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Sentences with two subordinate clauses:
syntactic and semantic analyses, underspecified semantic representation

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Abstract
I show that sentences with two subordinate clauses may receive two syntactic analyses, and that each syntactic analysis may receive two semantic interpretations. Hence, I put forward an underspecified semantic representation such that each syntactic analysis receives only one underspecified interpretation.

1 Introduction
Sentences with two subordinate clauses occur quite often in corpora. Theories and tools in Computational Linguistics are available now which allow us to study such sentences exhaustively, both at the syntactic and semantic level. It is what I intend to do in this paper, while using only well-known techniques.

Several sophisticated theories and discourse processing mechanisms have been designed which put forward a number of principles. This study on sentences with two subordinate clauses, which constitute one of the simplest cases of discourses, will question some of these principles (e.g., semantic dependency structures for discourses are tree shaped, discourse structure does not admit crossing structural dependencies). It therefore sheds light on discourse processing in general.

Section 2 focuses on the syntactic analysis of sentences with one or two subordinate clauses, including their linear order variants. The syntactic framework I use is LTAG. I show that sentences with two subordinate clauses may receive two syntactic analyses. Section 3 focuses on the semantic analysis of such sentences. The semantic framework I use is SDRT\(^1\), although I translate the conditions of an SDRS into a dependency graph. I show that sentences with two subordinate clauses may receive four semantic dependency structures. Section 4 studies the mapping between syntax and semantics and shows that each syntactic analysis for sentences with two subordinate clauses receives two semantic interpretations. Hence the need of an underspecified semantic representation (henceforth USR). Section 5 presents this USR. Finally, Section 6 compares this work with D-LTAG (Webber et al., 2003).

2 Syntax (in LTAG)

2.1 Sentences with one subordinate clause

Syntactically, subordinate clauses are adjuncts. Therefore in XTAG (XTAG Research Group, 2001) and FTAG (Abeillé et al., 2000), the English and French LTAG grammars, a subordinate conjunction (Conj) anchors an auxiliary tree, with two syntactic sentential (clausal) arguments, the foot node for the matrix clause and a substitution node for the subordinate clause.

Both in English and French, a subordinate clause may appear in three different positions relative to the matrix clause: (i) before the matrix clause separated by a punctuation mark (a comma), the linear order is then Conj\(a\) S2, S1, (ii) before the VP surrounded by two commas, and (iii) after the matrix clause optionally separated by a punctuation mark, the linear order is then S1 (,) Conj\(a\) S2. Therefore, in FTAG, a given subordinating conjunction anchors three auxiliary trees which correspond to these three positions. This is not the case in XTAG, where it anchors four auxiliary trees, two of them for the sentence final position: sentence final adjuncts without comma adjoin at a VP node, while those with a comma adjoin at the root S of the matrix clause. Let us quote (XTAG Research Group, 2001) p. 152 for the former ones. “One compelling argument is based on Binding Condition C effects. As can be seen from examples (1a-c) below, no Binding Condition violation occurs when the adjunct is sentence initial, but the subject of the matrix clause clearly governs the adjunct clause when it is in sentence final position and co-indexation of the pronoun with the subject of the adjunct clause is impossible.”

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\(^1\)SDRT stands for Segmented Discourse Representation Theory (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.
I agree with the data observed in (1a-c), however my point is that there would be no difference at all if the sentence final adjunct in (1b-c) were separated by a comma. Therefore, I see no reason to lay down two different trees - one adjoining at a VP node, the other one at a S node - for sentence final adjuncts with or without a comma. As in FTAG, I assume only one tree (with an optional comma) for sentence final adjuncts, which adjoins at the root S of the matrix clause. This solution presents the advantage not to rely heavily on the presence or absence of a comma, which is sometimes a matter of taste, as in (1c).

Because of lack of room, I leave aside subordinate clauses which appear before the VP of the matrix clause. To put it in a nutshell, I consider only two auxiliary trees for postposed and preposed subordinate clauses which appear before the VP of the matrix clause. The comma, which is sometimes a matter of taste, as in (1c).

Therefore any sentence of this form receives two syntactic analyses and corresponds to two sentences in the canonical order (Section 3.2). The variants (a1) and (c2) are both of the form Conj S, S Conj S., with a preposed and a postposed adjunct. Therefore any sentence of this form receives two syntactic analyses and corresponds to two sentences in the canonical order (Section 3.2). The variants (a1) and (c2) are both of the form Conj S, S Conj S.. The comma before the second conjunction is obligatory in (c2) and nearly forbidden in (a1). Therefore, these forms are nearly unambiguous. The variants (b1) and (c1) correspond to sentences which are syntactically unambiguous.

3 Semantics

3.1 Sentences with one subordinate clause

Following works in SDRT, I use an intermediate level of representation to determine the logical form of a discourse (what is said). This “semantic” 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.

A nice tool for the semantic level is dependency graphs. This is what is adopted in RST, but not in SDRT: discourse structures, called SDRSs, are represented as boxes with a Universe and a set of conditions. Nevertheless, it is easy to translate the conditions of an SDRS into a dependency graph (Danlos, 2004). Therefore, while adopting SDRT as a discourse framework, I can use a conventional semantic dependency representation for sentences of the type St(,) Conj S. 2 Namely, Conj denotes a discourse relation R, R is a predicate with two arguments π1 and π2, which correspond to the semantic representations of St and S2 respectively. These arguments are ordered: π1 precedes π2.

This semantic representation is graphically represented in the DAG besides, also simply written as R∗(π1, π2).

3.2 Semantics for linear order variants

We have seen in Section 2.1 that a subordinate clause can be postposed or preposed. Following works in MTT, a trace of the linear order should be recorded in a semantic dependency representation (giving so a piece of information on the communicative structure), however it should

\[ \gamma_1 \rightarrow \gamma_2 \]

\[ \gamma_2 \rightarrow \gamma_1 \]

In a derivation tree, a dashed line indicates adjunction, a solid line substitution; each line is labeled by the Gorn address of the argument at which the operation occurs; \( \gamma_0 \) stands for the LTAG tree for St.
not affect its dependency structure. From this principle, the position of subordinate clauses should not affect dependency structures: $SI(.) \text{Conj}_b \ S2$ and $\text{Conj}_a \ S2, \ SI$ are both represented as $R_b(\pi_1, \pi_2)$ in which $\pi_1$ precedes $\pi_2$.

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 $\text{Conj}_b \ S1, \ S2 \text{Conj}_a \ S3$, with a preposed and a postposed adjunct, corresponds in the canonical order either to $Y_1 = S2 \text{Conj}_b \ S1 \text{Conj}_a \ S3$ or to $Y_2 = S2 \text{Conj}_a \ S3 \text{Conj}_b \ S1$. $X$ receives two syntactic analyses: either (a2) - Figure 3 - from $Y_1$ (the first adjunct is preposed), or (b2) from $Y_2$ (the second adjunct is preposed). These analyses allow us to compute $Y_1$ and $Y_2$. From the above principle that the position of subordinate clauses does not affect dependency structures, $X$ does not yield any other DAGs than $Y_1$ and $Y_2$. As a consequence, our study on the dependency structures of sentences with two subordinate clauses can be limited to the study of such sentences in the canonical order.

3.3 Sentences with two subordinate clauses

We are going to show that sentences with two subordinate clauses may be interpreted in four different ways. Two interpretations are found in which one conjunction has wide scope over the other one, two other ones without wide scope. The former are represented in tree shaped DAGs, the latter in non tree shaped DAGs.

This semantics study is based on the following compositionality principle. Let $D_n$ be a DAG with $n$ leaves representing the dependency structure of a discourse $D_n$. If $D_p$ is a sub-DAG of $D_n$ with $p$ leaves, $1 < p < n$, then the discourse $D_p$ corresponding to $D_p$ should be inferable from $D_n$.

A) Wide scope of $\text{Conj}_b$: The wide scope of $\text{Conj}_b = \text{because}$ in (2a) can be seen in the dialogue in (2b-c) in which the answer is $\text{Because} S2 \text{Conj}_b, S3$. The semantic dependency structure of (2a) is DAG (A) in Figure 4. In this DAG, which is tree shaped, the dependency relations must be interpreted in the standard way used in mathematics or computer science: the second argument of $R_b$ is its right daughter, i.e. the tree rooted at $R_b$, which is the semantic representation of $S2 \text{Conj}_b, S3$. This reflects the fact that $\text{Conj}_b$ has wide scope and is in conformity with our compositionality principle: (A) includes the sub-DAG $R_b(\pi_2, \pi_3)$ and $S2 \text{Conj}_b, S3$ can be inferred, i.e. (2a) is true, then it is true that $\text{Fred played tuba while Mary was taking a nap}$.

(2) 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.

When while is not stressed, the question in (2b) may be given as answer only $\text{Because} S2$. The interpretation of (2a) corresponds then to DAG (C) presented below. (2a) when written could be considered as ambiguous with a scope ambiguity of $\text{because}$. The scope of $\text{because}$ is underspecified in the USR proposed in Section 5 for (2a).

B) Wide scope of $\text{Conj}_b$: The wide scope of $\text{Conj}_b = \text{in order that/to}$ in (3a) can be seen in the dialogue in (3b-c) in which the question is $\text{Why} S1 \text{Conj}_b, S2$. The semantic dependency structure of (3a) is DAG (B) in Figure 4. This tree shaped DAG must be interpreted in a way similar to (A), which reflects that $\text{Conj}_b$ has wide scope.

(3) a. Fred played tuba while Mary was taking a nap in order to bother her.
   b. - Why did Fred play tuba while Mary was taking a nap?
   c. - In order to bother her.

As for (2a), (3a) when written could be considered as ambiguous. The scope of $\text{in order that/to}$ is underspecified in the USR proposed in Section 5 for (3a).

C) $S2$ factorized: The clause $S2$ in (4a) is said to be factorized since both $S1 \text{Conj}_b, S2 = \text{Fred played tuba}$ while $\text{Mary was washing her hair}$ and $S2 \text{Conj}_b, S3 = \text{Mary was washing her hair before getting dressed for her party}$ can be inferred from (4a). A similar situation is observed in (4b).

(4) a. Fred played tuba while Mary was washing her hair before getting dressed for her party.
   b. Fred was in a foul humor because he hadn’t slept well that night because his electric blanket hadn’t worked.

In (4a), no conjunction has wide scope over the other one. Its semantic structure is DAG (C) in Figure 4. This DAG is not tree shaped: $\pi_2$ has two parents.

One could argue that tree shaped DAGs (A) and (B) should not be interpreted in the standard way. This is argued in RST in which dependency relations in trees are interpreted with the “nuclearity principle” (Marcu, 1996). With this principle, the arguments of a discourse relation can only be leaves of the tree, for example, the second argument of $R_b$ in (A) is $\pi_2$, and the first argument of $R_b$ in (B) is $\pi_1$. This amounts to interpreting (A) as (C), and

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On the other hand, the converse principle is not always true (Danlos, 2004): if a sub-discourse $D_p$ can be inferred from $D_n$, it does not always mean that the DAG $D_p$ is a sub-DAG of $D_n$.

To indicate that it is stressed when spoken, the word while is written in capital letters in (2).
(B) as (D) presented below. But then, cases with wide scope are not represented at all: they are not taken into account, which is unacceptable. As a consequence, tree shaped DAGs must be interpreted in the standard way, in which the arguments of a discourse relation may be either intermediary nodes or leaves.

It is generally assumed that semantic dependency structures for discourses should be tree shaped. As a consequence, to avoid DAGs, some authors use trees in which some predicate-argument relations are given by the nuclearity principle, while others are given by the standard interpretation. 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 can be formally defined. In (Danlos, 2004), I show that no rule can be laid down to choose one of these two interpretations. A mixed interpretation for trees must thus be discarded. Since the standard interpretation is needed for wide scope cases, the nuclearity principle should be discarded. As another consequence, one has to admit that discourse structures for discourses are DAGs.

D) S1 factorized: The clause S1 in (5) is said to be factorized since both S1 Conj$_a$, S2 = Fred prepared a pizza while it was raining and S1 Conj$_b$, S3 = Fred prepared a pizza before taking a walk can be inferred. The semantic structure of (5) is DAG (D) in Figure 4, which is in conformity with our compositionality principle. This DAG is not tree shaped.

(5) Fred prepared a pizza, while it was raining, before taking a walk.

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 advocated in RST.

DAG (D) exhibits crossing dependencies. It is thus a counter-example to the stipulation made by (Webber et al., 2003), namely “discourse structure itself does not admit crossing structural dependencies”.

Summary: A sentence with two subordinate clauses may receive one of the four interpretations represented in DAGs (A), (B), (C) and (D). In the next section, we will see that (A) and (C) are the interpretations of the syntactic analysis SA1, while (B) and (D) are those of SA2.

These four interpretations are the only possible ones. In particular, I cannot find any example in which S3

would be factorized, although I wrote all possible examples I could think of and Laurence Delort, who works on (French) corpus, could not find anyone neither. The factorization of S3 is represented as DAG (E) in Figure 5. Note that no compositional syntax-semantics rule could lead to (E) from the syntactic analyses SA1 and SA2, which are the only possible ones. More generally, in (Danlos, 2004), I show that any DAG with three ordered leaves other than (A)-(D) is excluded, i.e. does not correspond to coherent discourses with three clauses. For example, DAG (K) in Figure 5 is excluded. This comes from the “left1-right2 principle”, which is a weaker version of the adjacency principle.

4 Mapping between syntax and semantics

We are going to examine the interpretation(s) of the syntactic analyses put forward in Section 2. The criterion to be used is that of linear order. So, we are going to examine the linear order(s) for each interpretation (A)-(D).

A) Wide scope of Conj$_a$: The linear order variants of (2a), repeated in (6a), are shown in (6b-d).

(6) a. Mary is in a bad mood because Fred played tuba while she was taking a nap.
   b. Because Fred played tuba while she was taking a nap, Mary is in a bad mood.
   c. Mary is in a bad mood because, while she was taking a nap, Fred played tuba.
   d. Because, while she was taking a nap, Fred played tuba, Mary is in a bad mood.

These linear order variants correspond to the variants which are allowed with the first analysis SA1 (see Figure 3). On the other hand, the variants which are allowed with SA2 are forbidden: the discourses in (7) do not make sense (hence the sign #).

(7) a. # Because Fred played tuba, Mary is in a bad mood while she was taking a nap.
   b. # While she was taking a nap, Mary is in a bad mood because Fred played tuba.
   c. # While she was taking a nap, because Fred played tuba, Mary is in a bad mood.

To conclude, interpretation (A) corresponds to SA1, or conversely SA1 can be interpreted as (A).

B) Wide scope of Conj$_b$: The linear order variants of (3a), repeated in (8a), are shown in (8b-d). They correspond to the variants of SA2. I leave it to the reader to

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8Among 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 emphasize that (5) comprises only structural connectives (subordinating conjunctions) while its structure exhibits crossing structural dependencies.
check that the variants of SA1 are forbidden. To con-
clude, interpretation (B) corresponds to SA2, or con-
versely SA2 can be interpreted as (B).

(8) a. Fred played tuba while Mary was taking a nap in
order to bother her.
b. While Mary was taking a nap, Fred played tuba
in order to bother her.
c. In order to bother Mary, Fred played tuba while
she was taking a nap.
d. In order to bother Mary, while she was taking a
nap, Fred played tuba.

C) S2 factorized and D) S1 factorized: When S2 is
factorized, the linear order variants correspond to SA1,
when S1 is factorized, they correspond to SA2, as the
reader can check it.

Summary: A sentence with two subordinate clauses
may receive the syntactic analyses SA1 and SA2. SA1
can be interpreted as (A) or (C), SA2 as (B) or (D). In
the next section, I put forward underspecified semantic rep-
resentations (USRs) such that the syntactic analysis SA1
receives only one underspecified semantic representation,
USR1, which is specified in (A) or (C), and that SA2 re-
ceives only USR2 which is specified in (B) or (D).

5 Underspecified semantic representation

It is now classical to use USRs for quantifier scope am-
biguities (among other ambiguities). Following works
by (Duchier and Gardent, 2001), I adopt a scope under-
specification formalism based on dominance constraints.
Let us illustrate the overall idea briefly. The clause ev-
ery yoga has a guru is represented (in a simplified way)
as the “tree description” in Figure 6, in which a solid
line represents immediate dominance, a dotted line dom-
inance. Quantifier scopes are underspecified in this tree
description. The dominance constraints are solved in the
trees (a) and (b) in Figure 6 (in both (a) and (b), the root
dominates has(x, y)). Quantifier scopes are specified: in (a) forall(x) has wide scope, in (b) it is
exists(y). The USR I propose for subordinate con-
junctions follows this overall idea. However, it differs in
two ways: (i) “left-dominance” is used instead of dom-
inance, (ii) constraints are solved in DAGs which may be
not tree shaped.

Left-dominance: It has been seen in Section 3 that the
nuclearity principle is too restrictive (wide scope cases
are not taken into account). It will be seen below that
dominance relations are not restrictive enough. There-
fore, I introduce a new relation, called “left-dominance”,
which is intermediary and defined as follows.

A node X in a tree 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.

As an illustration, R_a left-dominates π1, R_b and π2 in
(A), while R_b left-dominates R_a, π1 and π3 in (B). Left-
dominance is more restrictive than (strict) dominance
(e.g. R_a strictly dominates π1, R_b π2 and also π3 in
(A)) and less restrictive than the nuclearity principle (e.g.
by this principle, R_a dominates only the leaves π1 and π2
in (A))10.

Syntax to semantics: Following works in semantics
with LTAG (Candito and Kahane, 1998) (Kallmeyer and
Joshi, 2003), I assume that (i) each elementary tree is
linked to an (underspecified) semantic representation, (ii)
the way the semantic representations combine with each
other depends on the derivation tree. I propose the fol-
lowing rule to link the elementary trees of a subordinate
conjunction to an USR.

Rule (R1): The USR for β1(Conj_a) and β2(Conj_a)11
in which Conj_a denotes a discourse relation R_a is the
description of a DAG in which R_a left-dominates π1 and π2,
the semantic representations of the arguments of Conj_a.
This rule is graphically represented in Figure 7, in which
a dashed-dotted line represents left-dominance.

Let us show how rule (R1) allows us to compute the
right interpretations for the syntactic analyses SA1 and
SA2 depending on their derivation trees.

Interpretations for SA1: From the derivation tree of
SA1 given in Figure 2, rule (R1) leads to USR1 given in
Figure 8. The constraints on left-dominance and order
in USR1 are solved in DAGs (A) and (C). (C) is identical
to USR1 except that immediate dominance replaces left-
dominance. In (A), R_a left-dominates π2. USR1 cannot
be solved in (B) since, in (B), R_b dominates π2 but does
not left-dominate it. On the other hand, in (Duchier and
Gardent, 2001) who use dominance, USR1 can be solved
in (B), which is not in accordance with the data. This is
why I have introduced the notion of left-dominance.

Interpretations for SA2: From the derivation tree of
SA2 given in Figure 2, rule (R1) leads to USR2 given in
Figure 8. The order of the multiple adjunctions to the
same node in SA2 is echoed by the order of the leaves
in USR2: π1 precedes π2 which precedes π3. The con-
straints on left-dominance and order in USR2 are solved
in DAGs (B) and (D) - which is correct - but also in (K)
given in Figure 512. However, (K) is excluded because it
does not follow the left1-right2 principle, see note 9.

To conclude, with (R1), SA1 can be interpreted only as
(A) or (C) and SA2 only as (B) or (D), which is correct.

10 More formally, the nuclearity principle states that, in a (bi-

tary) tree rooted at R, the arguments of R are the leaves

of the tree which are left-dominated by R.

11 Recall (Section 3.2) that linear order does not affect depen-
dency structures. So, β1(Conj_a) and β2(Conj_a) are both linked
to the same (underspecified) semantic representation.

12 I thank Laura Kallmeyer for drawing my attention on this point.
6 Comparison with D-LTAG

This study on sentences with two subordinates clauses is extended to other discourses. As requested by the reviewers, let me compare my approach to D-LTAG (Webber et al., 2003), which extends a sentence level grammar, namely XTAG, for discourse processing.

Let us first look at subordinating conjunctions. They anchor auxiliary trees in XTAG (or FTAG) and initial trees in D-LTAG. Why do they anchor initial trees in D-LTAG? The authors give the following answer: “One reason for taking something to be an initial tree is that its local dependencies can be stretched long-distance”. That is a wrong argument. One major advantage of TAG is that adjunction is possible both in initial and auxiliary trees (and iteratively). So local dependencies in any tree can be stretched long-distance. Moreover, as any other adjuncts, several subordinate clauses can iteratively modify the same matrix clause (Section 2.2). One may wonder how iterativity is taken into account when subordinate conjunctions anchor initial trees.

Secondly, let us examine the distinction made in D-LTAG between structural and anaphoric connectives. The status of some connectives (e.g., however) is admittedly not clear and so is determined on empirical grounds, using crossed structural dependencies as a test. In note 8, I have emphasized that (5) comprises only structural connectives - subordinating conjunctions are unquestionably valid. To distinguish structural and anaphoric connectives is not clear and so is determined on empirical grounds, using crossed structural dependencies as a test. In note 8, I have emphasized that (5) comprises only structural connectives - subordinating conjunctions are unquestionably valid. So the main test to distinguish structural and anaphoric connectives is not valid.

D-LTAG defends the idea that there is no gap between sentence and discourse processing. There exist discrepancies, e.g., discourse adverbials have one argument at the (syntactic) sentence level and two at the (semantic) discourse level13. Such discrepancies are handled in the D-LTAG parsing system (Forbes et al., 2002) by the use of two passes: one based on XTAG syntactic trees, the other one on D-LTAG semantic trees. This amounts in positing two levels as in my approach however without a well-defined syntax-semantics interface.

Finally, in D-LTAG, the logical form of a discourse is computed from its derivation tree, a level of representation which is poor compared to SDRSs, e.g., there is no notion of Universe which groups the discourse referents. As said in Section 3.1, a rich semantic level as the one proposed in SDRT is necessary for text understanding and also for text generation (Danlos et al., 2001). Moreover, the “anaphoric” behavior of discourse adverbials is seriously taken into account in SDRT. Unfortunately, I have no room left to discuss this issue.

13There is no such discrepancy for subordinating conjunctions.

References


Figure 1: Auxiliary and derivation trees for postposed and preposed subordinate clauses

SA1

SA2

Figure 2: Derived and derivation trees for SA1 and SA2

Figure 3: Other linear orders for SA1 and SA2

Figure 4: DAGs (A), (B), (C) and (D)
Figure 5: DAGs (E) and (K)

Figure 6: USR for every yogi has a guru, and representations with quantifier scope specified

Figure 7: Rule (R1)

Figure 8: USR1 and USR2 (Underspecified Semantic Representations for SA1 and SA2).