

# Polarity, veridicality, and temporal connectives

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I am strongly inclined to maintain that the rules for our grass-roots employment of temporal conjunctions - not only "at the same time", but also "before" and "after" - belong to the domain of formal logic.

Peter Geach, *Logic Matters*, 1972: 316.

## 1 Introduction

The purpose of this paper<sup>1</sup> is to draw attention to the semantical properties of *before*, *after*, and related elements. In particular, we shall raise the question whether the occurrence of negative polarity items in *before*-clauses can be described in terms of the semantic structure of the connective. In order to provide an answer, we adopt the analysis proposed by Landman (1991), which is based on Anscombe's (1964) discussion of *before* and *after*, and incorporates the findings of Heinämäki (1974), Hinrichs (1981), Partee (1984) and Oversteegen (1989). We then show that *before* is not only a monotone decreasing connective, but has the characteristic properties of an *n*-word.<sup>2</sup> This result will enable us to point out some unexpected connections between the phenomenon of negative polarity, on the one hand, and ontological assumptions about the flow of time, on the other. In particular, we will prove that *before* can only be analyzed as an *n*-word if the model of time underlying natural language is the model of linear time. We also discuss two other interesting features of Landman's account: *before* and *after* cannot be treated as converses, and *before* is what Montague (1969) calls nonveridical in that it doesn't force us to accept the truth of the clause it introduces.<sup>3</sup> Veridicality and monotonicity turn out to be related properties, since it can be shown that monotone decreasing connectives are nonveridical in nature.

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1. The work reported here is part of a larger project entitled *Reflections of Logical Patterns in Language Structure and Language Use*, which is supported by the Netherlands organization for scientific research (NWO) within the framework of the so-called *PIONIER*-program. We wish to thank Rainer Bäuerle, Erhard Hinrichs, Bill Ladusaw, and Henriëtte de Swart for their part in discussing the semantic properties of *before* and *after*.

2. The notion of an *n*-word is due to Laka Mugarza (1990), who uses the term to describe universal negatives like *nadie* 'no one', *nada* 'nothing' and *nunca* 'never' in Spanish. Though Laka herself regards these expressions as existential polarity items, Zanuttini (1991) argues that they should be treated as universal negatives. Van der Wouden and Zwarts (1993) maintain that Romance *n*-words are at times polarity items and at times universal negatives, a point of view which was advanced earlier in Zanuttini (1989). For present purposes, an *n*-word is simply a universal negative which has the semantic structure of what will hereinafter be referred to as an anti-additive expression.

3. We refrain from employing the terminology introduced by Heinämäki (1974), who calls *before* 'non-committal' instead.

## 2 Negative polarity items

The term polarity item, as applied to language, allows us to describe the behavior of certain words and phrases with respect to negation. One class of such expressions, usually referred to as the class of negative polarity items, requires the presence of a negative element in the sentence. As an illustration, consider the examples in (1).

- (1) a. None of the children noticed anything  
b. \*Each of the children noticed anything

The ungrammaticality of (1b) proves that the presence of the noun phrase *each of the children* is not sufficient to justify the occurrence of the polarity item *anything*. Apparently, it is only negative expressions such as *none of the children* that are capable of licensing such elements. We must not suppose that this is a peculiar feature of English. Similar patterns can be found in Dutch and German, as shown by the examples in (2) and (3).

### Dutch

- (2) a. Niemand zal zulk een beproeving hoeven te doorstaan  
*No one will such an ordeal need to go through*  
'No one need go through such an ordeal'  
b. \*Iedereen zal zulk een beproeving hoeven te doorstaan  
*Everyone will such an ordeal need to go through*  
'\*Everyone need go through such an ordeal'

### German

- (3) a. Keiner wird solch eine Prüfung durchzustehen brauchen  
*No one will such an ordeal to go through need*  
'No one need go through such an ordeal'  
b. \*Jeder wird solch eine Prüfung durchzustehen brauchen  
*Everyone will such an ordeal to go through need*  
'\*Everyone need go through such an ordeal'

Although the contrasts between these sentences may well seem perplexing at first, Ladusaw (1979) has shown that they can be explained in terms of the monotonicity properties associated with various words and phrases. By way of illustration, consider the conditional *At least one villager sang loudly*  $\rightarrow$  *At least one villager sang*. Provided that the structure of the universe is such that the class of individuals associated with the verb phrase *sang loudly* ( $VP_1$ ) is a subset of the class of individuals associated with the verb phrase *sang* ( $VP_2$ ), we may legitimately pass from the proposition *At least one villager sang loudly* to *At least one villager sang*. What this means is that noun phrases of the form *at least n N* have are monotone increasing: if NP  $VP_1$  and  $VP_1 \subseteq VP_2$ , then NP  $VP_2$ . The same test shows that expressions of the forms *some N*, *every*

$N$  and *both N* are also upward monotonic. For if the predicate *ate fish* applies only to what the predicate *ate* also applies to, then the following conditionals are all valid: *Some porters ate fish* → *Some porters ate*, *Every child ate fish* → *Every child ate*, *Both lawyers ate fish* → *Both lawyers ate*.

It turns out that monotone increasing noun phrases have a decreasing counterpart. To demonstrate this, we begin by considering the conditional *At most one villager sang* → *At most one villager sang loudly*. Whenever the state of affairs in the universe is such that the class of individuals associated with the verb phrase *sang* ( $VP_1$ ) is a superset of the class of individuals associated with the verb phrase *sang loudly* ( $VP_2$ ), we may legitimately pass from the proposition *At most one villager sang* to *At most one villager sang loudly*. This is important because it entails that noun phrases of the form *at most n N* are monotone decreasing: if  $NP VP_1$  and  $VP_2 \subseteq VP_1$ , then  $NP VP_2$ . In a similar manner, one easily shows that expressions of the forms *not every N*, *no N* and *neither N* are also downward monotonic. For if the predicate *ate* applies to whatever the predicate *ate fish* applies to, then the following conditionals are all valid: *Not every woman ate* → *Not every woman ate fish*, *No attorney ate* → *No attorney ate fish*, *Neither connoisseur ate* → *Neither connoisseur ate fish*.

In the light of the distinction between upward and downward monotonic noun phrases, the contrasts in (1), (2), and (3) admit only one explanation: the class of elements which are capable of licensing the occurrence of negative polarity items is coextensive with the class of monotone decreasing expressions. This conclusion is corroborated by the contrasting examples in (4).

- (4) a. At most five of the children noticed anything  
b. \*At least five of the children noticed anything

Of the two phrases *at most five of the children* and *at least five of the children*, it is only the first that can act as a licensing expression for the negative polarity item *anything* - a state of affairs which must be attributed to the circumstance that *at most five of the children* belongs to the class of monotone decreasing noun phrases, and *at least five of the children*, to the class of monotone increasing noun phrases.

## 2.1 Weak and strong polarity items

Negative polarity items can be either of the weak, or of the strong, type.<sup>4</sup> In order to get a clear view of the content of this distinction, one does well to take the following Dutch and German examples into consideration.

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4. A more elaborate discussion of weak and strong forms of polarity can be found in Zwarts (1993) and van der Wouden (1994).

## Dutch

- (5) a. Hoogstens één kind zal zich hoeven te verantwoorden  
*At most one child will himself need to justify*  
'At most one child need justify himself'
- b. Niemand zal zulk een beproeving hoeven te doorstaan  
*No one will such an ordeal need to go through*  
'No one need go through such an ordeal'
- (6) a. \*Hoogstens zes agenten hebben ook maar iets bemerkt  
*At most six cops have anything noticed*  
'At most six cops noticed anything'
- b. Niemand heeft van de regenbui ook maar iets bemerkt  
*No one has of the rain anything noticed*  
'No one noticed anything of the rain'

## German

- (7) a. Höchstens eine Frau wird sich zu verantworten brauchen  
*At most one woman will herself to justify need*  
'At most one woman need justify herself'
- b. Keiner wird solch eine Prüfung durchzustehen brauchen  
*No one will such an ordeal to go through need*  
'No one need go through such an ordeal'
- (8) a. \*Höchstens zehn Kinder haben auch nur irgendetwas bemerkt  
*At most ten children have anything noticed*  
'At most ten children noticed anything'
- b. Keiner von diesen Leuten hat auch nur irgendetwas bemerkt  
*None of these people has anything noticed*  
'None of these people noticed anything'

The contrast between (5) and (7), on the one hand, and (6) and (8), on the other, proves that expressions such as *ook maar iets* and *auch nur irgendetwas* place stronger restrictions on their environments than the negative polarity items *hoeven* and *brauchen* ('need'). As the ungrammatical sentences in (6) and (8) show, neither Dutch *ook maar iets* nor German *auch nur irgendetwas* is satisfied with the presence of a monotone decreasing expression of the form *hoogstens (höchstens) n N* 'at most n N'. Instead, both seem to require an *n*-word like *niemand (keiner)* 'no one' or *keiner von diesen Leuten* 'none of these N'. As a matter of fact, the distinction between weak and strong forms of negative polarity appears to correspond with that between monotone decreasing and so-called anti-additive noun phrases.

Monotonic noun phrases are characterized by the fact that they are closed under supersets or subsets. If they are closed under supersets, they are monotone increasing; if they are closed under subsets, they are monotone decreasing. This does not exhaust

the matter, for a closer look reveals that there are several alternative ways to determine whether a noun phrase is upward or downward monotonic. In fact, monotonic noun phrases can be given a number of logically equivalent characterizations. The next theorem provides the relevant details.

**Fact**

- (9) a. A noun phrase is monotone increasing iff the following two schemata are logically valid:  
 (a)  $\text{NP}(\text{VP}_1 \text{ and } \text{VP}_2) \rightarrow (\text{NP} \text{VP}_1 \text{ and } \text{NP} \text{VP}_2)$ ;  
 (b)  $\text{NP}(\text{VP}_1 \text{ or } \text{VP}_2) \rightarrow \text{NP}(\text{VP}_1 \text{ or } \text{VP}_2)$ .  
 b. A noun phrase is monotone decreasing iff the following two schemata are logically valid:  
 (a)  $\text{NP}(\text{VP}_1 \text{ or } \text{VP}_2) \rightarrow (\text{NP} \text{VP}_1 \text{ and } \text{NP} \text{VP}_2)$ ;  
 (b)  $\text{NP} \text{VP}_1 \text{ or } \text{NP} \text{VP}_2 \rightarrow \text{NP}(\text{VP}_1 \text{ and } \text{VP}_2)$ .

On the basis of these tests one can arrive at fairly accurate judgments concerning the presence of monotonicity properties. It is readily established, for instance, that expressions of the forms *many N*, *most N*, and *several N* are all upward monotonic. The class of monotone decreasing noun phrases, on the other hand, can be shown to include expressions of the forms *few N*, *no N*, and *not all N*.

The foregoing result gives us yet another way of characterizing the behavior of monotonic expressions. If we regard the semantic value associated with noun phrases as a function, the typical monotonicity patterns can be represented as in (10).<sup>5</sup>

	<b>Upward monotonic</b>		<b>Downward monotonic</b>
(10)	a. $f(x \cap y) \subseteq f(x) \cap f(y)$	c.	$f(x \cup y) \subseteq f(x) \cap f(y)$
	b. $f(x) \cup f(y) \subseteq f(x \cup y)$	d.	$f(x) \cup f(y) \subseteq f(x \cap y)$

It should be noted that the formulas in (10c) and (10d) correspond to one half of the first, and one half of the second, law of De Morgan, respectively. Inasmuch as these laws can be said to characterize the use of negation, monotone decreasing phrases may be regarded as being weakly negative. We can now show what the difference is between a monotonic expression and one which is additive or anti-additive. An element which is additive displays the pattern in (11a); one which is anti-additive exhibits the pattern in (11b).

	<b>Additive</b>		<b>Anti-additive</b>
(11)	a. $f(x \cup y) = f(x) \cup f(y)$	b.	$f(x \cup y) = f(x) \cap f(y)$

In other words, anti-additive phrases embody a stronger form of negation than downward monotonic ones in that they are governed by the first law of De Morgan as a

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5. Monotone increasing functions are sometimes said to be isotone. Their monotone decreasing counterparts, defined in (11), are accordingly referred to as antitone functions. See Birkhoff (1967: 3) and Stoll (1974: 55), among others.

whole. This logical difference is reflected in the behavior of the negative polarity items in (5)–(8). Whereas Dutch *hoeven* and German *brauchen* are content with a monotone decreasing expression like *hoogstens* (*höchstens*) *n N* as licensing element, *ook maar iets* and *auch nur irgendetwas* require the presence of an anti-additive phrase like *niemand*, *keiner* or *keiner von diesen Leuten*.

By way of illustration we give here a formulation of the laws which govern the distribution of negative polarity items.

### Laws of negative polarity

- (12) a. Only sentences in which a monotone decreasing expression occurs can contain a negative polarity item of the weak type.  
 b. Only sentences in which an anti-additive expression occurs can contain a negative polarity item of the strong type.

According to the first law, the presence of a monotone decreasing expression is a necessary condition for the appearance of negative polarity items of the weak type. The second law stipulates that negative polarity items of the strong type require the presence of an anti-additive expression as licensing element. To forestall any misunderstanding, we note that every anti-additive expression is also a monotone decreasing expression. It follows that negative polarity items of the weak type can also occur in sentences containing an anti-additive expression.

## 2.2 A hierarchy of negative expressions

Although the distinction between monotone decreasing and anti-additive expressions may not at first seem transparent, it finds its origin in the fact that phrases of the forms *no one*, *nothing*, *neither N* and *none of the N* embody a stronger type of negation than those of the forms *at most n N* and *few N*. This becomes apparent when we compare the logical behavior of such elements with that of the sentential prefix *it isn't the case that*. By way of illustration, we consider the biconditionals in (13).

- (13) a. It isn't the case that Jack ate or Jill ran  $\leftrightarrow$   
 It isn't the case that Jack ate and it isn't the case that Jill ran  
 b. It isn't the case that Jack ate and Jill ran  $\leftrightarrow$   
 It isn't the case that Jack ate or it isn't the case that Jill ran

One sees immediately that the equivalences in (13a) and (13b) must both be accepted as valid - a state of affairs which admits of no other explanation than that the operation in question is governed by the laws of De Morgan. This observation is important because it has frequently been argued that the logical patterns in (13) characterize the use of negation. Although such a conclusion is correct with respect to sentential negation and similar expressions, it must be regarded as misleading when it comes to other forms of negation. Not only does natural language contain a variety of negative expressions,

their logical behavior is also not the same. In order to convince ourselves of this fact, we consider the conditionals in (14).

- (14) a. Few trees will blossom or will die  $\rightarrow$   
Few trees will blossom and few trees will die  
b. Few trees will blossom and few trees will die  $\nrightarrow$   
Few trees will blossom or will die  
c. Few trees will blossom and will die  $\nrightarrow$   
Few trees will blossom or few trees will die  
d. Few trees will blossom or few trees will die  $\rightarrow$   
Few trees will blossom and will die

From these examples it is clear that the phrase *few trees*, though a negative expression, differs substantially from the prefix *it isn't the case that*. Of the four conditionals presented above, only two are valid: the one in (14a) and the one in (14d). In other words, the logical behavior of noun phrases of the form *few N* is governed by one half of the first law of De Morgan and one half of the second law of De Morgan. In this regard, they are by no means alone, for it requires little reflection to realize that monotone decreasing noun phrases of the forms *at most n N*, *not all N*, *only a few N* and *no more than n N* behave in much the same way. What this suggests is that such expressions embody a weak form of negation.

It turns out that there exists, in fact, a whole hierarchy of negative expressions. For not only do we have phrases of the forms *few N* and *at most n N*, but we also find anti-additive cases such as *no N*, *none of the N* and *no one*. The latter category differs from the former in that it expresses a stronger form of negation. The following conditionals provide a clear illustration.

- (15) a. No man escaped or got killed  $\rightarrow$  No man escaped and no man got killed  
b. No man escaped and no man got killed  $\rightarrow$  No man escaped or got killed  
c. No man escaped and got killed  $\nrightarrow$  No man escaped or no man got killed  
d. No man escaped or no man got killed  $\rightarrow$  No man escaped and got killed

From these examples we may conclude that the noun phrase *no man*, regarded as a negative expression, differs considerably from *few trees*. Of the four conditionals presented above, no less than three must be counted as valid: the one in (15a), the one in (15b), and the one in (15d). What this means is that the logical behavior of noun phrases of the form *no N* is determined by the first law of De Morgan as a whole and one half of the second law of De Morgan. We must not suppose that this is a mere accident, for it is easy to see that the property in question also holds of anti-additive noun phrases of the forms *none of the N*, *neither N* and *no one*. The conclusion must therefore be that expressions of this type embody a stronger form of negation than monotone decreasing phrases like *few N* and *at most n N*, though not as strong as the type of negation expressed by the sentential prefix *it is not the case that*.

There is another class of expressions which represents a stronger form of negation than the monotone decreasing ones, but which is independent of the class of anti-additive expressions. These are the so-called antimultiplicative elements, which are typically associated with the semantic pattern in (16b).

- (16)                    **Multiplicative**                    **Antimultiplicative**  
                          a.  $f(x \cap y) = f(x) \cap f(y)$     b.  $f(x \cap y) = f(x) \cup f(y)$

It is easy to see that the antimultiplicative expressions differ from their anti-additive counterparts in that they validate not the first, but the second law of De Morgan as a whole. Well-known representatives of this group are phrases of the forms *not all N*, *not every N* and *not always*.

### 3 Temporal connectives

Negative polarity items such as *anyone* and *ever* can occur in several temporal environments, among them *before*-clauses. As is illustrated by the contrast between (17) and (18), *before* differs in this respect from *after*, which does not allow such elements.<sup>6</sup>

- (17)    a. The children left before anyone had arrived  
           b. The boys died before they ever reached Nice
- (18)    a. \*The children arrived after anyone had left  
           b. \*The boys died after they ever reached Nice

We must not suppose that this is a peculiar feature of English. Similar patterns can be found in Spanish and Dutch, as shown by the examples in (19) and (20), which feature the negative polarity items *mover un dedo* 'lift a finger' and *ooit* 'ever'.

#### Spanish

- (19)    a. Juan se fué antes que María moviera un dedo para ayudarle<sup>7</sup>  
                   *Juan left before Maria lifted a finger to help him*  
                   'Juan left before Maria lifted a finger to help him'
- b. \*Juan se fué después que María ha movido un dedo para ayudarle  
                   *Juan left after Maria had lifted a finger to help him*  
                   'Juan left after Maria had lifted a finger to help him'

#### Dutch

6. See Heinämäki (1974) and Ladusaw (1979), among others.

7. Like its French counterpart *avant que* (see de Swart 1991), *antes que* requires the presence of a subjunctive in the clause it introduces. In what follows, it will be argued that this is a consequence of the non-veridical nature of both connectives. Henriëtte de Swart informs us that *avant que*, as opposed to *après que*, licenses the use of paratactic negation (so-called expletive *ne*) as well.



- (20) a. De kinderen vertrokken voordat zij ooit een tempel gezien hadden  
*The children left before they ever a temple seen had*  
 'The children left before they ever saw a temple'
- b. \*De kinderen vertrokken nadat zij ooit een tempel bezocht hadden  
*The children left after they ever a temple visited had*  
 'The children left after they ever visited a temple'

In view of the fact that expressions such as *anyone*, *ever*, *mover un dedo*, and *ooit* are typically restricted to downward monotonic contexts, this means that *before* must receive a monotone decreasing function as its semantic value. The temporal connective *after*, on the other hand, cannot be associated with such a function.

It is easy to establish that *before* is not only downward monotonic, but behaves like an anti-additive expression. As the Dutch examples in (21) clearly show, it is possible for the strong polarity item *ook maar iets* to appear in a clause which is introduced by *before*.

#### Dutch

- (21) a. De kinderen vertrokken voordat zij ook maar iets ontdekt hadden  
*The children left before they anything discovered had*  
 'The children left before they had discovered anything'
- b. Wij zullen vertrokken zijn voordat zij ook maar iets ontdekken  
*We will left have before they anything discover*  
 'We will have left before they discover anything'

Such patterns can be found in German as well. The strong polarity item *auch nur irgendetwas*, for example, may be part of a clause headed by *bevor* 'before'.

#### German

- (22) a. Er ist abgefahren bevor sie auch nur irgendetwas bemerkt hatten  
*He has left before they anything noticed have*  
 'He left before they noticed anything'
- b. Er wird abgefahren sein bevor sie auch nur irgendetwas bemerken  
*He will left have before they anything notice*  
 'He will have left before they notice anything'

This raises the question how the anti-additive behavior of elements like *voordat* and *bevor* can be derived from the associated semantic values.

## 4 Landman's analysis

At first sight, it is perfectly natural to regard *after* and *before* as converses. This way of portraying the matter entails that *p after q* (henceforth: *pAq*) should express the same as

$q$  before  $p$  (henceforth:  $qBp$ ). The definitions which Landman (1991: 141) proposes are given in (23).<sup>8</sup> Since he restricts his attention to *after* and *before* as past tense operators, they only characterize the retrospective use of these connectives. The corresponding prospective definitions are given in (24).

### Retrospective definitions

- (23) a.  $pAq(t_0)$  iff  $\exists x[x < t_0 \wedge p(x) \wedge \exists y[y < x \wedge q(y)]]$   
 b.  $pBq(t_0)$  iff  $\exists x[x < t_0 \wedge p(x) \wedge \exists y[x < y < t_0 \wedge q(y)]]$

### Prospective definitions

- (24) a.  $pAq(t_0)$  iff  $\exists x[t_0 < x \wedge p(x) \wedge \exists y[y < x \wedge q(y)]]$   
 b.  $pBq(t_0)$  iff  $\exists x[t_0 < x \wedge p(x) \wedge \exists y[t_0 < x < y \wedge q(y)]]$

From this it follows immediately that the statement *Juan arrived before Maria arrived* can only be true if *Maria arrived after Juan arrived* is a true statement as well. It is also clear, however, that the different behavior of *before* and *after* with respect to negative polarity items cannot be explained in this way. For that reason, Landman proposes that the retrospective definition in (23b) be replaced by the somewhat more complex characterization in (25a). The corresponding prospective definition is given in (25b).

- (25) a.  $pBq(t_0)$  iff  $\exists x[x < t_0 \wedge p(x) \wedge \forall y[(y < t_0 \wedge q(y)) \rightarrow x < y]]$   
 b.  $pBq(t_0)$  iff  $\exists x[t_0 < x \wedge p(x) \wedge \forall y[(t_0 < y \wedge q(y)) \rightarrow x < y]]$

Such an account is attractive in more than one respect. To begin with, it no longer forces us to infer from the truth of the whole sentence that the clause headed by *before* should also be true. That this is indeed the right approach is shown by the work of Heinämäki (1974), who points at the existence of sentences like (26).

- (26) They left the country before anything happened

Here we have a clear example of the nonveridical use of *before*: one can accept the truth of the whole sentence without being forced to accept the truth of the *before*-clause. Heinämäki (1974) speaks in such cases of 'non-committal' *before*. Following Anscombe (1964), she distinguishes two other uses as well: 'factual' and 'nonfactual' *before*. In the first case, the truth of the whole sentence implies the truth of the *before*-clause, as in (27).

- (27) John checked the car carefully before he bought it

In the second case, we may legitimately pass from the truth of the whole sentence to the falsity of the *before*-clause. According to Heinämäki, a typical example is the sentence

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8. Note that  $t_0$  is used to indicate an arbitrary moment of evaluation.

in (28).

- (28) Max died before he saw his grandchildren

Landman's treatment of *before* is compatible with all three uses and consequently doesn't force us to distinguish more than one lexical element. The definition in (25) makes *before* a nonveridical connective whose characteristic feature is that  $pBq$  doesn't necessarily imply  $q$ . This is reflected in the linguistic behavior of the Romance counterparts of *before*, which require the presence of a subjunctive in the clause they introduce. *After*, on the other hand, must be regarded as belonging to the class of veridical connectives: by definitions (23a) and (24a),  $pAq$  unconditionally implies  $q$ . We assume that such elements always select the indicative mood.

Even more important is the fact that Landman's analysis entails that *before* and *after* cannot be treated as converses. If  $pBq$  doesn't necessarily imply  $q$ , then we aren't forced to infer  $qAp$  either. A closer look reveals that this property holds in the opposite direction as well:  $qAp$  doesn't necessarily imply  $pBq$ . As observed by Heinämäki (1974), and before her by Anscombe (1964), we are not always able to pass from the truth of (29a) to the truth of (29b).

- (29) a. Doris travelled all over the world after she finished her studies  
b. Doris finished her studies before she travelled all over the world

In view of Landman's analysis, this need not surprise us. By virtue of definition (23a), the sentence in (29a) is true if there is a moment  $t_1$  at which *Doris travelled all over the world* is true and a moment  $t_2$  preceding  $t_1$  at which *Doris finished her studies* is true. Obviously, this is compatible with a situation in which *Doris travelled all over the world* is true both before and after the moment at which *Doris finished her studies* is true. However, in order to be able to infer (29b), every moment at which *Doris travelled all over the world* is true must be preceded by the moment at which *Doris finished her studies* is true. In other words, Landman's account not only predicts that  $pBq$  does not imply  $qAp$ , but it also predicts that  $qAp$  does not imply  $pBq$ .

The present treatment of *before* thus solves three problems: the observed lack of veridicality, the absence of a transition from  $pBq$  to  $qAp$  (as a result of the non-veridical nature of *before*) and the absence of a transition from  $qAp$  to  $pBq$  (as a result of the use of an existential quantifier over moments of time in the semantic characterization of *after*, but a universal quantifier over moments of time in the characterization of *before*). It remains to be seen how Landman's analysis deals with the fourth problem: the possibility of strong polarity items in *before*-clauses and the impossibility of negative polarity items in *after*-clauses.<sup>9</sup>

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9. Linebarger (1987) claims that the occurrence of the negative polarity item *budge an inch* in *\*The mule sighed before it budged an inch* leads to an ungrammatical sentence. In her opinion, this should be contrasted with *The mule sighed piteously for hours before the heartless owner budged an inch*, which is perfectly acceptable. As Jack Hoeksema reminds us, however, it is by no means clear that

## 5 The main theorem

To prove that *before* is anti-additive it is enough, in virtue of definition (11b), to prove that it validates the biconditional in (30).

$$(30) \quad pB(q \vee r)(t_0) \leftrightarrow (pB(q)(t_0) \wedge pB(r)(t_0))$$

We assume that the interpretation of disjunction in a temporal setting is the usual one. That is to say:

$$(31) \quad (q \vee r)(t_0) \leftrightarrow (q(t_0) \vee (r)(t_0))$$

It can be shown that from this, together with the characterization of *before* in (25), it follows that (30) is valid from left to right. For the reverse, we must assume that the model of time underlying natural language is the model of linear time.

### 5.1 The easy part

In what follows, we will restrict our attention to the retrospective use of *before*. It should be emphasized, however, that everything we say about retrospective *before* holds for prospective *before* as well.

We begin by noticing that the formulas in (25) and (31) allow us to expand  $pB(q \vee r)(t_0)$  into (32).

$$(32) \quad \exists x[x < t_0 \wedge p(x) \wedge \forall y[(y < t_0 \wedge (q(y) \vee r(y))) \rightarrow x < y]]$$

It is easy to see that within this formula the disjunction  $(q(y) \vee r(y))$  is part of the antecedent of a conditional. Because conditionals are monotone decreasing with respect to their antecedents, this means that the disjunction in question may be replaced by a stronger formula.<sup>10</sup> In particular, we wish to consider the formulas that result from replacing the occurrence of  $(q(y) \vee r(y))$  in (32) by any of its two proper subformulas.

$$(33) \quad \begin{array}{l} \text{a. } \exists x[x < t_0 \wedge p(x) \wedge \forall y[(y < t_0 \wedge q(y)) \rightarrow x < y]] \\ \text{b. } \exists x[x < t_0 \wedge p(x) \wedge \forall y[(y < t_0 \wedge r(y)) \rightarrow x < y]] \end{array}$$

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the observed contrast is a matter of well-formedness. Pragmatic factors influencing acceptability may be responsible instead. See also von Bergen and von Bergen (1993). The OED (s.v. *soldier*) gives the following example (from Melville's *White Jacket*): *off Cape Horn some 'sogers' of sailors will stand cupping, and bleeding, and blistering before they will budge.*

10. The relation of strength among formulas is usually defined in terms of entailment. We say that  $p$  is stronger than  $q$  if  $p$  entails  $q$ . In monotone decreasing contexts, this means that  $q$  may be replaced *salva veritate* by  $p$ . In monotone increasing contexts, on the other hand, we find the opposite to be the case:  $p$  may be replaced by the weaker formula  $q$ . See Kadmon and Landman (1993) for an interesting attempt to describe the distribution of *any* in terms of strength of propositions.

By definition (25), the formulas in (33a) and (33b) may be replaced equivalently by  $pBq(t_0)$  and  $pBr(t_0)$ , respectively. Clearly, these sentences may be conjoined by the introduction rule for  $\wedge$ , which gives us the result in (34).

$$(34) \quad pB(q \vee r)(t_0) \rightarrow (pBq(t_0) \wedge pBr(t_0))$$

In view of definition (9b), this shows that *before* is monotone decreasing with respect to the clause it introduces, as desired.

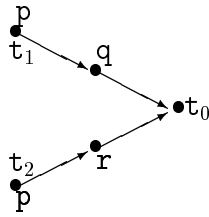
## 5.2 A counterexample

The argument from right to left is more difficult. As a matter of fact, without additional assumptions about the flow of time the relevant formula, given in (26), permits the construction of a countermodel.

$$(35) \quad (pBq(t_0) \wedge pBr(t_0)) \rightarrow pB(q \vee r)(t_0)$$

To see this, we consider the branching model in (36).

(36)



Notice, to start with, that according to the definition in (25)  $pBq$  holds at  $t_0$  if

1. there is a  $p$  point and it lies earlier than  $t_0$  itself; and
2. all points, if any, at which  $q$  is true lie between this  $p$  point and  $t_0$  itself

Look at any of the two branches in this model, for instance, the upper one. The only potentially falsifying  $q$  point is located on this branch, but is preceded by a  $p$  point and so  $p B q$  is verified by this branch and a fortiori by this model. Similarly, the only  $r$  point located on the lower branch is preceded by a  $p$  point and so there is no way of falsifying  $p B r$ . Consequently, we have shown that the model in (36) verifies  $(pBq) \wedge (pBr)$ .

On the other hand, notice that the  $q$  and  $r$  points in (36) are also  $(q \vee r)$  points. But the upper  $p$  point does not precede the lower  $(q \vee r)$  point. By the same token we can argue that the lower  $p$  point does not precede the upper  $(q \vee r)$  point. Hence, there is no  $p$  point in this model of which we can truthfully say that it precedes all the  $(q \vee r)$  points. This proves that  $pB(q \vee r)$  does not hold at  $t_0$ .

## 5.3 Eliminating the counterexample

The the above argument rests essentially on the branching nature of the relation of temporal precedence. If we assume that the model of time underlying natural language

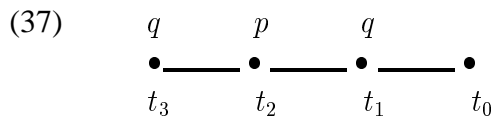
is linear, it can be shown that *before* is anti-additive. To see this it is enough to check what happens when we adopt a non-branching perspective. Suppose we merge the two branches. Let us concentrate on the three possibilities that arise with regard to the  $p$  point  $t_1$  and the only  $r$  point.

1. Suppose the  $r$  point is identified with the upper  $p$  point  $t_1$ . In this case the lower  $p$  point,  $t_2$ , will precede all the  $(q \vee r)$  points.
2. Suppose the  $r$  point precedes  $t_1$ . Once more the lower  $p$  point,  $t_2$ , will precede all the  $(q \vee r)$  points.
3. Suppose  $t_1$  precedes the  $r$  point. In this case, the upper  $p$  point,  $t_1$ , will precede all the  $(q \vee r)$  points.

Thus, we see that in such a setting our counterexample does not arise. In fact, it can be proven that no model in which the underlying precedence relation is transitive and connected falsifies the biconditional in (30).<sup>11</sup> This means that *before* is invariably anti-additive in linear models of time.

## 6 Restricted definitions

The truth definitions in (25) become inadequate when repetition is involved.<sup>12</sup> In order to see this, it is sufficient to take the situation in (37) into consideration.



It follows from the retrospective definition of *before* that if John lighted a cigarette and later he coughed and then lighted a cigarette again, we cannot truthfully say *John coughed before he lighted a cigarette*. The reason is that the existential and the universal quantifier in (25) are both unrestricted, ranging over the entire past, relevant or not. It should be clear that this leads to truth value evaluations which are not at all in accordance with our intuitions.

Interestingly, these problems were anticipated in Anscombe's (1964) discussion of *before* and *after*. One of the analyses of *before* which she considers is the following.

“p before q” means “There was some time at which  $p$  such that every time at which  $q$  was after it” (1964: 10)

Although such an account yields the right truth conditions for sentences which contain an occurrence of the negative polarity item *ever* in the *before*-clause, Anscombe rejects this analysis because it doesn't adequately deal with certain uses of plain *before*. To

11. A standard first-order argument showing this is presented in Sánchez Valencia, van der Wouden, and Zwarts (1993).

12. We owe this observation to Henriëtte de Swart.

quote her verbatim:

Now this formulation is right for “I was in Greece before you were *ever* in Italy”; but “I was in Greece before you were in Italy” may be true, although “I was in Greece before you were ever in Italy” is false. Or again “He studied his appearance in the glass before he used the telephone” may well be a true piece of narrative; it does not at all suggest that he studied his appearance in the glass before he ever in his life used the telephone. (1964: 13)

The foregoing passage clearly shows that Anscombe was aware of the difficulties that repetition creates for the truth definitions in (25). But it is equally clear that the source of these difficulties is the use of unrestricted quantification. This forces us to take the whole time axis into consideration when evaluating a sentence of the form  $pBq$ . In particular, if we find a situation as depicted in the diagram in (37), we will have to conclude that  $pBq$  is false, even if the points at which  $q$  is true are far apart and in some cases contextually irrelevant.

There are other considerations which suggest that tensed sentences should not be evaluated with respect to the whole time axis. One of the issues that Partee (1973) addresses is the problem of interpreting negated statements against the background of indefinite time. The sentence she discusses is *I didn't turn off the stove*, which illustrates the deictic use of the past tense morpheme. As Partee observes, when uttered halfway down the turnpike, such a sentence does not mean either that there exists some time in the past at which I did not turn off the stove or that there exists no time in the past at which I turned off the stove. The sentence clearly refers to a particular time whose identity is generally obvious from the context.

One way to obtain a correct semantics for Partee's example is to abandon the idea that sentences are to be evaluated at a single point. Instead, one evaluates at points with respect to a relevant time span. In the case at hand, this means that we propose that the unrestricted definition of retrospective *before* in (23b) be replaced by the restricted one in (38a), in which a definite time span  $I$  has been substituted for the indefinite past. The corresponding prospective definition is given in (38b).

- (38) a.  $pBq(I, t_0)$  iff  $\exists x \in I[x < t_0 \wedge p(x) \wedge \forall y \in I[(y < t_0 \wedge q(y)) \rightarrow x < y]$   
b.  $pBq(I, t_0)$  iff  $\exists x \in I[t_0 < x \wedge p(x) \wedge \forall y \in I[(t_0 < y \wedge q(y)) \rightarrow x < y]$

It should be emphasized that such an approach solves the problem of repetition as well. To see this, it is enough to take the model in (37) into consideration. If the relevant time span  $I$  includes  $t_1$ ,  $t_2$ , and  $t_3$ , then  $pBq(I, t_0)$  is false. But if this time span is restricted to  $t_1$  and  $t_2$ , then  $pBq(I, t_0)$  is true, as desired.

Note that the restricted definitions in (38) do not affect our reasoning with regard to the relationship between anti-additivity and the structure of time.

## 7 Nonveridicality

It is easy to see that the definitions in (25) and (38) make *before* a nonveridical connective one of whose pronounced features is that  $pBq$  doesn't necessarily imply  $q$ . Other connectives with this property are *or*, *unless* and *without*, among others. In many cases, the absence of veridicality is not a coincidence. Since it can be shown that monotone decreasing connectives are always nonveridical, the observed lack of veridicality must often be regarded as a consequence of the downward monotonic nature of the element in question. In order to demonstrate this, we will record a simple, but useful fact.

### Fact

(39) Let  $C$  be a connective which is both veridical and monotone decreasing with respect to its second argument. Then  $pCq \rightarrow q \wedge \neg q$ .

*Proof.* Suppose that  $pCq$  is true. Since  $(q \wedge \neg q) \rightarrow q$  is a logical truth, it follows from the monotone decreasing nature of  $C$  that  $pC(q \wedge \neg q)$  is true as well. Therefore, by the veridicality of  $C$ ,  $q \wedge \neg q$ .  $\square$

The above result proves that no connective can be both veridical and downward monotonic with respect to a given argument place. In other words: every connective which is monotone decreasing in a given argument place is nonveridical in that argument place and every connective which is veridical in a given argument place is either monotone increasing or nonmonotonic in that argument place.

## 8 A comparison of 'before' and 'after'

If we assume that the model of time underlying natural language is the model of linear time, then *before* must be classified as a connective which is both anti-additive and nonveridical in its second argument. Matters are different, however, when we turn to the first argument position. The presence of the existential quantifier in the definitions (25) and (33) is sufficient to make the element in question additive and veridical in its first argument. What this means is that the logical behavior of *before* is characterized by the valid formulas in (40).

- (40) a.  $(p \vee q)Br \leftrightarrow (pBr \vee qBr)$   
b.  $pB(q \vee r) \leftrightarrow (pBq \wedge pBr)$   
c.  $pBq \rightarrow p$

Accordingly, we expect to find negative polarity items in the subordinate clause, but not in the main clause. The examples below show that this is the right prediction.

- (41) a. The children left before anyone had arrived  
b. \*Anyone arrived before the children had left



In view of the fact that *before* is anti-additive in its second argument, we even expect to find strong polarity items in the subordinate clause. That this is indeed the case is shown by the Dutch and German examples in (21) and (22).

A closer look at the semantics of the temporal connective *after*, presented in (23b) and (24b), reveals that it is additive and veridical in both argument places. The logical behavior of the element in question can therefore be characterized by means of the valid formulas in (42).

- (42) a.  $(p \vee q)Ar \leftrightarrow (pAr \vee qAr)$   
 b.  $pA(q \vee r) \leftrightarrow (pAq \vee pAr)$   
 c.  $pAq \rightarrow p$   
 d.  $pAq \rightarrow q$

Consequently, we do not expect polarity items in either the main, or the subordinate, clause. The ungrammatical sentences in (43) confirm this expectation.

- (43) a. \*Anyone left after the children had arrived  
 b. \*The children arrived after anyone had left

## 9 A problem with 'since' and 'until'

The logical behavior of the temporal connectives *since* and *until* has been studied by Kamp (1968). He presents two truth definitions: one for the retrospective use of *since* and one for the prospective use of *until*.

- (44) a.  $pSq(t_0) \text{ iff } \exists x[x < t_0 \wedge q(x) \wedge \forall y[x < y < t_0 \rightarrow p(y)]]$   
 b.  $pUq(t_0) \text{ iff } \exists x[t_0 < x \wedge q(x) \wedge \forall y[(t_0 < y < x \rightarrow p(y)]]$

It is readily established that *since* and *until*, so defined, are multiplicative with respect to their first argument, and additive with respect to their second argument. Moreover, the existential quantifiers in (44) ensure that both connectives are veridical in the q position. If the relation of temporal precedence is not only linear, but dense, they will be veridical in the p position as well. This means that the logical behavior of the two connectives is characterized by the valid formulas in (45).

- (45) a.  $(p \wedge q)Sr \leftrightarrow (pSr \wedge qSr)$  e.  $(p \wedge q)Ur \leftrightarrow (pUr \wedge qUr)$   
 b.  $pS(q \vee r) \leftrightarrow (pSq \vee pSr)$  f.  $pU(q \vee r) \leftrightarrow (pUq \vee pUr)$   
 c.  $pSq \rightarrow p$  g.  $pUq \rightarrow p$   
 d.  $pSq \rightarrow q$  h.  $pUq \rightarrow q$

For the sake of clarity the semantical properties of *after* and *before*, *since* and *until* have been listed in table 1.

**Table 1: Semantical properties of four temporal connectives**

	<i>p after q</i>	<i>p before q</i>	<i>p since q</i>	<i>p until q</i>
<i>p</i> position	additive veridical	additive veridical	multiplicative veridical	multiplicative veridical
<i>q</i> position	additive veridical	anti-additive nonveridical	additive veridical	additive veridical

In view of the monotone increasing nature of *since* and *until*, both in the *p* and in the *q* position, Kamp's analysis predicts that we will not find negative polarity items in either clause. It is interesting to see that there are several counterexamples. Bolinger (1977: 31), for example, reports that the sentence *It's been a week since I bought any* is perfectly acceptable. In the corpus of English texts that Hoeksema is collecting, we also find a number of sentences which appear to involve the polarity item *anyone*. The relevant cases have been collected in (46).

- (46)
- a. It's two weeks since anyone was towed away from outside their door, the Computerland clerk tells me
  - b. 'You know, it's been a long time since anyone did that for me'. 'Did you like it?' I asked
  - c. 'W-what's that for?' 'It's been a while since anyone's been to the bathroom'

Curiously enough, Dutch does not allow polarity items at all in such examples. This might be taken to suggest that *any*-phrases differ substantially from other types of polarity items in their distributional properties. On the other hand, the Dutch grammarian Paardekooper (n.d.) tells us that *tot(dat)* 'until' is capable of licensing *ook maar iets* 'anything at all' in examples like (47):

- (47)
- Het zal heel lang kunnen duren totdat er hier ook maar iets verandert  
*It will very long can last until there here anything changes*  
 'It will take a long time before anything changes here'

Note, however, that sentence (48) which involves the perfect instead of the future is considerably worse:

- (48)
- ?Het heeft heel lang geduurd totdat er hier ook maar iets veranderde  
*It has very long lasted until there here anything changed*  
 'It took a long time before anything changed here'

This suggests that the polarity item *ook maar iets* in (47) is licensed by the future operator which is nonveridical, though not monotone decreasing.

## 10 A similar problem with ‘as soon as’

The temporal connective *as soon as* and its Dutch equivalent *zodra* present us with a similar problem. When used retrospectively these expressions are clearly veridical in both argument places. As prospective connectives, however, they appear to be non-veridical. A number of negative polarity items seem to be sensitive to this distinction, as is clear from the examples in (49).

- (49) a. \*De kinderen vertrokken zodra zij ook maar iets ontdekt hadden  
*The children left as soon as they anything discovered had*  
\*‘The children left as soon as they had discovered anything’<sup>13</sup>
- b. De kinderen zullen vertrekken zodra zij ook maar iets ontdekken  
*The children will leave as soon as they anything discover*  
‘The children will leave as soon as they discover anything’

We see that *ook maar iets* and *anything* are only compatible with *zodra* and *as soon as* if these elements are used as prospective connectives, with present or future tense. It is not clear, however, whether the polarity items are licensed by the connective or by the tense operator. It is also not clear whether the nonveridicality of prospective *as soon as* and *zodra* entails downward monotonicity.

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13. Greg Carlson informs us that the English equivalent is just as bad as the Dutch sentence.

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