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## Spatial, Temporal and Spatio-temporal Locating Adverbials in Discourse

### Adverbes de Localisation Spatiale, Temporelle et Spatio-temporelle dans le Discours

Nicholas Asher\* , Michel Aurnague\*\* , Myriam Bras\*\*\* , Laure Vieu\*\*\*

A Frédérique

#### Abstract

This paper deals with the semantics of French adverbials that can be used to localise the eventualities of a discourse (events and states) in space and/or in time. The discourses that are considered are narratives describing trajectories. We propose both a linguistic description and a formal representation in order to model the contribution of these adverbials to the spatio-temporal structure of a discourse. The descriptive part tries to classify temporal and spatial adverbials according to the different interpretations they can give rise (spatial, temporal and spatio-temporal). We show that several other factors also condition these possible interpretations (aspectuality, discourse context, etc.) The formalisation of adverbial semantics is done within Segmented Discourse Representation Theory.

#### Résumé

Cet article analyse la sémantique des adverbiaux du français utilisés pour localiser les éventualités du discours (événements et états) dans l'espace et/ou dans le temps. Les énoncés considérés sont des textes décrivant des trajectoires. Nous proposons une description linguistique et une représentation formelle du contenu sémantique de ces adverbiaux visant à modéliser leur contribution à la structure spatio-temporelle du discours. La partie descriptive introduit une classification temporelle et spatiale de ces marqueurs en fonction des interprétations auxquelles ils peuvent donner lieu (spatiale, temporelle, spatio-temporelle). Nous mettons également en évidence plusieurs autres facteurs conditionnant ces possibles interprétations. La formalisation de la sémantique des adverbiaux est effectuée dans le cadre de la Théorie des Représentations Discursives Structurées.

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## Introduction<sup>1</sup>

This paper deals with the semantics of French adverbials that can be used to localise the eventualities of a discourse (events and states) in space and/or in time. We propose both a linguistic description and a formal representation in order to model their contribution to the spatio-temporal structure of a discourse. The discourses that will be considered here are narratives describing trajectories.

We will study both adverbials operating temporal localisation such as *le 7 février 1995* (on February 7, 1995), *deux heures plus tard* (two hours later), and adverbials operating spatial localisation such as *devant la maison* (in front of the house), *trois kilomètres plus loin* (three kilometres further). We will show that some of these adverbials can also operate spatio-temporal localisation.

From a syntactic point of view, we consider adverbials modifying sentences (S-adjoins) as opposed to adverbials which constitute real arguments of a verb (complements) or which modify the verb phrase (VP-adjoins). An important characteristic of these sentential adverbials relies on the fact that, contrarily to verbal adverbials (3,4), their position in the whole sentence can be modified (1,2).

- (1) *Jean écouta la radio jusqu'à Toulouse* (Jean listened the radio all the way to Toulouse)
- (2) *Jusqu'à Toulouse Jean écouta la radio* (All the way to Toulouse Jean listened the radio)
- (3) *Jean alla jusqu'à Toulouse* (Jean went up to Toulouse)
- (4) *\*Jusqu'à Toulouse Jean alla* (\*Up to Toulouse Jean went)

The formalisation of adverbial semantics will be done within Segmented Discourse Representation Theory [Ash93], which provides a framework for constructing representations of discourses (SDRSs) consisting of constituents structured with discourse relations. The basic constituents of SDRSs are Discourse Representation Structures of DRT [KR93], consisting of a set of discourse referents and of a set of conditions on referents. Constructing a SDRS for a given discourse means first constructing the discourse constituent corresponding to the semantic content of a sentence and then "attaching" it to the representation of the previous sentences via (at least) one discourse relation with a constituent of attachment. The representation of a discourse is thus constructed dynamically sentence after sentence, and in a bottom-up fashion since each constituent is the result of combining compositionally the semantics of each phrase of the sentence according to its parse tree (see [Ash93] for details). The SDRS construction is carried out in a non monotonic logic, for discourse semantics is not separated from discourse pragmatics.

## 1. Linguistic description

### 1.1 Semantic properties of locating adverbials

From a referential point of view, an important property of locating adverbials is their dependency/independency from the context, be it related to the preceding discourse (anaphora) or to the context of utterance (deixis). The adverbials involved in narratives are, most of the time, dependant from the linguistic context, that is anaphoric ones, as for example *deux heures plus tard*, *trois kilomètres plus loin*. Nevertheless, we will also analyse some adverbials which have no anchor to the context, namely independent ones, as for example *le 7 février 1995*.

We also restrict our study to adverbials referring to single, identifiable temporal or spatial areas, thus excluding adverbials like *tous les matins* (every morning) and *un jour* (one day).

In this section, we deal with the way the spatial or temporal area referred to by the adverbial is identified. Each class of the categorisations we propose, respectively for time adverbials and space adverbials, correspond to a specific way of identifying this area<sup>2</sup>.

<sup>1</sup>We would like to thank Francis Cornish for his advices about acceptability of English examples.

<sup>2</sup>We won't consider here as categorization criteria the contextual or independent anchorage of the adverbials. This will be an additional parameter for our formalization in section 2.

### 1.1.1 Locating Time Adverbials (LTAs)

The linguistic description we give here for LTAs relies on previous works on time adverbials [Wet80], [Mol89]. Let us precise that we do not consider adverbials expressing a mere duration such as *pendant 3 jours*, *en 2 heures* (during 3 days, in 2 hours —with the reading it has in *Mary wrote the letter in 2 hours*), because they do not localise anything.

The first class (C0-T) of LTAs we examine contains simple adverbs such as *puis* (then), *après* (after), *auparavant* (before). Their semantics is purely intersentential, and thus anaphoric, for they introduce a temporal relation between the eventualities of the sentences they relate.

Then, we study adverbial phrases<sup>3</sup> of the following syntactic forms:

- (s1) PREP NP (where PREP can be  $\emptyset$ )  
 e.g. *dans la soirée* (in the evening)  $\emptyset$  *hier* (yesterday)  
       *à 3 heures* (at 3 o'clock) *depuis hier* (since yesterday)  
       *depuis trois jours* (for the last three days)
- (s2) NP1 PREP NP2 (where NP1 is a modifier and where NP2 can be empty)  
 e.g. *trois jours avant Noël* (three days before Christmas)  
       *trois jours avant* (three days before)

All the Noun Phrases involved in these structures include time nouns, as *jour*, *heure*, *mois*, *lundi*, *janvier*, *matin*... (day, hour/o'clock, month, Monday, January, morning...). These NPs express either a duration such as *deux heures*, *un mois* (two hours, a month), or a temporal location such as *ce matin*, *la semaine suivante* (this morning, the following week). They will be called respectively dur-NPs and loc-NPs.

As far as the semantic categorisation is concerned, the LTAs defined here above fall into four classes, depending on the two following distinctions [Mol89],[BM93]:

- whether or not the identification of the referent involves the identification of (at least) one of its boundaries. For example, in *après/avant ce jour* (after/before that day), the portion of time designated by the adverbial starts/ends at "that day"; in *depuis trois jours* (for the last three days), the portion of time designated by the adverbial starts at a point situated at a "three-day" distance from now/some other point mentioned in the discourse.

- whether or not the identification of the referent depends on the projection of a length of time on the temporal axis (from some given point). For example, for the adverbials *il y a 3 jours*, *3 jours avant Noël*, *depuis 3 jours* (3 days ago, 3 days after Christmas, for the last 3 days) the measure "3 days" is projected on the temporal axis, from the point "now" or "Christmas".

The combination of these two properties results in the following classes of LTAs:

C1-T: LTAs such as *à 8 heures* (at 8 o'clock), *hier* (yesterday), which directly designate areas of the temporal axis. Neither the identification of a boundary, nor the projection of a measure of time are necessary to identify the referent.

C2-T: The referent is identified through one of its boundaries. E.g. *jusqu'à 3 heures* (until 3 o'clock), *depuis ce jour* (since that day), *à partir du 22 février* (from February 22nd). As far as the relation between this referent and the eventuality the LTA localises is concerned, we will see in section 2 that C2-T LTAs introduce a relation between the end or the beginning of the eventuality and a referent representing the boundary of the LTA's referent. Moreover, for *depuis* another referent given by the context is needed to express the fact that the eventuality that starts at the boundary still holds at that landmark. For example in *Marie rendit visite à Paul. Il était malade depuis le 1er février*. (Mary visited Paul. He had been ill since February 1st), the state of Paul being ill still holds when Mary visits him.

C3-T: The referent is identified through the projection of a measure from a point which is given either explicitly (e.g. *3 jours avant Noël* (3 days before Christmas)), or implicitly: (e.g. *il y a 3 jours* (3 days ago), *3 jours avant* (3 days before)).

<sup>3</sup>We consider only phrasal adverbial and do not consider subordinate clauses which are sometimes called clausal adverbials.

C4-T: The referent is identified through one of its boundaries, which is in turn identified through the projection of a measure from a landmark given by the context. For instance, in *Le 3 février, Marie rendit visite à Paul. Il était malade depuis trois jours* (On February 3rd, Mary visited Paul. He had been ill for three days), the projected boundary marks the starting point of the state of Paul being ill, this point is located at a 3 day distance from a landmark which is here given by the preceding sentence, namely the event of Mary visiting Paul. The semantics of *depuis* also conveys the information that the state of Paul being ill is still true at this landmark.

Let us point out that the LTAs of C2-T and C4-T inform us on the duration of the eventuality they modify and also localise a part of it<sup>4</sup>.

The LTA category can be computed from syntactic and semantic information. C1-T, C2-T, C4-T LTAs correspond to structure (s1), while C3-T LTAs correspond to either to (s1), e.g. *il y a 3 jours*, or to (s2) e.g. *3 jours avant*. Features attached to the NP and to the PREP allow the disambiguation of adverbials of structure (s1). C1-T and C2-T LTAs involve only loc-NPs, while C4-T LTAs involve dur-NPs. In C3-T LTAs the first NP is durative and the second is locative. Then the combination of the PREP and of the NP features accounts for the category of the adverbial:

- for the PREPs<sup>5</sup> which are used only within one category pattern:

{à, pendant, ø} + loc-NP = C1-T  
 {jusqu'à, à partir de} + loc-NP = C2-T  
 {plus tard, il y a} + dur-NP = C3-T

- for the PREPs<sup>5</sup> which enter in the pattern of several categories :

<i>en</i> + loc-NP = C1-T	<i>en</i> + dur-NP = duration adverbial
<i>dans</i> + loc-NP = C1-T	<i>dans</i> + dur-NP = C3-T
<i>depuis</i> + loc-NP = C2-T	<i>depuis</i> + dur-NP = C4-T
<i>avant</i> + loc-NP = C2-T	<i>avant</i> + dur-NP1 = C3-T <i>avant</i> + dur-NP2 = C4-T

### 1.1.2 Space adverbials

The syntactic structures we examine for space adverbials are very similar to what has been set out for temporal markers. They can include Internal Localisation Nouns (ILN) such as *sommet* (top), *extrémité* (extremity), *bord* (edge), *devant* (front) which are used to operate a more precise localisation by pointing out portions of spatial entities (Borillo A. 92). In this study we consider the two following syntactic forms:

- (s3) PREP (ILN de) NP  
*devant la maison* (in front of the house), *jusqu'au sommet de la montagne* (up to the top of the mountain), *depuis 3 kilomètres* (for 3 kilometres)
- (s4) NP1 PREP (ILN de) NP2  
*2 kilomètres après la poste* (2 kilometres after the post-office), *200 mètres avant le sommet de la montagne* (200 meters before the top of the mountain), *500 mètres avant* (500 meters before).

Here again a classification can be made on the basis of two main parameters:

-whether the interpretation of the space adverbial calls for the calculation of a continuous area bounded by a spatial entity (paths are special instances of this class) or introduces a space portion localised with respect to an entity of reference<sup>6</sup> :

- (5) *à partir de la maison* (from the house)  
 (6) *depuis 3 km* (for 3 km)  
 (7) *devant la bibliothèque* (in front of the library)

<sup>4</sup>cf the "mixed function" adverbials in [Vet80].

<sup>5</sup>the list of PREPs given here is not exhaustive.

<sup>6</sup>The use of a continuous adverbial for the localization of an eventuality entails that the eventuality occurs at every sub-location of the location designated by the adverbial. These sub-locations should have a size corresponding to the size of the location pragmatically involved by the eventuality. On the contrary, the use of a non-continuous adverbial only indicates that the eventuality occurs somewhere in the location designated by the adverbial.

- (8) *3km à gauche de la mairie* (3km at the left of the town-hall)

-whether the space adverbial operates the localisation by directly designating an entity or by using a measure noun:

- (9) *à droite de l'arbre* (at the right of the tree)  
 (10) *depuis l'université* (from the university)  
 (11) *3 km avant* (3 km before)  
 (12) *depuis 400 m* (for 400 m)

The combination of these two criteria leads to the definition of four classes of space adverbials:

- |      |  |         |
|------|--|---------|
| C1-S | non-continuous localisation based on entities      | (7, 9)  |
| C2-S | continuous localisation based on entities          | (5, 10) |
| C3-S | non-continuous localisation based on measure nouns | (8, 11) |
| C4-S | continuous localisation based on measure nouns     | (6, 12) |

Adverbials of category C1-S follow the syntactic structure (s3) and call for internal prepositions (*sur* (on), *dans* (in), *à* (at)), or external prepositions (*devant* (in front of)/*derrière* (behind), *à gauche de* (at the left of)/*à droite de* (at the right of), *au-dessus de* (above)/*au-dessous de* (below), *près de* (near), *entre* (between), etc.). They can also take the prepositions *avant* (before)/*après* (after). Adverbials of category C2-S follow the structure (s3) and make use of dynamic prepositions such as *depuis* (from, since), *jusque* (up to, up until) or *à partir de* (from)). In C3-S we find adverbials having the syntactic structures (s3) or (s4) in which appear classical external prepositions (*à gauche de* (at the left of)/*à droite de* (at the right of), *au-dessus de* (above)/*au-dessous de* (below)) as well as more specific prepositions like *avant de* (before)/*après* (after, further (on)), *au bout de* (after) or *plus loin* (further (on)). At last, adverbials of C4-S follow the framework (s3) and call for the preposition *depuis* (for). This information on the kind of syntactic structures and on the semantic classes of prepositions each adverbial category calls for, together with the nature of the NP (spatial entity or spatial measure noun) allow us to calculate the category of each space adverbial.

## 1.2 Discursive effects of locating adverbials

A locating adverbial explicitly localises the eventuality of the sentence it modifies temporally or spatially, but except when it is the first sentence of a discourse or when there are both a spatial locating adverbial and a temporal locating adverbial in the sentence, this localisation is incomplete if we do not take into account the link of the sentence to the previous discourse, in other words, the attachment of the current constituent. Indeed, the complete localisation of the eventuality takes up at least one of the components, spatial or temporal, of the constituent to which we attach the current one. This is obvious when the adverbial is itself anaphoric, but this principle, that we call "spatio-temporal localisation principle", is more general as the following text illustrates it:

- (13) *Le 7 février 1995 au matin, Luc quitta Madrid. A 16 heures, il n'était qu'à la frontière. A Toulouse, Léa l'attendait avec anxiété.* (On the morning of February 7th, Luc left Madrid. At 4 PM, he was only at the border. At Toulouse, Léa was waiting for him anxiously.)

In the third sentence, the independent adverbial *à Toulouse* situates Léa's waiting spatially, but her waiting is also temporally localised by its discourse relation to the previous sentence: Léa is waiting for Luc *while* he is crossing the border. In a similar way, when an adverbial temporally localises an eventuality, the attachment of the current constituent spatially localises the eventuality, as in the third sentence of the following text, which clearly occurs in the waiting room:

- (14) *Léa arriva à l'aéroport. Elle s'installa dans la salle d'attente. Vingt minutes plus tard, on annonça que le vol de Madrid avait du retard.* (Léa arrived at the airport. She settled down in the waiting room. Twenty minutes later, the delay of the flight from Madrid was announced.)

The spatio-temporal localisation principle expresses the spatio-temporal coherence of narratives and thus extends the modelling of temporal coherence proposed in [LA93]. We will see in section 2.2 that this principle is implemented in the spatio-temporal semantic effects of discourse relations. So, an essential effect of locating adverbials on discourse semantics is to

interact with this principle on discourse coherence, possibly<sup>7</sup> shifting the time and the location of the constituent of attachment.

This effect is even more conspicuous when locating adverbials, be they spatial or temporal, actually localise both spatially and temporally, i.e., spatio-temporally. In texts describing trajectories, this happens in particular with anaphoric adverbials based on measure NPs (*deux minutes plus tard*, *deux kilomètres plus loin*), so that the temporal or spatial distance calculated has a clear spatial or temporal counterpart, along the trajectory. This phenomenon also occurs with simple adverbials like *après*, *avant* or *puis*. Consider the following text:

- (15) (1) *Le premier jour des vacances, Paul partit à la mer avec sa nouvelle voiture.* (2) *Il prit la route de Narbonne.* (3) *Il passa devant une station d'essence fermée.* (4) *Puis il prit un autopasseur.* (5) *Dix minutes plus tard / dix kilomètres plus loin, il tomba en panne d'essence.* (On the first day of holidays, Paul went to the sea in his new car. He took the route de Narbonne. He passed a closed gas station. Then he picked up a hitch-hiker. Ten minutes later / ten kilometres further, he ran out of gas.)

The adverbial *puis*, in the fourth sentence clearly has a temporal semantics, situating e4 in a time located after e3, but a deeper analysis shows that *puis* in this sentence has a spatio-temporal interpretation with respect to Paul's trajectory. This interpretation allows the inference "the hitch-hiker has been picked up well past the gas station, on the route de Narbonne towards the sea" showing that sentence (4) has been localised by the adverbial *puis* in time, as expected, and also in space. Sentence (5) gives a clearer illustration of this phenomenon, since a locating time adverbial (*dix minutes plus tard*) just as well as a locating space adverbial (*dix kilomètres plus loin*) localises both temporally and spatially the breakdown.

It is important to note that the eventuality thus localised is *not* a motion verb, otherwise the spatio-temporal shift along the trajectory would have been achieved by the eventuality itself. The spatio-temporal interpretation is possible even if the eventuality does not involve the "mobile" of the trajectory (here Paul), for sentences in which the existence of a perception event by the mobile is suggested, as in the following text:

- (16) (1) *Le premier jour des vacances, Paul partit à la mer avec sa nouvelle voiture.* (2) *Il prit la route de Narbonne.* (3) *Dix minutes plus tard / dix kilomètres plus loin, il se mit à pleuvoir.* (On the first day of holidays, Paul went to the sea in his new car. He took the route de Narbonne. Ten minutes later / ten kilometres further, it started to rain.)

But it is essential to observe that a spatio-temporal localisation is not done by the mere presence of a locating adverbial: it is a joint effect of the adverbial, the kind of eventuality present in the sentence it modifies, the "trajectory" context established by the previous text, the time and the location of the constituent of attachment and the semantics of the discourse relation used for the attachment. However, in a trajectory context, the role of the adverbial is the most determining in sentences that do not involve the mobile explicitly as in sentence (3) of example (16). As a consequence, we will focus more on this kind of examples in the remainder of this paper.

After analysing which adverbials may have a spatio-temporal interpretation, and when, in more details below, we will in section 2 give the formal semantics of some adverbials that explains this complex interaction and enables taking into account locating adverbials in the SDRT framework.

### 1.3 When does the spatio-temporal interpretation of locating adverbials occur?

Each locating adverbial seems to have two potential interpretations, a temporal or spatial one and a spatio-temporal one. So the question is: are all these adverbials ambiguous, and if they are, how is it possible to choose between the two interpretations?

#### 1.3.1 Time adverbials

As we just said, the trajectory context is necessary if we want to conclude to a spatio-temporal interpretation. For the LTAs we study in this paper, it is easy to observe that there is always a spatial counterpart to the temporal localisation of an event included in a trajectory context, as we have sketched it for C0-T and C3-T LTAs in the examples (15) and (16). The spatio-temporal interpretation is available even for C1-T LTAs for which the anaphoric link with the preced-

<sup>7</sup>For adverbials like *à ce moment là* (at that time), *pendant ce temps* (meanwhile), and *à cet endroit-là* (at that place), the shift is null.

ing sentences is less obvious, such as *à 10 heures*, as in (16'). We can also have a spatio-temporal interpretation with C2-T LTAs such as *jusqu'à midi* (until midday) as in the text resulting from extending (16') by (16'').

(16') *Le premier jour des vacances, Paul partit à la mer avec sa nouvelle voiture. A 10 heures, il prit la route de Narbonne. A 10 heures 10 minutes il se mit à pleuvoir.* (On the first day of holidays, Paul went to the sea in his new car. At 10 o'clock, he took the route de Narbonne. At 10 past 10, it started to rain.)

(16'') *Jusqu'à midi, il plut à torrents.* (Until midday, it poured with rain.)

So we may conclude that all LTAs are ambiguous with respect to the choice between temporal and spatio-temporal interpretation.

### 1.3.2 Space adverbials

Here, we try to characterise the different interpretations that can occur in narratives describing trajectories for each category of locating space adverbials.

Adverbials of category C1-S (non-continuous localisation based on entities) give rise to spatio-temporal (17,18) as well as to spatial (18,19) interpretations. The utterance (19) illustrates the fact that (18) can be perfectly interpreted in a purely spatial way, besides its spatio-temporal interpretation. On the other hand, (20) and (21) show that C1-S adverbials which make use of the prepositions *avant* (before) or *après* (after) only give rise to spatio-temporal interpretations (even when an imparfait is used as in (21)).

(17) *Jean quitta son domicile à 8h. Devant la gare il prit Paul.* (Jean left home at 8 o'clock. In front of the station he picked up Paul.)

(18) *Jean quitta son domicile à 8h. Sur le pont St Pierre des manifestants bloquaient la circulation.* (Jean left home at 8 o'clock. On the St Pierre bridge protesters were blocking/blocked the traffic.)

(19) *Jean quitta son domicile à 8h. Sur le pont St Pierre des manifestants bloquaient la circulation. Quand il arriva sur place, il y avait encore des pneus calcinés sur le sol.* (Jean left home at 8 o'clock. On the St Pierre bridge protesters were blocking the traffic. When he arrived there, there was still burned pneumatics on the ground.)

(20) *Jean quitta son domicile à 8h. Après la sortie du village un arbre tomba en travers de la route.* (Jean left home at 8 o'clock. After the village a tree fell across the road.)

(21) *Jean quitta son domicile à 8h. Après la sortie du village un arbre tombait en travers de la route.* (Jean left home at 8 o'clock. After the village a tree fell across the road.)

C2-S adverbials are most of the time interpreted in a spatio-temporal way:

(22) *Jean s'arrêta sur une aire de repos. Depuis l'entrée de l'autoroute il pleuvait à torrents.* (Jean stopped at a rest area. From the beginning of the motorway, it was pouring with rain.)

(23) *Jean quitta Toulouse à 8h. A partir de Montrejeau il plut à torrents.* (Jean left Toulouse at 8 o'clock. From Montrejeau on it poured.)

(24) *Jean quitta Toulouse à 8h. Jusqu'à Montréjeau il plut à torrents.* (Jean left Toulouse at 8 o'clock. All the way to Montréjeau it poured.)

Purely spatial interpretations of such adverbials are quite rare and very often involve eventualities related to perception:

(25) *L'avion piqua du nez. Depuis la tour de contrôle Jean le vit se précipiter vers le sol.* (The plain went into a nose-dive. From the control tower Jean saw it rushing to the ground.)

(26) *Jean sortit de l'autoroute. Jusqu'aux Pyrénées le ciel était entièrement dégagé.* (Jean left the motorway. Up to the Pyrenees the sky was completely clear.)

(27) *Les blindés s'approchaient de la ville. A partir du haut de la rue des Lilas on les apercevait progresser lentement.* (The tanks were approaching the town. From the rue des Lilas one could see them slowly advancing.)

For their part, adverbials of category C3-S fall into two subclasses. Those which use the preposition *plus loin* (further (on)) or external prepositions as *à gauche de* (at the left)/*à droite de* (at the right), *au-dessus de* (above)/*au-dessous de* (below), etc.) can be involved in spatial (28,31) as well as in spatio-temporal (28,30,31,32) descriptions. (29) clearly shows that



utterances like (28) or (31) (whose second sentence use an imparfait) can be interpreted not only in a spatio-temporal way but also in a mere spatial way.

- (28) *Jean s'arrêta au carrefour. 500m plus loin un camion citerne s'enflammait.* (Jean stopped at the T-junction. (At the very same time) 500m further (on), a tanker burst into flames.)
- (29) *Jean s'arrêta au carrefour. 500 m plus loin un camion citerne s'enflammait. Quand il arriva sur le lieu du sinistre l'engin était déjà complètement consumé.* (Jean stopped at the T-junction. At the very same time, 500m further (on), a tanker burst into flames. When he arrived at the scene of the blaze the vehicle was already completely burned out.)
- (30) *Jean s'arrêta au carrefour. 500m plus loin il prit un auto-stoppeur.* (Jean stopped at the T-junction. 500m further (on) he picked up a hitch-hiker.)
- (31) *Jean s'arrêta au carrefour. 500m à gauche de la mairie un camion citerne s'enflammait.* (Jean stopped at T-junction. 500m to the left of the town hall a tanker burst into flames.)
- (32) *Jean s'arrêta au carrefour. 500m à gauche de la mairie il prit un autostoppeur.* (Jean stopped at T-junction. 500m to the left of the town hall he picked up a hitch-hiker.)

On the contrary, C3-S adverbials in which the prepositions *avant* (before)/ *après* (after) and *au bout de* (after) appear can only be interpreted in a spatio-temporal way (even if we use an imparfait as in (34) and (36)):

- (33) *Jean s'arrêta au carrefour. 500m après un camion citerne s'enflamma.* (Jean stopped at the T-junction. 500m further (on) a tanker burst into flames.)
- (34) *Jean s'arrêta au carrefour. 500m après un camion citerne s'enflammait.* (Jean stopped at the T-junction. 500m further (on) a tanker burst into flames.)
- (35) *Jean sortit du village. Au bout de 3km un arbre tomba en travers de la route.* (Jean left the village. After 3km a tree fell across the road.)
- (36) *Jean sortit du village. Au bout de 3km un arbre tombait en travers de la route.* (Jean left the village. After 3km a tree fell across the road.)

Lastly, adverbials belonging to C4-S can only give rise to spatio-temporal interpretations:

- (37) *Jean prit la direction de St Gaudens. Depuis 2 km il pleuvait à torrents.* (Jean took the direction of St Gaudens. For 2km it had been pouring with rain.)

The following table summarises what has been set out up to now by giving the nature of the interpretation in terms of the category of adverbial.

	non continuous	continuous
spatial entities	<i>sur, dans, à</i> C1-S <i>devant, à gauche, etc.</i> <i>au sommet de, au bord de, etc.</i> spatio-temporal or spatial interpretation  <i>avant/après</i> spatio-temporal interpretation	<i>depuis, jusque, à partir de</i> C2-S spatio-temporal interpretation  (spatial interpretation -> perception)
measure nouns	C3-S <i>plus loin, à gauche/à droite</i> <i>au-dessus/au-dessous, etc.</i> spatio-temporal or spatial interpretation  <i>avant/après, au bout de</i> spatio-temporal interpretation	C4-S <i>depuis</i> spatio-temporal interpretation

## 2. Formalisation

The aim of this section is to model the contribution of temporal and spatial locating adverbials we have considered in this paper to discourse semantics. A basic assumption for us is that locating adverbials don't affect directly discourse structure.

Their semantics is spatio-temporal, so they entail spatio-temporal relations between discourse referents, possibly from different discourse constituents. Indeed, in SDRT a difference is made

between discourse (rhetorical) relations and other kinds of relations such as spatio-temporal ones. This is based on an important hypothesis in SDRT, namely that in a coherent discourse each constituent is attached to another one by a discourse relation, not only for space-time coherence, but also to account for general phenomena such as anaphora.

However, since discourse relations introduce spatio-temporal constraints between the constituents they relate, adverbials, through their spatio-temporal semantics, restrain the possible discourse relations between the constituents.

In section 2.1, we will first expound the lexical semantics of the adverbials, that is, their contribution to the construction of the "current constituent" corresponding to the sentence they modify. In section 2.2, we will see how this contribution modifies the spatio-temporal semantics of the two discourse relations we will consider here, Narration and Background, and thus how locating adverbials affect the structure of discourse.

## 2.1 Formalisation of adverbials

The adverbials we study here are all sentence adjoins, which means that they take a proposition  $P$  as argument and yield a new proposition representing the combination of the adverbial semantics with the content of  $P$ . We adopt the same  $\lambda$ -calculus formalism as in [Ash93].

In our formalisation we will make use of two series of functions, called  $t_\beta$  and  $l_\beta$ , introduced systematically for each constituent  $\beta$ . These functions that respectively take times and locations as arguments and assign them the same type of entities, express the contribution of locating adverbials to the principle of spatio-temporal localisation which has been introduced above.  $t_\beta$  models the shift on the time of the constituent of attachment  $\alpha$ , possibly introduced by an adverbial in the current constituent  $\beta$ . If there is no locating adverbial of time or space-time in  $\beta$ , then  $t_\beta$  is the identity function. Similarly,  $l_\beta$  models the shift on the location of  $\alpha$  possibly introduced by a locating adverbial of space or space-time in  $\beta$ .

Each constituent also systematically contains a discourse referent introduced by the VP called "main eventuality" [Ash93] and noted  $e_\beta$ . This referent designates the main event or state of the sentence, that is to say, the eventuality that locating adverbials we consider in this paper modify.

### 2.1.1 Locating Time Adverbials (LTA)

The axiom below models the semantics of anaphoric LTAs of category C0-T introducing a posteriority relation such as *puis*, *après*, or *ensuite*.

They introduce a time  $t$ , posterior to the main eventuality of the constituent of attachment  $P'$ , in which the main eventuality of the sentence  $P$  that the adverbial modifies is temporally included. This time is also used to fix the value of the function  $t_{\text{puis}(P)}$ , that is, the function of time shift associated to the proposition resulting from combining the semantics of the adverbial *puis* and the proposition  $P$  modelling the semantics of the sentence it modifies. Since these LTAs are purely temporal, they do not alter the location shift function associated to  $P$ , so here  $l_{\text{puis}(P)}$  is just  $l_P$ .

(Ad1)  $\llbracket \text{ALT-puis} \rrbracket = \lambda P \exists t \exists P' [\forall P' \& P'=? \& \text{Time}(t) \& e_P < t \& e_P \leq t \& t_{\text{puis}(P)} = t_{\text{puis}} \& \forall t' t_{\text{puis}(t')} = t \& l_{\text{puis}(P)} = l_P]$

The fact that *puis* is anaphoric is formally represented by the condition  $P'=?$ , which, like in DRT, calls for an anaphora resolution. The resolution will be achieved in SDRT after the attachment, so that in this case,  $P'$  will be identified with the constituent of attachment.

The same kind of axiom can be build to represent LTAs of category C3-T such as *deux heures plus tard*, *une semaine avant* :

(Ad2)  $\llbracket \text{LTA-deux-heures-plus-tard} \rrbracket = \lambda P \exists t \exists P' [\forall P' \& P'=? \& \text{Time}(t) \& \text{Distance}(\min_t(e_P, t_P(e_P)), t, 2h) \& \min_t(e_P, t_P(e_P)) < t \& e_P \leq t \& t_{2-h-p-t(P)} = t_{2-h-p-t} \& \forall t' t_{2-h-p-t}(t') = t \& l_{2-h-p-t(P)} = l_P]$

All adverbials of category C3 and C4 introduce a distance condition. In this case, a temporal distance of 2 hours is specified between the time of the adverbial  $t$  and a temporal referent anaphorically determined. This anaphoric referent usually is the main eventuality of the constituent of attachment  $e_P$ , but when this eventuality is a state, the distance has to be calculated from a time having more precise boundaries, given by the time shift function of the constituent  $P'$ , as in example (38) below. The choice between the two possibilities is carried out

by the function of temporal minimum,  $\min_t$ . The predicate Distance calls for the use of a component external to the discourse theory, TWK, for Temporal World Knowledge<sup>8</sup>.

(38) *A midi, Marie dormait. Deux heures plus tard, elle se leva.* (At noon, Marie was sleeping. Two hours later, she got up.)

For independent adverbials of C1-T such as *le 7 février 1995* we have the following axiom :

(Ad3)  $\llbracket \text{LTA-le-7-février-1995} \rrbracket = \lambda P \exists t [\forall P \& \text{Time}(t) \& \text{Day}(t) \& \text{Calend}(t, 7.02.95) \& e.p \subset t \& t.7-02-95(P) = t.7-02-95 \& \forall t' t.7-02-95(t') = t \& l.7-02-95(P) = l.p]$

These adverbials also make use of TWK, with the predicate Calend that anchors directly a time into the calendar.

We now give the semantics of an anaphoric adverbial of category C2-T, *jusqu'à midi*.

(Ad4)  $\llbracket \text{LTA-jusqu'à midi} \rrbracket = \lambda P \exists t \exists t' \exists P' [\forall P \& P'=? \& \text{Time}(t) \& \text{Day}(t) \& e.p \subset t \& \text{Time}(t') \& \text{Hour}(t') \& t' \subset t \& \text{Calend}(t', 12h) \& \text{End}(e.p) \subset t' \& t.j-a-m(P) = t.j-a-m \& \forall t'' t.j-a-m(t'') = t' \& l.j-a-m(P) = l.p]$

There is in this case a major difference with the adverbials we have seen: *jusqu'à midi* doesn't localise temporally the whole eventuality of the sentence it modifies at the time specified *midi*, but only the end of this eventuality. We actually assume that each eventuality  $e$  introduces two times, a first time  $\text{Init}(e)$  and a last time  $\text{End}(e)$ . These times are included in the time of  $e$  if it is an event, but only mark its boundaries if it is a state.

### 2.1.2 Spatio-temporal interpretation of LTAs (LTSA)

We only give the axiom expressing the spatio-temporal interpretation of *puis*, as used in sentence (4) of example (15). The axioms expressing the spatio-temporal interpretation of other LTAs can be derived the same way from (Ad1-4).

(Ad5)  $\llbracket \text{LTSA-puis} \rrbracket = \lambda P \exists t \exists l \exists P' [\forall P \& P'=? \& \text{Time}(t) \& e.p \subset t \& e.p \subset t \& \text{Loc}(l) \& \forall y \{ \text{Mobile}(y, e.p) \rightarrow (P(\text{ST}(y, t), \text{ST}(l)) \& \forall l' (P(\text{ST}(y, t), \text{ST}(l')) \rightarrow P(\text{ST}(l), \text{ST}(l')))) \} \& P(\text{ST}(e.p), \text{ST}(l)) \& t.puis(P) = t.puis \& \forall t' t.puis(t') = t \& l.puis(P) = l.puis \& \forall l' l.puis(l') = l]$

The spatio-temporal interpretation is expressed by the fact that the eventuality  $e.p$  is also spatially situated at a location  $l$  and that the value of  $l.puis(P)$  is now fixed by this location.  $l$  is determined indirectly by the time  $t$  explicitly introduced by the adverbial. It is the smallest location where all the mobile agents of  $e.p$  are situated at  $t$ . The situation in a location is expressed using the predicate  $P$  of spatio-temporal inclusion and the function  $\text{ST}$  which gives the space-time portion occupied by its first argument, possibly restricted by the time of the (optional) second argument. Locations, times, eventualities (events and states), objects, and space-time portions are the kinds of entities we have encountered up to here. A general view on the ontology and the theory of space-time on which our work is grounded may be found in [AAB94].

### 2.1.3 Locating Space Adverbials (LSAs)

The axiom (Ad6) models the semantics of anaphoric LSAs of C3-S such as *deux kilomètres plus loin, à un kilomètre de là*. Similarly to LTAs which introduce a time, these adverbials introduce a new referent of location  $l$ , in which the eventuality  $e.p$  is localised and that fixes the value of  $l_{adv}(P)$ :

(Ad6)  $\llbracket \text{LSA-deux-kilomètres-plus-loin} \rrbracket = \lambda P \exists l \exists P' [\forall P \& P'=? \& \text{Loc}(l) \& \text{Distance}(\text{Goal}(e.p), l, 2km) \& P(\text{ST}(e.p), \text{ST}(l)) \& l.2-k-p-l(P) = l.2-k-p-l \& \forall l' l.2-k-p-l(l') = l \& t.2-k-p-l(P) = t.p]$

The distance which determines the location  $l$  is calculated from the final location of the eventuality  $e.p$ , called  $\text{Goal}(e.p)$ . To correctly deal with the discourse effects of motion events, we indeed suppose that each eventuality introduces a Source location, a Goal location, as well as a sequence of locations, its Path; for details see [AAB94].

<sup>8</sup>This component encodes world knowledge about calendars and general time notions. In the case of the distance calculus, this component will be used to adjust the types of the first two arguments of the predicate, and to anchor the discourse referents into "absolute" referents which are sometimes necessary to check discourse coherence.

(Ad7) models the semantics of independent C1-S LSAs such as *à Toulouse, devant la maison de Jean*.

(Ad7)  $\llbracket \text{LSA-à-Toulouse} \rrbracket = \lambda P \exists l [\forall P \ \& \ \text{Loc}(l) \ \& \ \text{Toulouse}(l) \ \& \ P(\text{ST}(e.p), \text{ST}(l)) \ \& \ l_{\text{à-Toulouse}}(P) = l_{\text{à-Toulouse}} \ \& \ \forall l' l_{\text{à-Toulouse}}(l') = l \ \& \ t_{\text{à-Toulouse}}(P) = t_P]$

#### 2.1.4 Spatio-temporal interpretation of LSAs (LSTAs)

We give below the axiom expressing the spatio-temporal interpretation of anaphoric adverbial of category C3-S such as *dix kilomètres plus loin*, as used in examples (15,16) and with a similar adverbial in (28,30).

(Ad8)  $\llbracket \text{LSTA-dix-kilomètres-plus-loin} \rrbracket = \lambda P \exists l \exists t \exists P' [\forall P \ \& \ P'=? \ \& \ \text{Loc}(l) \ \& \ \text{Distance}(\text{Goal}(e.p), l, 10\text{km}) \ \& \ P(\text{ST}(e.p), \text{ST}(l)) \ \& \ \text{Time}(t) \ \& \ e.p < t \ \& \ \forall y \{ \text{Mobile}(y, e.p') \rightarrow (P(\text{ST}(y,t), \text{ST}(l)) \ \& \ \forall t' (P(\text{ST}(y,t'), \text{ST}(l)) \rightarrow (t' < t \rightarrow t' < \text{End}(e.p')))) \} \ \& \ e.p \subseteq t \ \& \ l_{10-k-p-l}(P) = l_{10-k-p-l} \ \& \ \forall l' l_{10-k-p-l}(l') = l \ \& \ t_{10-k-p-l}(P) = t_{10-k-p-l} \ \& \ \forall t' t_{10-k-p-l}(t') = t]$

The spatio-temporal interpretation is expressed by the fact that the eventuality  $e.p$  is also situated temporally in a time  $t$ , which also fixes the value of  $t_{10-k-p-l}(P)$ .  $t$  is linked to the location  $l$  explicitly introduced by the adverbial: it is the first time after  $e.p'$  when its mobiles are in  $l$ .

Adverbials of category C4-S, like *depuis deux kilomètres*, necessarily have a spatio-temporal interpretation and, in narratives, are always anaphoric, since the landmark used as the origin of the distance calculus comes from the eventuality of the constituent of attachment. These adverbials, as those of C4-T, are characterised by the use of two "boundaries" —the landmark  $e.p'$  and the pair of referents  $(t, l)$  given by the distance calculus— to specify the spatio-temporal extension of the eventualities they modify. They are also specific in the sense that they do not operate any shift on the time and location of the constituent of attachment, since the landmark, which is overlapped by the current eventuality, is precisely given by the main eventuality of the constituent of attachment.

(Ad9)  $\llbracket \text{LSTA-depuis-2-kilomètres} \rrbracket = \lambda P \exists l \exists t \exists P' [\forall P \ \& \ P'=? \ \& \ \text{Loc}(l) \ \& \ \text{Distance}(\text{Goal}(e.p'), l, 2\text{km}) \ \& \ P(\text{ST}(\text{Init}(e.p), \text{ST}(l)) \ \& \ \text{Time}(t) \ \& \ t < e.p' \ \& \ \forall y \{ \text{Mobile}(y, e.p') \rightarrow (P(\text{ST}(y,t), \text{ST}(l)) \ \& \ \forall t' (P(\text{ST}(y,t'), \text{ST}(l)) \rightarrow (t < t' \rightarrow \text{End}(e.p') < t')) \} \ \& \ \text{Init}(e.p) \subseteq t \ \& \ O_l(e.p, e.p') \ \& \ l_{d-2-k}(P) = l_P \ \& \ t_{d-2-k}(P) = t_P]$

#### 2.1.5 Sentence without LTA nor LSA

When a sentence doesn't include any locating adverbial, the time and location shift functions are the identity. It is important to note that this axiom is always used, for any sentence to initialise the value of  $t_P$  and  $l_P$ ,  $P$  representing the semantics of the sentence without its adverbials.

(Ad10)  $\text{no-loc-adv}(P) \rightarrow (t_P = I \ \& \ l_P = I)$

#### 2.1.6 Sentence with more than one adverbial

When there are two locating adverbials, both an LTA and an LSA, the semantics of the sentence is just the result of applying recursively each adjoin's semantics onto the main proposition, thus following compositionality rules.

However, further studies are needed to understand the interaction between two adverbials of the same type, or when one of the two is spatio-temporal. In some cases, the second adverbial only characterises further the time or location introduced by the first, as in:

(39) *Jean déjeuna à 8h. Puis, à 10 h, il alla à la piscine.* (Jean ate breakfast at 8 o'clock. Then, at 10, he went to the swimming pool).

In other cases, a two-step anaphora occurs, one with respect to the constituent of attachment, and the other with respect to the time or location introduced by the other adverbial. But the syntactic order of the adverbials doesn't always match the order of these anaphors, as may be seen in sentences (2) of the following texts that have exactly the same interpretation:

- (40) (1) *Jean quitta son domicile à 8h.* (2) *Après la sortie du village, à gauche de la route, un arbre tomba sur une maison.* (Jean left home at 8 o'clock. After the village, on the left of the road, a tree fell on a house).
- (41) (1) *Jean quitta son domicile à 8h.* (2) *A gauche de la route, après la sortie du village, un arbre tomba sur une maison.* (Jean left home at 8 o'clock. On the left of the road, after the village, a tree fell on a house)

We didn't study in more details such interactions yet, so we leave this problem for a later stage of this work.

## 2.2 Spatio-temporal effects of discourse relations

The results presented in this section take up the spatio-temporal semantics of two discourse relations, narration and background, as axiomatised in [AAB94]. They modify those axioms to account for the possible time or location shift introduced by adverbials, so improving on the (quick) analysis of locating adverbials proposed in [AAB94].

In [AAB94], building on the previous analyses of [LA93], a relation of narration between two constituents  $\alpha$  and  $\beta$  is shown to entail a temporal overlap between the resulting state of  $e_\alpha$ ,  $\text{Poststate}(e_\alpha)$ , and the state preceding  $e_\beta$ ,  $\text{Prestate}(e_\beta)$ , in absence of locating adverbials. It is also shown, from general spatio-temporal properties of these states and from the semantics of motion events, that both a relation of temporal precedence between the eventualities  $e_\alpha$  and  $e_\beta$ , and an identity relation between  $\text{Goal}(e_\alpha)$  and  $\text{Source}(e_\beta)$  hold.

Our modification just needs to integrate the possible time shift of a possible adverbial in  $\beta$  over the time taken from the constituent of attachment,  $\text{Poststate}(e_\alpha)$ . This leads to the following axiom:

$$(\text{Ar1}) \text{ Narration}(\alpha, \beta) \rightarrow O_t(t_\beta(\text{Poststate}(e_\alpha)), \text{Prestate}(e_\beta))$$

As far as the spatial effects are concerned, it is important to note that, as in [AAB94], the effects of narration on locations are a joint consequence of this axiom and of more general properties of eventualities.

As regards the semantics of the background relation, it is assumed in [AAB94] that a background relation between two constituents  $\alpha$  and  $\beta$  entails a relation of spatio-temporal overlap between the space-time portions occupied by the two eventualities  $e_\alpha$  and  $e_\beta$ .

The modification due to the possible presence of an adverbial in  $\beta$  is the replacement of  $\text{ST}(e_\alpha)$  by the space-time portion of a location which is the result of applying the location shift function over its final location  $\text{Goal}(e_\alpha)$ , at a time which is the result of applying the time shift function over the time of  $e_\alpha$ . This is expressed by means of the following axiom:

$$(\text{Ar2}) \text{ Background}(\alpha, \beta) \rightarrow O_{st}(\text{ST}(l_\beta(\text{Goal}(e_\alpha)), t_\beta(e_\alpha)), \text{ST}(e_\beta))$$

## Conclusion

In this work we have described and formalised the contribution of locating adverbials of space and time to the spatio-temporal structure of discourse. First, the linguistic analysis of these adverbials has brought out the different ways a locating adverbial can refer to an area of space or time. At the discursive level, the linguistic study has pointed out different kinds of interpretations (temporal, spatial or spatio-temporal). Then, we have modelled these interpretations to account for the adverbials contribution in the construction of a SDRS.

Concerning these interpretations, we have not tackled the problem of adverbials ambiguity. We have seen that time adverbials are always ambiguous, whereas space adverbials are only so in certain cases (cf §1.3.2), according to syntactic-semantic properties specific to the adverbial. The other parameters that have to be taken into account to disambiguate are related to the sentence, e.g. to the kind of eventuality it contains, and more generally to the discourse context, e.g. to the fact that the current sentence is involved or not in the description of a trajectory. So, a

complete study should identify all these parameters and analyse in detail their complex interactions in order to be able to calculate the nature of the interpretation.

There is another unsolved ambiguity which is syntactic. When a locating adverbial is postponed, it may be verb complement (argument), VP-adjoin or S-adjoin. Verb complements are easily detected from the argument structure of the verbs but work need to be done in order to distinguish between the two other cases. Moreover, it may be the case that for the sentential adverbials we have dealt with, their position (preposed or postponed) have an influence on the discursive aspects of their interpretation. As discussed in [dSw94], topicalization sometimes occurs when adverbials are preposed. We have left this point for further studies.

At last, and more generally, locating adverbials surely have an additional effect on discourse structure through the construction of topics [Ash93], at least in what regards their spatio-temporal content. This last point comes within the scope of a work we are currently carrying out on the construction of topics in SDRT for narratives describing trajectories.

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