Discourse dependency structures as constrained DAGs

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Abstract

I show that the semantic structure for discourses, understood as a dependency representation, can be mathematically characterized as DAGs, but these DAGs present heavy structural constraints. The argumentation is based on a simple case, i.e. discourses with three clauses and two discourse connectives. I show that only four types of DAGs are needed for these discourses.

1 Introduction

Within a multi-level approach to discourse processing, this paper focuses on the semantic level. This level reflects the discourse structure (*how things are said, how the discourse is rhetorically organized*). This structure plays an important role, e.g., it constrains both anaphora resolution and the attachment of incoming propositions in understanding. I assume that the informational content level (*what is said*) is based on first order logic.

A nice tool for the semantic level is dependency graphs. This is what is adopted in RST (rhetorical structures correspond roughly to dependency structures), but it is not the case in SDRT[1]: discourse structures, called SDRSs, are represented as boxes. Nevertheless, it is easy to translate the conditions of an SDRS into a dependency graph (Section 2.1).

Our goal in this paper is to determine to which mathematical object dependency structures for discourses correspond. In RST, it is a basic principle that this object is a tree. In SDRT, the issue is not discussed. I will show that this object is an ordered directed acyclic graph (DAG), which may be not tree shaped. Some authors, e.g. (Bateman, 1999) and (Blackburn and Gardent, 1998), have already brought forward discourse structures which are not tree shaped. However nobody says explicitly that discourse dependency structures are DAGs considering seriously all the consequences of this claim[2].

Our argumentation is based on one of the simplest cases of discourses, namely discourses of type *S1* $Conn_a$ *S2* $Conn_b$ *S3* with two discourse connectives ($Conn_{a/b}$) and three clauses (*Si*). A discourse connective *Conn* can be either a subordinating or coordinating conjunction or a discourse adverbial. It denotes a discourse relation R, a predicate with two arguments. I will show (Section 3) that they are topologically only four types of DAGs for these discourses. This allows us to state that DAGs for these discourses are not arbitrary: they satisfy structural constraints (Section 5). I stipulate that this result can be extrapolated to discourses in which sentences are simply juxtaposed without discourse connective. It can also be foreseen that dependency structures for more complex discourses (e.g. discourses with more than three clauses) are also constrained DAGs.

This can be seen as an important result since many authors in the discourse community hang on trees as discourse structures, even if it means to use artificial trees as shown in Section 2.4. They reject DAGs because they view them as completely unconstrained (except the acyclicity constraint) and so as unusable in discourse processing. This is truly not the case. Semantic dependency structures for discourses are ordered DAGs but these DAGs present heavy structural constraints, which can help us to cut down the number of possibilities when processing discourses (although this issue is not discussed here).

Before getting to the heart of the matter, let us give some preliminaries.

[1] SDRT stands for Segmented Discourse Representation Theory (Asher, 1993) (Asher and Lascarides, 2003). It is an extension of DRT, Discourse Representation Theory (Kamp and Reyle, 1993). (S)DRS stands for (Segmented) Discourse Representation Structure. RST stands for Rhetorical Structure Theory (Mann and Thompson, 1987).

[2] For example, (Blackburn and Gardent, 1998) exhibits an example the structure of which is a “re-entrant graph”, see (6c). However, in (Duchier and Gardent, 2001), the semantic representations of discourses are always tree shaped.

2 Preliminaries

2.1 Translation of an SDRS into a DAG

Formally, an SDRS is is a couple of sets $\langle$**U**,**Con**$\rangle$. **U** is a set of labels of DRS or SDRS which may be viewed as "speech act discourse referents". **Con** is a set of conditions on labels of the form:

- $\pi : K$, where π is a label from **U** and K is a (S)DRS (*labelling*);
- *R*(π_i, π_j), where π_i and π_j are labels and *R* a discourse relation (*structuring*).

The set of conditions can be translated into a dependency graph by applying the following rules.

- A condition *R*(π_i, π_j) is translated as a binary tree, the root of which is *R*, the ordered leaves are π_i and π_j. π_i is the first argument of *R* (it corresponds generally to the "nucleus" in RST), π_j its second argument (it corresponds generally to the "satellite" in RST).
- A condition $\pi : K$ in which K is a SDRS leads to a sub-graph obtained by translating recursively the conditions in K, this sub-graph is labeled π.
- A condition $\pi : K$ in whick K is a DRS is simply translated as π.

Figures 1 and 2 give examples of this translation mechanism.

2.2 Linear order

Subordinate conjunctions (noted as *Conj*) are the only discourse connectives which allow us to invert the order of the sentences: a subordinate clause can be postposed (the linear order is then the "canonical" one *S1 Conj (,) S2*) or preposed (then the non canonical order is *Conj S2, S1*). Following works in MTT[3], a trace of the linear order can be recorded in a semantic dependency representation, however it should not affect its structure. From this principle, the position of subordinate clauses should not affect semantic structures. That is to say that *S1 Conj S2* and *Conj S2, S1* are both represented as *R*(π_1, π_2) in which π_i is the semantic representation of S_i.

What happens for a sentence with two subordinate clauses? Establishing the canonical order with only postposed subordinate clauses may generate ambiguities: for example, a sentence X of the type *Conj*$_a$ *S1, S2 Conj*$_b$ *S3*, with a preposed subordinate clause and a postposed one, corresponds, in the canonical order, either to Y_1 = *S2 Conj*$_a$ *S1 Conj*$_b$ *S3* or to Y_2 = *S2 Conj*$_b$ *S3 Conj*$_a$ *S1*. In (Danlos, 2003), I have shown, using LTAG as a syntactic formalism, that X receives two syntactic analyses which allow us to compute Y_1 and Y_2. From the principle that the position of subordinate clauses does not affect semantic structures (see above), X does not yield any other semantics than Y_1 and Y_2, i.e. the semantics of X is included in the semantics of Y_1 and Y_2.

As a consequence, our study on the semantics of sentences with two subordinate clauses can be limited to the study of such sentences in the canonical order. Since subordinate conjunctions are the only discourse connectives which allow us to invert the order of the sentences, our study on the semantics of discourses with three clauses and two discourse connectives can be limited to discourses which satisfy the linear order *S1 Conn*$_a$ *S2 Conn*$_b$ *S3*.

2.3 Compositionality principle

Let $\mathcal{D}_n$ be a DAG with n leaves representing the dependency structure of a discourse D_n. It will be shown that the following principle is true: if $\mathcal{D}_p$ is a sub-graph of $\mathcal{D}_n$ with p leaves, $1 < p < n$, then the discourse D_p corresponding to $\mathcal{D}_p$ can be inferred from the discourse D_n. On the other hand, it will be shown that the converse principle is not always true, i.e. if a sub-discourse D_p can be inferred from D_n, it does not always mean that the graph $\mathcal{D}_p$ is a sub-graph of $\mathcal{D}_n$.

2.4 Interpretation of dependency relations in trees

Two different ways can be used to interpret dependency relations in trees: the standard one used in mathematics and computer science, and the "nuclearity principle" put forward in RST (Marcu, 1996). Let us illustrate them with the tree in Figure 3. With the standard interpretation, the first argument (nucleus) of R$_c$ is its left daughter (the *tree* rooted at R$_a$), while with the nuclearity principle, it is π_1 (the *leaf* which is the first argument (nucleus) of R$_a$). Similarly, with the standard interpretation, the second argument (satellite) of R$_a$ is its right daughter (the *tree* rooted at R$_b$), while with the nuclearity principle, it is π_2 (the *leaf* which is the first argument (nucleus) of R$_b$). To put it in a nutshell, the arguments of a discourse relation can be intermediary nodes or leaves with the standard interpretation, while they can only be leaves with the nuclearity interpretation.

I will show (Section 4) that the standard interpretation should be adopted. The point I want to make now is that one could argue that the nuclearity interpretation should be adopted instead, but one should not feel free to use both interpretations for the same tree. This is however what is done by some authors. For example, in (Webber et al., 2003), the tree in Figure 4 is the discourse structure associated with (1).

[3] MTT stands for Meaning to Text Theory, a dependency formalism for sentences (Mel'cuk, 2001).

(1) a. Although John is very generous -
b. if you need some money,
c. you only have to ask him for it -
d. he's very hard to find.

Let us show that some predicate-argument relations are given by the nuclearity interpretation and other ones by the standard interpretation in their tree. From (1), (2) can be inferred. This is evidence that the arguments of the discourse relation "concession" in their tree are a and d. These predicate-argument dependencies are given by *the nuclearity interpretation*.

(2) a. Although John is very generous,
d. he's very hard to find.

From (1), (3) can also be inferred. This is evidence that the arguments of "elaboration" in their tree are a and the tree rooted at "condition". These dependencies are given by *the standard interpretation*.

(3) a'. John is very generous -
b. if you need some money,
c. you only have to ask him for it.

Nevertheless, one should not feel free to use trees relying on a mixed interpretation (the standard and nuclearity ones), **except if** the conditions governing the use of one or the other interpretation are formally defined[4] . In Section 4, I will make an attempt to lay down rules on the choice of one of these two interpretations according to the "coordinating or subordinating" type of discourse relations. However, this enterprise leads to a failure: no general rule can be laid down. Mixed interpretation for trees should thus be discarded. As a consequence, one has to admit that discourse structures are DAGs, for example, the DAG in Figure 5 for (1). This DAG is conform to our compositionality principle: it can be viewed as the fusion of the dependency graphs for (2) and (3), while the discourse in (1) can be viewed as the fusion of the discourses in (2) and (3), with the factorization of *John is very generous* which corresponds to the factorization of "a" in the DAG.

3 DAGs for *S1 Conn$_a$ S2 Conn$_b$ S3*

It is standardly assumed that the arguments of a discourse relation expressed through a discourse connective are given by text units[5] which are adjacent to the discourse connective (Mann and Thompson, 1987), (Duchier and Gardent, 2001). However, there exist counter-examples to this adjacency principle, see (7) below. So I make a weaker assumption, that I call "left1-right2 principle" which states the following: the first (resp. second) argument of a discourse relation expressed through a discourse connective is given by a text unit which occurs on the left (resp. right) of the discourse connective. This principle makes sense only for discourses in the canonical order. Recall (Section 2.2) that our study can be limited to discourses which satisfy the canonical linear order *S1 Conn$_a$ S2 Conn$_b$ S3*.

A consequence of the left1-right2 principle in discourses of the type *S1 Conn$_a$ S2 Conn$_b$ S3*, is that the first argument of R$_a$ is compulsorily π_1, the only text unit which occurs on the left of *Conn$_a$*. On the other hand, its second argument may vary depending on scope. More specifically, it may *a priori* be:

- either the representation of the whole right hand side of *Conn$_a$*, i.e. the semantic representation of the text unit *S2 Conn$_b$ S3*. I call this case "wide scope" of *Conn$_a$* or R$_a$. It leads to DAG (A) in Figure 6[6]. The dependency relations in (A), which is tree shaped, must be interpreted in the standard way: the second argument of R$_a$ is its right daughter, i.e. the tree rooted at R$_b$.

- or the representation of one of the two clauses on the right of *Conn$_a$*. This case leads either to tree (A1) = R$_a(\pi_1, \pi_2)$ or to tree (A2) = R$_a(\pi_1, \pi_3)$.

Similarly, the second argument of R$_b$ is compulsorily π_3, the only text unit on the right of *Conn$_b$*, but depending on the scope of *Conn$_b$*, its first argument may *a priori* be R$_a(\pi_1, \pi_2)$, see (B) in Figure 6, or π_2 in (B1) = R$_b(\pi_2, \pi_3)$ or π_1 in (B2) = R$_b(\pi_1, \pi_3)$.

We are now ready to study the combinatory coming from the fusion of DAGs (Ai) and (Bj). The goal is to distinguish the DAGs which correspond to coherent discourses *S1 Conn$_a$ S2 Conn$_b$ S3* from those which do not (i.e. which cannot be linguistically realized).

A) Graph (A): This graph is linguistically realized in (4a)[7]. The wide scope of *Conn$_a$* = *because* can be seen in the dialogue in (4b-c) in which the answer is *Because S2 Conn$_b$ S3*[8]. In conformity with our compositionality principle, (A) includes the sub-graph R$_b(\pi_2, \pi_3)$ and *S2 Conn$_b$ S3* can be inferred: if (4a) is true, then it is true that *Fred played tuba while Mary was taking a nap*. The reader will check that the adverbial *Conn$_a$* = *therefore* in (4d) has also wide scope.

[4] I thank an anonymous reviewer for drawing my attention on this point.

[5] A text unit (noted as $\mathcal{U}$) is either a clause or, recursively, a non discontinuous sequence $\mathcal{U}_i$ *Conn* $\mathcal{U}_j$.

[6] In this figure, as well as in other subsequent figures, the label for the sub-graph is omitted.

[7] To indicate that it is stressed when spoken, the word *while* is written in capital letters in (4).

[8] When *while* is not stressed, the question in (4b) may be given as answer only *Because S2*. The interpretation of (4a) corresponds then to DAG (C) in Figure 6.

(4) a. Mary is in a bad mood because Fred played tuba WHILE she was taking a nap.
b. - Why is Mary in a bad mood?
c. - Because Fred played tuba WHILE she was taking a nap.
d. Fred wanted to bother Mary. Therefore, he played tuba WHILE she was taking a nap.

B) Graph (B): This graph is linguistically realized in (5a). The wide scope of *Conn*$_b$ = *in order that/to* can be seen in the dialogue in (5b-c) in which the question is *Why S1 Conn*$_b$ *S2?* In conformity with our compositionality principle, (B) includes the sub-graph R$_a(\pi_1, \pi_2)$ and *S1 Conn*$_b$ *S2* can be inferred from (5a). The adverbial *Conn*$_b$ = *therefore* in (5d) has also wide scope.

(5) a. Fred played tuba WHILE Mary was taking a nap in order to bother her.[9]
b. - Why did Fred play tuba WHILE Mary was taking a nap?
c. - In order to bother her.
d. Fred played tuba WHILE Mary was taking a nap. Therefore, she is in a bad mood.

C) Graphs (A1) and (B1): The fusion of (A1) and (B1) leads to DAG (C) in Figure 6. This DAG is not tree shaped: $\pi 2$ has two parents. It is linguistically realized in (6a), in which S2 is said to be "factorized" since both *S1 Conn*$_a$ *S2 = Mary is in a bad mood because her son is ill* and *S2 Conn*$_b$ *S3 = Her son is ill. Specifically, he has an attack of bronchitis* can be inferred from (6a), which is in conformity with our compositionality principle since (C) includes both (A1) = R$_a(\pi_1, \pi_2)$ and (B1) = R$_b(\pi_2, \pi_3)$. A similar situation is observed in (6b) and (6c).

(6) a. Mary is in a bad mood because her son is ill. Specifically, he has an attack of bronchitis.
b. Fred played tuba. Next he prepared a pizza to please Mary.
c. Fred was in a foul humor because he hadn't slept well that night because his electric blanket hadn't worked.[10]

D) Graphs (A1) and (B2): The fusion of (A1) and (B2) leads to DAG (D) in Figure 6. This DAG is not tree shaped: $\pi 1$ has two parents. It is linguistically realized in (7a), in which S1 is said to be "factorized" since both *S1 Conn*$_a$ *S2 = Fred prepared a pizza to please Mary* and *S1 Conn*$_b$ *S3 = Fred prepared a pizza. Next he took a nap* can be inferred, in conformity with our compositionality principle. A similar situation is observed in (7b) and (7c).

[9]When *while* is not stressed, the interpretation of (5a) may correspond to DAG (D) in Figure 6.

[10]This discourse is a modified version (including discourse connectives) of an example taken in (Blackburn and Gardent, 1998). These authors acknowledged that the structure of this discourse is a "re-entrant graph".

(7) a. Fred prepared a pizza to please Mary. Next, he took a nap.
b. Fred prepared a pizza, while it was raining, before taking a walk.
c. Fred is ill. More specifically, he has an attack of bronchitis. Therefore, Mary is in a bad mood.

In discourses analyzed as (D), *S3* is linked to *S1* (which is not adjacent) and not to *S2* (which is adjacent). Therefore, these discourses are counter-examples to the adjacency principle adopted in RST.

The DAG (D) exhibits crossing dependencies and it does correspond to coherent discourses. (D) is thus a counter-example to the stipulation made by (Webber et al., 2003), namely "*discourse structure itself does not admit crossing structural dependencies*"[11].

E) Graphs (A2) and (B1): The fusion of (A2) and (B1) leads to DAG (E) in Figure 7, in which $\pi 3$ has two parents. I cannot find any discourse corresponding to (E), i.e. with *S3* factorized, although I wrote down all possible examples I could think of. Laurence Delort, who works on (French) corpus neither. I cannot prove that something does not exist, I can just stipulate it. However there is some evidence, coming from syntax, which supports my stipulation when *Conn*$_a$ and *Conn*$_b$ are both subordinating conjunctions (*Conj*). Namely, no standard syntactic analysis of sentences of the type *S1 Conj*$_a$ *S2 Conj*$_b$ *S3* can lead, in a compositional way, to an interpretation in which *S3* is factorized[12]. As I see no reason to make a difference between subordinating conjunctions and other discourse connectives at the semantic level (see note 11), I extrapolate this result to other discourse connectives.

F) Graphs (A2) and (B2): The fusion of (A2) and (B2) leads to DAG (F) in Figure 7. This graph cannot represent a discourse *S1 Conn*$_a$ *S2 Conn*$_b$ *S3* since it does not include π_2.

So far, we have examined only cases where a discourse relation has two arguments. It remains to examine what is called "multi satellite or nucleus cases" in RST, in which a discourse relation is supposed to have more than two arguments.

G) Graphs (A1), (A2) and (B2): The fusion of (A1), (A2) and (B2) leads to DAG (G) in Figure 7. This DAG could be said to be linguistically realized in (8a): since

[11]Among discourse connectives, (Webber et al., 2003) distinguish "structural connectives" (e.g. subordinating conjunctions) from discourse adverbials including *then, also, otherwise*, ... They argue that discourse adverbials do admit crossing of predicate-argument dependencies, while structural connectives do not. I don't make any distinction between discourse connectives at the semantic level, but I emphasize that (7b) comprises only structural connectives (subordinating conjunctions) and its structure exhibits crossing structural dependencies.

[12]Recall that I feel entitled to make this claim because I have studied in detail the syntactic analyses of sentences of the type *S1 Conj*$_a$ *S2 Conj*$_b$ *S3* in (Danlos, 2003).

both *S1* $Conn_a$ *S2* and *S1* $Conn_a$ *S3* can be inferred from (8a), one may be willing to lay down both R$_a(\pi_1, \pi_2)$ and R$_a(\pi_1, \pi_3)$, i.e. to consider (8a) as a multi-satellite case with R$_a$ = Elaboration. R$_b$ = Narration links π_2 and π_3. The following question arises: is R$_b$ in a dependency relation with R$_a$? It is hard to give an answer for (8a). However the answer seems positive for (8b), which could also be analyzed as a multi-satellite case with R$_a$ = Explanation. R$_b$ = Joint links π_2 and π_3. This leads to DAG (G') in Figure 7. However, consider (8c) which differs from (8b) only by the use of *or* instead of *and*. Graphs (G) or (G') would not do justice to (8c): neither $R_a(\pi_1, \pi_2)$ nor $R_a(\pi_1, \pi_3)$ can be laid down. (8c) can only be represented as DAG (A) with R$_a$ = Explanation and R$_b$ = Disjunction.

(8) a. Guy experienced a lovely evening last night. More specifically, he had a fantastic meal. Next he won a dancing competition.[13]
b. Mary is in a bad mood because she had'nt slept well and it is raining.
c. Mary is in a bad mood because she had'nt slept well or it is raining.

It seems clear that (8b) and (8c) should be represented at the semantic level as the very same graph. This graph can only be (A), which is the only possibility for (8c). For the sake of homogeneity and compatibility with SDRT, (8a) should also be represented as (A)[14]. Recall moreover that (4a) with wide scope of $Conn_a$ is also represented as (A). All in all, (A) happens to be a semantic structure which is shared by discourses whose informational content shows quite different relations between the eventualities at stake. Is it a problem? I would say no, because, from (A), semantic to content rules, based on the values of R_a and R_b, can make the difference: they can compute the following (simplified) logical forms, which show that the discourses in (8) and (4a) do not have the same type of informational content as far as the relations between eventualities are concerned, althoug they share the same (dependency) semantic structure:

- for (8a) with R$_a$ = Elaboration and R$_b$ = Narration: $e_1 \wedge e_2 \wedge e_3 \wedge precede(e_2, e_3)$ $\wedge\, subevent(e_1, e_2) \wedge subevent(e_1, e_3)$
- for (8b) with R$_a$ = Explanation and R$_b$ = Joint: $e_1 \wedge e_2 \wedge e_3 \wedge cause(e_1, and(e_2, e_3))$ $\rightarrow e_1 \wedge e_2 \wedge e_3 \wedge cause(e_1, e_2) \wedge cause(e_1, e_3)$
- for (8c) with R$_a$ = Explanation and R$_b$ = Disjunction: $e_1 \wedge e_2 \wedge e_3 \wedge cause(e_1, or(e_2, e_3))$ $\rightarrow e_1 \wedge e_2 \wedge e_3 \wedge (cause(e_1, e_2) \vee cause(e_1, e_3))$
- for (4a) with R$_a$ = Explanation and R$_b$ = Circumstances: $e_1 \wedge e_2 \wedge e_3 \wedge overlap(e_2, e_3)$ $\wedge\, cause(e_1, overlap(e_2, e_3))$

We have touched here a crucial question in discourse processing (within a multi-level approach): to what extent should the semantic (dependency) level (*how things are said*) echo the informational content level (*what is said*)? I don't pretend to give a general answer to this fundamental question. However we have seen that the same semantic dependency structure (or SDRS) can lead to quite different informational contents according to the values of the discourse relations at stake. What is called multi-satellite case in RST, e.g. (8a) or (8b), leads to a logical form in which the same eventuality variable, here e_1, occurs conjunctively multi-times as the argument of the same predicate, e.g. $pred_a(e_1, e_2) \wedge pred_a(e_1, e_3)$ with $pred_a = subevent$ in (8a) and $pred_a = cause$ in (8b). It is unnecessary to represent such a case at the semantic level trough a predicate - a discourse relation - with more than two arguments. The multi-satelitte analysis in RST comes from the following principle: if a subdiscourse D_p can be inferred from a discouse D_n, with $1 < p < n$, then the graph $\mathcal{D}_p$ must be a sub-graph of $\mathcal{D}_n$. This principle is simply wrong. On the other hand, the converse implication is true.

H) Graphs (A1), (B1) and (B2): The fusion of (A1), (B1) and (B2) leads to a DAG which could be said to be linguistically realized in (9). This discourse allows us to infer both *S1 Conn$_b$ S3* and *S2 Conn$_b$ S3*. So it would be classified as a multi-nucleus case in RST. However, by the same argumentation as previously, it should be represented as (B).

(9) Fred washed the dishes and Guy cleaned up the bathroom, while Mary was taking a nap.

I) Graphs (A1), (A2) and (B2): The fusion of these graphs lead to DAG (I) in Figure 8. I cannot find any example corresponding to this DAG.

J) Graphs (A2), (B1) and (B2): Along the same lines, the fusion of these graphs lead to a DAG for which I cannot find any instance.

No other fusion of graphs (A$_i$) and (B$_j$) leads to a DAG which corresponds to a coherent discourse. So we have arrived at the following result:

> The dependency structure of a discourse *S1 Conn$_a$ S2 Conn$_b$ S3* is one of the four DAGs (A), (B), (C) and (D). (A) and (B), which are tree shaped, cover wide scope cases (and multi satellite or nucleus cases in RST). (C) and (D),

[13] This discourse is a modified version (including discourse connectives) of an example taken in (Asher and Lascarides, 2003).

[14] The (A) analysis is the translation of the SDRS proposed by (Asher and Lascarides, 2003) for (8a), namely the SDRS in Figure 1 with R$_a$ = Elaboration and R$_b$ = Narration. π_1 is considered as the "topic" (common theme) for π_2 and π_3.

which are not tree shaped, cover multi parent cases (factorization of a sentence). (D) exhibits crossing dependencies.

Before commenting on this result, let us come back to the interpretation of dependency relations in trees.

4 Interpretation of dependency relations in trees (concluding episode)

First, let us underline the following point. Interpreting tree shaped graphs (A) and (B) with the nuclearity principle amounts to interpreting (A) as (C), and (B) as (D)[15]. But then, cases with wide scope are not taken into account, which is unacceptable. Therefore, the standard interpretation of dependency relations in a tree is needed.

Next, the following question arises: is it possible to state that the dependency relations in a tree should be computed sometimes by the standard interpretation and some other times by the nuclearity one? In the tree (B), this question is instantiated in the following way: should the first argument of R_b be given sometimes by the standard interpretation (it is then the tree rooted at R_a) and some other times by the nuclearity principle (it is then π_1, and (B) is equivalent to (D))[16]? An answer to this question is sound only if it is possible to define formally "sometimes". The only sound answer consists in stating that there exist two types of discourse relations: the dependency relations are computed with the standard interpretation for the first type, and computed with the nuclearity interpretation for the second one. The only types of discourse relations which have been put forward up to now are the "coordinating and subordinating" types (Hobbs, 1979), (Asher and Lascarides, 2003), (Asher and Vieu, 2003). Laurence Delort in (Delort, 2004) has examined, in the framework of SDRT, my DAGs (A)-(D) in studying for each relation R_a or R_b if it could be of the coordinating and/or subordinating type. Her results are summarized in Table 1. This table shows that (B) is possible only when R_a is coordinating and (D) only when R_a is subordinating (in both cases, R_b can be equally coordinating or subordinating). Therefore, it is possible to lay down the following rule: the dependency relations in the tree (B) are computed with the standard interpretation when R_a is coordinating, and with the nuclearity interpretation when R_a is subordinating.

However, let us examine the situation for the tree (A). From Table 1, the reader can check that no rule can be laid down for the dependency relations in (A) when R_b is coordinating: they can be computed with either the standard or the nuclearity interpretation. These two cases are illustrated in (10) with R_a = Contrast and R_b = Narration: (10a) should be analyzed with the standard interpretation of (A) with wide scope of *Conn*$_a$, while (10b) should be analyzed with the nuclearity interpretation of (A), i.e. as (C) with *S2* factorized.

(10) a. Fred has made no domestic chore this morning. However, this afternoon, he wed up the dishes. Next he ran the vacuum cleaner.

b. Fred has made no domestic chore this morning. However, this afternoon, he washed up the dishes. Next he went to see a movie.

In conclusion, a mixed interpretation for trees must be discarded: the coordinating or subordinating type of discourse relations does not allow us to choose between the standard and nuclearity interpretations. As a consequence, since the standard interpretation is needed for wide scope cases, the nuclearity principle should be discarded.

5 Analysis of the result and conclusion

The result I arrived at does not take into account the discourse connectives / relations at stake. However, for a given pair of connectives, it may happen that only some of the DAGs among (A)-(D) are observed. For example, if *Conn*$_a$ is an adverbial and *Conn*$_b$ a subordinate conjunction, then (B) with wide scope of R_b should be excluded. On the top of part of speech considerations, the lexical value of each connective may exclude some of these DAGs. Finally, the distinction between coordinating and subordinating discourse relations must be taken into account. Table 1 from (Delort, 2004) presented as in Table 2 shows that a given DAG among (A)-(D) never corresponds to the $2 \star 2 = 4$ possibilities given by the combinatory $R_{a/b}$ coordinating or subordinating discourse relation.

To put it in a nutshell, there is a maximum of four ordered DAGs representing the semantic structures of discourses *S1 Conn*$_a$ *S2 Conn*$_b$ *S3*. I stipulate that this result can be extrapolated to cases where sentences are simply juxtaposed without discourse connective.

It can be considered that there is only **a few** DAGs corresponding to coherent discourses with three clauses[17]. First, recall that the left1-right2 principle (Section 3) discards right away a number of DAGs, for example (K) in Figure 8 (in (K), R_a is not the mother of π_1). Secondly, among the DAGs which satisfy the left1-right2 principle, some are not instantiated, e.g. (E), and also (F). A look

[15] With the nuclearity principle, the second argument of R_a in (A) is $\pi 2$, and the first argument of R_b in (B) is $\pi 1$.

[16] For the other dependency relations in (B), both interpretations give the same result.

[17] In RST, there are only 2 trees (2 is the number of binary trees with 3 leaves), namely trees (A) and (B), which are supposed to be interpreted with the nuclearity principle (being so interpreted as (B) and (D) respectively). We have seen that this is too restrictive: wide scope cases are not taken into account.

on the topology of the ordered DAGs (A)-(D) allows us to bring forward this other structural constraint: *R_a must "left-dominate"* π_2. The definition of left-dominance in a tree is the following (Danlos, 2003): a node X left-dominates a node Y iff Y is a daughter of X (immediate dominance) or there exists a daughter Z of X such that Y belongs to the left-frontier of the tree rooted at Z. For example, R_a left-dominates $\pi 1$, R_b and $\pi 2$ in (A), while R_b left-dominates R_a, $\pi 1$ and $\pi 3$ in (B)[18].

Let us here examine the consequences of this left-dominance constraint in non formal terms. R_a must be the mother of π_1 and must left-dominate π_2. This means that R_a establishes some semantic link between *S1* and *S2*[19]. This result may sound trivial on psycho-linguisitics grounds: what would be a discourse in which the second clause is not linked at all to the first one?[20] It has the following consequence: the semantic representation of a discourse with four clauses and three discourse connectives cannot be DAG (L) in Figure 8. In (L), R_a does not left-dominate π_2, or informally, there is no link between *S1* and *S2*. (L) includes two crossing dependencies.

I have just half-opened the door towards an extension of this study to discourses with more than three clauses. I stipulate that the conclusion of this forthcoming study will be the same. Namely, semantic dependency structures for discourses are ordered DAGs which satisfy heavy structural constraints, which can help us to cut down the number of possibilities when processing discourses.

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[18] Left-dominance is a notion more restrictive than dominance (e.g. R_a dominates $\pi 1$, R_b, $\pi 2$ and also $\pi 3$ in (A)) and less restrictive than the nuclearity principle (e.g. by this principle, R_a dominates only the leaves $\pi 1$, and $\pi 2$ in (A)).

[19] This result can be seen as a weaker version of the adjacency principle for the first two clauses of a discourse.

[20] The link between the first two clauses can be given by a third sentence, as in (11) in which *S3* establishes a joint link between *S1* and *S2* through its plural subject. The DAG for (11) is (B) with R_a = Joint and R_b = Comment.

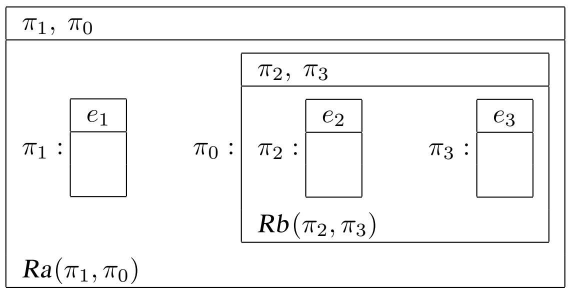
(11) It is raining. Ted arrived late. These two facts irritated Mary.

	R_a coor.	R_a sub.	R_b coor.	R_b sub.
(A)	+	+	+	-
(B)	+	-	+	+
(C)	+	-	+	+
	-	+	-	+
(D)	-	+	+	+

Table 1

Ra \ Rb	coordinating	subordinating
coordinating	(A), (B), (C)	(B), (C)
subordinating	(A), (D)	(C), (D)

Table 2



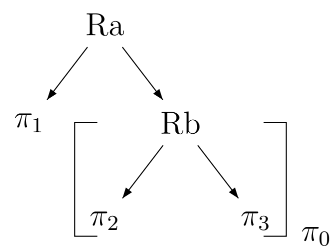
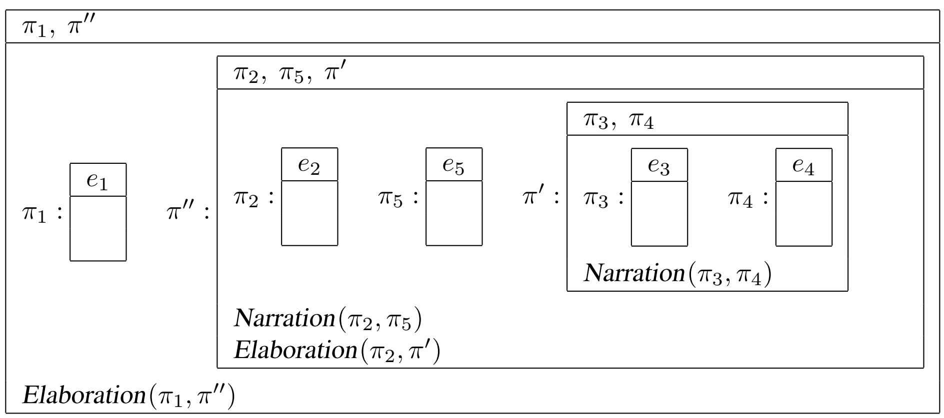


Figure 1: Translation of an SDRS into a DAG



(12) 1 Max experienced a lovely evening last night.
2 He had a fantastic meal.
3 He ate salmon.
4 He devoured lots of cheese.
5 He won a dancing competition.

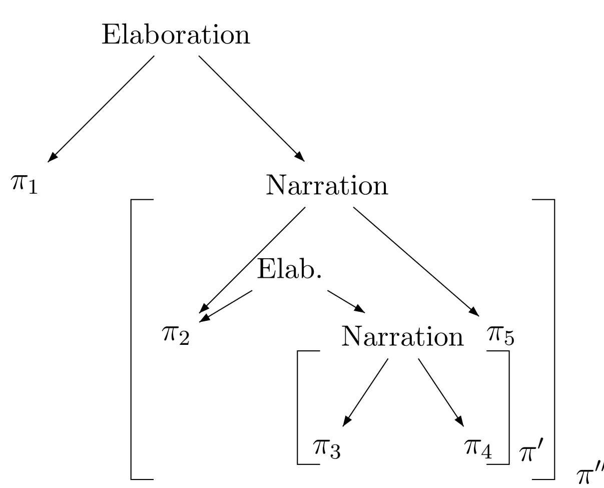


Figure 2: Translation of the SDRS for (12) into a DAG
- (12) and its SDRS are taken from (Asher and Lascarides, 2003) -

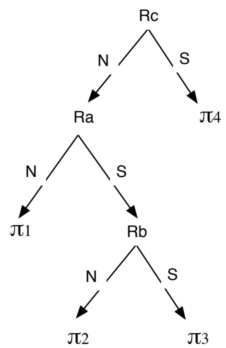


Figure 3: Binary tree

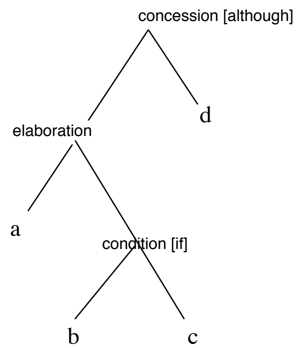


Figure 4: Artificial tree for (1)

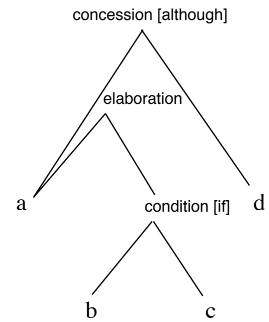
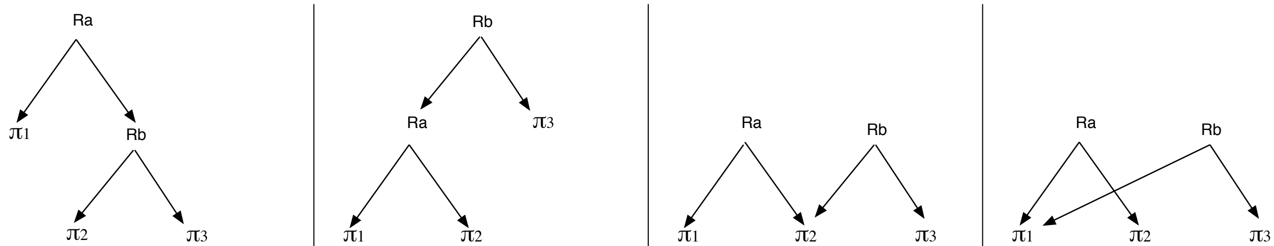
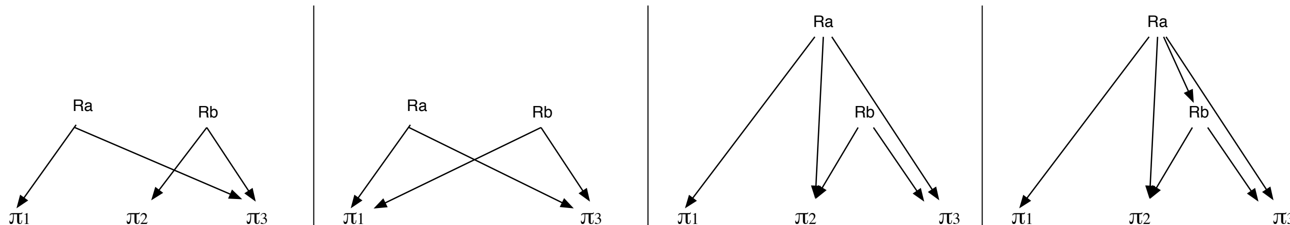


Figure 5: DAG for (1)



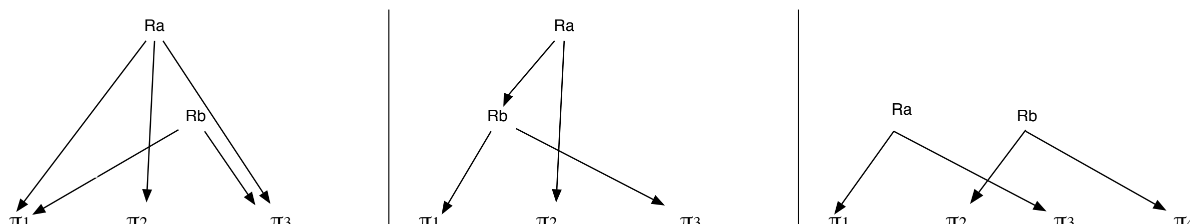
(A) (B) (C) (D)

Figure 6: DAGs (A), (B), (C) and (D)



(E) (F) (G) (G')

Figure 7: DAGs (E), (F), (G) and (G')



(I) (K) (L)

Figure 8: DAGs (I), (K) and (L)