argument in favor of a quantificational analysis of the perfect. Let's quickly show that the MIP takes care of each possible reading for (112), beginning with the reading where we have an E-TIA and an E-perfect. This is derived from the LF in (113).

(113) [three days] 1 PRES PERF PFV [Mary be sick] [in RT] t_1

What needs to be shown is that the addition of the perfect won't affect the information collapse observed in (113)'s simple past counterpart. I leave to readers the tedious task of deriving the meaning of (113), which is stated in (114).

(114) $\exists t^1(\mu_d(t^1) = 3 \wedge \exists t^2 \in T \cap O(rb(s, t^2) \wedge \exists e(mbs_u(e) \wedge \tau_u(e) \sqsubseteq_i t^1 \wedge \tau_u(e) \sqsubseteq_i t^2)))$

We don't get the temporal Russian dolls we had on the sentence's G-TIA reading. (114) states that there exists an mbs-event of which two things are true. First, it is included in a three day long time. Second, it is included in a PTS right-bounded by s. We already saw how, on account of the subinterval property, specifying the duration of a time that includes an mbs-event is redundant. This remains true here: if an mbs-event is in a PTS, part of that event will always be a momentaneous mbs-event that is both in that PTS and in a three day long time. (114) is equivalent to (115).

(115) $\exists t \in T \cap O(rb(s, t) \wedge \exists e(mbs_u(e) \wedge \tau_u(e) \sqsubseteq_i t))$

We run into the same information collapse here as we did with (113)'s simple past counterpart. The MIP blocks this reading. Let's now turn to (112) on a reading with an E-TIA and a U-perfect. The LF for this reading is (116).

(116) [three days] 1 PRES PERF IMPV [Mary be sick] [in RT] t_1

Our task is now to show that the imperfective aspect doesn't impact the information collapse. The meaning we get from (116) is (117), where we do observe temporal Russian dolls, but in a new configuration.

(117) $\exists \mathtt{t}^1(\mu_\mathtt{d}(\mathtt{t}^1) = 3 \land \exists \mathtt{t}^2 \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s}, \mathtt{t}^2) \land \exists \mathtt{e}(\mathtt{mbs}_\mathtt{u}(\mathtt{e}) \land \mathtt{t}^2 \sqsubseteq \tau_\mathtt{u}(\mathtt{e}) \sqsubseteq_\mathtt{i} \mathtt{t}^1))$

Two statements must hold of an `mbs`-event for the formula to be true. It must include a PTS right-bounded by `s`, and it must be included in a three day long time. The second statement is again redundant: if an `mbs`-event includes a PTS right-bounded by `s`, then that event has a part that includes a smaller PTS right-bounded by `s` and is included in a three day long time. This is true no matter the numeral's value. (117) is equivalent to (118), and we thus once again face information collapse. The MIP rules out this reading as well.

(118) $\exists \mathtt{t} \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s}, \mathtt{t}) \land \exists \mathtt{e}(\mathtt{mbs}_\mathtt{u}(\mathtt{e}) \land \mathtt{t} \sqsubseteq_\mathtt{i} \tau_\mathtt{u}(\mathtt{e})))$

Let's now move on to readings of (112) where we have a G-TIA. Since we already discussed in detail why the E-perfect version of this reading is unacceptable, only the U-perfect reading remains to be accounted for. The LF for that reading is (119).

(119) [three days] 1 PRES PERF [IMPV Mary be sick] [in ID] t_1

There are striking parallels between the interaction of an E-TIA with an atelic VP and the interaction of a G-TIA with an AspP headed by the imperfective operator. We can highlight these parallels by deriving from the AspP the property in (120).

(120) $\lambda \mathtt{t} \lambda \mathtt{w}.[\![\text{IMPV Mary be sick}]\!]^\mathtt{w}(\mathtt{t}) = \lambda \mathtt{t} \lambda \mathtt{w}.\exists \mathtt{e}(\mathtt{mbs}_\mathtt{w}(\mathtt{e}) \land \mathtt{t} \sqsubseteq_\mathtt{i} \tau_\mathtt{w}(\mathtt{e}))$

This is the property of times which are include in an `mbs`-event. Any time that is part of a time included in an `mbs`-event is also included in that event. This has the subinterval property! Of course, we've only defined the subinterval property when it comes to properties of events, but we can generalize it to properties of any type provided we have a map from that type's domain to the domain of times.

(121) Given a map $\mathtt{M}_{\sigma \mathtt{i}}$, a property $\mathtt{P}_{\sigma \mathtt{st}}$ has the generalized subinterval property, $\mathtt{GSUB}(\mathtt{M}, \mathtt{P})$, iff $\forall \mathtt{x}_\sigma\ \forall \mathtt{t}\ \forall \mathtt{w}(\mathtt{P}(\mathtt{x}, \mathtt{w}) \land \mathtt{t} \sqsubseteq_\mathtt{i} \mathtt{M}(\mathtt{x}) \rightarrow \exists \mathtt{y}_\sigma(\mathtt{P}(\mathtt{y}, \mathtt{w}) \land \mathtt{t} = \mathtt{M}(\mathtt{y})))$

With this in mind, we can now take a look at the meaning we derive from (119).

(122) $\exists \mathtt{t}^1(\mu_\mathtt{d}(\mathtt{t}^1) = 3 \land \exists \mathtt{t}^2 \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s}, \mathtt{t}^2) \land \exists \mathtt{e}(\mathtt{mbs}_\mathtt{u}(\mathtt{e}) \land \mathtt{t}^2 \sqsubseteq_\mathtt{i} \tau_\mathtt{u}(\mathtt{e}) \land \mathtt{t}^2 \sqsubseteq_\mathtt{i} \mathtt{t}^1)))$

This says that some PTS right-bounded by `s` is (a) in a three day long time and (b) in an `mbs`-event. Given the subinterval property, any part of this PTS is in the `mbs`-event. Moreover, for any number of days `n`, we can find a smaller PTS that is part of the first one and also included in a time that lasts `n` days. The TIA is once again redundant! (122) is equivalent to (123).

(123) $\exists \mathtt{t} \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s}, \mathtt{t}) \land \exists \mathtt{e}(\mathtt{mbs}_\mathtt{u}(\mathtt{e}) \land \mathtt{t} \sqsubseteq_\mathtt{i} \tau_\mathtt{u}(\mathtt{e})))$

Without any additional stipulations, the MIP blocks the three other readings of (112). Moreover, because the TIAs are redundant under each of these readings, they will be redundant when in the scope of any logical operator. This correctly predicts that (112)'s negation is unambiguously interpreted with an G-TIA and an E-perfect. These are very encouraging results. As we are about to see, however, some of them hinge on the perfect being an indefinite expression.

5.1.2 A Definite Perfect

We've been assuming that, rather than denote *the* PTS of a sentence, the perfect quantifies over a set of PTSs. Instead of arguing for this choice, I was content to show that it made no difference for the purpose of deriving (124)'s G-TIA reading.

(124) Mary hasn't been sick in three days.

I will show that a definite treatment of the perfect predicts that (124)'s positive counterpart should be acceptable on a U-perfect reading. Before doing so, I need to flesh out a reasonable treatment of the perfect as a definite description. In (124), a definite perfect should refer to $\mathtt{o}(\mathtt{pts}(3,\mathtt{d},\mathtt{s}))$. The simplest way of doing this is to have the perfect combine with two expressions, each of which specifies one of the interval's its boundaries. The tense will naturally set its RB, whereas its LB will be specified by a perfect-level adverbial.[20] In the case of (124), the present sets the PTS's RB while the TIA is what sets its LB.

As we have defined them, G-TIAs don't pick a point in time that we can just equate with a PTS's LB. Instead, they denote a set of times with an upper bound on their duration. We can nevertheless make our analysis of TIAs consistent with a definite perfect: we will say that, in (124), the perfect picks out the largest open interval whose RB is $\mathtt{s}$ and which is included in a three-day time. To make composition as simple a possible, I will be assuming that the perfect forms a constituent with the tense and the perfect-level adverbial.

(125) $[\![\text{PERF}_{\text{df}}]\!] := \lambda \mathtt{I}_{\mathtt{it}} \lambda \mathtt{t}^1.\mathtt{max}^{\sqsubseteq_\mathtt{i}}(\lambda \mathtt{t}^2.\mathtt{t}^2 \in \mathtt{T} \cap \mathtt{O} \wedge \mathtt{rb}(\mathtt{t}^1,\mathtt{t}^2) \wedge \mathtt{I}(\mathtt{t}^2))$

The perfect takes in a set of times $\mathtt{I}$ and a time $\mathtt{t}$, and outputs the largest open interval in $\mathtt{I}$ that is right-bounded by $\mathtt{t}$. The values for $\mathtt{I}$ and $\mathtt{t}$ are provided by the adverbial and tense, respectively. Here, we want the adverbial to consist of all and only the times that are included in a three-day time. This meaning is derived through syntactical manipulations on the TIA, as shown in (126).

(126) $[\![\mathtt{2}\ [\text{ three days }]\ \mathtt{1}\ [\ [\text{ in ID }]\ \mathrm{t}_1\ ]\ \mathrm{t}_2]\!] = \lambda \mathtt{t}^2.\exists \mathtt{t}^1(\mu_\mathtt{d}(\mathtt{t}^1) = 3 \wedge \mathtt{t}^2 \sqsubseteq_\mathtt{i} \mathtt{t}^1)$

We are now able to have the perfect refer to the interval we want.

(127) $[\![\text{PRES PERF}_{\text{df}}\ \mathtt{2}\ [\text{ three days }]\ \mathtt{1}\ [\ [\text{ in ID }]\ \mathrm{t}_1\ ]\ \mathrm{t}_2]\!]^{\mathtt{s}}$
$= \mathtt{max}^{\sqsubseteq_\mathtt{i}}(\lambda \mathtt{t}^2.\mathtt{t}^2 \in \mathtt{T} \cap \mathtt{O} \wedge \mathtt{rb}(\mathtt{s},\mathtt{t}^2) \wedge \exists \mathtt{t}^1(\mu_\mathtt{d}(\mathtt{t}^1) = 3 \wedge \mathtt{t}^2 \sqsubseteq_\mathtt{i} \mathtt{t}^1))$
$= \mathtt{o}(\mathtt{p}(3,\mathtt{d},\mathtt{s}))$

The positive counterpart of (124), on an E-perfect G-TIA reading, has the LF in (128-a). The meaning we get is (128-b), which is the same meaning obtained on a quantificational analysis of the perfect. We already know that the MIP rules this out.

[20] In the absence of an overt adverbial, we must assume that a covert one is present (*cf.* Vlach, 1993; Iatridou et al., 2003).

(128) a. [PRES PERF$_{df}$ 2 [three days] 1 [[in ID] t_1] t_2] PFV Mary be sick
b. $\exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s})))$

But now we turn to the U-perfect reading of this sentence, whose LF is now (129-a). Assuming a quantificational perfect, we saw that the G-TIA was redundant, which explained the unacceptability of this reading. However, we now obtain a different reading, viz. the one in (129-b).

(129) a. [PRES PERF$_{df}$ 2 [three days] 1 [[in ID] t_1] t_2] IMPV Mary be sick
b. $\exists \mathtt{e}(\mathtt{mbs_u}(\mathtt{e}) \wedge \mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s})) \sqsubseteq_{\mathtt{i}} \tau_{\mathtt{u}}(\mathtt{e}))$

Far from being redundant in (129-b), the definite perfect fixes the lower limit on the durations of the mbs-events in the imperfective's domain of quantification. By looking at the property in (130), we can show that the G-TIA can be maximally informative in (129-a).

(130) $\lambda \mathtt{n} \lambda \mathtt{w}.\exists \mathtt{e}(\mathtt{mbs_w}(\mathtt{e}) \wedge \mathtt{o}(\mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s})) \sqsubseteq_{\mathtt{i}} \tau_{\mathtt{w}}(\mathtt{e}))$

The property is strictly downward scalar: an mbs-event that includes $\mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$ will include smaller PTSs, but not necessarily larger ones. The property has a maximally informative number provided there is a largest PTS included in an mbs-event. This is exactly what Figure 22 depicts.

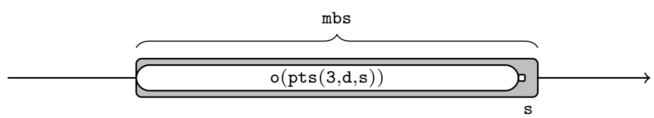

Figure 22: A largest open PTS included in an mbs-event.

The event runtime includes $\mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s}))$, with which it shares its LB. As soon as we extend the PTS's LB further back in time, it will precede that of the event. As a result, the PTS will no longer be included in it. We see that, if we were to assume a definite perfect, the MIP would not rule out G-TIAs in imperfective positive sentences. We now have our argument in favor of a quantificational perfect.

5.2 *Since*-Adverbials in the E- and U-Perfect

5.2.1 *Since*-Adverbials and Maximal Informativity

In von Fintel & Iatridou (2003), and later von Fintel & Iatridou (2019), the authors observe that *since-when* questions like (131) lack the E-/U-perfect ambiguity of their declarative counterparts.

(131) Since when has Mary been sick?

The question demands the LB of a PTS throughout which Mary was sick; this is its U-perfect reading. What it lacks is an E-perfect reading which asks for the LB of a PTS in which, at some point, Mary was sick. In von Fintel & Iatridou (2019), Fox & Hackl (2006) are credited with an explanation of this discrepancy, albeit in a previous version of their published article. The way von Fintel & Iatridou report their explanation is as follows, where I've allowed myself to make slight changes to better suit my example in (131):

'[...the E-perfect's] unacceptability is due to the fact that it is not possible to satisfy the presupposition of the definite in the *since*-clause. The reason is that the domain of time is dense. As a result, it is not possible to find "the time since which an event happened". On the other hand, with a U-perfect this extraction is fine because the definite description picks out the time at which [Mary's sickness] started'.

Without the context of the original paper, the quote is difficult to understand.[21] I take Fox & Hackl to assume that (131) presupposes the existence of a specific PTS, whose LB is the earliest time that follows an $\mathtt{mbs}$-event. Since time is dense, there is never an immediate successor to a given time; for any time that follows the event, there always exists an earlier time between it and the event. In contrast, the question's U-perfect reading presupposes the existence of a PTS whose LB is simply the start of Mary's sickness.

I hope my reconstruction does not do injustice to Fox & Hackl's original discussion. However, assuming it is more or less accurate, there are issues with this explanation. The E-perfect interpretation of (131) should not ask for the LB of a PTS that *follows* an $\mathtt{mbs}$-event, but rather the LB of a PTS that *includes* an $\mathtt{mbs}$-event. If we make this change, do we still capture the question's lack of ambiguity? After fleshing out some of the details of the semantics of interrogatives, I will show that this is only guaranteed if we assume closed runtimes and open PTSs. Let's begin by showing how we can derive the desired U-perfect reading for (131).

In the spirit of Hamblin (1973) and Karttunen (1977), I take a question to denote (at least at some point in the course of its derivation) a set of propositions that consists of its possible answers.[22] This is the question's *Hamblin set*. On present assumptions, the Hamblin set for (131)'s U-perfect interpretation should be $\mathtt{H}^1$ below.

(132) $$\mathtt{H}^1 \coloneqq \{\lambda \mathtt{w}.\exists \mathtt{t}^1 \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s},\mathtt{t}^1) \wedge \mathtt{lb}(\mathtt{t}^2,\mathtt{t}^1) \wedge \exists \mathtt{e}(\mathtt{mbs}_\mathtt{w}(\mathtt{e}) \wedge \mathtt{t}^2 \sqsubseteq_\mathtt{i} \tau_\mathtt{w}(\mathtt{e}))) \mid \mathtt{t}^2 \in \mathtt{D}_\mathtt{i}\}$$

Each answer in the set consists of worlds at which, for some time $\mathtt{t}$, Mary was sick throughout a(n open) PTS left-bounded by $\mathtt{t}$ and right-bounded by $\mathtt{s}$. One answer will consist of worlds where Mary was sick throughout the three days preceding $\mathtt{s}$, another of worlds where she was sick throughout the four preceding days, *etc.* $\mathtt{H}^1$ is equivalent to (133), where the answers take on a more familiar form.

(133) $$\{\lambda \mathtt{w}.\exists \mathtt{e}(\mathtt{mbs}_\mathtt{w}(\mathtt{e}) \wedge \mathtt{o}(\mathtt{pts}(\mathtt{n},\mathtt{d},\mathtt{s})) \sqsubseteq_\mathtt{i} \tau_\mathtt{w}(\mathtt{e})) \mid \mathtt{n} \in \mathbb{R}^+\}$$

Each answer is now defined as the set of worlds at which, for some positive real $\mathtt{n}$, an $\mathtt{mbs}$-event includes $\mathtt{o}(\mathtt{pts}(\mathtt{n},\mathtt{d},\mathtt{s}))$. We are missing a final ingredient to get at the meaning of questions. Indeed, a Hamblin set does not by itself a question make. Questions are subject to their own maximal informativity requirement: in the Hamblin set of any question, there must be an answer which is both true and which entails all other true answers (Dayal, 1996). This requirement is introduced by a covert answerhood operator ANS, sister to the

[21] In the published version of Fox & Hackl (2006), the authors discuss the similar case of *before-when* questions like (i).

(i) *Before when did John arrive.

They rule out (i) by assuming that it presupposes the existence of an earliest time following John's arrival. If we assume that time is dense, we can always find an earlier point in time after John's arrival.

[22] Rather than follow Karttunen (1977) in assuming this set to include only the question's true answers, I stick closer to Hamblin (1973) and assume that it includes all of its (relevant) possible answer.

constituent that denotes the Hamblin set. The extension of a question is thus its maximally informative true answer.[23]

(134) $[\![\text{ANS}]\!]^{\mathtt{u}} \coloneqq \lambda \mathtt{Q}_{(\mathtt{st})\mathtt{t}}.\mathtt{max}^{\vDash}(\mathtt{u}, \lambda \mathtt{p} \lambda \mathtt{w}.\mathtt{Q}(\mathtt{p}) \wedge \mathtt{p}(\mathtt{w}))$

We can assume that a question is unacceptable when there can never be a maximally informative true answer in its Hamblin set. This won't be a problem for the U-perfect reading of (131), whose meaning is given in (135).

(135) $[\![\text{ANS}]\!]^{\mathtt{u}}(\lambda \mathtt{p}.\mathtt{p} \in \mathtt{H}^1)$
$= \mathtt{the}(\lambda \mathtt{p}.\mathtt{p} \in \mathtt{H}^1 \wedge \mathtt{p}(\mathtt{u}) \wedge \forall \mathtt{q}(\mathtt{q} \in \mathtt{H}^1 \wedge \mathtt{q}(\mathtt{u}) \rightarrow (\lambda \mathtt{w}.\mathtt{p} \in \mathtt{H}^1 \wedge \mathtt{p}(\mathtt{w}) \vDash \lambda \mathtt{w}.\mathtt{q} \in \mathtt{H}^1 \wedge \mathtt{q}(\mathtt{w}))))$
$= \mathtt{the}(\lambda \mathtt{p}.\mathtt{p} \in \mathtt{H}^1 \wedge \mathtt{p}(\mathtt{u}) \wedge \forall \mathtt{q}(\mathtt{q} \in \mathtt{H}^1 \wedge \mathtt{q}(\mathtt{u}) \rightarrow (\mathtt{p} \vDash \mathtt{q})))$

How do we determine whether or not there can be a maximally informative true element in $\mathtt{H}^1$? As it turns out, we just saw this is possible, albeit under another guise. $\mathtt{H}^1$ is intimately related to the property in (130), repeated below: every member of $\mathtt{H}^1$ is obtained by inputting a positive real into (130), and every positive real inputted into (130) returns a member of $\mathtt{H}^1$. It is not hard to see that there is a maximally informative true answer in $\mathtt{H}^1$ iff the number that returns this proposition for (130) is also maximally informative in (130).

(130) $\lambda \mathtt{n} \lambda \mathtt{w}.\exists \mathtt{e}(\mathtt{mbs}_{\mathtt{w}}(\mathtt{e}) \wedge \mathtt{o}(\mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s})) \sqsubseteq_{\mathtt{i}} \tau_{\mathtt{w}}(\mathtt{e}))$

The scenario in Figure 22 is one where $\mathtt{3}$ is not only maximally informative in (130), but where the maximally informative true answer in $\mathtt{H}^1$ is $\lambda \mathtt{w}.\exists \mathtt{e}(\mathtt{mbs}_{\mathtt{u}}(\mathtt{e}) \wedge \mathtt{o}(\mathtt{pts}(\mathtt{3}, \mathtt{d}, \mathtt{s})))$. So we expect our question to have a U-perfect reading. Let's now turn to (131)'s unavailable E-perfect reading, whose Hamblin set is $\mathtt{H}^2$.

(136) $\mathtt{H}^2 \coloneqq \{\lambda \mathtt{w}.\exists \mathtt{t}^1 \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s}, \mathtt{t}^1) \wedge \mathtt{lb}(\mathtt{t}^2, \mathtt{t}^1) \wedge \exists \mathtt{e}(\mathtt{mbs}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}^2)) \mid \mathtt{t}^2 \in \mathtt{D}_{\mathtt{i}}\}$

The members of this set consists of all worlds at which a PTS includes an mbs-event, and differ only in terms of the PTS's LB. Once again, we can define the members of this set in more familiar terms, as in (137).

(137) $\{\lambda \mathtt{w}.\exists \mathtt{e}(\mathtt{mbs}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{o}(\mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s}))) \mid \mathtt{n} \in \mathbb{R}^+\}$

It is now easy to show that a maximally informative true element in (137) is logically impossible. The reasons for the unavailability of an E-perfect reading of (131) are entirely analogous to those for the polarity sensitivity of G-TIAs. Indeed, the property in (101), repeated below, bears the very same relationship to $\mathtt{H}^2$ as (130) did to $\mathtt{H}^1$. A proposition is maximally informative in $\mathtt{H}^2$ iff the number that returns that proposition for (101) is maximally informative there.

(101) $\lambda \mathtt{n} \lambda \mathtt{w}.\exists \mathtt{e}(\mathtt{mbs}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{o}(\mathtt{pts}(\mathtt{n}, \mathtt{d}, \mathtt{s}))$

We've seen in detail why a maximally informative number can never be defined for (101): there can never be a smallest open PTS that includes the closed runtime of an mbs-event.

[23] We should not confuse this with the extension of a declarative statement, which is not a proposition but a truth-value. Likewise, whereas the intension of a declarative is a proposition, that of an interrogative is a set of world-proposition pairs, where each world is mapped onto the maximally informative true answer at that world. If a question is defined at all worlds, this set can be used to partition the logical space, with equivalence classes defined according to which answer worlds are mapped to.

There can thus never be a maximally informative true element in $\mathtt{H}^2$, ruling out (131)'s E-perfect reading. In §4, we saw that it was difficult to guarantee the unacceptability of G-TIAs in simple positive sentences without stipulating open PTSs and closed runtimes. For the same reasons, it is difficult to rule out (131)'s E-perfect reading without those very same stipulations. This is our first piece of independent motivation for our assumptions.

5.2.2 The Bounds of E- and U-Perfects

We just saw that the interrogative counterpart of (138) bolsters confidence in the assumption that the perfect is restricted to open intervals while runtimes are closed. In this section, we will see that the behavior of the declarative in (138) also hints at this fact.

(138) Mary has been sick since Monday.

Mittwoch (1988) makes a remarkable observation about (138): the left-boundary of its PTS seems to change depending on whether the sentence is interpreted as an E-perfect or a U-perfect. On its E-perfect reading, Monday is excluded from the PTS in which Mary's sickness took place. She may well have been sick *on* Monday, but this is immaterial to the truth or falsity of the sentence. What matters is whether she was sick *after* Monday. On its U-perfect interpretation, however, part of Monday must be included in the period of Mary's sickness.

Mittwoch accounts for this discrepancy in terms of an ambiguity in both the meaning of the perfect and in that of the *since*-adverbial. Whether the PTS includes or excludes the event depends on the meaning assigned to the perfect. Likewise, whether or not the PTS's LB includes part of Monday is a matter of the meaning assigned to the *since*-adverbial.

> "[...*S*]*ince* itself is ambiguous. *Since 7.00* can mean *from 7.00 till now* or *at some time between 7.00 and now*. In the first sense *since 7.00* is a durational adverbial; in the second it is an extended time *when* (or frame) adverbial, like *last year*, *in January*, *during the vacation*."

Mittwoch is not totally explicit about why each meaning of the *since*-adverbial is only available for one of the meanings assigned to the perfect. My best guess would be that she takes this to follow from more general assumptions on the distributions of durational and frame adverbials. While we've been assuming that the E-/U-perfect ambiguity is a matter of grammatical aspect, as opposed to an ambiguity in the meaning of the perfect itself, it seems fairly straightforward to adapt her proposal into our own framework. But, as it turns out, there is no need for us to assume an ambiguity for *since* at all. Indeed, provided we assume that the interval identified by *Monday* is closed, what she observes is exactly what we would expect from closed runtimes and open PTSs. Given the lexical entry we've been assuming for *since Monday*, which left-bounds a PTS at `mday`, (138)'s E-perfect interpretation is (139).

(139) $\exists \mathtt{t} \in \mathtt{T} \cap \mathtt{O}(\mathtt{rb}(\mathtt{s}, \mathtt{t}) \wedge \mathtt{lb}(\mathtt{mday}, \mathtt{t}) \wedge \exists \mathtt{e}(\mathtt{mbs}_{\mathtt{u}}(\mathtt{e}) \wedge \tau_{\mathtt{u}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{t}))$

In the PTS ranging from the endpoint of `mday` up to `s`, there is an `mbs`-event. This is true in scenarios like Figure 23.

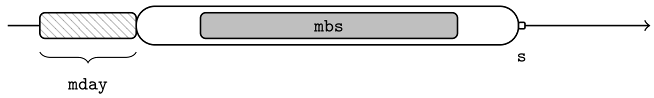

Figure 23: Scenario verifying (139).

Naturally, if the open PTS's LB is the RB of mday, it follows that mday precedes the whole of that event. In other words, assuming a closed runtime and an open PTS explains why, on its E-perfect interpretation, whether or not Mary was sick on that day is irrelevant to the truth or falsity of (138). Now we turn our attention to the U-perfect interpretation of our sentence, whose meaning is (140).

(140) $\exists t \in T \cap O(rb(s, t) \wedge lb(mday, t) \wedge \exists e(mbs_u(e) \wedge t \sqsubseteq_i \tau_u(e)))$

Here, it is an mbs-event that includes the PTS ranging from the end of mday up to s. For an mbs-event e to include an open interval, it must be that part of its runtime is coextensive with the interval. Here is where the way in which we defined the closed subinterval property, repeated below, becomes important.

(111) A property of events P_{svt} has the closed subinterval property, CSUB(P), iff
$\forall e^1 \forall t \forall w(P(e^1, w) \wedge t \sqsubseteq_i \tau_w(e^1) \rightarrow \exists e^2(P(e^2, w) \wedge c(t) = \tau_w(e^2)))$

Suppose that (111) holds of the property of mbs-events. It follows that, whenever an mbs-event includes an open interval, the closed counterpart of that interval is the runtime of an mbs-event. So if an mbs-event includes a PTS left-bounded by mday, that PTS's closed counterpart is the runtime of an mbs-event. Being closed, the interval will include mday's RB. If we are willing to treat mday as closed, it thus follows that it overlaps with — at the very least at its final moment — a momentaneous mbs-event. In other words, our assumptions derive the observation that, in order for (138)'s U-perfect interpretation to be true, Mary must have been sick on Monday. A scenario where this is true looks like Figure 24.

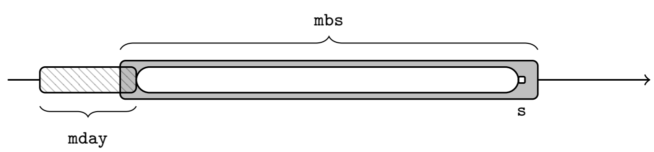

Figure 24: Scenario verifying (140).

We now have our second independent piece of motivation for the view that event runtimes are closed and PTSs open. Before wrapping things up, I would like to point out two additional predictions that we make. First, we predict that whether or not Mary was sick at s should be irrelevant to the truth-conditions of (138)'s E-perfect interpretation. Second, we expect that its U-perfect interpretation can only be true if Mary is sick at s. These predictions follow from the fact that an mbs-event can only be included in an open PTS if its own RB precedes that of the PTS, while an mbs-event can only include a PTS if it includes the PTS's RB.

It is very clear that the U-perfect reading does imply that Mary is still sick at s. What is harder to tell is whether the prediction about the E-perfect is correct. Part of the problem is that, because of the (closed) subinterval property, the U-perfect entails the E-perfect. Indeed, because part of Mary's sickness in Figure 24 is included in the PTS, the scenario verifies (139). However, we can get rid of the entailment from a perfect of the imperfective to a perfect of the perfective if we look at sentences in which the VP is telic.

(141) a. Mary has written up a paper since Monday.
b. Mary has been writing up a paper since Monday.

The E-perfect reading in (141-a) can only be true if the totality of Mary's paper writing is included in the PTS. This means that the sentence is true only if the start of Mary's paper writing began after Monday. What's more, the sentence implies that Mary completed her paper before $\mathtt{s}$. As Heny (1982) puts it, we want "a (minimal) element of 'pastness'" in the semantics of the (perfective) perfect.[24] This is in contrast to (141-b), which implies both that Mary was in the process of writing her paper *on* Monday, and that she is still in this process at $\mathtt{s}$. These readings are precisely what we predict for both sentences, further supporting our assumptions about the bounds of runtimes and those of PTSs.

6 Comparison with Previous Accounts of G-TIAs

6.1 Downward Entailment and its Subproperties

One approach to capturing the polarity sensitivity of G-TIAs, found in the work of Hoeksema (2006) and Gajewski (2005, 2007, 2011), finds its roots in Ladusaw's (1979) seminal work on the distribution of NPIs. We can follow von Fintel (1999) in presenting Ladusaw's insights by way of a cross-categorial notion of entailment.

(142) Cross-Categorial Entailment:
a. $\mathtt{p} \vDash_{\mathtt{t}} \mathtt{q}$ iff $\mathtt{p} \rightarrow \mathtt{q}$
b. $\mathtt{p} \vDash_{\sigma\tau} \mathtt{q}$ iff $\forall \mathtt{x}_{\sigma}(\mathtt{p}(\mathtt{x}) \vDash_{\tau} \mathtt{q}(\mathtt{x}))$

Cross-categorial entailment is defined recursively, with the base case given in terms of material implication. Higher-level entailment is always defined in terms of lower-level entailment: a function entails another iff the output it returns for any given argument entails the output that this argument returns for the other. Ultimately, higher-order entailment is always grounded in the base case; it is only defined for functions which can be uncurryed into truth-functional functions. We can now define what it means for a function to be *downward entailing*.

(143) Downward Entailingness:
A function $\mathtt{f}_{\sigma\tau}$ is downward entailing, $\mathtt{DE}(\mathtt{f})$, iff $\forall \mathtt{x}_{\sigma}, \mathtt{y}_{\sigma}(\mathtt{x} \vDash_{\sigma} \mathtt{y} \rightarrow \mathtt{f}(\mathtt{y}) \vDash_{\tau} \mathtt{f}(\mathtt{x}))$.

A function $\mathtt{f}$ is downward entailing if it reverses the entailment that holds between its arguments. Thus, if $\mathtt{x}$ entails $\mathtt{y}$, a downward entailing function is one such that $\mathtt{f}(\mathtt{x})$ is entailed

[24] Mittwoch (1988) disputes this with examples like (i), which can be uttered by a sports commentator who times his utterance with the event's final moment.

(i) Mary has touched the finishing line.

I do agree that the sentence is fine in situations such as those, but there is something markedly funny about them. My best guess would be that in such sentences, the speaker forces the audience to evaluate the sentence at a point which follows its moment of its utterance.

by $\mathtt{f(y)}$. Ladusaw draws the link between polarity sensitivity and downward entailingness by proposing that NPIs are only licensed in downward entailing environments. The way von Fintel implements this idea is by requiring NPIs to be in the scope of an expression which denotes a downward entailing function.

(144) NPI Licensing Condition:
An NPI is licensed iff it is in the scope of some α such that $\mathtt{DE}(\llbracket\alpha\rrbracket^{\mathtt{u,s,g}})$.

Negation is the most straightforward example of a downward entailing function: if a material implication holds from $\mathtt{p}$ to $\mathtt{q}$, then the contrapositive holds from $\neg\mathtt{q}$ to $\neg\mathtt{p}$. Naturally, (144) explains why NPIs are not licensed in simple positive sentences but are licensed in the scope of negation.

If we restrict our attention to G-TIAs in either simple positive sentences or in the scope of negation, we easily capture their distribution in terms of (144). However, Hoeksema (2006) notes that this condition is too weak to properly capture the distribution of G-TIAs, which is more restricted than that of many other NPIs. Drawing from Zwarts (1998), both he and Gajewski (2005, 2007, 2011) account for the licensing of G-TIAs in terms of a subproperty of downward entailingness.

I have restricted my attention to G-TIAs in simple positive sentences and in the scope of a negation operator, paying no mind to the many complications that surround their distribution. I did so deliberately in an effort to avoid scope creep in what is already quite a lengthy discussion of TIAs. Without engaging with these complications head on, I want to take a second to discuss some of the consequences that come from relying on downward entailingness (or a stronger property) to account for the acceptability of G-TIAs. On a unified treatment of TIAs, a condition like (144) would restrict the distribution of E-TIAs as much as it does that of G-TIAs. This incorrectly predicts E-TIAs to be NPIs. NPI licensing conditions like (144) are therefore fundamentally incompatible with a unified treatment of TIAs. In light of everything we've discussed in this article, I find this result both deeply unappealing and quite implausible. I will not discuss here whether the MIP successfully accounts for the broader distribution of G-TIAs. But even if it were to fail in this regard, I wouldn't lose any sleep over it. Perhaps the MIP will turn out to be too weak to capture the full distribution of TIAs, but downward entailingness is far too powerful. We can easily strengthen the MIP and discover further insights into the distribution of TIAs, but how to go about weakening (144) while remaining true to its insights is a far more nebulous task.

6.2 Subintervals of the PTS

The second line of approach used to capture the polarity sensitivity of G-TIAs is exemplified by the work of Chierchia (2013) and Iatridou & Zeijlstra (2021). Although both proposals were formulated to deal with the polarity sensitivity of bare TIAs like *in days* and *in years*, they apply very naturally to G-TIAs whose measure phrases include a numeral. Much like myself, these authors ground the fact that G-TIAs are NPIs in the fact that they generate pathological implicatures in simple positive sentences. Although the insight is quite similar, the manner in which pathology is produced here is different. Since Chierchia's presentation of the matter is given more informally, my discussion will be based on Iatridou & Zeijlstra's implementation of the idea. Adapting their proposal into our own framework, where (145)'s intension is (145-a), we will assume that the sentence has the members of $\mathtt{Alt}^1$ as alternatives.

(145) *Mary has been sick in three days.

a. $\lambda w.\exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i o(\mathtt{pts}(3, d, s)))$

b. $\mathtt{Alt}^1 := \{\lambda w.\exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i t \mid t \sqsubseteq_i o(\mathtt{pts}(3, d, s))\}$

Whereas (145-a) consists of worlds where an mbs-event is included in the $o(\mathtt{pts}(3, d, s))$, its alternatives all consist of worlds where such an event is included in a time included in this PTS. We can already mention that there is something artificial about the way in which these alternatives are defined. Alternatives of a given sentence are most commonly derived from substitutions of scalar material (Horn, 1972; Gazdar, 1979). For example, an alternative for *Mary ordered soup or salad* will be *Mary ordered soup and salad*, where the conjunction is substituted for the disjunction. There is no clear material that we can substitute in (145)'s LF which will produce all and only the alternatives in (145-b). Moreover, even if what we assumed were alternatives defined by a restricting of the domains of quantifiers (Krifka, 1995; Chierchia, 2013), it still won't be possible to derive these alternatives. Indeed, further restriction of the perfect's domain of quantification can only return propositions where an mbs-event is included in an interval that is right-bounded by s. Of course, since neither Chierchia nor Iatridou & Zeijlstra provide a derivation of the sentence's meaning, my comments can only be based on the compositional steps that I am assuming for its derivation. It may well be that a different account of its composition will provide a natural path for defining these alternatives.

If we ignore the difficulties in defining the sentence's alternatives, we can see how they can be used to derive the sentence's unacceptability. The core idea is that we draw from it the implicature that every member of (145-b) that strictly entails (145-a) is false. Put differently, we derive the implicature that (145-a) is the maximally informative true member of (145-b).

(146) $\mathtt{max}^{\vDash}(u, \lambda p \lambda w.p \in \mathtt{Alt}^1 \wedge p(w)) = \lambda w.\exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i o(\mathtt{pts}(3, d, s)))$

Since every member of (145-b) entails (145-a), it can only be the maximally informative true member of $\mathtt{Alt}^1$ if it this is the set's only true member. However, if $o(\mathtt{pts}(3, d, s))$ includes an mbs-event, then so must a time properly included in $o(\mathtt{pts}(3, d, s))$. The unacceptability of the sentence thus follows from the fact that it generates a pathological implicature.[25] Turning to the sentence's negative counterpart in (147), we now have the proposition in (147-a) and the alternatives in (147-b).

(147) Mary hasn't been sick in three days.

a. $\lambda w.\neg\exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i o(\mathtt{pts}(3, d, s)))$

b. $\mathtt{Alt}^2 := \{\lambda w.\neg\exists e(\mathtt{mbs}_w(e) \wedge \tau_w(e) \sqsubseteq_i t \mid t \sqsubseteq_i o(\mathtt{pts}(3, d, s))\}$

Here too, it is assumed that we derive the implicature that (147-a) is maximally informative among its alternatives. But things are different here, as every member of the set is now entailed by (147-a). In any world where (147-a) is true, it is also the maximally informative true element of $\mathtt{Alt}^2$.

[25] This follows from the fact that the PTS is open and the event runtime closed. Under Iatridou & Zeijlstra (2021), who do not assume PTSs are open, this is because the property of mbs-events has the subinterval property. However, they incorrectly predict G-TIAs to be fine in positive sentences with telic VPs. Indeed, a closed PTS can be coextensive with an mwp-event, in which case it includes it while none of its subintervals do. This result can be escaped if the inclusion relationship established by the perfective aspect is one of *proper* inclusion. A proper inclusion relation is, in fact, what Chierchia (2013) explicitly assumes.

(148) $\mathtt{max}^{\vDash}(\mathtt{u}, \lambda \mathtt{p} \lambda \mathtt{w}.\mathtt{p} \in \mathtt{Alt}^2 \wedge \mathtt{p}(\mathtt{w})) = \lambda \mathtt{w}.\neg \exists \mathtt{e}(\mathtt{mbs}_{\mathtt{w}}(\mathtt{e}) \wedge \tau_{\mathtt{w}}(\mathtt{e}) \sqsubseteq_{\mathtt{i}} \mathtt{o}(\mathtt{pts}(3, \mathtt{d}, \mathtt{s})))$

Proposals like those in Chierchia and Iatridou & Zeijlstra are obviously quite close to my own. However, because they were designed to account only for the polarity sensitivity of G-TIAs, they don't offer much insight into the distribution of E-TIAs. Indeed, the sets of alternatives we end up with are defined in terms of a PTS and the times that are part of it, which does not offer a natural way to think about the distribution of TIAs in sentences that lack a perfect. On account of this, this family of approaches misses the important insight that unifies the constraints on the acceptability of E- and G-TIAs, viz. that the TIA must be capable of providing a maximally informative measure.

7 Concluding Remarks

It is hard to believe how much one can find to say about TIAs in English. What is even more remarkable is how much more there is left to say. We began our discussion with a simple observation: we can distinguish E-TIAs from G-TIAs both in terms of what they contribute to the meaning of a sentence and in terms of what restrictions there are on their distributions. I went on to argue that these distinctions are illusory: there is only one meaning for and one distributional constraint on TIAs. What distinguishes the two varieties is simply their syntactic locus and the semantic interactions that arise from it.

In my discussion of TIAs, I have attempted to provide insights both on polarity sensitivity as well as on the semantics of the perfect. *Qua* expressions that are NPIs in only *some* linguistic environments, TIAs turn out to be a particularly strong argument in favor of placing the mechanisms at the root of polarity sensitivity squarely within the semantics. Indeed, whether or not they are NPIs can be determined solely based on the meanings they give rise to. In what concerns the perfect, it is thanks to the remarkable distribution of TIAs that we were able to highlight curious facts about it. Ultimately, this made it possible to argue that the perfect is a quantifier restricted to open intervals.

There are obvious next steps to take in expanding our study of TIAs. One of them will need to be an investigation into the broader distribution of G-TIAs. As I mentioned earlier, it is well known that these are so-called *strong* NPIs, a fact that I have failed to properly address. Another obvious next step will be to understand where TIAs like *in the last three days* and *in days* fit into this account. Finally, it will be crucial to eventually investigate the cross-linguistic picture surrounding TIAs. What can we learn about either polarity sensitivity or the semantics of the perfect by observing the behavior of these expressions across the world's languages? It is my great hope that the present work can serve as a foundation upon which new research can develop insights into these questions.

References

Bach, E. (1986). The algebra of events. *Linguistics and Philosophy*, *9*(1), 5–16. doi: 10.1007/bf00627432

Beck, S., & Rullmann, H. (1999). A Flexible Approach to Exhaustivity in Questions. *Natural Language Semantics*(7), 249-298. doi: https://doi.org/10.1023/A:1008373224343

Bennett, M. (1981). On tense and aspect: One analysis. In P. Tedeschi & A. Zaenen (Eds.), *Syntax and semantics volume 14: Tense and aspect.* New York, New York: Academic Press Inc.

Bennett, M., & Partee, B. (1972). Toward the logic of tense and aspect in English. *Indiana University Linguistics Club*. doi: 10.1002/9780470751305.ch4

Champollion, L. (2017). *Parts of a whole: Distributivity as a bridge between aspect and measurement.* Oxford University Press.

Chierchia, G. (2013). *Logic in grammar.* New York: Oxford University Press.

Chierchia, G., Fox, D., & Spector, B. (2012). Scalar implicature as a grammatical phenomenon. In C. Maienborn, K. von Heusigner, & P. Portner (Eds.), *Semantics: An international handbook of natural language meaning* (Vol. 3, pp. 2297–2331). Berlin: Mouton de Gruyter.

Comrie, B. (1976). *Aspect.* Cambridge: Cambridge University Press.

Dayal, V. (1996). *Locality in wh quantification: questions and relative clauses in Hindi.* Kluwer Academic Publishers.

Dowty, D. R. (1979). *Word meaning and Montague Grammar: The semantics of verbs and times in Generative Semantics and in Montague's PTQ.* Kluwer Academic Publishers.

von Fintel, K. (1999). NPI licensing, strawson entailment, and context dependency. *Journal of Semantics*, *16*, 97-148.

von Fintel, K., Fox, D., & Iatridou, S. (2014). Definiteness as maximal informativeness. In L. Crnič & U. Sauerland (Eds.), *The art and craft of semantics: A Festschrift for Irene Heim* (Vol. 1, pp. 165–174). MITWPL 70.

von Fintel, K., & Iatridou, S. (2003). *Since ~~since~~.*

von Fintel, K., & Iatridou, S. (2019). Since ~~since~~. In D. Altshuler & J. Rett (Eds.), *The semantics of plurals, focus, degrees, and times: Essays in honor of Roger Schwarzschild* (pp. 305–333). Springer Verlag.

Fox, D., & Hackl, M. (2006). The Universal Density of Measurement. *Linguistics and Philosophy*, *29*(5), 537–586. doi: 10.1007/s10988-006-9004-4

Gajewski, J. (2005). *Neg-raising: Presupposition and polarity* (Unpublished doctoral dissertation). Cambridge.

Gajewski, J. (2007). Neg-raising and polarity. *Linguistics and Philosophy*, *30*(3), 289–328. doi: 10.1007/s10988-007-9020-z

Gajewski, J. (2011). Licensing strong NPIs. *Natural Language Semantics*, *19*(2), 109–148. doi: 10.1007/s11050-010-9067-1

Garey, H. B. (1957). Verbal aspect in french. *Language*, *33*(2), 91–110. doi: https://doi.org/10.2307/410722

Gazdar, G. (1979). *Pragmatics: Implicature, presupposition and logical form.* New York: Academic Press.

Hackl, M. (2001). *Comparative quantifiers* (Doctoral dissertation). Massachusetts Institute of Technology.

Hamblin, C. L. (1973). Questions in Montague English. *Foundations of Language*, *10*(1), 41–53.

Heim, I., & Kratzer, A. (1998). *Semantics in generative grammar.* Malden, MA: Blackwell.

Heny, F. (1982). Tense, aspect and time adverbials: Part II. *Linguistics and Philosophy*, *5*(1), 109–154. doi: 10.1007/bf00390694

Hoeksema, J. (2006). In days, weeks, months, years, ages: A class of negative polarity items. In D. Gilbers & P. Hendriks (Eds.), *Rejected papers: Feestbundel voor Ron van Zonneveld* (p. 72-85). Groningen: University of Groningen.

Horn, L. (1972). *On the semantic properties of the logical operators in english* (Doctoral dissertation). UCLA.

Horn, L. (1985). Metalinguistic negation and pragmatic ambiguity. *Language*, *61*(1), 121-174. doi: https://www.jstor.org/stable/413423

Horn, L. (1989). *A natural history of negation.* Chicago, IL: The University of Chicago University Press.

Iatridou, S., Anagnostopoulou, E., & Izvorski, R. (2003). Observations about the form and meaning of the perfect. In *Ken Hale: A life in language.* MIT Press.

Iatridou, S., & Zeijlstra, H. (2017). Negated perfects and temporal in-adverbials. In C. Halpert, H. Kotek, & C. van Urk (Eds.), *A pesky set: Papers for David Pesetsky* (p. 65-74). Cambridge: MIT Working Papers in Linguistics.

Iatridou, S., & Zeijlstra, H. (2021). The complex beauty of boundary adverbials: In years and until. *Linguistic Inquiry*, *52*, 89-142.

Karttunen, L. (1977). Syntax and semantics of questions. *Linguistics and Philosophy*, *1*(1), 3–44. doi: 10.1007/bf00351935

Kitagawa, Y. (1986). *Subjects in Japanese and English* (Doctoral dissertation). University of Massachusetts, Amherst.

Klein, W. (1994). *Time in language.* London and New York: Routledge.

Koopman, H. J., & Sportiche, D. (1991). The position of subjects. *Lingua*, *85*, 211-258. Retrieved from `https://api.semanticscholar.org/CorpusID:42793484`

Krantz, D. H., Luce, R. D., Suppes, P., & Tversky, A. (1971). *Foundations of measurement.* New York and London: Academic Press.

Krifka, M. (1989). Nominal reference, temporal constitution and quantification in event semantics. In R. Bartsch, J. F. A. K. van Benthem, & P. van Emde Boas (Eds.), *Semantics and contextual expression* (pp. 75–115). Foris.

Krifka, M. (1991). Telicity in movement. In P. Amsili, M. Borillo, & L. Vieu (Eds.), *Time, space and movement* (pp. 63–76). Université Paul Sabatier and Université Toulouse-Le Mirail: Chateau de Bonas.

Krifka, M. (1995). The semantics and pragmatics of polarity items. *Linguistic Analysis*, *25*, 209-57.

Krifka, M. (1998). The origins of telicity. In S. Rothstein (Ed.), *Events and grammar* (p. 197-235). Dordrecht: Kluwer.

Ladusaw, W. (1979). *Polarity sensitivity as inherent scope relation* (Doctoral dissertation). University of Texas, Austin.

Levinson, S. C. (2000). *Presumptive meaning.* Cambridge, MA: The MIT Press.

Link, G. (1983). The logical analysis of plurals and mass terms: A lattice-theoretical approach. In R. Bäuerle, C. Schwarze, & A. von Stechow (Eds.), *Meaning, Use, and Interpretation of Language* (p. 302-324). Dordrecht: De Gruyter.

Link, G. (1998). *Algebraic semantics in language and philosophy.* CSLI Publications.

McCawley, J. (1971). Tense and time reference. In C. J. Fillmore & D. T. Langendoen (Eds.), *Studies in linguistic semantics* (p. 97-113). New York: Holt, Rinehart and Winston.

McCawley, J. (1981). Notes on the english present perfect. *Australian Journal of Linguistics*, *1*(1), 81–90. doi: https://doi.org/10.1080/07268608108599267

McCoard, R. W. (1978). *The English Perfect: Tense Choice and Pragmatic Inferences.* Amsterdam: North-Holland Press.

Mittwoch, A. (1982). On the difference between 'eating' and 'eating something': activities versus accomplishments. *Linguistics Inquiry*, *13*(1), 113–22.

Mittwoch, A. (1988). Aspects of english aspect: On the interaction of perfect, progressive and durational phrases. *Linguistics and Philosophy*, *11*(2), 203–254. doi: 10.1007/bf00632461

Partee, B. H. (1973). Some structural analogies between tenses and pronouns in english. *Journal of Philosophy*, *70*(18), 601–609. doi: 10.2307/2025024

Richards, B. (1982). Tense, aspect and time adverbials: Part I. *Linguistics and Philosophy*, *5*(1), 59–108. doi: 10.1007/bf00390693

Taylor, B. (1977). Tense and continuity. *Linguistics and Philosophy*, *1*(2), 199–220. doi: 10.1007/bf00351103

Vendler, Z. (1957). Verbs and times. *Philosophical Review*, *66*(2), 143–160. doi: https://doi.org/10.2307/2182371

Vendler, Z. (1967). *Linguistics in philosophy.* Ithaca, New York: Cornell University Press.

Vlach, F. (1993). Temporal adverbials, tenses and the perfect. *Linguistics and Philosophy*, *16*(3), 231–283. doi: 10.1007/bf00985970

White, M. (1994). *A computational approach to aspectual composition* (PhD disertation). University of Pennsylvania.

White, M., & Zucchi, S. (1996). Twigs, sequences, and the temporal constitution of predicates. In T. Galloway & J. Spence (Eds.), *SALT VI* (pp. 329–346). Rutger University: CLC Publications, Cornell University.

Winter, Y. (2016). *Elements of formal semantics*. Edinburgh: Edinburgh University Press.

Zagona, K. (1982). *Government and proper government of verbal projections* (Doctoral dissertation). University of Wasgington, Seattle.

Zwarts, F. (1998). Three types of polarity. In F. Hamm & E. Hinrichs (Eds.), *Plurality and quantification* (p. 177-238). Dordrecht: Kluwer.

Appendix

In this short appendix to §2, I quickly go over why it is always possible to describe a sum of overlapping individuals in terms of non-overlapping ones. I will also clarify the assumptions I make about the part structures imposed on the domains of events and times. Let's first cover the definitions below, which are defined for some domain of individuals $\mathtt{D}$:

(D. 1) $\mathtt{x} \sqsubseteq \mathtt{y} :\leftrightarrow \mathtt{x} \oplus \mathtt{y} = \mathtt{y}$ (*Part-Whole Relation*)
(D. 2) $\mathtt{x} \subseteq \mathtt{y} :\leftrightarrow \mathtt{x} \sqsubseteq \mathtt{y} \wedge \mathtt{x} \neq \mathtt{y}$ (*Proper Part-Whole Relation*)
(D. 3) $\mathtt{x} \otimes \mathtt{y} :\leftrightarrow \exists \mathtt{z}(\mathtt{z} \sqsubseteq \mathtt{x} \wedge \mathtt{z} \sqsubseteq \mathtt{y})$ (*Overlap*)
(D. 4) $\bigoplus \mathtt{X} = \mathtt{x} :\leftrightarrow \forall \mathtt{y}(\mathtt{y} \in \mathtt{X} \rightarrow \mathtt{y} \sqsubseteq \mathtt{x}) \wedge \forall \mathtt{z}(\forall \mathtt{z}'(\mathtt{z}' \in \mathtt{X} \rightarrow \mathtt{z}' \sqsubseteq \mathtt{z}) \rightarrow \mathtt{x} \sqsubseteq \mathtt{z})$ (*Join*)

We've already discussed (D. 1-3). What (D. 4) adds is a general definition of sum: for a given set of individuals $\mathtt{X}$, $\bigoplus \mathtt{X}$ returns $\mathtt{X}$'s least upper bound relative to $\sqsubseteq$. Let's also add to our definitions that of $\mathtt{A}$, which consists of the atomic individuals in $\mathtt{D}$. $\mathtt{A}$ may or may not be empty.

(D. 5) $\mathtt{A} := \{\mathtt{x} \in \mathtt{D} \mid \neg \exists \mathtt{y}(\mathtt{y} \sqsubset \mathtt{x})\}$ (*Atoms*)

The axioms in (A. 1-4) define a part structure equivalent to the one assumed in Krifka (1989, 1998).

(A. 1) $\forall \mathtt{x}(\mathtt{x} \sqsubseteq \mathtt{x})$ (*Reflexivity*)
(A. 2) $\forall \mathtt{x}, \mathtt{y}, \mathtt{z}((\mathtt{x} \sqsubseteq \mathtt{y} \wedge \mathtt{y} \sqsubseteq \mathtt{z}) \rightarrow \mathtt{x} \sqsubseteq \mathtt{z})$ (*Transitivity*)
(A. 3) $\forall \mathtt{x}, \mathtt{y}((\mathtt{x} \sqsubseteq \mathtt{y} \wedge \mathtt{y} \sqsubseteq \mathtt{x}) \rightarrow \mathtt{x} = \mathtt{y})$ (*Antisymmetry*)
(A. 4) $\forall \mathtt{x}, \mathtt{y}(\mathtt{x} \sqsubset \mathtt{y} \rightarrow \exists! \mathtt{z}(\neg \mathtt{x} \otimes \mathtt{z} \wedge \mathtt{x} \oplus \mathtt{z} = \mathtt{y}))$ (*Remainder Principle*)

Axioms (A. 1-3) together define a partial order. The remainder principle in (A. 4) constrains this into a part structure. On the one hand, it rules out structures with a bottom element (i.e. an individual that is part of every individual). More generally, it ensures that any individual with a proper part $\mathtt{x}$ is the summation of $\mathtt{x}$ and some complement part $\mathtt{y}$.

I am happy to assume only (A. 1-4) for the domain of events $\mathtt{D_v}$. However, I will assume that the domain of times $\mathtt{D_i}$ satisfies two additional axioms.

(A. 5)	$\forall \mathtt{x} \exists \mathtt{y} \in \mathtt{A} : \mathtt{y} \sqsubseteq \mathtt{x}$	(*Atomicity*)
(A. 6)	$\forall \mathtt{X} \subseteq \mathtt{A} : \mathtt{x} \neq \emptyset \rightarrow \exists \mathtt{x}(\bigoplus \mathtt{X} = \mathtt{x})$	(*Completeness*)

Atomicity ensures that times are always decomposable into a set of moments. Completeness ensures that all non-empty sets of moments define a unique time.

Now suppose that we have overlapping times $\mathtt{t}^1$ and $\mathtt{t}^2$. We can show that $\mathtt{t}^1 \oplus \mathtt{t}^2$ can be written without reference to overlapping times. Suppose that $\mathtt{t}^1 \sqsubseteq \mathtt{t}^2$; $\mathtt{t}^1 \oplus \mathtt{t}^2$ can simply be rewritten as $\mathtt{t}^2$. The same reasoning applies if $\mathtt{t}^2 \sqsubseteq \mathtt{t}^1$. Now suppose that $\mathtt{t}^1 \not\sqsubseteq \mathtt{t}^2$ and $\mathtt{t}^2 \not\sqsubseteq \mathtt{t}^1$. It follows that there is some $\mathtt{t}^3$ which is a proper part of both $\mathtt{t}^1$ and $\mathtt{t}^2$. By the remainder principle, this means that $\mathtt{t}^3$ and some $\mathtt{t}^4$ with which it does not overlap are such that $\mathtt{t}^1 \oplus \mathtt{t}^2 = \mathtt{t}^3 \oplus \mathtt{t}^4$. No matter the case, we can always rewrite the sum of overlapping parts without overlap.