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NPI licensing in temporal clauses

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Abstract This paper offers a systematic semantically-based approach to NPI licensing in temporal clauses based on Beaver and Condoravdi (2003, in progress). It motivates the presuppositional nature of temporal clauses and shows how temporal ordering induces an ordering of semantic strength in each case. The proposed analysis is uniform across veridical and non-veridical readings of *before* and brings under the semantic fold seemingly exceptional or pragmatically-based cases of NPI licensing observed with *after, since* and *until*. Crucial throughout is the more restricted, presupposition-dependent notion of entailment, Strawson entailment, proposed by von Fintel (1999). The paper also relates Strawson entailment to the alternative-based analysis of NPIs by Krifka (1995), proposing a particular kind of contextual update, Strawson update, for calculating informational strength.

Keywords NPI licensing · Semantics of temporal clauses · Veridical and non-veridical *before* · Strawson entailment · NPI-triggered alternatives · Semantic and pragmatic presuppositions · Contextual entailments

1 Introduction

1.1 Monotonicity and NPIs in temporal clauses

According to monotonicity-based accounts of NPI licensing, such as that of Fauconnier (1975, 1979) and Ladusaw (1979), NPIs are licensed in environments where strengthening inferences are valid. Negation clearly supports strengthening inferences:

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(1) Ed didn't walk.
∴ Ed didn't walk fast.

More generally, supposing $\sqsubseteq$ is a relation of semantic strength between two expressions of the same type, an expression α is downward monotone/entailing if it reverses the relation of semantic strength, that is, whenever β and γ are expressions to which α can apply and $[\![\beta]\!] \sqsubseteq [\![\gamma]\!]$, then $[\![\alpha(\gamma)]\!] \sqsubseteq [\![\alpha(\beta)]\!]$. An expression α is upward monotone/entailing if it preserves the relation of semantic strength, that is, whenever β and γ are expressions to which α can apply and $[\![\beta]\!] \sqsubseteq [\![\gamma]\!]$, then $[\![\alpha(\beta)]\!] \sqsubseteq [\![\alpha(\gamma)]\!]$.

As is well known, NPIs are licensed in temporal clauses headed by *before* but not in those headed by *after*:

(2) Ed left before there was anyone in the room.

(3) * Ed left after there was anyone in the room.

We would expect then that the strengthening inference in (4) ought to be valid. However, intuitively, the strengthening inferences in (4) and (5) do not differ in validity: both are judged invalid.

(4) Ed left before we were in the room.
∴ Ed left before we were in the room standing by the window.

(5) Ed left after we were in the room.
∴ Ed left after we were in the room standing by the window.

It appears, therefore, that *before* is no more downward entailing with respect to the temporal clauses it heads than *after* is and so its status as an NPI licenser remains unaccounted for.

Intuitive judgments of validity are based on the full information conveyed by premise and conclusion, so let us consider in more detail what this information is. *Before* and *after* sentences give rise to three kinds of implications: an implication that the main clause is true (**MC**), an implication that the temporal clause is true (**TC**), and an implication about the relative ordering between the events or states of affairs described by the main and by the temporal clause (**O**).[1] Rewriting (4) into (6) and (5) into (7), we can see that the conclusions of (4) and (5) share the same **TC**—they both imply that we stood by the window at some point while in the room. The problem is that the corresponding premises do not guarantee the truth of that implication in either case. Adding the restrictive clause *standing by the window* may well lead to falsity, since there can be situations in which we were in the room but did not stand

[1] In the informal discussion in this section I will use labels such as **MC**, **TC**, **O** and others below to refer primarily to the *kinds* of implications associated with sentences with temporal clauses and occasionally to the *content* of the corresponding implications associated with particular (utterances of) such sentences. The surrounding context should make clear which use is intended.

by the window at all. *Before* and *after* are both **upward** entailing with respect to the **TC** implication, just as they are with respect to the **MC** implication.[2]

(6) a. *Premise*
Ed left. (**MC**)
We were in the room. (**TC**)
Ed's departure occurred before we were in the room. (**O**)
b. *Conclusion*
Ed left. (**MC**)
We were in the room standing by the window. (**TC**)
Ed's departure occurred before we were in the room standing by the window. (**O**)

(7) a. *Premise*
Ed left. (**MC**)
We were in the room. (**TC**)
Ed's departure occurred after we were in the room. (**O**)
b. *Conclusion*
Ed left. (**MC**)
We were in the room standing by the window. (**TC**)
Ed's departure occurred after we were in the room standing by the window. (**O**)

The asymmetry of *before* and *after* rather lies in the **O** implication. This is shown by the variants of (4) and (5) in (8) and (9), respectively, where the truth of the temporal clause of the conclusion is taken for granted. **O** necessarily follows from the premises in the case of (8) but not in the case of (9).

(8) We were in the room and stood by the window.
Ed left before we were in the room.
∴ Ed left before we were in the room standing by the window.

(9) We were in the room and stood by the window.
Ed left after we were in the room.
∴̸ Ed left after we were in the room standing by the window.

With respect to the **O** implication, *before* is downward entailing, while *after* is upward entailing. Now, if *before* is upward entailing with respect to the **TC** implication and downward entailing with respect to the **O** implication, why is the tie resolved in such a way so as to make **O** count and **TC** not count? Note that if we could somehow set aside the **TC** implication in the conclusions of (4) and (5)—for instance, by making the strengthening inferences to consider the ones in (8) and (9), rather than the ones in (4) and (5)—*before* would be downward entailing in a relativized sense with respect

[2]Because *before* and *after* are upward entailing with respect to **MC** they do not license NPIs in the main clause.

to the temporal clause but *after* would not. The question then is on what grounds the **TC** implication can be set aside.

Traditionally, *before* and *after* sentences are assumed to differ in the truth-conditional status of their respective **TC** implications, as I discuss in the following section. My aim in this paper is to argue instead that the **TC** implications of sentences with **any** type of temporal connective have the same status, which differs from the status of their **O** and **MC** implications. But in either case, whether the special status of **TC** is confined to *before* or is shared by all connectives, monotonicity-based accounts of NPI licensing have to make precise which aspects of meaning are to be taken into account when judging the validity of strengthening inferences.

1.2 Monotonicity and the status of the TC implication

Ladusaw (1979) distinguished between truth-conditional and implicative meaning, claiming that strengthening inferences are based solely on truth-conditional content and that, therefore, we should abstract away from implications due to presuppositions or conventional implicatures when judging the validity of strengthening inferences. However, his brief discussion on *before* and *after* (pp. 166–167) does not address the status of the **TC** implication of *before* and *after* sentences.

A popular view of the semantics of *before* and *after* treats **TC** as a truth-conditional entailment of *after* sentences but not of *before* sentences. As shown in (10), this view takes *before* to universally quantify over the times in the denotation of the temporal clause and *after* to existentially quantify over them (Heinämäki 1972; Landman 1991; Valencia et al. 1992; Ogihara 1995; Zwarts 1995).[3]

(10) a. A Before B iff $(\exists t \in A)(\forall t' \in B)\ t < t'$
b. A After B iff $(\exists t \in A)(\exists t' \in B)\ t > t'$

The semantics in (10) was primarily motivated by the asymmetries in *before* and *after*'s inferential properties pointed out by Anscombe (1964)[4]—*before* is antisymmetric and transitive, *after* is neither—but has also been used to account for their asymmetry in licensing NPIs. The implications about the truth of main and temporal clauses amount to (11).

(11) a. $\mathbf{MC} = \exists t \in A$
b. $\mathbf{TC} = \exists t \in B$

Since (10b) requires the existence of a time at which the temporal clause is true, **TC** has the same status as **MC**, and **O** as an entailment in the premise and conclusion of (5). The corresponding **TC** implications in the premise and conclusion of (4), on the other hand, do not constitute an entailment since the domain of the universal quantifier may be empty and the condition in (10a) satisfied vacuously.

[3] $<$ is the relation of temporal precedence and $>$ its converse. For purposes of the discussion in this section, I will not fix any assumptions about the domain of times. I do so in connection with the analysis in Sect. 2.1.

[4] (10) is a reconstruction of Anscombe (1964), who considers and rejects the quantificational analysis. For a more faithful reconstruction of Anscombe's own proposal see del Prete (2005).

With respect to the temporal clause then, (10) makes *before* non-veridical and downward entailing (DE) and *after* veridical and non-DE. Hence, (10) makes (4) valid and (5) invalid. The basis of the intuitive judgment of invalidity of (4) is that speakers take the premise and the conclusion to have the (strengthened) meaning corresponding to (12) rather than (10a). But, the argument goes, the assessment of semantic strength should be based on the meaning proper, an analytically informed notion, rather than the full range of implications one might associate with the relevant sentences.

(12) $(\exists t \in B)(\exists t' \in A)(\forall t'' \in B)\ t' < t''$

Landman (1991, 143) defends this view about the validity of inferences like (4) explicitly: "The fact that the inference is weird doesn't mean that it is invalid. This issue clearly has to do with the question whether *p before q* entails that *q* took place or *presupposes* or *implicates* that *q* took place. Entailments cannot be canceled, implicatures can." Endorsing the universal semantics, Zwarts (1995) argues that it is nonveridicality that "plays a role in the temporal system of many languages, particularly in connection with connectives like *before*" (p. 286) and that the universal semantics "makes *before* a nonveridical connective whose characteristic feature is that pBq[5] doesn't necessarily imply q." (p. 299)

This is a simple and elegant account that preserves the monotonicity-based account of NPI licensing in *before* clauses by giving a principled reason for the difference between the **MC** and **O** implications, on the one hand, and **TC**, on the other. But it is not an adequate analysis of *before*, unless the status of the **TC** implication is fixed.[6] According to (10), **TC** is not a truth-conditional entailment, but what is it? I will argue that once we understand the status of the **TC** implication, we would need to integrate an analysis of NPI licensing in *before* clauses with the implications associated with *before* clauses.

Although on the face of it, it would appear that non-veridical readings of *before*, in which the **TC** implication is absent, support this view, there are two related observations about veridical and non-veridical readings of *before* that call for an explanation. First, as seen in (13), the **TC** implication of a *before* sentence, when present, is no more cancelable than the same implication of an *after* sentence.

(13) a. #Ed left before we were in the room. In fact, we never made it into the room at all.
b. #Ed left after we were in the room. In fact, we never made it into the room at all.

Secondly, as seen in (14) and (15), non-veridical readings of *before* are associated with modal implications, on the basis of which they can be characterized as 'counter-

[5] B is the logical operator Zwarts associates with *before*.

[6] The same is true of analyses which, instead of a universal quantifier, have a negative existential. One such analysis is del Prete's (2008) analysis of Italian *prima*, analyzed in terms of the comparative marker *piú*. del Prete appeals to the downward monotonicity of negation to account for NPI linensing in *prima* clauses.

factual' or 'non-committal'. In the counterfactual reading of (14) the implication that the temporal clause is false is accompanied by a counterfactual implication.

(14) a. The mice died before they showed an/any immune response.
No immune response. (¬**TC**)
The mice might have shown an immune response had they lived longer. (◇^{CF}**TC**)[7]
b. The mice died before we (ever) tested their immune response.
No tests for immune response. (¬**TC**)
We might have tested the mice's immune response had they lived longer. (◇^{CF}**TC**)

In the non-committal reading of (15) the implication of speaker uncertainty as to the truth of the temporal clause is accompanied by a temporally dependent likelihood implication. (I provide the full context of the naturally occurring example in (15a) as it supplies the information supporting both the likelihood implication and the implication of speaker uncertainty. Out of context (15a) may well be construed veridically.)

(15) a. I left Trafalgar Square about half an hour ago and it started to look scary. The happy crowd that had made its way towards the square for some reason got cut off by the police and the Trade Union Congress march was prevented from getting in for their planned meeting. I gather that McDonalds has been trashed. Tourists seemed to be mingling curiously with the demonstrators in the square, but there was no violence at that time. Yet the police seem to be blocking off all the exits. I decided to leave before there was any trouble.[8]
Trouble looked likely before I left and may or may not have come about. (**LTC**, ◇ **TC**, ◇¬ **TC**)[9]
b. We lost touch before he (ever) did (any) government work.
Before we lost touch there was a chance that he would do government work and he may or may not have done so. (**LTC**, ◇**TC**, ◇¬ **TC**)

As Heinämäki (1972) showed, the (non-)veridicality of *before* clauses is highly context-dependent and the different readings of *before* are tied to information in the context in which a *before* sentence is uttered. For instance, the examples in (15) can also be construed veridically—in which case they would simply imply that there was trouble, or that he did government work at some point—or even counterfactually, in the presence of contextual assumptions that I could have been the instigator of trouble, or crucial in his getting to do government work.

Given the context-dependency of the implications associated with *before* clauses, to show that the **TC** implication is, or is not, cancelable, it does not suffice to show

[7] ◇^{CF} is meant to represent counterfactual possibility. The apparent conditioning of the counterfactual implication on the falsity of the main clause can be dispensed with, as will become clear in Sect. 3.2.

[8] www.rcpbml.org.uk/ww2000/d00-81.htm.

[9] **LTC** is the label for the implication that **TC** is considered likely at some point before the main clause becomes true. ◇ is meant to represent epistemic possibility.

that it can, or cannot, be explicitly negated. One, in addition, would have to construct the example in such a way that a counterfactual or a non-committal reading is implausible for it. Example (13), used above to show that the **TC** implication is not cancelable, was constructed with that in mind. The claim is *not* that there is no context that can support a counterfactual or non-committal construal for (13). The claim is rather that in contexts which do not support such construals the veridical implication is inevitable and uncancelable.

The generalization then is that *before* sentences give rise to one of the following three clusters of implications with respect to the temporal clause, characterizing three distinct readings: (a) uncancelable **TC** (veridical reading), (b) $\neg$**TC**, $\Diamond^{\text{CF}}$**TC** (counterfactual reading), (c) **LTC**, $\Diamond$**TC**, $\Diamond\neg$**TC** (non-committal reading). Even though the analysis in (10) separates out the **TC** implication as a non-entailment, simply assuming that **TC** is an implicature or a presupposition is not sufficient to account for this generalization and neither Landman nor Zwarts undertook such a task.

1.3 Relativized monotonicity

In order to account for its context dependence and explain its veridical and modal implications, Heinämäki (1972) and Ogihara (1995) associate a presupposition with *before*, sticking to (10) as the truth-conditional content of *before* and *after* sentences. Their proposals differ in several significant respects, otherwise, including the presupposition they assign to *before*. Heinämäki makes **TC** a semantic presupposition of veridical *before* which can be filtered out under certain conditions.[10] In that case $\neg$**TC** arises as an entailment of the utterance of the *before* sentence.[11] The status that Heinämäki gives to the counterfactual implication seems to be that of a pragmatic presupposition.

Ogihara makes **LTC** a uniform pragmatic presupposition of veridical and non-veridical *before*.[12] Pragmatic presuppositions can be construed as requirements for successful update on the common ground and this is what Ogihara assumes. Following Stalnaker (1978), Ogihara takes a pragmatic presupposition to be satisfied in a given context c iff it is true in every world of the context set of c. Departing from the Ladusaw-Landman-Zwarts line about strengthening inferences, where presuppositional content is abstracted away from, Ogihara assumes that presuppositions, including pragmatic presuppositions, are taken into account in strengthening inferences relevant for NPI licensing: for premise and conclusion "to be comparable, the same

[10] Heinämäki's semantics makes distinct provisions for veridical and counterfactual *before*: the clause giving rise to the veridical reading applies, unless **MC** along with some contextually given facts entails $\neg$**TC**. Heinämäki's semantics amounts, in effect, to the following, where Γ is a set of contextual assumptions:

$$\text{A Before B} \quad \text{iff} \quad \begin{cases} (\exists t \in A)(\forall t' < t)\ \neg(t' \in B) & \text{if } \Gamma \models (\forall t \in A)\ \neg((\exists t' > t)\ t' \in B) \\ (\exists t' \in A)(\forall t \in B)\ t' < t & \text{provided } (\exists t \in B) \\ \text{undefined otherwise} \end{cases}$$

[11] Heinämäki just calls it an entailment; a more accurate description is that it is a contextual entailment as in Beaver and Condoravdi's (2003) analysis, to be discussed below.

[12] I will not discuss Ogihara's proposal here except as it pertains to the role of pragmatic presuppositions in NPI licensing.

presupposition must be shared by them" (p. 282). Since the presupposition of the conclusion is more specific than that of the premise it must be the shared presupposition.

On this view, therefore, we can check whether (14a) entails (16a), or whether (15a) entails (16b), only relative to contexts where both premise and conclusion can be felicitously asserted, that is, relative to contexts that satisfy their respective presuppositions. This means that the inference from (14a) to (16a) has to be assessed against contexts where it is taken for granted that the mice were likely to show an immune response and that the existence of an immune response necessarily implied the existence of a strong immune response at some point. Correspondingly, the inference from (15a) to (16b) has to be assessed against contexts where it is taken for granted that trouble was likely and that the existence of trouble necessarily implied the existence of serious trouble at some point.

(16) a. The mice died before they showed a strong immune response.
b. I decided to leave before there was (any) serious trouble.

Although the proposition expressed by (14a) is compatible with worlds in which the mice have no chance of ever showing a strong immune response and the proposition expressed by (16a) is compatible with worlds in which the mice first show a weak immune response and then die, such worlds are excluded from consideration in strengthening inferences involving (14a) and (16a) as premises or conclusions. In general, if the temporal clause in the premise is presumed likely to be instantiated only once (in the relevant time frame), then the two temporal clauses across premise and conclusion must be presumed equivalent; if the temporal clause in the premise is presumed likely to be instantiated more than once, then the temporal clause in the conclusion must be presumed likely to be instantiated at least once.

This approach then gives context a special role, over and above its contribution in determining propositional content: the notion of semantic strength relevant for NPI licensing becomes crucially context-dependent. This way of factoring out presuppositional content in strengthening inferences results in a weaker notion of entailment given the strong requirements on the informativity of the contexts in which the entailment can be assessed, specifically the requirement that the context entail that if the presupposition of the premise holds then the presupposition of the conclusion holds as well. The truth of the premise along with the information in the context have to guarantee the definedness of the conclusion.

More recently, von Fintel (1999) has motivated the kind of qualification Ogihara employed on more general grounds and formulated it in somewhat different terms. He proposed a more restricted notion of entailment, Strawson entailment, as coming into play when checking strengthening inferences. The main idea is that the truth of the conclusion is checked only relative to the parameters of evaluation in which the premise is true *and* the conclusion is defined (i.e., has a truth value). In other words, the truth of p^G, the proposition based on the more general expression, is not required to guarantee the definedness of p^S, the proposition based on the more specific expression. The requirement is rather that p^G restricted to those worlds in which p^S is defined entail p^S.

From this perspective, and assuming for the moment that **TC** is a presupposition of *before* and *after* sentences (something to be justified and made precise below), it

becomes clear why the inference patterns to consider for purposes of accounting for NPI licensing are the ones (8) and (9), repeated below, as opposed to our original (4) and (5).

(17) We were in the room and stood by the window.
Ed left before we were in the room.
∴ Ed left before we were in the room standing by the window.

(18) We were in the room and stood by the window.
Ed left after we were in the room.
⁄∴ Ed left after we were in the room standing by the window.

The main aim of this paper is to show that this relativized notion of entailment comes into play in all cases of NPI licensing in temporal clauses. NPI licensing is observed not just with *before* but under certain circumstances also with *after* (Linebarger 1987, 1991), *since* (Zwarts 1995; von Fintel 1999), and, as noted in this paper, *until*. This means that the **TC** implication of *after*, *since* and *until* clauses is not truth-conditional, as commonly assumed, but presuppositional. The commonly assumed semantics for these connectives existentially quantifies over the temporal clause, as seen for *after* in (10b) and shown schematically for *since* and *until* in (19) (see e.g. Zwarts 1995).

(19) a. A Until B iff $(\exists t \in B)(\forall t' < t)\ t' \in A$
b. A Since B iff $(\exists t \in B)(\forall t' > t)\ t' \in A$

The main claim of the paper is that quantification over temporal clauses and over main clauses is connective-independent and the presuppositional implication of temporal clauses is to be attributed to the operators operating on temporal clauses prior to their composition with temporal connectives. A perhaps surprising aspect of this claim is that the presuppositional analysis, properly construed as a semantic definedness condition, extends to the **TC** implication of non-veridical *before*.

The rest of the paper shows how Strawson-entailment coupled with a semantics of temporal connectives as relations between times and composing with temporal clauses via the mediation of certain operators gives a uniform analysis of NPI licensing in temporal clauses. With this perspective, seemingly exceptional or pragmatically-based cases of NPI licensing can be brought under the fold of semantically-based accounts of NPI licensing. The proposed analysis integrates NPI licensing with the veridical and modal implications of temporal clauses and accounts for the so far unobserved synonymy of positive *after* clauses with an NPI and the corresponding negative *after* clauses.

One final note: this paper is primarily concerned with characterizing the monotonicity properties of the environment created by four temporal connectives—*before, after, since, until*—which is meant to explain the appearance of a class of NPIs, weak NPIs, in such environments. It does not provide an analysis of NPIs per se other than *any*.

2 Semantics of temporal clauses

2.1 Formal preliminaries

Let $\mathcal{W}$ be the domain of worlds and $\mathcal{T}$ be the domain of non-null temporal intervals, partially ordered by the subinterval relation $\subseteq_\mathcal{T}$. $\mathcal{T}_\mathcal{P}$, the set of temporal points, is the set of the atomic elements of $\mathcal{T}$ relative to $\subseteq_\mathcal{T}$. The relation of temporal precedence $\prec$ is a linear ordering on $\mathcal{T}_\mathcal{P}$, inducing a partial order $<$ on $\mathcal{T}$ such that $t < t'$ iff for all time points $t_p \subseteq_\mathcal{T} t$ and for all time points $t'_p \subseteq_\mathcal{T} t'$, $t_p \prec t'_p$. $>$ is the converse of $<$ and $\leq$ is the union of $<$ and $=$. The summation operation $\oplus$ on $\mathcal{T}$ gives the sum of two intervals (the smallest interval that has each one as a subinterval). The operation $\bigoplus$ generalizes over a set of intervals. An interval t is convex iff for any time points t', t'', t''' if $t' \subseteq_\mathcal{T} t$, $t'' \subseteq_\mathcal{T} t$ and $t' \prec t''' \prec t''$, then $t''' \subseteq_\mathcal{T} t$ (intuitively, t is convex if it has no gaps).

Left bounded and right bounded subsets T of $\mathcal{T}$ have a greatest lower bound and a least upper bound, respectively. The greatest lower bound of $T \subset \mathcal{T}$, $glb(T)$, if defined, is the latest time in $\mathcal{T}$ which is earlier than any of the times in T except possibly itself.[13] The least upper bound of $T \subset \mathcal{T}$, $lub(T)$, if defined, is the earliest time in $\mathcal{T}$ which is later than any of the times in T except possibly itself.[14] $glb(T)$ and $lub(T)$ may or may not be elements of T. On the basis of these notions we can define the right and the left bounds, if they exist, of intervals. For any interval t, let $Set(t) = \{t' \in \mathcal{T} \mid t' \subseteq_\mathcal{T} t\}$. Then $rb(t) = lub(Set(t))$ and $lb(t) = glb(Set(t))$, if defined.

I assume that verbs have times as arguments and I take sentence radicals to denote temporal properties, mappings from worlds to sets of times. The aspectual properties of a predicate determine properties of the denotation of the corresponding sentence radical. The denotation of a stative predicate, lexical or derived, is closed under the subinterval relation: if a time t is in it, then every subinterval of t, down to points, is also in it. The denotation of an activity predicate is closed under the subinterval relation up to a certain level of granularity. Accomplishment predicates have proper, though possibly non-convex intervals, in their denotation. Simple (that is, 'once only') accomplishment predicates like *Ed build this hut* would be singletons, whereas complex accomplishment predicates like *Ed build a hut* would be sets of potentially overlapping intervals (an interval for every building of a hut by Ed). Achievement predicates, like *Ed leave* or *someone leave*, are usually taken to have points in their denotation—if not, they are just a special case of accomplishments.

A property of sentence radicals that will play a role in Sect. 5 is that of cumulativity. A set of objects from a domain for which the summation operation is defined, such as a set of times T, is cumulative iff it is closed under the summation operation, i.e., if whenever $t_1 \in T$ and $t_2 \in T$, then $t_1 \oplus t_2 \in T$.[15] Whether a sentence

[13] $glb(T)$, if defined, is that $t \in \mathcal{T}$ such that (a) for any $t' \in T$, $t \leq t'$, and (b) for any $t'' \in \mathcal{T}$ such that for any $t' \in T$, $t'' \leq t'$, $t'' \leq t$.

[14] $lub(T)$, if defined, is that $t \in \mathcal{T}$ such that (a) for any $t' \in T$, $t' \leq t$, and (b) for any $t'' \in \mathcal{T}$ such that for any $t' \in T$, $t' \leq t''$, $t \leq t''$.

[15] The notion of cumulativity can be generalized for n-place relations (see e.g. Krifka 1992).

radical is cumulative or not depends on its internal composition and the assumptions one makes about which verbal projections can be pluralized (see Kratzer 2007 for discussion). Following Krifka (1992) and Kratzer (2007), I will assume that verbs have cumulative denotations and that the cumulativity of verbal projections depends on the cumulativity of the terms the verb takes as arguments, with mass terms and bare plurals preserving cumulativity.[16] So the sentence radical *Ed build a hut* is not cumulative, whereas *Ed build huts* is.

The meanings specified in what follows make reference to time t instantiating in world w a temporal property corresponding to temporal abstract $\lambda t'\phi[t']$, designated as $at(w, t, \lambda t'\phi[t'])$.

(20) For any w, t, ϕ, $at(w, t, \lambda t'\phi[t'])$ iff $[\![\phi[t]]\!]_w = 1$.

We will also need to make reference to a mapping from sets of intervals to sets of points such that a set of intervals is mapped to a set of those points that are the right bounds of each interval. The function *itop*, defined only if $T \neq \emptyset$, specifies this mapping:

(21) $itop.T = \{t \in \mathcal{T}_\mathcal{P} \mid \exists t' \in T : rb(t') = t\}$ if defined.

This way from a set of potentially overlapping intervals we get a set of ordered points.

2.2 A uniform semantics for *before* and *after*

Beaver and Condoravdi (2003, in progress) argue that *before* and *after* differ neither in quantificational force nor in presuppositionality. Rather, the apparent universal or existential force of the connectives over the temporal clause is due to an operator—the same operator for both—which picks out a unique time based on the denotation of the temporal clause. Instead of the truth conditions traditionally associated with *before* and *after*, repeated in (22), we proposed the truth conditions in (23), where the contribution of *before* and *after* differs just in the temporal ordering relation.[17]

(22) a. A Before B iff $(\exists t \in A)(\forall t' \in B)\ t < t'$
b. A After B iff $(\exists t \in A)(\exists t' \in B)\ t > t'$

(23) Provided $earliest.B$ is defined

a. A Before B iff $(\exists t \in A)\ t < earliest.B$
b. A After B iff $(\exists t \in A)\ t > earliest.B$

[16] Krifka (1992) and Kratzer (2007) operate within an event-based framework, but the relevant notions can be reconstructed outside of such a framework.

[17] Rohrer (1977) is an early proposal where the ordering in *before* and *after* sentences is with respect to the initial or final point in the denotation of the temporal clause.

For left-bounded non-empty sets of times T containing their greatest lower bound, *earliest*.T is that $t \in T$ such that $t = glb(T)$. Otherwise—that is, if T is empty, or not left-bounded, or left-bounded but $glb(T) \notin T$—*earliest*.T is undefined. The primary interest in Beaver and Condoravdi (2003) was to account for the inferential asymmetries of *before* and *after* sentences observed by Anscombe (1964) and so we made the simplifying assumption that sentence radicals, when instantiated, denote left-bounded sets of times that include their greatest lower bound. We then showed that the operator *earliest* gets the desired asymmetry in inferential properties between *before* and *after*, and that in case the temporal clause B is such that *earliest*.B is defined, the truth conditions in (23) are identical to those in (22).[18]

Since the operator needs to apply to temporal properties, let us relativize *earliest* to a world of evaluation:

(24) For any $w \in \mathcal{W}$ and temporal property X,
earliest$_w$.X = *earliest*.$\lambda t\ at(w, t, X)$
provided *earliest*.$\lambda t\ at(w, t, X)$ is defined,[19] else undefined.

For a stative predicate like *Ed be in the room*, *earliest*$_w$ picks out the very first moment Ed is ever in the room in w, and for one like *there be someone in the room* it picks out the very first moment the first person to ever enter the room in w is in the room in w.[20] *earliest* as defined in Beaver and Condoravdi (2003) was not meant to account for accomplishment predicates, for which it makes the wrong predictions. For instance, consider the simple case of a simple accomplishment predicate like *Ed build this hut*.[21] *earliest*$_w$ would pick the entire interval during which Ed was building this hut in w, which is the unique interval in $\lambda t\ at(w, t,$ *Ed-build-this-hut*$)$. Thus, *Bill built this mansion before Ed built this hut* is predicted to be true only if the entire interval during which Bill was building this mansion preceded the entire interval during which Ed was building this hut. But as Heinämäki (1974) observed, *before* does allow for overlap in such cases as long as the culmination of Bill's building of this mansion preceded the culmination of Ed's building of this hut.[22]

In order to properly account for the ordering between main clauses and temporal clauses regardless of the aspectual category of the predicate in the temporal clause, I generalize *earliest* as in (25).

[18] Pratt and Francez (2001) and von Stechow (2002) also attribute the quantificational force of *before* and *after* clauses to an operator that picks out a unique time but the operators they employ presuppose that the predicate in the temporal clause can hold of only one time and would thus be defined only for simple accomplishment or achievement predicates. If one were to assume that simple stative predicates are not closed under the subinterval relation and yield the maximal interval at which the stative property holds, the uniqueness presupposition of the operators would be satisfied but then *before* and *after* would be predicted to be exactly parallel in both their inferential properties and NPI licensing.

[19] *earliest*.$\lambda t\ at(w, t, X)$ would be defined only if $\lambda t\ at(w, t, X)$ is non-empty and left-bounded.

[20] Of course, the domain of relevant times need not be $\mathcal{T}$ but may be restricted by a contextually supplied interval or a set of such intervals.

[21] Complex accomplishment predicates, like *Ed build a hut*, which allow for overlapping intervals, provide a bigger challenge.

[22] It is worth noting that these problems also arise for the traditional analysis of *before*, since the universal quantification is over the times in the denotation of the temporal clause.

(25) $earliest.T = glb(itop.T)$ if defined

itop, as defined in (21), collects the right bounds of every element in T. Points constitute their own right bounds, so any point in T would also be in $itop.T$. *earliest* as defined in Beaver and Condoravdi (2003) is a special case of *earliest* as defined in (25). They come down to the same thing for any temporal property X for which $itop.\lambda t\ at(w, t, X)$ is a subset of $\lambda t\ at(w, t, X)$ and which contains its own *glb*. This is the case for stative predicates like those discussed above. For accomplishment predicates *itop* will collect the culmination points and *glb* will pick the earliest among them. (25) allows for $earliest.T \notin T$ and this is exactly what is required for accomplishment predicates. For a complex accomplishment predicate like *Ed build a hut*, $earliest_w$ would pick out the culmination point of that hut building by Ed that culminates first. (25) also allows for $earliest.T \notin itop.T$.

The application of an operator like *earliest* to a clause gives rise to a semantic presupposition that the temporal clause is instantiated, ultimately giving rise to the **TC** implication of temporal clauses. Departing from common practice, Beaver and Condoravdi (2003) do not make the semantic definedness condition of *earliest* a pragmatic presupposition of the connectives. Common practice follows Stalnaker (1978), who postulated the requirement that the proposition expressed by an assertive utterance have a truth value in each possible world in the context set, requiring in effect that every semantic presupposition be a pragmatic presupposition. Stalnaker wanted to motivate this requirement on general, conceptually uncontroversial considerations: "the point of an assertion is to reduce the context set in a certain determinate way. But if the proposition [expressed by an assertive utterance] is not true or false at some possible world, then it would be unclear whether that possible world is to be included in the reduced set or not. So the intentions of the speaker will be unclear." (p. 326) Instead, Beaver and Condoravdi (2003) assume that in updating a context with a sentence, the truth conditions are checked pointwise for each world in the context and worlds in which the sentence is true are retained, while worlds in which it is false or has no truth value are discarded.[23] So semantic presuppositions end up not as pragmatic presuppositions but as contextual entailments, i.e., entailments of the output rather than the input context. The existential implication for *after* and for veridical *before*, that is the **TC** implication, is then a contextual entailment. Any context consistently updated with 'A after B' or 'A before B' construed veridically will entail that B is instantiated.

3 NPI licensing by *before*

3.1 Veridical *before*

In Beaver and Condoravdi (2003) we remained neutral as to whether *earliest* is specified in the lexical meaning of the connectives or comes into play in the process of

[23] I believe this kind of contextual update can also be motivated on conceptually natural grounds but this is beyond the scope of this paper.

compositional built-up through a type-shifting operation. In current work we pursue the second idea in more detail, and this is what I will follow here. *Before* denotes the relation of temporal precedence $<$, and *after* its converse $>$. As relations between times, *before* and *after* cannot directly compose with a clause. In order for them to apply to a sentence radical, the operator *earliest* has to apply first, supplying a particular time determined by the temporal property the sentence radical denotes. As discussed in Sect. 2.2, that time may or may not be an element of the sentence radical's denotation.

Taking X and A to be sentence radicals denoting the temporal properties X and A, and assuming that there is only one semantic tense taking scope over both main and temporal clause[24] and that main clauses and temporal clauses compose intersectively, the meaning of *before* and *after* clauses and that of their combination with a main clause is as in (26).

(26) a. $[\![\text{before X}]\!]_w = \lambda t\ t < earliest_w.X$ if defined
b. $[\![\text{after X}]\!]_w = \lambda t\ t > earliest_w.X$ if defined
c. $[\![\text{A before X}]\!]_w = \lambda t\ (at(w, t, A) \wedge t < earliest_w.X)$ if defined
d. $[\![\text{A after X}]\!]_w = \lambda t\ (at(w, t, A) \wedge t > earliest_w.X)$ if defined

Assuming further that tenses instantiate the resulting temporal property at a time that stands in a particular temporal relation to the time of utterance, we can specify the meaning of past tense as in (27) and that of the full *before* and *after* sentences as in (28).

(27) $[\![\text{PAST}]\!]^c_w = \lambda P\, \exists t \in \mathcal{T}(t < now_c \wedge at(w, t, P))$

(28) a. $[\![\text{PAST(A before X)}]\!]^c_w = \exists t \in \mathcal{T}(t < now_c \wedge at(w, t, A) \wedge t < earliest_w.X)$ if defined
b. $[\![\text{PAST(A after X)}]\!]^c_w = \exists t \in \mathcal{T}(t < now_c \wedge at(w, t, A) \wedge t > earliest_w.X)$ if defined

Supposing Y is a temporal property at least as specific as X, then for any world w for which $earliest_w$ is defined for both Y and X:

(29) a. $\lambda t\ at(w, t, Y) \subseteq \lambda t\ at(w, t, X)$
b. $earliest_w.X \leq earliest_w.Y$
c. $\lambda t\ t < earliest_w.X \subseteq \lambda t\ t < earliest_w.Y$
d. $\lambda t\ t > earliest_w.Y \subseteq \lambda t\ t > earliest_w.X$
e. $\lambda t\ (at(w, t, A) \wedge t < earliest_w.X) \subseteq \lambda t\ (at(w, t, A) \wedge t < earliest_w.Y)$
f. $\lambda t\ (at(w, t, A) \wedge t > earliest_w.Y) \subseteq \lambda t\ (at(w, t, A) \wedge t > earliest_w.X)$

(29a) follows from the assumption that Y is at least as specific as X. Then, as shown in (29b), the earliest time at which Y is instantiated in world w cannot be earlier

[24] This is a simplifying assumption that does not affect the main proposal. Tenses can instead be construed as restrictive modifiers on temporal properties, with existential quantification coming in separately.

than the earliest time at which X is instantiated in w. Given this temporal ordering, the temporal relation $<$ induces a reversal of the original subset relation in (29a), as shown in (29c); on the other hand, the temporal relation $>$ preserves the original subset relation in (29a), as shown in (29d).[25] Intersecting the sets in (29c) and (29d) with the set of times instantiating A in w preserves the subset relations, as shown in (29e) and (29f).

Given the specificity relation between Y and X, (30) holds:

(30) $W_{earl}(Y) \subseteq W_{earl}(X)$, where $W_{earl}(P) = \{w \in \mathcal{W} \mid earliest_w.P \text{ is defined}\}$

Moving on to the propositional level, (30) and (29e) imply (31a), while (30) and (29f) imply (31b).

(31) a. $\{w \in W_{earl}(Y) \mid \exists t \in \mathcal{T}\ (at(w, t, A) \wedge t < earliest_w.X)\} \subseteq$
$\{w \in W_{earl}(Y) \mid \exists t \in \mathcal{T}\ (at(w, t, A) \wedge t < earliest_w.Y)\}$
b. $\{w \in W_{earl}(Y) \mid \exists t \in \mathcal{T}\ (at(w, t, A) \wedge t > earliest_w.Y\} \subseteq$
$\{w \in W_{earl}(Y) \mid \exists t \in \mathcal{T}\ (at(w, t, A) \wedge t > earliest_w.X)\}$

(31a) essentially corresponds to an inference pattern like that of (17) in Sect. 1, and (31b) corresponds to an inference pattern like that of (18). *Before* sentences, therefore, satisfy strengthening inferences based on Strawson entailment. An exclusively veridical *before* would still be an NPI licenser. By contrast, *after* sentences satisfy weakening inferences based on Strawson entailment.

Using $\sqsubseteq_{str}$ to designate the relation of generalized (cross-categorial) Strawson entailment, what we have shown is that whenever [[Y]] $\sqsubseteq_{str}$ [[X]],[26] *before* reverses $\sqsubseteq_{str}$ while *after* preserves it:

(32) a. [[before X]] $\sqsubseteq_{str}$ [[before Y]]
b. [[after Y]] $\sqsubseteq_{str}$ [[after X]]
c. [[A before X]] $\sqsubseteq_{str}$ [[A before Y]]
d. [[A after Y]] $\sqsubseteq_{str}$ [[A after X]]
e. [[PAST(A before X)]] $\sqsubseteq_{str}$ [[PAST(A before Y)]]
f. [[PAST(A after Y)]] $\sqsubseteq_{str}$ [[PAST(A after X)]]

3.2 Non-veridical *before*

The reasoning of the specificity reversal induced by *before* outlined in the previous section should carry over to non-veridical *before*. In order to show this, we need to determine what set of times [[before X]]$_w$ yields when X is not instantiated in w, i.e.,

[25] If $earliest_w.X \prec earliest_w.Y$, then $\lambda t\ t < earliest_w.X \subset \lambda t\ t < earliest_w.Y$ since any time t' such that $earliest_w.X < t' < earliest_w.Y$ is in the set $\lambda t\ t < earliest_w.Y$ but not in $\lambda t\ t < earliest_w.X$; similarly, $\lambda t\ t > earliest_w.Y \subset \lambda t\ t > earliest_w.X$ since any time t' such that $earliest_w.X < t' < earliest_w.Y$ is in the set $\lambda t\ t < earliest_w.X$ but not in $\lambda t\ t < earliest_w.Y$.

[26] $\sqsubseteq_{str}$ allows for undefinedness of [[Y]] and [[X]].

when the set $\lambda t\ at(w, t, X)$ is empty. Given the analysis as presented so far, in that case $earliest_w.X$ would simply be undefined. Therefore, the way the analysis should be extended in order to cover non-veridical construals of *before* sentences is to allow for an *earliest*-based operator which is not necessarily undefined in case the temporal clause is not instantiated in the world of evaluation. As argued in Sect. 1, accounting for NPI licensing ought to be part and parcel of deriving the modal implications.

Beaver and Condoravdi (2003) provide a semantic account of the modal dimension of *before* and attribute it not directly to *before* but the operator *earliest*. The proposal is that when *earliest* is undefined in the world of evaluation, it is relativized to a set of alternative worlds to the world of evaluation. If X is instantiated in some such alternative world, the corresponding *before* sentence will have a truth value; otherwise, *earliest* will remain undefined and the *before* sentence will lack a truth value. The set of alternative worlds are related to the world of evaluation in such a way that (a) the modal implications of *before* sentences are the result of their truth-conditional content and information in the context of utterance, (b) *after* remains veridical when construed with *earliest* relativized to a set of alternative worlds.

Let us first specify how *earliest* is relativized to a set of worlds W:

(33) $earliest_W.X = earliest.\lambda t\,(\exists w \in W)\,at(w, t, X)$ if defined

$earliest_W.X$ is defined only if $(\exists w \in W)(\exists t \in \mathcal{T})\,at(w, t, X)$. Specifically, if $W = \emptyset$, $earliest_W.X$ is undefined. Now the meaning of *before* clauses can be generalized as in (34), with the set of alternative worlds to world w at time t in which X is instantiated, $alt_c(w, t, X)$, defined in (35).

(34) $[\![\text{before X}]\!]^c_w = \lambda t\ t < earliest_{alt_c(w,t,X)}.X$ if defined

(35) $$alt_c(w, t, X) = \begin{cases} \{w\} & \text{if } \exists t' \in \mathcal{T}\ at(w, t', X) \\ \{w' \in rph_c(w, t) \mid \exists t' \in \mathcal{T}\ at(w', t', X)\} & \text{otherwise} \end{cases}$$

When X is instantiated in the world of evaluation—the first case of (35)—we have the familiar case of veridical *before*, as $earliest_w.X = earliest_{\{w\}}.X$. When X is not instantiated in the world of evaluation—the second case of (35)—the alternative worlds are selected from among the historical alternatives of the world of evaluation relative to a given time.[27] They are the reasonably probable alternatives among those, designated by *rph*, in which the temporal property is instantiated. What counts as reasonably probable depends on the context, hence the relativization of *rph*, and *alt* to a context c, which makes *before* clauses context-dependent. Beaver and Condoravdi (2003) leave the notion of 'reasonably probable' unanalyzed. Condoravdi and Kaufmann (2009) show that it has to be distinct from the relation of maximal similarity involved in counterfactual conditionals, as well as from the standard notion of likelihood, and make a preliminary proposal about how it should be understood. The analysis of NPI licensing developed here, which is based on a semantic analysis of the modal dimension of *before*, is, in any case, compatible with different formal

[27] See Beaver and Condoravdi (2003) for details.

reconstructions of the notion of 'reasonably probable'. Finally, if the temporal property is not instantiated in any of these alternatives, in which case $alt_c(w, t, X) = \emptyset$, $[\![\text{before X}]\!]^c_w$ will be undefined.

Let us now see how specificity reversal is guaranteed for the non-veridical case. Supposing Y is a temporal property at least as specific as X, then for any context c, any world w and time t for which $earliest_{alt_c(w,t,X)}$ is defined and $alt_c(w, t, X) \neq \{w\}$:

(36) a. $alt_c(w, t, Y) \subseteq alt_c(w, t, X)$
b. $earliest_{alt_c(w,t,X)}.X \leq earliest_{alt_c(w,t,Y)}.Y$ if $earliest_{alt_c(w,t,Y)}$ is defined[28]
c. $[\![\text{before X}]\!]^c_w \subseteq [\![\text{before Y}]\!]^c_w$ if $[\![\text{before Y}]\!]^c_w$ is defined, where $[\![\text{Y}]\!] = Y$

Y may be instantiated only in a subset of the worlds in which X is instantiated, but still the earliest time at which Y is instantiated in some world will be no earlier than the earliest time at which X is instantiated in any world. The account does not require that there be worlds in $rph_c(w, t)$ in which Y is instantiated. The claim is simply that if there are such worlds, then we get the reversal in the semantic specificity relation of the denotations of the two temporal clauses that is the hallmark of downward monotonicity. Generalizing across veridical and non-veridical construals, we have established that $[\![\text{before X}]\!] \sqsubseteq_{str} [\![\text{before Y}]\!]$ whenever $[\![\text{Y}]\!] \sqsubseteq_{str} [\![\text{X}]\!]$.

Crucial for the subset relation between the two sets of worlds in (36a) (and for the consequent Strawson entailment between $[\![\text{before X}]\!]$ and $[\![\text{before Y}]\!]$) is keeping the context the same. That is, premise and conclusion are evaluated relative to the same contextual assumptions as to what is deemed reasonably probable. This is in fact a requirement on strengthening inferences that von Fintel (1999) independently argues for: "contextual parameters need to be kept constant *even if in a natural conversation they would normally evolve in a certain way.*" (p. 135)

This analysis of NPI licensing in *before* clauses is uniform across veridical and non-veridical construals. The Strawson downward entailingness of non-veridical *before* clauses is directly linked to their truth-conditional content and the mechanism responsible for their modal implications. In calculating the relative semantic strength of *before* clauses, the role of context is confined to determining definedness at individual worlds, without consideration for global properties of the context. On Ogihara's (1995) analysis, by contrast, when the temporal clause is not instantiated in the world of evaluation, as is the case in the counterfactual reading, monotonicity is satisfied by vacuous universal quantification. Recall that Ogihara adopts the traditional analysis in (10a)/(22a) for the truth-conditional content of *before* clauses. The presupposition to which Ogihara attributes the modal implications plays a role only in the background, in limiting assessment of monotonicity properties relative to those contexts that satisfy the presupposition of the more general and the more specific *before* clauses.

[28] $earliest_{alt_c(w,t,Y)}.Y$ would be defined only if $alt_c(w, t, Y) \neq \emptyset$.

As mentioned in Sect. 2.2, in Beaver and Condoravdi (2003) the semantic definedness condition of *earliest* is not made into a pragmatic presupposition. In other words, it is not made into a precondition for successful update, requiring that the context contain the necessary information to ensure that the temporal clause is instantiated across all the worlds in the context set. One reason is that such a pragmatic presupposition cannot be specified in a context independent way and accommodating it would essentially amount to local accommodation. To see this consider a context to be updated with (37). Such a context may not entail that the main clause is true, in this case that the mice died, or it may be consistent with the reverse temporal ordering between main and temporal clause, in this case immune response before death. So there is no presupposition that can be accommodated globally if the presupposition is to allow for an assertion of (37) to be informative.

(37) The mice died before they showed an immune response.

The contextual update we assumed allowed us to characterize veridical and non-veridical readings as contextual entailments, that is entailments of particular types of contexts when updated with a *before/after* sentence. This kind of contextual update can, in fact, be seen as a way of reconstructing local accommodation, that is, of getting the effects of local accommodation without assuming any accommodation at all.

TC and the other kinds of implications with a negated or modalized **TC** discussed in Sect. 1 are contextual entailments arising out of information in a particular context and context-dependent interpretation. In each case the meaning requires definedness of *earliest*, which would be satisfied if the temporal property that is the denotation of the temporal clause is instantiated in the world of evaluation or in a set of alternative worlds determined by it. Updating a context c with 'A before B', if consistent, will result in a context c' entailing **TC** or its variants, depending on properties of c. For instance, c' will entail $\neg$**TC** when the input context c entails that A's instantiation makes B's later instantiation impossible, and $\Diamond^{\text{CF}}$**TC** when at least some of the worlds in c in which B is not instantiated have some reasonably probable historical alternatives relative to the time at which A is instantiated in which B is instantiated.

To compare this analysis with an analysis that requires pragmatic presuppositions to be taken into account in strengthening inferences relevant for NPI licensing, let us look at inferences based on a veridical and on a counterfactual construal of the *before* sentences and consider the properties of the contexts in which their validity can be assessed. The inference from (38a) to (38b) is an example of the first kind, the inference from (37) to (39) an example of the second kind.

(38) a. The mice were tested before they showed an immune response.
b. The mice were tested before they showed a strong immune response.

(39) The mice died before they showed a strong immune response.

On the pragmatic presupposition analysis, the entailment of (38b) by (38a) can only be assessed in contexts entailing that the mice showed an immune response (so that

the presupposition of the premise is satisfied) and that the mice showed a strong immune response (so that the presupposition of the conclusion is satisfied). On the view presented here, the requirement on the context is that there be *some* world in the context set in which premise and conclusion have a defined semantic value. Intuitively, the strengthening inference we want to check is as in (40).

(40) It is possible that the mice showed an immune response and that (one of) the immune response(s) was a strong one.
The mice were tested before they showed an immune response.
∴ The mice were tested before they showed a strong immune response.

Similarly, on the pragmatic presupposition analysis, the entailment of (39) by (37) could only be assessed in contexts c where the intersection of all of $rph_c(w,t)$, for w in c in which the mice die and the temporal order between the death and the immune response is the asserted one, entails both that the mice show an immune response (so that the presupposition of the premise is satisfied) and that the mice show a strong immune response (so that the presupposition of the conclusion is satisfied). On the view presented here, the requirement on the context is that there be *some* world in the context set in which premise and conclusion have a defined semantic value. For the entailment of (39) by (37) to be assessed, what is required is simply that there be some $w \in c$ such that $rph_c(w,t)$ is consistent with the mice showing an immune response (so that the premise is defined) and with the mice showing a strong immune response (so that the conclusion is defined). Intuitively, the strengthening inference to check is as in (41).

(41) It is possible that the mice might have shown an immune response and that (one of) the immune response(s) could have been a strong one.
The mice died before they showed an immune response.
∴ The mice died before they showed a strong immune response.

Since the requirements on the context are weaker, strengthening inferences can be assessed in a wider range of contexts and hence we end up with a stronger notion of monotonicity based on contextually valid inferences.

4 Alternatives and Strawson entailment

Heim (1984) and Krifka (1995) have proposed a different type of relativization of downward monotonicity, where monotonicity is assessed on the basis of more specific expressions tied to the NPIs themselves. Krifka (1995) developed this idea further, providing an explanation for NPI licensing on the basis of the meaning of NPIs and their alternatives, which induce an ordering of semantic specificity, and the type of contextual update different kinds of assertions are associated with. The familiar strength-based inferences are valid for exhaustive NPIs. An NPI is exhaustive iff the union of the semantic values of the alternatives is identical to the ordinary semantic

value of the NPI. Krifka (1995) characterizes weak NPIs as exhaustive NPIs.[29] Krifka proposes that *any* phrases are indefinites whose descriptive content is a property and their alternatives are indefinites with a more specific property as descriptive content. For example, the ordinary semantic value of *any immune response* is equivalent to the meaning of *an immune response*, and its alternatives are indefinites like *a strong immune response*, *a weak immune response*, etc.

Krifka's (1995) explanation for the polarity sensitivity of weak polarity items rests on the assumption that they give rise to scalar assertions. Scalar assertions are assertions in which what is actually asserted is informationally ordered with respect to each one of the alternatives. The kind of informational strength assumed by Krifka is given in (42). For purposes of this discussion, contexts are identified with their context set. Regular contextual update +, on which the notion of informational strength is based, is assumed to be as in (43). Update with scalar assertions is assumed to be as in (44).

(42) p is informationally at least as strong as p' iff for any context c, $c + p \subseteq c + p'$.

(43) $c + p = \{w \in c \mid [\![p]\!]^c_w = 1\}$

(44) $ScalAssert(\langle p, Alt(p)\rangle, c) =$
$\{w \in c \mid w \in [\![p]\!]_c \wedge \neg(\exists p' \in Alt(p)\,(w \in [\![p']\!]_c \wedge c + p' \subset c + p))\}$

Scalar assertions result in a more informative context than plain assertions: in addition to asserting the proposition expressed, they negate any informationally stronger alternative propositions. Weak polarity items in a licensing environment give rise to a proposition that is informationally at least as strong as all its alternatives. In that case, $c + p = ScalAssert(\langle p, Alt(p)\rangle, c)$. Weak polarity items in a non-licensing environment give rise to a proposition that is informationally weaker than all its alternatives. In that case, $ScalAssert(\langle p, Alt(p)\rangle, c) = \emptyset$ even when $c + p \neq \emptyset$.

Now, if the relevant alternatives are associated with semantic presuppositions, we need to adjust the notion of informational strength to take into account the fact that some of the alternative propositions may be undefined in some worlds of the context. To see why some provision has to be made for alternatives that are undefined, consider an alternative p' of p that is not false in any world in which p is true and which is consistent with c but is undefined in some $w' \in c$ relative to which p is defined.[30] Then $w' \notin c + p'$, but if p is true in w', $w' \in c + p$, which implies that $c + p' \subset c + p$. The problem is that p' counts as informationally stronger than p not because of its truth but because of its undefinedness. In such a situation, any world $w \in c$ in which p' is true cannot be in $ScalAssert(\langle p, Alt(p)\rangle, c)$. It is worth noting that this situation arises even when every element in $Alt(p)$ is consistent with

[29] Extra considerations need to be brought to bear for non-exhaustive NPIs, which Krifka takes to characterize strong NPIs, and I will not discuss them here.

[30] This is precisely the kind of case discussed in the previous section in connection with (38a) and (38b) and with (37) and (39).

the input context c. So if some of the alternatives are undefined, we cannot maintain that $c + p = ScalAssert(\langle p, Alt(p)\rangle, c)$ when a weak polarity item is in a licensing environment. In fact, if for every $w \in c$ there is an alternative $p' \in Alt(p)$ which is undefined in w, $ScalAssert(\langle p, Alt(p)\rangle, c) = \emptyset$.

In line with the choice of not making every semantic presupposition a pragmatic presupposition, that is, a precondition for contextual update, I would like to propose the revised notion of informational strength in (45).[31] It is based on what we might call 'Strawson contextual update', defined as in (46).[32] The update for scalar assertions is accordingly revised as in (47).

(45) p' is informationally no stronger than p iff for any context c,
$c + p +_{str} p' = c + p$

(46) $c +_{str} p = c \setminus \{w \in c \mid [\![p]\!]^c_w = 0\}$

(47) $ScalAssert(\langle p, Alt(p)\rangle, c) =$
$\{w \in c \mid w \in [\![p]\!]_c \wedge \neg(\exists p' \in Alt(p)(w \in [\![p']\!]_c \wedge c + p +_{str} p' \neq c + p))\}$

Taking a context c to be partitioned into the set of worlds c^{p^t} in which p is true, the set of worlds c^{p^f} in which p is false, and the set of worlds c^{p^u} in which p is undefined, then $c + p = c^{p^t}$ and $c +_{str} p = c^{p^t} \cup c^{p^u}$. The idea behind (45) is that once a context c has been updated with p, then Strawson-updating with p' adds no more information. If $[\![p]\!] \sqsubseteq_{str} [\![p']\!]$, then p' is informationally no stronger than p.

We can combine Krifka's (1995) analysis of NPIs as introducing alternatives with von Fintel's Strawson entailment by considering the specificity ordering between the ordinary semantic value and the NPI-triggered alternatives that yield a semantic value. In these terms, the reversal induced by *before* would be with respect to the temporal property derived on the basis of the ordinary content of an NPI in a temporal clause and alternative temporal properties derived on the basis of the alternatives associated with the NPI, as shown schematically in (48) (more concrete examples are found in the following sections).

(48) [[before Z]] $\sqsubseteq_{str}$ [[before Z^A]]

Given the way the NPI-triggered alternatives are specified, $[\![Z^A]\!] \sqsubseteq_{str} [\![Z]\!]$.

5 NPI licensing by *after*

Linebarger (1987, 1991) has argued against semantic accounts of NPI licensing and proposed an alternative of her own, called the NI (Negative Implication) theory. The

[31] Otherwise, we would have to assume that $ScalAssert(\langle p, Alt(p)\rangle, c)$ is defined only relative to contexts c that satisfy the presuppositions of p and those of each one of the elements of $Alt(p)$.

[32] Stalnaker's (1978) requirement that every semantic presupposition be a pragmatic presupposition ensures the equivalence of the contextual updates as defined in (43) and in (46).

main idea of Linebarger's NI account is that an NPI in a sentence "signals to the hearer that among the implicata of the host sentence there is some negative proposition which 'justifies' the use of the NPI" (Linebarger 1987, 346). The relevant NI may be an entailment or a conversational implicature of the asserted sentence and it has to satisfy the following Strength requirement: "the truth of NI, in the context of the utterance, virtually guarantees the truth of P [the asserted sentence]" (Linebarger 1987, 346).[33] Linebarger's argument for her NI theory is based on the observation that NPIs can be acceptable in a non-downward entailing environment as long as the sentence in which they appear can give rise to a negative implication of some sort.

As part of her critique against monotonicity-based accounts of NPI licensing, Linebarger noted that, though not downward entailing, *after* can license NPIs under certain conditions. This occurs when *after* is combined with some measure phrases, such as *long*, or *years*, but not others, such as *seconds* or *shortly*. Using examples like (49a, b, c),[34] she argued that NPIs in *after* clauses are correlated with the associated italicized negative implications (NIs).

(49) a. She persisted long after she had any hope at all of succeeding.
NI = *She persisted (even) when she didn't have any hope of succeeding.*
b. The mad general kept issuing orders long after there was anyone to obey them.
NI = *The mad general kept issuing orders (even) when there wasn't anyone to obey them.*
c. He kept writing novels long after he had any reason to believe they would sell.
NI = *He wrote novels (even) when he didn't have any reason to believe they would sell.*

In (50) I give some naturally occurring examples from the web along with their associated negative implication, of the kind Linebarger claimed is responsible for NPI licensing in *after* clauses. (50a) is like Linebarger's examples in that the situation described by the main clause is implied to hold both while the situation described by the temporal clause obtained and afterwards: (50a) implies that Holly Solomon was a beloved figure in the Manhattan art world both while people went to her gallery and when no one went to her gallery anymore. (50b, c), by contrast, have no such implication of continuity and simply order the situations described by the main and temporal clause. (50b, c) are like Linebarger's examples in having a stative predicate in the *after* clause, while (50a) has an eventive predicate interpreted iteratively.

(50) a. Holly Solomon was a beloved figure in the Manhattan art world long after anyone ever went to her gallery, or indeed knew if she had one or not.[35]

[33] Linebarger (1991) adds two more requirements of a more vague character. They are meant to ensure that the NI is salient in the context of utterance and that the NI and the information contributed by the NPI are not backgrounded.

[34] Examples (142a), (143a), and (144a) in Linebarger (1987).

[35] http://www.independent.co.uk/news/obituaries/holly-solomon-645982.html.

NI = *Holly Solomon was a beloved figure in the Manhattan art world (even) when no one ever went to her gallery anymore.*

b. I believe that this is how fiction will be written and published in the future, that this will become the new standard long after anyone remembers that Ho Springs ever existed.[36]
NI = *This will become the new standard when no one remembers anymore that Ho Springs ever existed.*

c. Over months however the reality of the situation emerged, though long after anyone still cared.[37]
NI = *The reality of the situation emerged when no one cared anymore.*

The generalization to draw from examples like (49) and (50) is that an NPI in an *after* clause is associated with the implication that the situation described by that clause ended at some point and that the situation described by the main clause is asserted to hold after that point. So (49) and (50) give rise not just to a plain **TC** implication but to an implication that **TC** holds over a period of time—let's call that period the positive phase—and that ¬**TC** holds over a subsequent period of time—let's call that period the negative phase. For instance, the temporal clauses in these examples are stative predicates assumed to hold over a continuous stretch of time, as in (49), or multiple and overlapping such states involving different agents, as in (50b, c), or eventive predicates interpreted iteratively, as in (50a). The ordering of the main clause is with respect to the onset of the negative phase, which is equivalent to saying that the time of the main clause is after *every* time at which the temporal clause is true. We can thus rewrite the implications associated with (49a) as in (51a), and those associated with (50c) as in (51b).

(51) a. She persisted long after she had any hope at all of succeeding.
She first had hope of succeeding and then she ran out of hope.
She persisted long after she had run out of hope.

b. Over months however the reality of the situation emerged, though long after anyone still cared.
People first cared and then stopped caring.
The reality of the situation emerged long after people had stopped caring.

It is interesting to observe that the kind of reading forced by an NPI in an *after* clause arises independently of the presence of an NPI. (52a) has two incompatible readings and (52b) is synonymous with (52c).

(52) a. There were major climatic changes long after there were dinosaurs on the planet. (2 readings)
Climatic changes during vs. after dinosaurs' presence on the planet

b. There were major climatic changes long after there were any dinosaurs on the planet. (1 reading)
Climatic changes after dinosaurs' presence on the planet

[36] http://www.huffingtonpost.com/pamela-redmond-satran/reinventing-the-novel_b_509622.html.

[37] www.defencetalk.com/forums/showthread.php?p=91461.

c. There were major climatic changes long after there were no dinosaurs on the planet. (1 reading)
Climatic changes after dinosaurs' presence on the planet

(53) a. There were major climatic changes long after there were mammals on the planet.
Climatic changes during mammals' presence on the planet
b. #There were major climatic changes long after there were any mammals on the planet.

On one reading, (52a) implies that major climatic changes occurred within the period during which there were dinosaurs, and, on what we might call the strengthened reading, that major climatic changes occurred after the extinction of dinosaurs.[38] The presence of the NPI in (52b) is only compatible with the second reading and the question is what forces the strengthened reading and how the existential DP *any dinosaurs* comes to be equivalent to the negative DP *no dinosaurs*. (53a) lacks the strengthened reading because it is commonly known that the temporal clause has not ceased to hold. For the same reason (53b) is pragmatically odd, as it implies that mammals no longer exist.

According to Linebarger (1991, 176), "on the NI account, the acceptability of NPIs in sentences of the form *P (long) after Q* depends upon whether or not they are paraphraseable as *P when not Q*." This kind of NI meets the Strength requirement: "if, for simplicity, we consider only the claim about the relative ordering of P and Q in 'P after Q', it would seem that an NI 'when P occurred, Q was not the case anymore' establishes this order more explicitly than the host sentence itself." (Linebarger 1987, 371). However, Linebarger does not analyze how the required negative implications arise, or how they relate to truth-conditional content. In the cases at hand, for instance, the question is what is responsible for the implication of the transition from a positive phase when Q holds to a negative phase when Q ceases to hold. Linebarger's reference to 'Q was not the case anymore' in the formulation of the NI presupposes precisely such a transition. If we take *any* to be an existential, the meaning of the temporal clause implies the existence of the positive Q phase. What remains an open question is what supports the implication of an eventual transition to a non-Q phase and how the meaning of *after* is strengthened so as to order the time of the main clause after *every* time at which the temporal clause is true, rather than simply *some* or the *earliest* such time.

To the extent that she addresses this question, which she does not consider explicitly, Linebarger attributes the effect to the measure modifiers: "The tendency to 'close down' the previous situation associated with the expressions 'long after' or 'years after' (but not 'seconds after') gives rise to the NI appropriate for NPI licensing." (Linebarger 1987, 370). By "close down" Linebarger must mean the implication of a transition from a positive to a negative phase. But this just shifts the question to

[38] The strengthened reading is, of course, compatible with the truth-conditional content of *after* clauses, regardless of whether it is based on existential quantification or the operator *earliest*, so, in the absence of the NPI facts, one could have a pragmatic story for its existence.

why *long* might do so and how it effects the necessary strengthening. The two readings of (52a) and the acceptability of (53a) show that measure phrases like *long* need not give rise to an implication of a transition from a positive to a negative phase. Even assuming that *long* in *P long after Q* can somehow give rise to the implication that '*Q* and then not-*Q*', it could still leave underspecified whether *P* occurs at a *Q* time or an non-*Q* time.

One could suppose that the strengthening of *after* exhibited by the NI will arise if the contextual standard for *long* measuring the distance between two times is presumed to be higher than the maximal duration of the situation described by the temporal clause. Such a contextual assumption along with the meaning of *long after* would guarantee that the main clause holds at a time after the situation described by the temporal clause has come to an end. Incorporating measure phrases into the analysis presented in Sect. 3.1, we can specify the meaning of *long after* as in (54), where $\mathbf{s}_c$**(long)** is the relevant contextual standard, $|t|$ gives the duration of an interval, $|t' - t|$ is the duration of the maximal interval between times t and t' (intuitively, the temporal distance between two times), and $\leq$ is the greater-than-or-equals relation on measures of duration.

(54) a. $[\![\text{long after}]\!]^c_w = \lambda t \lambda t' \ (t' > t \ \wedge \ \mathbf{s}_c(\mathbf{long}) \leq |t' - t|)$
b. $[\![\text{long after X}]\!]^c_w = \lambda t \ (t > earliest_w.X \ \wedge \ \mathbf{s}_c(\mathbf{long}) \leq |t - earliest_w.X|)$

However, there is no indication that strengthened readings of *after* or the licensing of NPIs in *after* clauses are correlated in any way with such a contextual assumption. No such implications arise for any of (49), (50), or (52b). Moreover, both readings for (52a) can arise relative to the *same* contextual standard for *long*.

Linebarger also argues that *(long) after* is not downward entailing but, interestingly, to do so she uses examples like (55), rather than examples of the type in (49) that are associated with an implication of a transition from a positive to a negative phase.

(55) John got sick (long) after he ate a green vegetable.
⁄. John got sick (long) after he ate kale.

The inference from (56a) to (56b), on the other hand, would seem to be valid as long as the **TC** implication of (56b) can be assumed to hold. This is exactly parallel to strengthening inferences with veridical *before*, as discussed in Sect. 1. On the strengthened interpretation of *after* discussed above, strengthening inferences are valid, suggesting that the semantic account of NPI licensing, based on Strawson downward entailment, is applicable here as well.

(56) a. He kept writing novels (long) after he had reason to believe they would sell.
b. He kept writing novels (long) after he had good reason to believe they would sell.

Beaver and Condoravdi (in progress) propose that in addition to *earliest*, the operator *max* can be applied to a sentence radical to yield a unique time. Like *earliest*, *max*

is defined only if the sentence radical to which it applies is instantiated. *earliest* and *max* give different interpretations for *after* but identical ones for *before*. The semantics does not constrain which operator is applied but in the case of *after* the choice of operator will determine the implications of the sentence (coming about/into existence vs. ceasing to hold/be) as well as the validity of strengthening inferences.

I will attribute the restriction on the kinds of temporal clauses that yield strengthened readings with *after* discussed above to a definedness condition on *max*. For left and right bounded, instantiated sets of times T, $max.T$ is defined only if T is strictly cumulative (has at least two elements whose sum does not equal either of them and is closed under summation); $max.T = \bigoplus(T \cup \{glb(T), lub(T)\})$ when defined. The reason for applying $\bigoplus$ to the union of T with the set containing its greatest lower bound and its least upper bound is so as to ensure that we get a unique time as the value of $max.T$. By restricting the sentence radicals that can be construed with *max* to those that are cumulative, the ordering expressed by the temporal connective is ensured to be with an interval that is in the denotation of the temporal clause.[39] The relativization of *max* to a world w is given in (57).

(57) For any $w \in \mathcal{W}$ and temporal property X,
$max_w.X = max.\lambda t\ at(w, t, X)$
provided $max.\lambda t\ at(w, t, X)$ is defined,[40] else undefined.

In order for the temporal clauses in (49), (50) and (52b) to be guaranteed to be cumulative, the only additional assumption we need to make is that *any* and *anyone/anything* do not impose any cardinality restriction so that the terms they head or constitute can be cumulative.[41] The denotation of the corresponding sentence radicals is strictly cumulative when instantiated. The unacceptability of Linebarger's (58) can thus be attributed to the non-strict cumulativity of the achievement predicate *he retire to any Caribbean island*.

(58) *He kept writing novels long after he retired to any Caribbean island.

On this view then, the strengthened readings observed in (49), (50) and (52a, b) are semantic, not just due to pragmatic strengthening, and it is precisely in the construal with *max* that *after* is predicted to license NPIs. *After* in construal with *earliest*, as we have seen, does not induce the necessary specificity ordering reversal for strengthening inferences to be valid. If there is an NPI in an *after* clause, *max* will have to apply to the temporal clause. The implication of a transition from a positive to a negative phase seen with (49), (50), (52b), and one reading of (52a) is a contextual entailment due to the definedness conditions of *max*. Consequently, Linebarger's NI is the result of *max*'s requirement for a right bounded set and *after*'s truth-conditional content.

[39] More precisely, we ensure that there is $t \in T$ such that $max.T = glb(T) \oplus t \oplus lub(T)$.

[40] $max.\lambda t\ at(w, t, X)$ is defined only if $\lambda t\ at(w, t, X)$ is strictly cumulative, which guarantees that it is instantiated, and left and right bounded. Whether X is instantiated at two non-overlapping times and whether it is left or right bounded in a given world w would, in general, depend on w.

[41] Note that in these examples *any* combines with mass or plural nouns.

Concretely, let us consider the three kinds of temporal clauses in (52) and their meaning. Due to the presence of the NPI *any*, (59c) is associated with an ordinary semantic value, given in (59f), and a set of alternative semantic values, each one of which is as in (59g).

(59) a. X = There be dinosaurs on the planet
b. Y = There be no dinosaurs on the planet
c. Z = There be any dinosaurs on the planet
d. $[\![\mathrm{X}]\!]_w = \lambda t\ at(w, t, \lambda t' \exists x\ (dinos(x)\ \wedge\ on\text{-}planet(x, t')))$
e. $[\![\mathrm{Y}]\!]_w = \lambda t\ at(w, t, \lambda t' \neg\exists x\ (dinos(x)\ \wedge\ on\text{-}planet(x, t')))$
f. $[\![\mathrm{Z}]\!]_w = \lambda t\ at(w, t, \lambda t' \exists x\ (dinos(x)\ \wedge\ on\text{-}planet(x, t')))$
g. $[\![\mathrm{Z}^A]\!]_w = \lambda t\ at(w, t, \lambda t' \exists x\ (dinos^A(x)\ \wedge\ on\text{-}planet(x, t'))$

X and Y can both be construed with *earliest* since they contain no NPIs. X and Z are strictly cumulative,[42] so they can both be construed with *max*.[43] Y will denote a left bounded set of times, as required by the definedness conditions of *earliest*, and X, Z, Z^A a right bounded set of times, as required by the definedness conditions of *max*, only relative to worlds in which dinosaurs (or in the case of Z^A more specific kinds of dinosaurs) become extinct. For any such world w, (60a) holds; consequently, (52b) construed with *max* and (52c) construed with *earliest* have identical truth conditions. Also, for any such world w and for any alternative Z^A of Z defined in w, (60b) holds; consequently, the specificity relation $[\![\mathrm{Z}^A]\!] \sqsubseteq_{str} [\![\mathrm{Z}]\!]$ is reversed to $[\![\text{after Z}]\!] \sqsubseteq_{str} [\![\text{after } \mathrm{Z}^A]\!]$ once *after* construed with *max* applies to the temporal clause.

(60) a. $\lambda t\ t > earliest.[\![\mathrm{Y}]\!]_w = \lambda t\ t > max.[\![\mathrm{Z}]\!]_w$
b. $\lambda t\ t > max.[\![\mathrm{Z}]\!]_w \subseteq \lambda t\ t > max.[\![\mathrm{Z}^A]\!]_w$

Finally, the effect of the two types of measure modifiers on NPI licensing observed by Linebarger is a direct consequence of their semantics (see, for instance, (54)). The measure phrases in *long after, years after* preserve the specificity ordering seen above between $[\![\text{after Z}]\!]$ and $[\![\text{after } \mathrm{Z}^A]\!]$ when *after* is construed with *max*, whereas those in *shortly after, seconds after*, in general, do not.[44] Here is the reasoning informally for *long* and *shortly*. Consider the two sets of times in (60b). Any time later than $max.[\![\mathrm{Z}]\!]_w$ and at a distance d from it will also be later than $max.[\![\mathrm{Z}^A]\!]_w$ and at a distance d or greater from it, for any alternative Z^A of Z. If d counts as long, then any distance longer than d will count as long as well. So adding the measure phrase *long* preserves the subset relation between the two sets of times for any alternative. But if d counts as short, then there are distances longer than d that will not count as short and those may well be distances from $max.[\![\mathrm{Z}^A]\!]_w$ for some alternative Z^A of Z.

[42] They are cumulative since, on the assumption that *dinos* and *on-planet* are cumulative, for any $w \in \mathcal{W}$ and $t_1, t_2 \in \mathcal{T}$, if $at(w, t_1, \lambda t' \exists x(dinos(x) \wedge on\text{-}planet(x, t')))$ and $at(w, t_2, \lambda t' \exists x(dinos(x) \wedge on\text{-}planet(x, t')))$, then $at(w, t_1 \oplus t_2, \lambda t' \exists x(dinos(x) \wedge on\text{-}planet(x, t')))$. They are strictly cumulative relative to any world in which dinosaurs existed at distinct, non-overlapping times.

[43] Y is also strictly cumulative but it does not appear to have a construal with *max*. I leave it as an open question why that is.

[44] *Seconds after* does not preserve the specificity ordering if interpreted as *only seconds after*, as it tends to be.

6 NPI licensing by *since* and *until*

NPIs are generally unacceptable in *since* clauses or *until* clauses:

(61) a. *I've been sitting over here since anyone paid any attention to me.
b. *I stayed in the room until anyone noticed me.

Zwarts (1995), citing Bolinger (1977), notes that *it's two weeks since, it's a long time since, it's been a while since* license *any*. Von Fintel (1999) makes a similar observation, citing examples like (62), and uses this case as another (suggestive) instance of licensing of NPIs based on Strawson entailment.

(62) It's been five years since I saw any bird of prey in this area.

Observing that while the inference in (63) is invalid, the adjusted inference in (64) is valid, von Fintel concludes the following regarding (62): "This construction is not downward entailing as the problematic inference in (63) shows. Nevertheless, (62) shows that NPIs are licensed by this construction. We observe that *it's been five years since p* asserts that *p* hasn't been true since five years ago and presupposes that *p* was indeed true five years ago. The Strawson-DE experiment in (64) works fine." (p. 107)[45]

(63) It's been five years since I saw a bird of prey in this area.
$\not\Rightarrow$ It's been five years since I saw an eagle in this area.

(64) It's been five years since I saw a bird of prey in this area.
Five years ago I saw an eagle in this area.
$\therefore$ It's been five years since I saw an eagle in this area.

Now it would be desirable to derive the implications of (62) without appeal to any construction-specific presuppositions. In addition to being theoretically preferable, it would be empirically more adequate since *for a week/for a long time until* similarly license NPIs, as seen in the following naturally occurring examples. In the *until* cases, the measure modifiers are clearly measure modifiers of the main clause predicate rather than the connective.

(65) The package was in the office for a week until anyone noticed it.
(heard on NPR, March 2006)
No one noticed the package for (at least) a week.
Someone eventually noticed the package.

(66) a. It was a long time until anyone knew who'd really fathered Amy. [Google]
For a long time no one knew.
Someone eventually got to know. / Eventually people started learning.

[45] (62), (63) and (64) correspond to examples (21), (20) and (22) in von Fintel (1999).

b. She sat at the Fandangle for a long time until anyone acknowledged her presence. [Google]
For a long time no one acknowledged her presence.
Someone eventually acknowledged her presence. / Eventually people started acknowledging her presence.
c. It will be a long long time until any other party takes control.[46]
No other party will have control for a very long time.
Some other party may eventually take control.[47]

What are (65) or (66) supposed to presuppose? How do their negative and positive implications and their implied ordering come about?

We can use the general apparatus developed so far, associating definedness conditions with the operators *earliest* and *max* instead of the connectives themselves or particular constructions in which the connectives appear, to account for the meaning of (62), (65), (66), as well as the exceptional NPI licensing in *since* and *until* clauses.

6.1 *Since*

Iatridou (2003) looks more closely at *it's been 5 years/a long time since* constructions, what she calls 'temporal existentials'. She argues that temporal existentials have a uniqueness presupposition in addition to the existential presupposition associated with the *since* clause. On her approach, the acceptability of the NPI *any* in (62) is based on the validity of the strengthening inference in (67), where the italicized premise spells out the combined presupposition of the basic premise—the one based on the more general expression in the *since* clause—and of the conclusion.

(67) It's been five years since I saw a bird of prey in this area.
The only time I saw a bird of prey in this area I saw an eagle.
∴ It's been five years since I saw an eagle in this area.

However, the naturally occurring examples in (68) and (69) clearly show that there is no uniqueness presupposition necessarily associated with the *since* clause in temporal existentials. Rather, we get the familiar phase implications that we have seen with *after* in Sect. 5. (68) and (69) imply that there was a positive phase during which the temporal clause was instantiated continuously or repeatedly, followed by a negative phase whose duration is specified by the main clause.

(68) a. It's been a long time since he rock'n'rolled.[48]
b. It's a long time since I drank champagne.[49]
c. It's been a long while since I watched HardBall.[50]

[46] http://blogs.guardian.co.uk/news/2005/11/bush_and_the_po.html.

[47] The weaker possibility implication is generally seen with temporal clauses in sentences in the future.

[48] http://www.independent.co.uk/arts-entertainment/music/features/jimmy-page–its-been-a-long-time-since-he-rocknrolled-1854570.html.

[49] http://therumpus.net/2010/08/its-a-long-time-since-i-drank-champagne/.

[50] http://www.huffingtonpost.com/social/NoPretenses/msnbcs-new-anchor-lineup_n_715006_60342979.html.

(69) a. It's been a long time since anyone's died.[51]
For a while people were dying.
No one has died in a long time.
b. It has been over five years since there was any film in our office.[52]
There used to be film in the office.
There has been no film in the office for over five years.
c. It's been a long time since anyone attempted a new side-scrolling beat-em-up, and a much longer time since anyone did it right.[53]
People used to attempt new side-scrolling beat-em-up's and some did them right.
No one has attempted a new side-scrolling beat-em-up in a long time, and no one has done it right in an even longer time.

I propose that *since* is lexically a relation between a time and intervals extending from that time onwards: $\lambda t_1 \lambda t_2\ (t_2 > t_1 \wedge \text{convex}(t_1 \oplus t_2))$. The lexical meaning of *since* is thus a specialization of the lexical meaning of *after*. As with *before* and *after*, *since* combines with the temporal clause through the mediation of the operators *earliest* or *max*, whose definedness conditions give rise to the implication that the temporal clause is instantiated, accounting for the existential implication of *since* clauses. When NPIs appear in the temporal clause, *since* must be construed with *max* in order to get the appropriate entailment relation between the asserted sentence and its alternatives. Therefore, an NPI in a *since* clause is correlated with phase implications, which, exactly as with *after*, arise as contextual entailments due to the definedness conditions of *max* and *since*'s truth-conditional content.

To see why NPIs are licensed in these special cases let us consider the analysis of (63), given in (70). Following Iatridou (2003) and previous work cited therein, I take the perfect to scope over the result of main and temporal clause composition. For the case at hand, main and temporal clauses can compose intersectively.

(70) a. X = It be 5 years
b. Z = I see any bird of prey
c. $[\![\text{Z}]\!]_w = \lambda t\ at(w, t, \lambda t' \exists x(birds(x) \wedge see(I, x, t'))$
d. $[\![\text{Z}^A]\!]_w = \lambda t\ at(w, t, \lambda t' \exists x(birds^A(x) \wedge see(I, x, t'))$
e. $[\![\text{X}]\!]_w = \lambda t\ 5\text{-}years \leq |t|$
f. $st_w = max.[\![\text{Z}]\!]_w$
g. $st_w^A = max.[\![\text{Z}^A]\!]_w$
h. $[\![\text{since Z}]\!]_w = \lambda t\ (t > st_w \wedge \text{convex}(st_w \oplus t))$
i. $[\![\text{since Z}^A]\!]_w = \lambda t\ (t > st_w^A \wedge \text{convex}(st_w^A \oplus t))$
j. $[\![\text{X since Z}]\!]_w = \lambda t\ (5\text{-}years \leq |t| \wedge t > st_w \wedge \text{convex}(st_w \oplus t))$
k. $[\![\text{X since Z}^A]\!]_w = \lambda t\ (5\text{-}years \leq |t| \wedge t > st_w^A \wedge \text{convex}(st_w \oplus t))$

[51] http://board.lemmingtrail.com/t.php?id=56471&r=6.

[52] www.moosepeterson.com/f6.html.

[53] www.gamepro.com/sony/psx/games/reviews/5717.shtml.

l. $[\![\text{PERF}]\!]_w = \lambda P \lambda t\ \exists t'\ (t = rb(t') \wedge at(w, t', P))$[54]
m. $[\![\text{PRES}]\!]^c_w = \lambda P\ at(w, now_c, P)$
n. $[\![\text{PRES}(\text{PERF}(\text{X since Z}))]\!]^c_w = \exists t' \in \mathcal{T}\ (rb(t') = now_c \wedge 5\text{-}years \leq |t'| \wedge t' > st_w \wedge \text{convex}(st_w \oplus t'))$
o. $[\![\text{PRES}(\text{PERF}(\text{X since Z}^A))]\!]^c_w = \exists t' \in \mathcal{T}\ (rb(t') = now_c \wedge 5\text{-}years \leq |t'| \wedge t' > st^A_w \wedge \text{convex}(st^A_w \oplus t'))$

For any w and any alternative Z^A defined in w, st^A_w is a subinterval of st_w and, therefore, either $rb(st^A_w) = rb(st_w)$ or $rb(st^A_w) \prec rb(st_w)$. Intuitively, the last time I saw a bird of prey of a particular kind can be no later than the last time I saw a bird of prey. If $st^A_w = st_w$, then $[\![\text{since Z}]\!]_w = [\![\text{since Z}^A]\!]_w$; if $st^A_w \subset_{\mathcal{T}} st_w$, then $[\![\text{since Z}]\!]_w$ and $[\![\text{since Z}^A]\!]_w$ are disjoint.[55] This means that there is no specificity relation between $[\![\text{since Z}]\!]$ and $[\![\text{since Z}^A]\!]$, so, in general, there is no NPI licensing in *since* clauses. But when they combine with main clauses like X which simply specify an upward monotonic measure on intervals, the resulting propositions are related by Strawson entailment: $[\![\text{PRES}(\text{PERF}(\text{X since Z}))]\!]^c \sqsubseteq_{str} [\![\text{PRES}(\text{PERF}(\text{X since Z}^A))]\!]^c$, for any alternative Z^A of Z.[56] For any world w in which there is a time t extending from the last time I saw a bird of prey to the time of utterance now_c that is at least five years in duration, there is also a time t', $t \subseteq_{\mathcal{T}} t'$, extending from the last time I saw a bird of prey of a particular kind to now_c that is at least five years in duration. The reverse is not true, since it can be that the last time I saw an eagle was 5 years ago but the last time I saw a bird of prey of any kind was only two years ago. Therefore, an assertion of (62) constitutes a scalar assertion as discussed in Sect. 4 with the proposition expressed being stronger than the alternative propositions.

The exceptional NPI licensing in *since* clauses can, therefore, be accounted for on the basis of a compositional analysis of the construction *it's been 5 years/a long time since X* and without postulating any construction-specific presuppositions. On the analysis presented here, the main clause does not have to combine with *since* first so as to create a downward entailing functor which can then take the sentence radical of the temporal clause as an argument. Rather, as is generally the case, the *since* clause is assigned a meaning which then composes with the meaning of the main clause.

6.2 *Until*

Similarly, we can take *until* to be lexically a relation between a time and intervals extending up to that time: $\lambda t_1 \lambda t_2\ (t_2 < t_1 \wedge \text{convex}(t_1 \oplus t_2))$. The lexical meaning of *until* is thus a specialization of the lexical meaning of *before*. As with *before*, *earliest* and *max* give identical denotations for *until* clauses, though, of course, the contextual

[54] More generally, we can make the λ-abstracted time a final subinterval of the existentially quantified time. As I take *now* to be a point, having t be the right bound of t' amounts to the same thing once PRES applies to the temporal abstract (if we disregard whether t' includes its right bound).

[55] To see this consider that the left bound of every interval in $[\![\text{since Z}]\!]_w$ is $rb(st_w)$ and the left bound of every interval in $[\![\text{since Z}^A]\!]_w$ is $rb(st^A_w)$.

[56] As with the temporal clauses, $[\![\text{X since Z}]\!]_w$ and $[\![\text{X since Z}^A]\!]_w$ are either identical or disjoint.

entailments for the two construals are different. This implies that sentences with NPIs in an *until* clause need not give rise to the implication that there was a positive phase during which the temporal clause was instantiated continuously or repeatedly. This is reflected in the implications associated with (65) and (66). In my rendering of the implications, *someone eventually ...* is due to the construal with *earliest*, and *eventually people started ...* to the construal with *max*.

Let us first consider cases where the main clause just specifies the measure of an interval. (71) gives the analysis of (66a) on the *earliest* construal.

(71) a. $\mathrm{X} =$ It be a long time
b. $\mathrm{Z} =$ Anyone knows who fathered Amy
c. $[\![\mathrm{Z}]\!]_w = \lambda t\ at(w, t, \lambda t' \exists x(person(x) \wedge know(x, \mathrm{WFA}, t')))$
d. $[\![\mathrm{Z}^A]\!]_w = \lambda t\ at(w, t, \lambda t' \exists x(person^A(x) \wedge know(x, \mathrm{WFA}, t')))$
e. $[\![\mathrm{X}]\!]^c_w = \lambda t\ \mathbf{s}_c(\mathbf{long}) \leq |t|$
f. $ut_w = earliest.[\![\mathrm{Z}]\!]_w$
g. $ut^A_w = earliest.[\![\mathrm{Z}^A]\!]_w$
h. $[\![\text{until Z}]\!]_w = \lambda t\ (t < ut_w \wedge \mathrm{convex}(ut_w \oplus t))$
i. $[\![\text{until Z}^A]\!]_w = \lambda t\ (t < ut^A_w \wedge \mathrm{convex}(ut^A_w \oplus t))$
j. $[\![\mathrm{X}\text{ until Z}]\!]^c_w = \lambda t\ (t < ut_w \wedge \mathrm{convex}(ut_w \oplus t) \wedge \mathbf{s}_c(\mathbf{long}) \leq |t|)$
k. $[\![\mathrm{X}\text{ until Z}^A]\!]^c_w = \lambda t\ (t < ut^A_w \wedge \mathrm{convex}(ut^A_w \oplus t)\ \mathbf{s}_c(\mathbf{long}) \leq |t|)$
l. $[\![\mathrm{PAST}(\mathrm{X}\text{ until Z})]\!]^c_w = \exists t \in \mathcal{T}\ (t < now_c \wedge t < ut_w \wedge \mathrm{convex}(ut_w \oplus t) \wedge \mathbf{s}_c(\mathbf{long}) \leq |t|)$
m. $[\![\mathrm{PAST}(\mathrm{X}\text{ until Z}^A)]\!]^c_w = \exists t \in \mathcal{T}\ (t < now_c \wedge t < ut^A_w \wedge \mathrm{convex}(ut^A_w \oplus t) \wedge \mathbf{s}_c(\mathbf{long}) \leq |t|)$

For any w and any alternative Z^A defined in w, either $ut_w = ut^A_w$ or $ut_w \prec ut^A_w$. If $ut_w = ut^A_w$, then $[\![\text{until Z}]\!]_w = [\![\text{until Z}^A]\!]_w$; if $ut_w \prec ut^A_w$, then $[\![\text{until Z}]\!]_w$ and $[\![\text{until Z}^A]\!]_w$ are disjoint.[57] This means that there is no specificity relation between $[\![\text{until Z}]\!]$ and $[\![\text{until Z}^A]\!]$, so, in general, there is no NPI licensing in *until* clauses. But when they combine with main clauses like X which simply specify an upward monotonic measure on intervals, the resulting propositions are related by Strawson entailment: $[\![\mathrm{PAST}(\mathrm{X}\text{ until Z})]\!]^c \sqsubseteq_{str} [\![\mathrm{PAST}(\mathrm{X}\text{ until Z}^A)]\!]^c$, for any alternative Z^A of Z. The proposition expressed Strawson-entails the alternative propositions but not the reverse, and therefore, an assertion of (66a) constitutes a scalar assertion.

Examples like (65) and (66b) present more of a challenge since their main clauses have additional content, whose truth need not be preserved from intervals to super-intervals. For instance, if the package is in the office until ut_w, what guarantees that it is in the office until some later time ut^A_w? It is interesting to observe that the temporal clauses of these examples contain predicates like *notice* and *acknowledge her presence* which are themselves presuppositional; for someone to acknowledge her presence at some time, she must be present at the relevant place at that time. This implies that if the temporal clauses based on alternatives is defined, then the main

[57] To see this consider that the right bound of every interval in $[\![\text{until Z}]\!]_w$ is ut_w and the bound of every interval in $[\![\text{until Z}^A]\!]_w$ is ut^A_w.

clause remains true until the later time. If that is so, then we get the necessary entailment relation (Strawson entailment) between the basic proposition and the alternative propositions.

7 Conclusion

Instead of piecemeal analyses we can have a uniform analysis of NPI licensing in temporal clauses. The operators *earliest* and *max*, rather than the temporal connectives, are responsible for quantification over temporal clauses. An implication about the truth of a temporal clause with any kind of temporal connective is a semantic presupposition due to the definedness condition associated with *earliest* and *max*. This allows us to properly factor out presuppositional content in strengthening inferences and apply von Fintel's (1999) presupposition-dependent notion of Strawson entailment.

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