Until-phrases as obligatory free choice items[1]

Frank STANISZEWSKI — *Massachusetts Institute of Technology*

Abstract. Following Mittwoch (1977), Iatridou and Zeijlstra (to appear), I attempt a unified account of *until* (which has proven challenging for reasons I discuss). I propose a basic weak meaning, which obligatorily strengthens in upward-entailing environments in a manner similar to free-choice. Infelicity then results in cases where this strengthened meaning contradicts contextual knowledge about the sentences that the *until* phrase modifies. I argue that this account avoids the empirical problems of previous accounts, and also provides a way to understand *until*'s status as a 'strong' NPI: Its restricted distribution in (merely) Strawson downward-entailing environments can be explained with independently motivated mechanisms governing the interaction between presuppositions and implicatures.

Keywords: negative polarity, free choice, tense, temporal adverbials, exhaustivity, implicatures, presuppositions.

1. Introduction

1.1. *Until*'s puzzling distribution

The paradigm in (1)-(2) presents a challenge for an analysis of *until*. Its use in (1a-b) can appear with or without negation, while its use in (2a-b) requires negation (see Karttunen, 1974; Mittwoch, 1977; and many others).

(1)   a.   Charlie was asleep until nine.
      b.   Charlie wasn't asleep until nine.

(2)   a.   *Hana left until nine.
      b.   Hana didn't leave until nine.

Before proposing an account of the paradigm in (1)-(2), the following subsections will discuss additional data that has proven challenging for previous unified analyses of *until*-phrases (UPs).

1.2. Scopal account

Mittwoch (1977), a.o. propose a uniform meaning for UPs as adverbials that select for predicates with the subinterval property (whenever a predicate holds at an interval, it also holds at every one of its subintervals). This rules out telic VPs like (2a). The acceptability of (2b) then requires *until* to scope over the negated VP as in (3) (with the additional assumption that negation is a predicate modifier that can create a [+subinterval] predicate).

(3)   [until nine [NOT [Hana left]]]

Assuming that UPs can scope freely with negation then gives rise to an ambiguity when they combine with atelic VPs like in (1b). The "not-throughout" reading corresponds to a parse with

negation scoping over *until* (consistent with a situation where Charlie was asleep, but woke up at eight). The "throughout-not" reading corresponds to *until* scoping over negation (throughout a salient interval that ends at nine, Charlie was not asleep).

1.3. Against a scopal account

While elegant, this unified view is challenged by a contrast in the status of the actuality inference (AI) that is associated with UPs depending on the presence of negation (Karttunen, 1974). When a [-subinterval] predicate is negated, it comes with a non-cancelable AI (that the event occurred), as illustrated by the infelicity of the continuation in (4a).[2] With [+subinterval] predicates in positive sentences, however, this inference is cancelable, as in (4b). If negation creates a [+subinterval] predicate for *until* to modify, (4a-b) should behave similarly, contrary to fact. Once wide scope of *until* over negation is assumed, it becomes hard to understand the contrast.

(4)   a.   Hana didn't leave until 9... #I don't know if she left later.
       b.   Hana was home until 9... I don't know if she left later.

This is a key motivation for Karttunen's proposal that there are two *until*s. One combines with [-subinterval] predicates, is an NPI, and comes with an obligatory AI, and the other combines with [+subinterval] predicates, is not an NPI, and has a cancelable AI. Other researchers have also argued for a lexical ambiguity (Giannakidou, 2002; Condoravdi, 2008, a.o.). I assume that reasons of parsimony favor unified accounts and will not discuss *two until* approaches further for reasons of space. I direct the reader to Iatridou and Zeijlstra (to appear)for a survey of the key cross-linguistic arguments.

1.4. Iatridou and Zeijlstra's unified account

Iatridou and Zeijlstra (to appear) (I&Z) propose a unified account of UPs within the broader context of an analysis that includes the *in years* class of strong NPIs. While space limitations prohibit a detailed discussion of their analysis and the points of connection with *in years*, this section introduces some of the elements that I adopt in my proposal as well as the crucial points of departure. As a starting point, I&Z adopt Chierchia (2013)'s analysis of NPIs and assume that UPs are scalar items that trigger subdomain alternatives (alternative propositions involving quantification over subsets of an original domain). These then must be factored into the meaning through an exhaustification operator that negates stronger alternatives. Depending on the polarity of the logical environment, exhaustification can then negate alternatives that contradict the assertion and lead to ungrammaticality (thus polarity sensitivity).

I&Z then modify Chierchia's analysis in a setting where UPs interact with grammatical aspect in crucial ways. They assume that UPs set the right boundary of an interval that they call the *until time span* (UTS), which serves as the topic time of a clause. The relation between VP event time and topic time is then mediated by aspectual operators (PFV = VP time is contained in topic time; IMPF = Topic time is contained in VP time (Klein, 2013; a.o.)).

(5) $[[PFV\phi]]^t = 1$ iff $\exists t' \subseteq t:\ [[\phi]]^{t'} = 1$

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[2]See Karttunen (1974), Condoravdi (2008), Iatridou and Zeijlstra (to appear) for similar data that supports the AI contrast.

(6) $[[IMPF\phi]]^t = 1$ iff $\exists t' \supseteq t$: $[[\phi]]^{t'} = 1$

Key to this analysis is that the interaction of exhaustification with the containment relations specified by grammatical aspect then determines the polarity of the environments the constructions can appear in.

With perfective VPs in positive sentences, subdomain alternatives that assert that VP time is contained in a smaller topic time (=UTS) interval are stronger than those that assert containment in a larger interval. Since these are stronger alternatives, they all are negated by the exhaustivity operator, which leads to a logical contradiction with the assertion. Under negation, however, the alternatives are entailed and don't create contradictory implicatures. This means that UPs require a negative environment when they modify perfective VPs.

When UPs modify imperfective VPs, however, entailment relations are reversed. Similar to the way $\forall$ quantification is downward-entailing (DE) on its domain, the subdomain alternatives that assert that a smaller topic time interval is contained within VP time are weaker than ones that assert that a larger interval is contained within VP time. This means that UPs that modify imperfective VPs do not require negation. These are in fact PPIs that require local exhaustification under negation.[3] This relates ungrammaticality of non-negated *until* to formal perfectivity.

1.5. Outline

The goal of this article is to provide a new analysis for UPs that builds on the accounts reviewed above but avoids some of their empirical problems. Section 2 lays out the challenges to these accounts, and sections 3-4 introduce the new analysis and its technical implementation. Section 5 discusses how the current proposal provides a way to understand *until*'s status as a 'strong' NPI. Section 6 introduces open issues and concludes.

2. Challenge to previous unified accounts

2.1. UPs modifying perfective activity predicates do not require negation

A result of I&Z's unified account of UPs as discussed above is given in (7).

(7)   Interaction of exhaustification with the relations specified by aspect results in:
        a.   UPs require a negative environment when they modify perfective VPs
        b.   UPs do not require a negative environment when they modify imperfective VPs
              (which is equivalent to $\forall$ quantification and is DE on its domain)

This analysis accounts for the pattern (1)-(2), but it incorrectly predicts ungrammaticality for a large class of *activity* predicates, like *sleep* which are perfective, but appear with non-negated *until*, as in (8).[4]

(8)   Charlie slept until nine.

The following shows that *sleep* cannot be imperfective in the crucial sense that affects entailment (VP event time cannot contain topic time). To support this, note that *sleep* gives rise to

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[3]This follows Zeijlstra (2017)'s analysis of universal PPIs.
[4]See also Karttunen (1974) for similar examples.

readings with obligatory backshift with a past tense embedded under another past, as in (9a). Also, *sleep* is ungrammatical in the simple present, as in (9b).

(9) a. Hana said that Charlie slept.   (only backshift possible)
       cf. Hana said that Charlie was sleeping.   (simultaneous reading possible)
     b. #Charlie sleeps.   (# on non-habitual reading)
       cf. Charlie is sleeping.   ([OK] on non-habitual reading)

The grammaticality of (8) given (9) motivates an analysis that more directly reflects Mittwoch's insight relating the ungrammaticality of (2a) not to formal perfectivity but directly to the subinterval property. I&Z acknowledge cases like (8), and rightly argue that it is the subinterval property that is crucial for modification by *until* in positive sentences, and that perfectives like *sleep* have this property due to the absence of a culmination. While this is true, I suggest that this poses a non-trivial problem for their implementation, which relies crucially on entailment relations that result directly from the meanings of the grammatical aspectual heads. The account I offer avoids this problem and will also be argued to have additional advantages in section 5. Given this, and the aforementioned problem of Mittwoch's account in capturing the constrast in cancelability of the AI, the challenge for a unified account is summarized in (10).

(10) a. Give an account for why UPs modifying [-subinterval] predicates require negation ((11a-b)) that doesn't rely on wide scope for *until*, as this makes it impossible to capture the AI contrast between negated and positive *until* ((12a-b)).
     b. Account for grammaticality of UPs modifying perfectives like *sleep* ((8)).

(11) a. *Hana left until nine.
     b. Hana didn't leave until nine.

(12) a. Hana didn't leave until 9... #I don't know if she left later.
     b. Hana was home until 9... I don't know if she left later.

3. Overview of the proposal

3.1. The basic paradigm

Under negation, sentences like (11b) are good because *until* scopes under negation, where it has a weak, existentially quantified meaning (similar to *before*). In upward-entailing (UE) environments like (11a), it strengthens obligatorily to a universal meaning (similar to *throughout*). This strengthening happens uniformly with perfective and imperfective VPs, but leads to infelicity only when it applies to [-subinterval] VPs (like *leave*), as contextual (world) knowledge tells us that they cannot be true throughout an interval.

3.2. Analogy with Free Choice:

UPs behave similar to free-choice disjunction (FC), which exhibits a strong conjunctive meaning in UE sentences and a weak disjunctive one under negation.

(13) a. You are allowed to sing or dance. ($\diamond[p \lor q]$)
            $\approx$ You are both allowed to sing and allowed to dance. ($\diamond p \land \diamond q$).

    b.   You aren't allowed to sing or dance. $(\neg \Diamond [p \vee q])$
         $\not\approx$ You aren't both allowed to sing and allowed to dance. $(\neg [\Diamond p \wedge \Diamond q])$

Kratzer and Shimoyama (2002), Fox (2007), a.o. argue that the basic meaning is the weak one, which undergoes strengthening in UE environments but remains basic under negation. A growing body work extends FC analyses to different domains (Bowler, 2014; Bar-Lev and Margulis, 2014; Meyer, 2015; Bassi and Bar-Lev, 2016; Singh et al., 2016, a.o.). I propose a similar account for *until*.

3.3. Contrast in distribution and AI

To derive the properties of UPs with a uniform mechanism, I follow I&Z in assuming that UPs interact with exhaustification in important ways but make crucially different assumptions about the alternatives and the way they contribute to the meaning. Rather than relying on the quantificational contribution of aspectual heads, I assume a basic weak meaning and derive additional components of the meaning as grammatically generated implicatures. In a way to be made precise in the following section, I assume that UPs trigger alternatives that make assertions about both smaller intervals (subdomains) and larger intervals (superdomains), but that they lack a stronger universal alternative. The attested implicatures are then generated when exhaustification applies in different logical environments.

In UE environments, subdomain alternatives are stronger than the basic meaning. Exhaustification will lead to the inclusion (assertion) of these alternatives which derives strengthening that is analogous to FC and gives rise to Mittwoch's condition restricting UPs to [+subinterval] predicates. Under negation, since entailment relations are reversed, the subdomain alternatives are entailed and no FC strengthening is generated. The superdomain alternatives, however, are stronger. Exhaustification thus leads to their exclusion (negation) which generates the AI.

4. Technical implementation

In this section, I attempt a unified semantic analysis for *until* phrases (UPs) that accounts for the data in the previous sections, and meets the challenge expressed in (10).

As a general framework, I will assume that sentences are evaluated relative to a index parameter (represented with the variable i) that is a pair of a world and a time ($\langle w_i, t_i \rangle$). The intension of a sentence then is a function from world-time pairs to truth values. I will also assume that tenses are Priorian quantificational operators. In the entry in (14), *PAST* is a two-place operator that comes with a covert contextual restrictor argument (Ogihara, 1995; a.o.), and is also encoded with a non-emptiness presupposition (von Fintel and Heim, 2016).

(14)   For any i, $[[PAST]]^{i,g} = \lambda r: \underline{\exists t\ [t \prec t_i\ \&\ r(\langle w_i, t \rangle) = 1]}.$
       $\lambda q. \exists t\ [t \prec t_i\ \&\ r(\langle w_i, t \rangle) = 1\ \&\ q(\langle w_i, t \rangle) = 1]$

4.1. *Until* as a modifier of tense

With the entries in (15) and (16), I propose an analysis of *until* phrases (UPs) as temporal modifiers of type $< s, t >$ that adjoin to the first argument of tense (which will be realized in the syntax as a silent type $< s, t >$ pronoun) and will combine via predicate modification.

(15) $[[until]]^{i,g} = \lambda$m: <u>m is a moment of time</u>. λj. $t_j \in \{t'|t'$ is before m$\}$

(16) $[[until\ 9]]^{i,g} = \lambda$j. $t_j \in \{t'|t'$ is before 9$\}$

To form the UP, *until* combines with an expression that denotes a moment of time and sets this time as the right boundary of the *until* time span (UTS). The left boundary is not specified within the UP but will be effectively set to the left boundary of the restrictor argument of tense. This is because the UP time is intersected with the the restrictor time via PM. Any parts of the UP time that stretch before this left boundary then do not enter the truth conditions. Effectively, a UP restricts the first argument of the quantificational tense by providing a specific right boundary.

In this system, UPs are treated like frame adverbials in that they uniformly assert that the evaluation time is contained within the UTS. This means that aspectual heads specify the containment relation of the event time relative to the evaluation time, but unlike I&Z's proposal, do not affect the containment relation relative to the UTS. The aspectual and lexical predicate entries are given below.
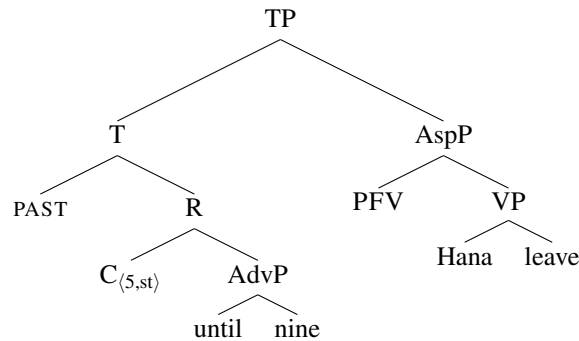
(17)   a. $[[PFV]]^{i,g} = \lambda P_{\langle v,t \rangle}. \exists e$ [e occurs in $w_i \wedge$ Run(e) $\subseteq t_i \wedge$ P(e) = 1]
         b. $[[IMP]]^{i,g} = \lambda P_{\langle v,t \rangle}. \exists e$ [e occurs in $w_i \wedge$ Run(e) $\supseteq t_i \wedge$ P(e) = 1]

(18) $[[leave]]^{i,g} = \lambda x\ \lambda e$. e is an event of x leaving.

To see how the pieces combine, consider the discourse in (19) and the LF for A's response in (20).[5]

(19)   Q: What did Hana do on September 3rd, 2019?
         A: #Hana left until 9.

(20)

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                              TP
                  _____/ _____
                 /                         \
                T                          AspP
            ___/ \___                    __/  \__
           /         \                  /        \
        PAST          R               PFV         VP
                   __/ \__                       /   \
                  /       \                   Hana   leave
              C_{⟨5,st⟩}   AdvP
                          /    \
                       until   nine
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Assuming that the context for (19) supplies the assignment function g_c, the value of the type $< s,t >$ tense restrictor pronoun is given in (21), and the intension of (20) is given in (22).[6]

(21) $[[C_5]]^{i,g_c} = g_c(5) = \lambda$j. t_j is within Sept. 3 in w_j

(22) $[[^{\wedge}(20)]]^{i,g_c} = \lambda$i:
         a. $\exists t$ [t $\prec t_i$ & t is within Sept. 3 in w_i
                <u>& t $\in \{t'|t'$ is before 9$\}$ in w_i].</u>

b. $\exists t\ [t \prec t_i\ \&\ t$ is within Sept. 3 in w_i
      $\&\ t \in \{t'|t'$ is before 9$\}$ in w_i
      $\&\ \exists e.[e$ occurs in $w_i \wedge$ leave(e, Hana) $\wedge$ Run(e) $\subseteq t$]

At this point, the definedness and truth conditions in (22) don't explain the infelicity of A's utterance in (19). It simply states that Hana left at some point before nine on September 3rd. The following section will derive the infelicity as the result of an obligatorily strengthening of the meaning in (22) that will contradict world knowledge.

4.2. Strengthening

4.2.1. Subdomain alternatives

Following Chierchia (2013)'s analysis of polarity sensitive items and I&Z, I assume that *until* invokes subdomain alternatives. These alternatives are given in (23).

(23)   Alt((20)) = $\{\ \lambda i.\ \exists t \prec t_i :$ t is within Sept. 3 in $w_i\ \&$
        t is within the interval t'' in $w_i\ \&$
        $\exists e[e$ occurs in $w_i \wedge$ leave(e, Hana) $\wedge$ Run(e)$\subseteq$ t] $|\ t'' \subseteq \{t'|t'$ is before 9$\}\}$

These alternatives are the set of propositions that are created by substituting the original UTS interval of the assertion with its different subintervals.

4.2.2. Exhaustification

An exhaust operator (EXH) then applies (obligatorily cf. Magri (2009)). For concreteness, I assume the EXH from Bar-Lev and Fox (2017) in (24). This derives free choice inferences in a similar manner to the EXH in Fox (2007). The addition of the notion of inclusion, however, allows it to generate the inferences with a single application, rather than the recursive applications required by the operator in Fox (2007).

(24)   a. $[[\text{EXH}]]^{i,g} = \lambda A_{\langle st,t \rangle}.\ \lambda p_{\langle s,t \rangle}.\ \forall q \in \text{IE}(p, A)[\neg q(\langle w_i, t_i \rangle)]$
        $\wedge \forall r \in \text{II}(p, A)[r(\langle w_i, t_i \rangle)]$
    b.   Given a sentence p and a set of alternatives A:
        (i) $\text{IE}(p,A) = \bigcap\{A' \subseteq A: A'$ is a maximal set in A, s.t.
              $\{\neg q: q \in A'\} \cup \{p\}$ is consistent$\}$
        (ii) $\text{II}(p,A) = \bigcap\{A'' \subseteq A: A''$ is a maximal set in A, s.t.
              $\{r: r \in A''\} \cup \{p\} \cup \{\neg q: q \in \text{IE}(p,A)\}$ is consistent$\}$

Here, EXH takes as arguments a prejacent (*p*) and set of alternatives (*A*) and returns the negation of all IE alternatives, as well as the assertion of all the II alternatives. The IE alternatives are those that can be negated consistently without contradicting the prejacent, and without making arbitrary choices (thus each IE alternative must be in all the maximal sets). The II alternatives are those that can be asserted without contradicting the prejacent and without contradicting the negated IE alternatives (and also each must be in all the maximal sets).

Following work that extends free-choice analyses to different domains (Bowler, 2014; Bar-Lev and Margulis, 2014; Meyer, 2015; Bassi and Bar-Lev, 2016; Singh et al., 2016, a.o.), I assume

that *until* lacks a stronger universal alternative (something like *'throughout the interval that extends to 9'*). This creates a space of alternatives that is not closed under conjunction, which is the property that allows for strengthening that yields free-choice via EXH (Fox 2007).

4.2.3. Effects of EXH in UE sentences

In upward-entailing (UE) sentences, application of EXH leads to strengthening. The LF for (25a) is given in (25b). EXH takes the prejacent in (26) as an argument, and focus-associates with the UP to determine the alternative set A. Considering a toy model in which the basic UTS interval consists of three subintervals, the alternative set is given in (27) (with formulas abstracting away from intensions and past shifting for ease of readability). They are also sketched graphically on the timeline in (28).[7]

(25)   a.   # Hana left until nine
       b.   [EXH$_A$ [Hana left [until nine]$_F$]]

(26)   Prejacent proposition:
       λi. $\exists t$ [$t \prec t_i$ & t is within Sep 3 & $t \in \{t'|t'$ is before $9\}$ & $\exists e.$[e occurs in $w_i \wedge$ leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t]]

(27)   Alt. set A:
       { $\exists t$ within [12, 7] & $\exists e.$[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t],
       $\exists t$ within [7, 8] & $\exists e.$[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t],
       $\exists t$ within [8,9) & $\exists e.$[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t] }

(28)   Assertion UTS and subdomains:
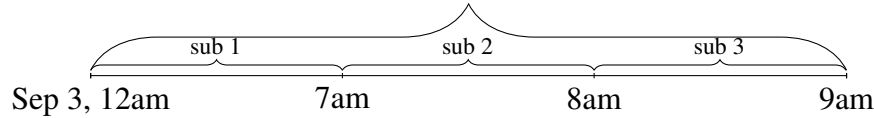
In the timeline above, the largest brace that encompasses the entire timeline represents the UTS of the prejacent assertion in (26) spanning from the beginning of Sep 3rd to 9am. The three subintervals are marked by the three smaller braces. Here, the space of alternatives is analogous to free choice disjunction in the sense that **no subdomain alternatives will be IE**. It is easy to see that they all cannot be excluded without contradicting the assertion. Excluding any two alternatives would arbitrarily include the other one. Thus, none are in all maximal sets.

All of the alternatives, however, are II and are asserted. As shown in (29b), there is one maximal set that can all be asserted without contradiction, and this is the set of II alternatives. Similar to how the disjunctive alternatives are asserted in the case of FC disjunction giving rise to a conjunctive meaning, $\exists$ strengthens to $\forall$ quantification over subintervals with *until*. This strengthened assertion (the 'subinterval implicature') is the output of EXH given in (29c).

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[7]For current purposes, I will assume a domain of intervals that is not dense. See Gajewski (2009) for a discussion of EXH's interaction with dense domains. While a full discussion of these issues is beyond the scope of this paper, I will point out that free choice readings are available when quantifying over temporal domains in sentences like *'You're allowed to leave any time'*. Thus, it will be desirable for EXH-based accounts of FC-type inferences to be formulated in a way that is consistent with quantification over intuitively dense domains like times.

(29)   a.   IE = ∅

        b.   II = {∃t within [12, 7] & ∃e.[leave(e, Hana) ∧ Run(e)⊆ t],
            ∃t within [7, 8] & ∃e.[leave(e, Hana) ∧ Run(e)⊆ t],
            ∃t within [8, 9) & ∃e.[leave(e, Hana) ∧ Run(e)⊆ t]}

        c.   Output of EXH (the conjunction of the prejacent and II alts. above):
            ∀t. t within [12, 9) → ∃e.[leave(e, Hana) ∧ Run(e)⊆ t]   (subinterval implicature)

This strengthened meaning is now incompatible with world knowledge about leaving. Here, no logical contradictions are generated (as I assume an EXH operator that is contradiction free), but deviant sentences can arise if they clash with extra-grammatical knowledge about how the world works (leaving doesn't happen repeatedly throughout an interval). This brings the account closer in spirit to Mittwoch's intuition that the starred exampless like (25a) are "not really ungrammatical, but merely pragmatically odd" (Mittwoch, 1977). When a parallel derivation applies to (30), the sentence is fine, as *sleep* is compatible with the subinterval implicature.

(30)   Hana slept until nine.

4.2.4. EXH in DE sentences

When a matrix EXH applies to a negated sentences as in (31), all subdomain alternatives are entailed and they have no effect (no problematic implicature is generated). It is simply the negation of the basic meaning.

(31)   a.   Hana didn't leave until nine

        b.   EXH$_A$[NEG [Hana left [until nine]$_F$]]

(32)   a.   Prejacent:
            λi. ¬∃t [t ≺ t_i & t is within Sep 3 & t ∈ {t'|t' is before 9} & ∃e.[e occurs in w_i ∧ leave(e, Hana) ∧ Run(e) ⊆ t]]

        b.   Alt. set A (simplified for readability):
            { ¬∃t within [12, 7) & ∃e.[leave(e, Hana) ∧ Run(e) ⊆ t],
            ¬∃t within [7, 8) & ∃e.[leave(e, Hana) ∧ Run(e) ⊆ t],
            ¬∃t within [8,9) & ∃e.[leave(e, Hana) ∧ Run(e) ⊆ t] }

Globally weaker readings (e.g., the reading of (33a) where Charlie was asleep but woke up at 8) can be derived with EXH embedded under negation (as in (33b)). In these cases, the strengthening proceeds as it does for the parse in (25b), and then this enriched meaning is negated.

(33)   a.   Charlie wasn't asleep until nine.

        b.   NEG [EXH$_A$ [Charlie was asleep [until nine]$_F$]]

This also brings the current analysis in line with Mittwoch's scopal account with a key modification that the various readings of (33a) are not the result of different scopal relations between negation and the UP but between negation and an EXH operator.[8,9]

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[8]Thank you to Luka Crnič (p.c.) for pointing out this connection.

[9]I&Z's analysis also uses embedded EXH for not-throughout readings, but in their case EXH applies vacuously to rescue negated PPI imperfectives modified by a UP.

4.3. Deriving the actuality inference (AI) contrast with superdomain alternatives

To explain the contrast in (34a-b) observed by Karttunen (1974), I will assume that *until* also triggers superdomain alternatives.[10,11].

(34)   a.   Hana didn't leave until 9... #I don't know if she left later.
        b.   Hana was home until 9... I don't know if she left later.

These alternatives are the set of propositions that are created by substituting all of the different larger intervals that contain the original UTS interval of the assertion. The alternatives of (34b) uttered in the same context as (19), for example, are given in (35).

(35) $\text{Alt}^{\text{super}}((34b)) =$
    $\{\ \lambda i.\ \exists t \prec t_i : t$ is within Sep 3 in w_i &
    t is within the interval t'' in w_i &
    $\exists e\ [e$ occurs in $w_i \wedge$ be home$(e,$ Hana$) \wedge$ Run$(e) \supseteq t\ ]\ |$
    $t'' \supseteq \{t'|t'$ is before $9\}\}$

Note that because each substitution of the UTS is conjoined with the contextual restriction, only larger intervals that extend beyond the right boundary (past nine) on September 3rd are considered. Any times that extend to the left before Sep 3 are filtered out.

4.3.1. EXH of superdomain alts. in UE sentences

Consider the same toy model as the previous section extended to contain two superdomain alternatives. As noted before, the contextual restrictor filters out any times before Sept 3, so the two superdomain intervals will start at the same time as the original UTS and stretch beyond the right boundary. As shown in the timeline below, the original UTS stretches to 9, and the superdomain intervals stretch to 10 and 11 respectively.

(36)   Superdomain alternatives:
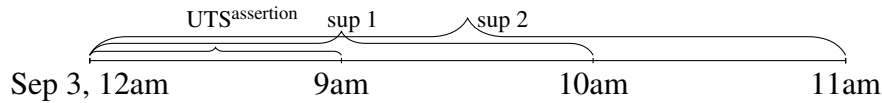
With matrix EXH applied to UE sentences like (37), no subdomain alternatives in (38b) are IE, but all are II and derive the subinterval implicature in (38d) (just as with (25b)). The superdomain alternatives in (38c) are entailed and are vacuously II and have no effect. Nothing new is asserted about the times after nine, and the continuation in (34b) is fine.

(37) EXH_{A} [Hana was home [until nine]$_F$]

(38)   a.   Prejacent:
        $\exists t$ within $[12, 9)$ & $\exists e.$[be home$(e,$ Hana$) \wedge$ Run$(e) \supseteq t$]

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[10]These are similar to the scalar alternatives assumed in Condoravdi (2008), but which are applied only to NPI *until* within a lexical ambiguity analysis.

[11]See also Chierchia (2013) for a brief discussion of the consideration of superdomain alternatives in the context of NPI *any*.

   b.   Alt. set A (subdomain):
{$\exists$t within [12, 7] & $\exists$e.[be home(e, Hana) $\wedge$ Run(e)$\supseteq$t],
$\exists$t within [7, 8] & $\exists$e.[at home(e, Hana) $\wedge$ Run(e)$\supseteq$ t],
$\exists$t within [8, 9) & $\exists$e.[at home(e, Hana) $\wedge$ Run(e)$\supseteq$t]}

   c.   Alt. set A (superdomain):
{$\exists$t within [12, 10) & $\exists$e.[be home(e, Hana) $\wedge$ Run(e)$\supseteq$ t],
$\exists$t within [12, 11) & $\exists$e.[be home(e, Hana) $\wedge$ Run(e)$\supseteq$t]}

   d.   Output of EXH
$\forall$t. t within [12, 9) $\rightarrow$ $\exists$e.[at home(e, Hana) $\wedge$ Run(e)$\supseteq$ t]

4.3.2. EXH of superdomain alts. in negative sentences generates AI

With matrix EXH applied to negated sentences like (39) the subdomain alternatives are entailed as illustrated in (40b). The superdomain alternatives shown in (40c), however, are stronger than the prejacent. These are IE and are negated, deriving the implicature that Hana left in the smallest superdomain (at the border of the UTS). The conjunction of the prejacent with the negation of the IE alternatives is shown in (41).

(39)   a.   Hana didn't leave until nine.
       b.   EXH$_A$ [NEG [Hana left [until nine]$_F$]]

(40)   a.   Prejacent:
$\neg\exists$t within [12, 9) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t]
       b.   Alt. set A (subdomain):
{ $\neg\exists$t within [12, 7) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t],
$\neg\exists$t within [7, 8) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t],
$\neg\exists$t within [8,9) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t] }
       c.   Alt. set A (superdomain):
{ $\neg\exists$t within [12, 10) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t],
$\neg\exists$t within [12, 11) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t]}

(41)   Output of EXH
       a.   Prejacent:
$\neg\exists$t within [12, 9) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e) $\subseteq$ t] $\wedge$
       b.   Negation of IE alternatives:
$\neg\neg\exists$t within [12, 10) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e)$\subseteq$ t] $\wedge$
$\neg\neg\exists$t within [12, 11) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e)$\subseteq$ t] =
       c. $\neg\exists$t within [12, 9) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e)$\subseteq$ t] $\wedge$
$\exists$t within [12, 10) & $\exists$e.[leave(e, Hana) $\wedge$ Run(e)$\subseteq$ t]

The enriched meaning in (41c) explains the infelicity of the continuation in (34a) with the added assumption that the implicatures generated are obligatory. I propose that these implicatures are not cancelable because *until* requires exhaustification, and I assume a condition that prohibits vacuous application of EXH (Spector and Sudo, 2017, Fox and Spector, 2018).[12]

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[12]While EXH of UPs can't be vacuous, I do assume that some coarseness is allowed in the implicature calculation in both the positive and negative cases. Thus, (ia) only requires blinking events during intervals of a contextually relevant size, and (ib) allows the marriage event to follow the meeting in only the smallest contextually relevant

4.4. What polarity sensitivity reveals about the syntax of UPs

I also note that crucial to deriving the correct AI is having superdomain alternatives that extend only past the right boundary of the original UTS. This is what derives an AI that happens right at the right boundary. If they also extended to the left, an AI could be derived that occurs at some time before the original UTS, contrary to the attested inference. This is a key motivation for the syntax assumed here in which the UP is adjoined to the contextual restrictor C (argument of tense) rather than serving as the first argument itself. This makes it possible to understand the alternatives as supersets and subsets of the original interval. Also, assuming that the full set of alternatives is created by simply substituting different values for the right boundary wouldn't create subdomain alternatives rich enough to generate the subinterval implicature. This is because they would all be entailed by the alternative with the smallest subinterval in UE sentences, and would thus not be includable. With this option untenable, the simplest way to filter out intervals that stretch before the left boundary is to assume an intersection with C.

This also has the benefit of unifying the syntax of UPs with the syntax for the canonical PSI *any*. As illustrated in (42)[13], the constituent responsible for the alternatives that generate polarity sensitivity are uniform across constructions, as they are both restrictors of the first argument of their respective quantifiers. For *any*, this is the domain restrictor variable D (Chierchia, 2013), and for UPs, it is the UP itself that restricts the first argument of the quantificational tense. The alternatives generated in both cases can be viewed as alternate values for this element.[14]

(42)
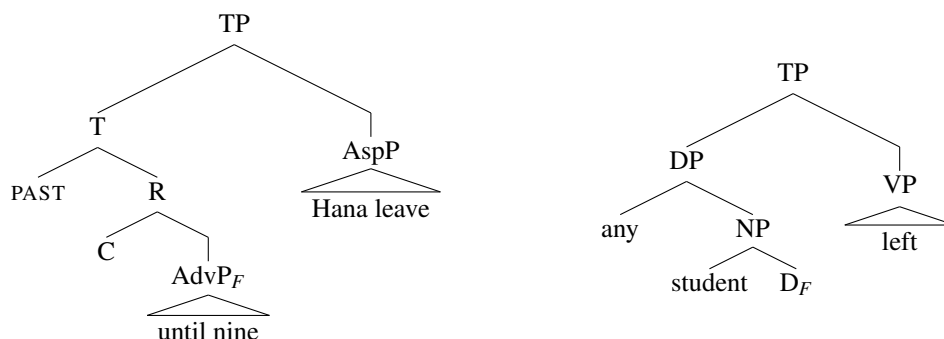
4.5. Interim summary

In this account, UPs are uniformly associated with strengthening in all logical environments. The structure of the alternatives gives rise to different implicatures in positive vs negative environments, which derives the core properties of UPs that have been discussed in the literature. In positive environments, there is an obligatory subinterval implicature, and in negative cases,

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interval, not the instant they met. Reasons of space prevent further discussion of this important issue.

(i) a. Katy blinked until her eyes adjusted to the new level of darkness.
    b. Nancy didn't marry until she met Henry.   (Karttunen)

[13]I assume that some operation is needed to generate the sentence-final word order of the UP, possibly extraposition. An alternate possibility attributed to Mitya Privoznov in von Fintel, K. and I. Heim (2016) (class notes), is that the tense head takes its arguments in the opposite order. Although this breaks the analogy with *any* in terms of linear order, the unification remains on a structural level. More work is needed to determine the right approach.
[14]The idea that temporal adverb PSIs and *any* are unified in both triggering domain alternatives is already present in Chierchia (2013) and I&Z. The suggestion here is explicitly extending this parallel to the syntax as in (42).

an obligatory AI. Infelicity results when these implicatures contradict contextual knowledge.

4.6. Independent motivation for alternatives

The present analysis relies on the assumption that UPs invoke subdomain and superdomain alternatives. These alternatives would not have to be stipulated if this could be made to follow from a more general algorithm of alternative generation. This section will sketch a path towards doing this by using the independently-motivated proposal for generating formal alternatives in Katzir (2007). A summary of Katzir's algorithm is given in (43).

(43)   Formal alternatives (Katzir, 2007)
        ALT(S) = $\{S'|$ S can be transformed into S$'$ by a finite series of deletions, contractions, and replacements of lexical items with lexical items of the same category$\}$

Using the formula in (43), the alternatives of a sentence modified by a UP will be the set of all sentences that are generated by replacing the UP with other possible constituents of equal or lesser complexity that denote propositions (which will be intersected with the contextual restrictor C) as in (44).[15]

(44)   Alt([$_{TP}$ [$_T$ TENSE [$_R$ C [$_{AdvP}$ until XP]$_F$]]AspP]) =
        $\{$ [$_{TP}$ [$_T$ TENSE [$_R$ C [$_{AdvP}$ Y [XP$'$]]] AspP] $\mid$ $[\![$ $Y[XP']$ $]\!]$ $\in$ D$_{<s,t>}$ $\}$

Again, since the propositions that these substituted items denote are intersected with the contextual restrictor of tense C, only propositions that pick out intervals within the interval determined by C will enter the truth conditions of the alternatives. Returning to our example above, this is the set of all intervals that are within September 3rd. Now, given that the original UTS in the example is the interval before 9 on September 3rd, the alternative set will contain both the subdomain and superdomain alternatives given in the previous section. But here, rather than being stipulated, they are generated with Katzir's algorithm.

4.6.1. Sets of alternatives not previously discussed

In addition to the subdomain and superdomain intervals that were shown to generate the attested implicatures in the previous section, there will also be additional types of alternatives generated by Katzir's algorithm. For example, there will be those in which the UTS is an interval that overlaps with the original UTS but is not a subinterval or superinterval as illustrated below. These alternatives would be II in UE sentences and IE in DE sentences but would not add anything new to the overall meaning.

(45)   Overlapping alternatives:

UTS^{assertion} alt 1

Sep 3, 12am   8am   9am   10am

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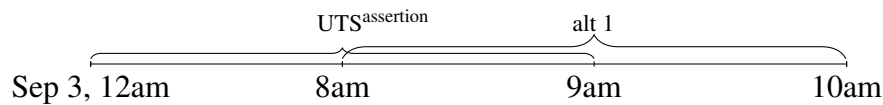
[15]This closely follows Crnič (2019)'s proposal for a principled approach to generating alternatives for polarity sensitive *any*. An important difference, however, is that the constituent being substituted with *any* is a domain restrictor pronoun, while with UPs it is a syntactically complex phrase. A more fleshed out discussion of lexical substitution that takes into consideration the internal complexity of UPs is left to future work.

There would, however, also be alternatives in which the UTS is disjoint with the original UTS of the assertion as illustrated in (46).

(46)   Disjoint alternatives:

$$\underbrace{\hspace{3.5cm}}_{\text{UTS}^{\text{assertion}}} \quad \overbrace{\hspace{2.5cm}}^{\text{alt 1}} \quad \overbrace{\hspace{2.5cm}}^{\text{alt 2}}$$

Sep 3, 12am   9am   10am   11am
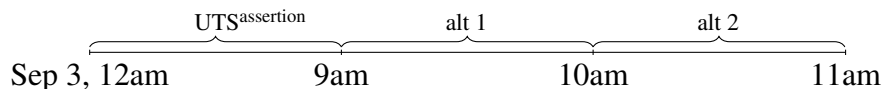
These will be IE in both positive and negative sentences and will derive additional implicatures. In positive sentences, excluding (negating) these alternatives will derive an implicature that there is no time after the UTS in which the sentence is true. This is not a bad result for sentences like (47) which intuitively do imply that Hana was not home after nine. The continuation in (47b), however, indicates that this implicature is cancelable.

(47)   a.   Hana was at home until nine.
        b.   ... I don't know if she left after.

In negative sentences, the result of excluding alternatives with intervals disjoint from the UTS leads to a pathological result. In (48), for example, this would lead to the implicature that Hana did leave in every interval after nine. This is clearly unattested and would have to be canceled.

(48)   Hana didn't leave until nine.

The remainder of this subsection will sketch a way to understand why some of the generated inferences are cancelable, and others are not.

4.6.2. Constraints on pruning

Within an exhaustification framework, it is often assumed that alternatives that are not relevant can be ignored (pruned), and thus certain implicatures will not be generated. This being the case, the alternatives that contain UTS intervals that are disjoint with the assertion UTS could be generated in accordance with Katzir's alogrithm but deemed irrelevant and pruned. The challenge then is in explaining why the alternatives that generate the subinterval implicature and the AI are obligatory and can't be pruned, while these other disjoint alternatives can.

To capture the attested facts, I will assume that pruning is in general possible, but it is limited in systematic ways. Following work by Katzir (2014), Bar-Lev and Fox (2017), Crnič (2019), I assume that only IE alternatives can pruned (see the aforementioned work for motivation and technical implementation). This means that the subinterval implicature in the positive cases is obligatory even when it leads to pathological results since it is the result of II alternatives.

The rest of the implicatures discussed are the result of negating IE alternatives. The AI in positive sentences (like the one that implies that Hana was not home after nine in (47a) for example) results from IE alternatives, so it is cancelable. Like many implicatures, however, a specific context and an explicit cancelation like the continuation like in (47b) is required to do so, which conforms to what is known about context-sensitive implicatures in general.

In negative sentences, the pathological implicature that states that the sentence is true within every time after the UTS (like the one that asserts that Hana left at all times after nine in (48))

is also the result of IE alternatives. This means these can be pruned. And, since the implicature is pathological, it seems reasonable that this does not require explicit cancelation.

In negative sentences, there is also the implicature that generates the AI. This is derived through negating the IE superdomain alternatives. I will suggest that this implicature is obligatory since pruning all of the superdomain alternatives would lead to a vacuous application of EXH. This is the essential difference between (49a) and (49b). In (49a), the negative case, pruning the alternatives responsible for the AI would lead to vacuous EXH. In (49b), however, pruning the IE alternatives in the positive case does not result in vacuous EXH, as in those cases EXH strengthens the assertion by asserting the II alternatives and deriving the subinterval implicature.

(49) a. Hana didn't leave until 9... #I don't know if she left later.
      b. Hana was home until 9... I don't know if she left later.

While banning vacuous EXH is a stipulation, independently-motivated economy conditions have been proposed to this effect (Spector and Sudo, 2017; Fox and Spector, 2018). Also, thinking of polarity-sensitivity in this way constitutes a potential conceptual advantage over systems of polarity sensitivity based on Chierchia (2013) in which exhaustification of PSIs can derive logical contradictions. This is because in this system, NPIs are grammatical only when EXH is semantically vacuous which is arguably unintuitive from the perspective of economy principles.

5. Extensions: Towards an explanation of *until's* stronger licensing conditions.

It is known that UPs have stricter licensing conditions than NPI *any*. While *any* is good in (merely) Strawson DE environments, UPs modifying [-subinterval] VPs are not (Gajewski, 2011; Chierchia, 2013; a.o.). This is evident, for example, in the scope of DE factives, conditional antecedents, and restrictors of universal and negative quantifiers:

(50) a. Noah is unaware that Bill fell asleep at any time during the talk.
      b. *Noah is unaware that Bill fell asleep until 9.

(51) a. If Charlie leaves on any Tuesday, he will get a discount.
      b. *If Charlie leaves until tomorrow, he will miss Hana's talk.

(52) a. Every/no student that left during any of the talks experienced problems.
      b. *Every/no student that left until yesterday experienced problems.

Since my analysis of UPs relies on an exhaustification mechanism that is sensitive to entailment, as it currently stands, UPs modifying [-subinterval] predicates are predicted to be good in the Strawson DE environments in (50)-(52) above, contrary to fact. An additional mechanism, then, is needed to explain why these are unacceptable. The following work by Marty and Romoli (2020) (M&R) indicates that an independently-needed mechanism could explain these facts.

5.1. Presupposed free choice (Marty and Romoli, 2020)

M&R (building on Gajewski and Sharvit, 2012; Spector and Sudo, 2017; a.o.) note that free choice (FC) implicatures show up in the presupposition of Strawson DE factives:

(53)   Noah is unaware that Olivia can take Logic or Algebra.   (M&R)
            a.   Noah doesn't believe that Olivia can take either one. ASSERTION
            b.   ⤳ Olivia can take Logic and can take Algebra. PRES FREE CHOICE

In (53), there is no strengthening in the DE assertion in (53a), but the strengthened FC inference appears in the UE factive presupposition in (53b). As the present analysis of UPs has an analogous logical structure to free choice, I suggest that it is now possible to understand the badness of (54) in analogy to (53).

(54)   *Noah is unaware that Bill fell asleep until 9. (⤳Presup: Bill fell asleep until 9.)

Assuming that UPs strengthen in UE presuppositions similar to the inferences discussed by M&R, these inferences would lead to presuppositions that contradict contextual knowledge. A hope is that this reasoning could generalize to derive Gajewski (2011)'s licensing condition that strong NPIs are unacceptable in DE environments with intervening UE presuppositions. This would follow if strengthening shows up in these presuppositions as well, as indicated in (55).

(55)   a.   *If Charlie leaves until tomorrow, he will miss Hana's talk.
            b.   UE Presupposition: It is possible that Charlie will leave until tomorrow.

(56)   a.   *Every/no student that left until yesterday experienced problems.
            b.   UE presupposition: There exists a student that left until yesterday.

Additional work is needed to develop the technical details of how these inferences are generated within the broader context of the interaction of presuppositions. The data above, however, indicates that *until*'s licensing conditions in these environments can be reduced to the phenomena discussed by M&R, once it is understood that free choice disjunction and UPs share similar underlying features to the exclusion of 'weak' NPIs.[16]

In more formal terms, I hypothesize that since *until*'s subdomain alternatives are II in UE environments, they are asserted in the UE presupposition of other operators. These presuppositions then yield clashes with extra-grammatical knowledge in the relevant cases. NPI *any*'s domain alternatives, however, are neither IE nor II in unembedded UE environments. Thus, they are neither obligatorily asserted nor negated in the UE presupposition of other operators and don't yield problematic inferences.[17]

6. Open Issues and conclusion

6.1. The 'Beyond Expectation Inference' (BEI)

Previous work on *until* (Karttunen, 1974; Condoravdi, 2008; I&Z; a.o.) attributes negated *until* not only with an obligatory AI but an additional inference that the eventuality that the UP modified happened later than expected. The following is from I&Z:

(57)   a.   I expected her to arrive at 5pm but she didn't arrive until 7pm.
            b.   #I expected her to arrive at 5pm but she didn't arrive until 3pm.

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[16]See I&Z for a different explanation of *until*'s sensitivity to intervening presuppositions that relates it to the idea that for Strong NPIs like *until*, the existence of the domain (the UTS) is presupposed rather than asserted. A full discussion and comparison of this idea with the one suggested here is left to future work.
[17]Another point of contrast is that a presupposed universal (FC) reading for *any* would not necessarily contradict contextual knowledge the same way it does for [-subinterval] VPs modified by a UP.

As it stands, my account does not directly derive a BEI. There is, however a suggestive connection with the use of *only* in (58) below.[18]It is know that *only* can give rise to inferences about scales of expectation (cf. Beaver and Clark, 2009; a.o.). And since EXH is often argued to be a type of covert version of *only*, it is perhaps not surprising that obligatorily exhaustified sentences exhibit similar effects. Developing this connection further is left to future work.

(58) a.   I expected her to arrive at 5 but she only arrived at 7.
      b.   #I expected her to arrive at 5 but she only arrived at 3.

6.2. Concluding remarks

The analysis in this article follows Mittwoch and I&Z in insisting on a unified semantics for UPs and also builds on many of their insights. I argue, however, that their analyses face some empirical problems. Mittwoch's analysis is unable to derive the contrast in actuality inferences in positive vs negative sentences (as pointed out by Karttunen), and I&Z's analysis incorrectly predicts ungrammaticality for some perfective activity VPs.

My proposal relies on assuming that UPs have important formal similarities with free choice. Within a framework that generates implicatures with exhaustification, the core properties of UPs are shown to fall out as the result of the assumed space of alternatives, and its similarity to FC. The full range of alternatives considered causes UPs in positive sentences to strengthen in such a way as to be incompatible with predicates that don't have the subinterval property and those under negation to derive an actuality inference. The formal similarities to FC is also shown to have promising consequences for understanding UPs' interactions with presuppositional elements, in light of recent work on interactions between presupposition and implicature.

The analysis presented here also raises questions about what role the mechanisms that derive the properties of UPs play in other temporal adverbs. A general theory will have to explain why some adverbs have these properties and some don't.[19] The logic of this account suggests that it should follow from the semantics and alternatives attributed to each item as well as their obligatory vs optional interaction with EXH.[20] In future work, I hope to not only explore these challenges but investigate whether similar pragmatic approaches can help to explain the properties of durational adverbs (*for an hour*) and the *in years* class of polarity sensitive adverbials.

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[18]thank you to Luka Crnič (p.c.) for pointing out this parallel. See also Giannakidou (2002); Condoravdi (2008); I&Z for the comparison to Greek *para mono* (*but only*).

[19]Thank you to Anastasia Giannakidou, p.c. for raising this important point.

[20]Thank you to a SuB reviewer for raising the question of motivation for the stipulated alternatives.

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