FROM NATURAL LANGUAGE TO COGNITIVE STYLE

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1. Introduction

It can be assumed that the general purpose of Cognitive Science is to better understand the processes used by the human mind to perform some cognitive tasks such as reasoning, solving a problem or taking a decision *and* to try to simulate them with computer science ([Johnson-Laird 89]). We think, like Langacker ([Langacker 87]), that the understanding and the production of natural language is one of the most interesting cognitive abilities and that it should be studied in relation with the others.

But, analyzing texts in natural language, we don't want to focus on *what is meant* in them (which is the domain of semantics) but rather on *the way it is expressed* (on the *surface structure*) because, as there are different ways to express the same meaning, choosing one may be revealing about *individual particularities*. Our basic hypothesis is that each of us tend to privilege some linguistic structures (lexical, syntactic and discursive ones) in our productions and that a systematic research of these regularities will lead us to cognitive parameters : like [Daniel & alii 92], from the linguistic style, we try to deduce (or abduct) a « cognitive style », dependent on the individual and not on the domain. As a matter of fact, whereas a paraphrase is a different way to give the same meaning, a style characterizes similarities in the ways to give different meanings.

If it is assumed that individuals use mental structures (*internal representations*, whatever their nature) to perform certain tasks then it is natural to expect that these structures leave traces in their language. Like [Allen & Perrault 80], but by different means, we want to infer from texts internal structures. By analyzing the structure of individual discourses, following [Grosz and Sidner 86], we expect to analyze the structure of the plans underlying the behavior ([Hamburger & Crain 87]). We suppose that such plans used to perform a cognitive task can be rebuilt from clues to be detected in the production of the language. To do this, we propose a new (computable) representation for discourses, constituted of two levels : a syntactico-semantic one and a cognitive one. The « cognitive level » can be compared to an algorithm structure that implements a plan. Since our representation can also be compared to Dynamic Predicate Logic ([Harel 84], [Groenendijk & Stockhof 91]), it tends to assimilate natural language as « a programming language for the mind » ([Israel 93]).

All texts may not be equally interesting for our purposes. What are needed here are discourses in which the author expresses his own feelings, his own personality confronted with the world while performing some other cognitive task. Texts written in the first person singular will then be preferred. Furthermore, to detect cognitive regularities, different texts written by the same individual in comparable contexts will have to be analyzed (and different sets of these kinds of

texts to see inter-individual differences). We have finally chosen to focus on a restricted class of texts : those in which someone relates a decision he has taken. As a matter of fact, taking a decision is a very interesting cognitive process that has already been very much studied ([Cognition 93]). We will study the grammatical aspects of the narration of a decision process, hoping that the rebuilt structure that will be inferred from the text has something to do with the decision process itself and the plan that have directed it.

In the first part of this paper, we explicit and justify our approach with an example and, as this study is a multidisciplinary one, we give some theoretical background and presuppositions in the terms of the different domains concerned by cognitive science ([Gardner 85]) : linguistics, philosophy, cognitive psychology and artificial intelligence. Then, in the second part, we present the formal model in two levels we have developed to represent discourses. It allows us to automatically extract relevant cognitive parameters from texts. Finally, we propose in the third part the complete analysis of an extract of a corpus with our model, to exemplify the kind of study we want to promote. This leads us to a definition of the cognitive style.

2. General presentation

The existence of *plans* underlying the execution of a task is to be assumed to give account of *redundancies* in the behavior. The redundancies we want to focus here are cognitive and linguistic ones. They are linked to the notion of *style*. A style characterizes individual redundancies, it is thus probably due to individual plans. But different levels of planification can be considered. We have chosen two main ones : the cognitive level and the linguistic level. How can a linguistic style reflect a cognitive style ? This is the object of our research.

It implies that we consider texts not as referencing to external objects or situations, to *meanings*, but rather as giving indications on the internal states of their authors, on their internal plans. We want to study what language tells us about the one who tells it. After a first example, we will explicit the linguistic, philosophical and psychological justifications of this approach.

2.1. An example

Let us consider two very simple texts where an individual relates how he (she) has taken a decision :

<u>text 1</u>
I looked at the trousers. There were red ones and I thought that they would suit me well. I bought them.

<u>text 2</u>
When I saw the car, I immediately liked its color. I said to myself that I would like to drive it and I decided to steal it.

The usual representations (with logical formulas, semantic networks or any other formalism) that could be built from the analysis of these two texts would nearly have nothing in common. As a matter of fact, the two texts are very different from a linguistic point of view : the lexical items, the syntactic structures and the semantic domains are different. Nevertheless, they seem to share, at a relevant level of abstraction, certain style, certain « cognitive » characteristics which can be summed-up as follows :

- each of the decision processes expressed starts with a state of being where the narrator (« I ») has a visual perception (« looked », « saw ») of a material thing (« trousers »,

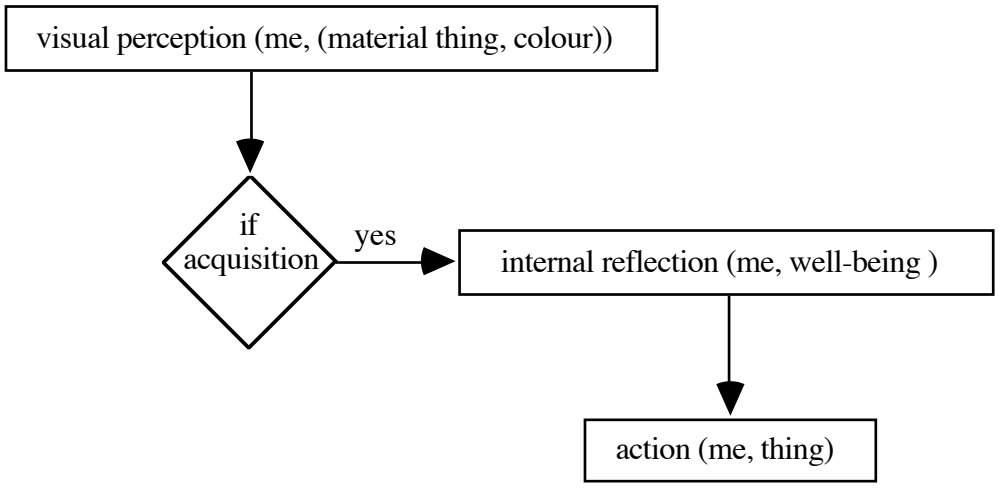
« car ») whose color (« red », « color » non explicated) is noticed. We can say that both beginnings of the texts fit with the « structure » (to be fomalized later) :
visual perception (me, (material thing, color)) ;

- each of them is followed by an implicit test (which can be deduced from the use of the conditional mode for the verbs « suit » and « like ») about the possible acquisition of this material thing (you can add at the end of the second proposition of both texts *if I acquired them (it)*) ;
- the result of this test is an account given in the mode of an internal reflection (« I thought », « I said to myself ») concluding a well-being (« it would suit me well », « I would like »). The common structure of these two parts is then :
internal reflection (me, well-being) ;
- each text ends with an explicit decision dealing with an act applied to the material thing (« I bought them », « I decided to steal it »). The corresponding structure can be written :
action (me, thing).

One of our major interests will be to automatically perform an analysis as the one exposed here, and to define a formal model to represent it.

In fact, the result of this analysis is that the sequence of internal states and internal actions experienced by the narrator of both texts during the decision process are (nearly) the same, although the circumstances related are not.

We can give a first unique pseudo-formal representation of theses texts, that displays their structure and give account of their similarities :



This representation is inspired by algorithm diagrams and by the model defined by A. Finkel ([Finkel 92]) to formalize the subjective experience of an individual (as the one expressed in a text, but not only). The representation he proposes is based on *internal states* and *internal actions* and is leading to an *automaton* (in the sense given to this word by theoretical computer science). In his sense, a state expresses the way the individual feels and what he pays attention to, in a precise circumstance : it is a vector of features belonging to the different classes of perception means (what are the characteristics of the image : color, size... , of the sound and of the feelings perceived ?). An action allows to go from one state to another.

This is the kind of paradigm we will use for our study. But, to describe a decision process, the model of algorithms fits better than the one of automata. The idea is that a decision can be described, in first approximation, as a path between an « indecisive » state and a « decisive » one and by the actions performed at each change of state.

These states are only mental states, since during the decision process, the external context and situation are supposed to remain the same. So, what is important in this representation is not the information itself (the facts, what the decision is about) but the way it is selected and treated (which sensitive canals are used, which feelings or values are taken into account, in which order...).

The actions considered are of two kinds : control structures and elementary actions. The control structures include the common points of all programming languages : the sequence (« ; »), the test (« if... then... else »), and a loop or a GOTO instruction. They are necessary to describe the chaining rules of elementary actions. The set of elementary actions is harder to define. In the linguistic domain, they can be assimilated to the set of intentions, which is open-ended ([Grosz & Sidner 86]). At the moment, we will just consider that the predicates used in each proposition express the elementary actions performed.

This representation does not explain the rationality of the decision (it does not express a logical reasoning) but it displays the parameters of choice considered (the perception of colors, the well-being feeling) and the way they are put forward (the implicit test, the internal reflection). It is still rudimentary and will be much improved in the following of the paper. The main problem will be to precisely analyze and define the notions of « states » (the *data structures* of the plan) and of « actions » (the *instructions*)and to explain how to extract them from a text.

The hypothesis we want to test is that there are in the human mind such kind of structures that can be compared to scripts ([Schank & Abelson 77]) which would not be related to a situation (for example a diner in a restaurant), but to *a mental attitude* (for example a decision process) and which would be specific to an individual. If these scripts (or cognitive plans) exist, we expect to be able to extract them from a narration. Probably, a decision process is a complex mixture between a situation and the mental attitude of the one who takes this decision but, as most studies have focused on the situation, we want to focus on the attitude as it is expressed in the *data structure* and in the *control structure* of the narration of the decision.

This paper will expose a generalization and a formalization of the approach proposed in this example. But, before giving in details the formal model we have developed to perform such an analysis from a text, let us explicate our theoretical choices.

2.2. Commentaries

The example is an over-simplified one. To be able to develop a complete model, we have to have a bias towards usual Cognitive Science paradigms and methods. As a matter of fact, this study concerns different domains and uses tools or concepts from many of them. All these domains also impose constraints and limits to the study, that need to be laid.

<u>From a linguistic point of view</u>

For practical reasons, we have restricted our work to the study of written texts and, as the analysis must be done automatically, the grammatical parsing is supposed to be easily computable. This is a restriction on the *syntactic structure* of the texts considered.

Our study deals with the analysis of texts. But the purpose of the analysis we want to perform is not to *understand* texts, but to *rebuild their conditions of productions*. Language is thus not seen as a communication tool but as a way to express one's personal feelings. This fundamental choice has strong consequences on our linguistic approach. It justifies that texts relating « objective » descriptions or relations are neglected, and that the verbalization of a cognitive process as the decision making is preferred. This is a restriction on the *content* of the texts considered.

In fact, what interests us has something to do with the linguistic *performance* more than with the linguistic *competence* ([Chomsky 65]), and the representation we propose can be considered

as a (partial) formal model of this performance. We will admit that the competence is correctly explicated by a given formal grammar, and we will study what personal use of this grammar each author of the texts do. A formal structure is compatible with individual choices ([Diguier 93]).

At which levels do these choices appear ? Our model is constituted of two levels :

- a syntactico-semantic level, where both the lexical choices and the functional organization of the sentences (the predicate/argument structures) are put forward through a selection of features ; at this level, the propositions will be represented by « formulas » resembling the « structures » used in the example ;
- a « cognitive level », where discourses are represented by a sequence of « mental states », themselves defined as a set of « unifiable formulas » (of course, all these terms will be precisely defined) ; a first idea of the corresponding representation is the global algorithm of the example ;

The cognitive level is distinct from the semantic level. Its relevance has already been noticed ([Hamburger & Crain 87]) and is proved by the example given in 2.1. where it is introduced to give account of a new kind of homonymy that other usual levels fail to identify. We suppose that this level can be built from the syntactico-semantic level, although in the production process it is obviously the first one.

While the *linguistic style* can be measured by redundancies at the syntactico-semantic level, the *cognitive style* will be defined at the cognitive level, as redundancies in the cognitive plans.

From a philosophical point of view

Our approach is a functionalist and a cognitivist one. It is justified by the fact that the mental processes we have chosen to study (the taking of a decision and the relation of it) are high level processes that need symbolic computations.

We admit the Church-Turing thesis applied to these processes, i.e. we assume that, to take a decision, an individual uses a (or a finite number of) computable procedure(s). As we try to rebuild such a procedure from the *linear* discourse that goes with it or that describes it, the model of *sequential algorithm* is the best possible one to represent it.

Our hypothesis is that some sequences of computations done by a human mind to take a decision have been automated, and consequently that its behavior is characterized by redundancies. However, it is not clear whether the redundancies we expect to find in texts rely only on the taking of the decision or on its narration. The cognitive style should not be linguistic-dependent. It should also be possible to detect it from an observation of other cognitive abilities. But we assume that thought precedes and directs language ([Fodor 75]), and that the linguistic process by which the texts we study have been produced (see the « psychological point of view ») correctly reflects the cognitive process of the decision itself.

The notion of *intention* ([Searles 83]), [Grosz & Sidner 87]) will be a fundamental one as it is, for us, at the interface between cognitive and linguistic abilities.

From a psychological point of view

In cognitive psychology, a cognitive process is seen as a sequence of treatments operating on intermediary representations ([Ghiglione, Bonnet & Richard 90]). We pretend to go back to the original representation (the « cognitive plan ») from an analysis of the final one (the text). This is a reconstruction work.

The nature of the cognitive plan we want to rebuild is best described as a *symbolic procedural metarepresentation* ([Pitrat 91]). As a matter of fact it is a structure that expresses *constraints* on the *types* of structures to be taken into account during the execution of a cognitive process. This general and abstract cognitive plan (or *metaplan*) is then instanciated into an actual plan when the

situation requires it. But, as we are not interested in the situation effects, only abstract features will be extracted from texts. The influence of the *content* of the knowledge or of the believes of the individuals is also neglected (but not the fact that it is a different propositional attitude to *know* something or to *believe* it). This is why only daily and not crucial decisions (decisions that are taken nearly « without thinking of them ») are studied. They are the most likely to have been automated.

The study of a narration is fluently used by psychologists to get indications on underlying cognitive processes such as diagnosis ([Patel & Groen 86], [Lemieux & Bordage 92]). In order to obtain interesting corpuses, this method must be carefully controlled. We have first interviewed the individuals to be tested. We have asked them to relate us several recent concrete decisions they had taken, encouraging them not to rationally (re)interpret their behavior but to « live it again ». This is what we call an « explicitation interview ». Then the individuals were asked to write the corresponding texts by themselves as soon as possible.

Our work is closely related to psycholinguistic studies, as it deals with the interactions between linguistics and cognitive styles. But the psycholinguistic study of the *production process* of language is far less developed than the one of the *analysis process* ([Caron 89]). Nevertheless in this domain, it has already been postulated ([Garett 80], [Garett 82], [Levelt 89])) that, between the global conceptual level of planification of discourses and the positional level of production of a narration, there exists a « functional level » where the selection of the words to be used is performed (through a choice of their abstract semantic characteristics) as well as a determination of their function in the sentence. It is precisely this level that we call « cognitive » and that we pretend to reconstruct from the analysis of texts.

<u>From an AI point of view</u>

As the model we have developed is designed to be computable, our work also belongs to Artificial Intelligence (AI), more precisely to the field of the treatment of Natural Language. Nevertheless, the implementation of the model does not intend to *simulate* a human behavior but to better *understand* it. The computability of our method of analysis is a guaranty ,a constraint so as to rigorously test it.

We have been deeply influenced by numerous works done in AI. A lexical semantics based on features has been chosen ([Le Ny 89]) and the traditional predicate/argument structure of logical propositions is the basis of the syntactic representation. The syntactico-semantic level can thus be defined as a *structured language of features*. For the analysis of discourses and the definition of the cognitive level, classical approaches ([Schank & Abelson 77]) as well as more recent theories such as Discourse Representation Theory ([Kamp & Reyle 93]) have provided useful tools.

Other fields are close to our preoccupation. This is the case of the recognizing of intentions and plan inferences ([Allen & Perrault 80], [Pollack 90]), even if they are mainly concerned with the content of utterances more than with their style. We are convinced that these approaches are complementary and that they should become integrated.

It is now time to come to the definition of our formal model.

3. A formal model

We now propose a formal model in two levels to represent texts in natural language. This model is computable and it is built to display all « cognitively relevant » parameters of texts.

The first level (the syntactico-semantic one) is built in two steps. In the first step, features are selected among the lexical morphemes (the predicates and the noun phrases) of the texts. The second step reconstitutes the syntactic structure of the propositions and gives a status to the

grammatical morphemes as well as to the adverbial complements. The syntactico-semantic level is finally represented by a sequence of *formulas*.

The cognitive level is inferred from the syntactico-semantic one. It consists in regrouping compatible formulas so as to build a *mental state*.

3.1. Classification of features for the lexical choices

To automatically perform an analysis as the one exposed in 2.1., it is obvious that *classes* need to be defined, in which will be regrouped the lexical items that are « cognitively » close (as « looked » and « saw »). These classes must be abstract enough not to depend on the situation but on state of mind of the individual.

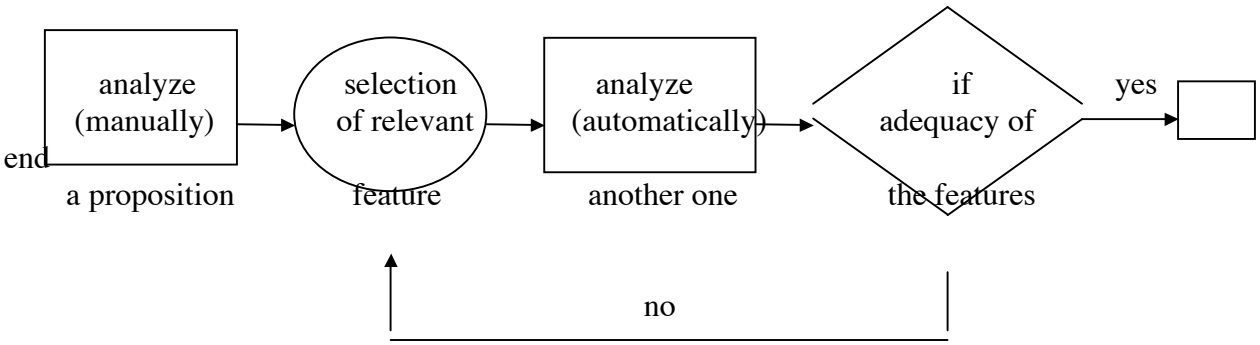
For each significant item (i.e. each lexical morpheme), the purpose is to focus on the parameters (or features) that are considered as relevant in the context of a cognitive process : for us, the taking of a decision.

For example, it is interesting to notice whether the narrator refers to past choices or, on the contrary, imagines the consequences in the future of his decision. So temporal references are to be noticed (they depend on the conjugation of the verbs). The semantic nature of the lexical items used is also interesting as far as they rely on the way the information is selected. For example, whether the verbs used report a perception, a reflection or an action is to be noticed, and whether the main noun phrases describe material things, abstract concepts or affective feelings as well.

<u>methodology</u>

The classification of such features is a long and complicated task (in [Ortony, Clore & Foss 87] is done such a work for the affective lexicon). Moreover, the relevant features and the way they are organized may depend on every individual. In order not to be stopped at this first step, we prefer proposing very simple and general classifications.

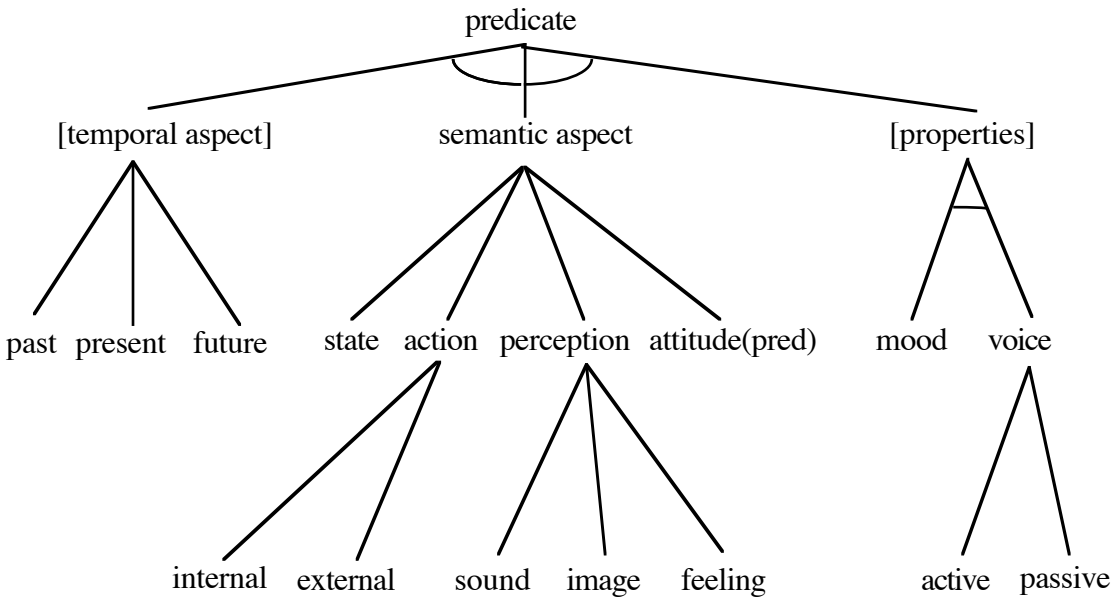
We have chosen to present our classification of relevant features in and/or trees. The study of texts as the ones of our example have lead us to build trees whose nodes and leaves are abstract enough to give account of most redundancies encountered. Once they are built, they serve to the analysis of other texts and are eventually improved until they seem relevant to all kind of texts. Our general method of definition is thus an inductive one, and it can be represented by the following algorithm :



As the predicate/argument distinction is the basis of the syntactic structure of propositions, two trees are necessary : one for the predicates (in English : all the verbs) and one for the nouns phrases.

<u>Classification of features for the predicates</u>

A (partial) classification of the parameters we want to extract from the predicates can be presented as follows :



In this tree, « and » branches are linked together, whereas (exclusive) « or » branches are not. Parameters into square brackets are optional ones. Parameters into usual brackets refer to other features of this tree (or of other trees).

This representation means that from predicates only a finite set of features will be considered. The only one which is compulsory is the semantic aspect of this predicate : whether it expresses a state (like « be »), an internal (« think ») or external (« run ») action, a perception (explicated by the mean of perception) or an attitude (« believe », « want », « can »...). For this latter, it will have to be explicated by what this attitude relies to. Generally, it relies to another predicate : « want to run »; this is why we indicate that an attitude is a kind of function over a predicate : attitude(pred). Here, « pred » is equivalent with the root « predicate », so that the structure we define is in fact a recursive one.

The temporal aspect of the predicate is part of its morphology (it is optional because in the case of infinitive verbs, no temporal indication is given). Finally, what are called « properties » are other parameters such as the grammatical mood (« indicative », « subjunctive », « imperative ») or the active/passive voice. For a better readability of this paper, we will admit in the following that these « properties » features can be omitted.

From a predicate used in a sentence, will be extracted the vector of parameters appearing in it. This will define the *class* the predicate belongs to.

<u>example 1</u>

In the sentence « I can see a car. », the complex predicate « can see » will be represented as :
[present, attitude([image perception])].

Of course, the tree can be modified to include other cognitively relevant parameters, but this one will be enough in a first approach.

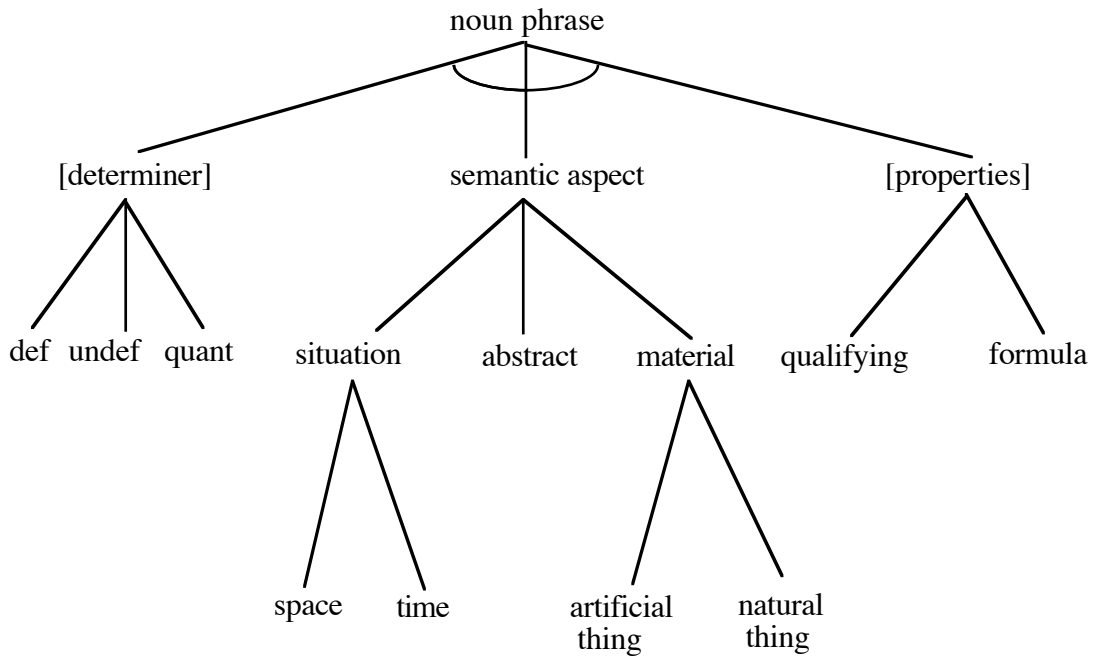
<u>Classification of features for the noun phrases</u>

The same method is used to classify relevant features of noun phrases.

The difference relies in the fact that a noun phrase is a more structured set of words than a predicate. We consider that it is constituted of an optional determiner (it can be omitted for example if the noun phrase is a proper name), a main noun whose semantic features are relevant

and optional properties, either expressed by adjectives or by relative propositions. This structure is also recursive, as a relative proposition can include noun phrases as well.

The tree representing the relevant features extracted from noun phrases is the following one :



A noun phrase is considered to have a semantics which can be either a situation (that describes the « conditions of possibility » of the experience defined by the philosopher E. Kant) or an abstract or material content. The determiner can be definite, indefinite or a quantification., and the properties can be expressed by qualifying adjectives or by formulas (which represent relative propositions). The precise definition of what is a formula is given in the next section.

<u>example 2</u>
« the black cat » is represented by [det, natural thing, color] where « color » is to be taken as a possible value of « qualifying » (it is not possible to display the global tree here).

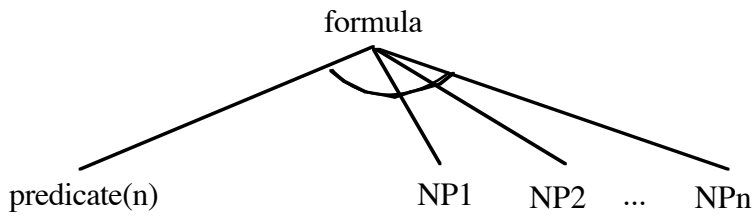
These trees don't pretend to give an ontological classification of the objects or processes described by the language, but are rather a classification of interesting features, relatively to our study.

3.2. A functional representation for proposition

We have chosen to separate predicates from noun phrases because we think that, in propositions, the functional structure [predicate](argument) is the most general one (Shaumyan 82]). So, the fundamental relationship to be considered here is the functional application of a predicate of arity n with n arguments (i.e. n noun phrases). The result of such an application is precisely what we call a *formula*. It is of the form :

$[\text{predicate}]_n$ $(\text{noun phrase})_1 ... (\text{noun phrase})_n$.

This structure can also be expressed, if we want to keep a uniform presentation for the lexical and the syntactic structures, with a tree :



Let us represent in this framework the formula associated with some simple propositions.

example 3
« I looked at the red trousers. » is represented by the formula :
[past, image perception] ([definite, material thing, color]) (me)

This representation means that the proposition is composed of a main predicate (« looked at ») indicating, in the past tense, a visual perception performed by me (« I », the last argument) whose object is a material thing (« trousers »; the first argument) introduced by a definite determiner (« the ») and qualified by a color (« red ») property. Slightly more precise classification trees than the ones presented before are used here (the pronoun « me » is a peculiar noun phrase). The order in which the arguments are related to the main predicate is the one usually used in logical languages : the grammatical subject is the last argument of the predicate.

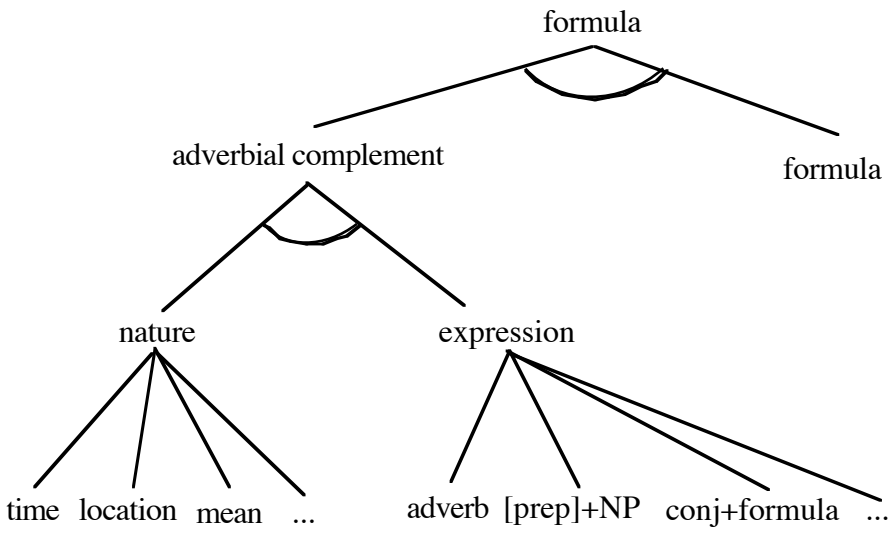
example 4
« I want to steal the car that I like. » is represented by :
[present, want ([action])] ([definite, artificial thing(x), [present, feeling](x)(me)]) (me)

Here again, our classification trees are supposed a bit more precise : « want » is a special case of the « attitude » parameter. But the most interesting thing to be noticed here is the recursive structure of the first argument, representing « the car that I like ». This noun phrase denotes an artificial thing (the « car ») qualified by the relative proposition « that I like » which can be represented by the formula [present, feeling](x)(me). The « x » used has to be considered as an indicator to identify the direct object of the predicate « like » with the « car ».

3.3. Extensions

This way, we have defined a complete artificial language. Nevertheless, several extensions need to be defined to represent all sentences in natural language. Let us give here the way to represent adverbial complements.

They are all considered as belonging to a specific case. The number and the nature of all possible cases is controversial, but we will restrict ourselves to an elementary list including time, location, mean, manner, purpose... An adverbial complement can be expressed by an adverb (« quickly », « tomorrow »), by an NP eventually preceded by a preposition (« with a knife »), by an infinitive predicate (« to test ») or by a complete subordinated proposition (« when he entered the room »). The global structure of a formula should then include all these possibilities. A and/or tree can again can express this situation :



Notice that the recursivity of this structure allows us to combine several adverbial complements in a same formula.

example 5

The sentence : « When I saw Paul, I was running fast. » will be represented by the formula :
[[time, *conj*+[past, visual percep](person)(me)],[[manner, *adv*],[past continuous, action](me)]]

As we have not defined the different classes of adverbs, we just consider the term *adv* as a key word being accepted in a formula to instanciate the type « adverb » (the same for *conj*).

This language is logic-like, but it cannot be associated with any semantic interpretation giving truth values to propositions. Its purpose is to represent some characteristics (a selection of morphological, syntactical and semantic features) of propositions expressed in natural language. For example, the level of bracketing of a relative proposition is represented in this language by the number of recursive inclusions in the corresponding noun phrase.

The formulas of this language can be automatically obtained from an analysis of the corresponding propositions in natural language. This operation has been implemented in C-Prolog on SUN workstations thanks to the use of a Categorial Grammar ([Oehrle, Bach & Wheeler 88]) based on the Lambek Calculus ([Lambek 58]) and associated with a translation process inspired by Montague's ([Dowty, Wall & Peters 81]) and using λ-calculus.

In this process, lexical morphemes are associated with their class (their corresponding vector of features) while grammatical morphemes are associated with expressions (including λ-abstractions and indicators as the « x » that was needed in example 4) expressing how the lexical morphemes are combined in the sentence ([Rozier & Tellier 92]).

Montague's system has often been criticized because it is fully compositional. We are not concerned by these critics here because our representation is not semantical. The only compositionality we assume is then a *compositionality of mental states*. As we neglect the « context effects », it seems perfectly acceptable to say that the mental state expressed in a sentence only depends on the elementary cognitive features of this sentence and of their mode of combination.

3.4. The Cognitive level

Let us recall that we are mostly interested in analyzing discourse structures. It is then necessary to take into account the links between the propositions.

Cognitive states

The first possible operation in our framework is the unification of compatible consecutive formulas.

For example, let us consider a simple discourse constituted of two propositions :

« I looked at the trousers. I could see the red ones. »

They are respectively represented by :

[past, image perception] ([definite, material thing]) (me))

[past, image perception] ([definite, x, color]) (me))

These two formulas share several features at the same place (i.e. playing the same syntactic role). They can be unified into one :

[past, image perception.]([definite, material thing(x), color])(me))

The corresponding mental state can been represented as :

[past, image perception.]([definite,_,_])(me))
[past, image perception] ([definite, material thing]) (me)) [past, image perception] ([definite, x, color]) (me))

In this representation (resembling a DRS, [Kamp & Reyle 93]), the header of the box displays the common points of the formulas it contains. We will call a *structure* a such a formula with eventual undetermined features.

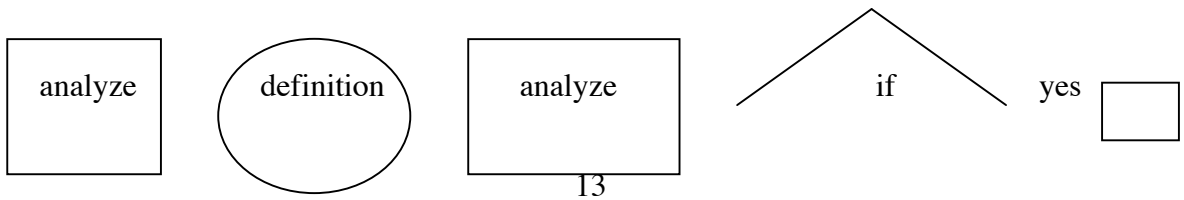
More generally, we will say that the narrator stays in the same *state of mind relatively to a certain feature* if this feature keeps the same value at the same place in a sequence of propositions. This sequence of propositions is then grouped into a structure of this kind that will be called a *cognitive state*.

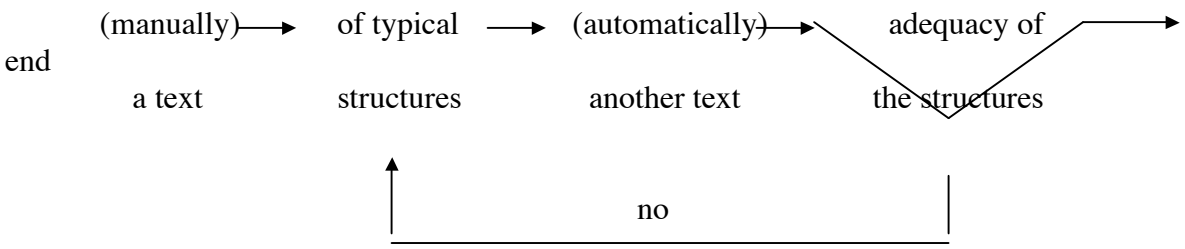
If, for example, the temporal aspect of every main predicate of a text always keeps the same value, then all the formulas translating the propositions of this text will be unifiable relatively to this feature and the corresponding cognitive states will be reduced to one. This situation is not a very interesting one, as we want to focus on the different cognitive states experienced during a decision process.

The problem will thus be to correctly *choose* the features (and their place in the formulas) relatively to which the unification between formulas will be performed. This choice cannot be done *a priori*. As it characterizes a link between what is said and the way it is said, it is closely related to the style of every individual and depends on him (her).

So a first manual analysis of texts is necessary to select the relevant structures used by their author and characterizing a unique « state of mind ». Heuristics can be used for this purpose, that will be exemplified in the next section. If the typical structures found for the first text do not allow to distinguish the different cognitive states expressed in a new text, then the definition of these structures will be enriched. After the analysis of three or four texts, we hope to reach to a definition which will fit for every other text

So, here again, our method at the cognitive level has the same form as the one used at the lexico-semantic level (cf. 3.1) :





Maybe this schema characterizes our cognitive style (!).

Cognitive Axioms

In fact, now that we have a sequence of *states* , our initial idea was to extract from it an algorithm by inferring the underlying control structures.

By default, the transition will be the sequence « ; ». The eventual loops can be simulated by GOTO instructions, when unifiable formulas are recognized at different discontinuous points of the discourse.

But, as we have seen in the example (in 2.1), implicit tests may have to be recognized as well. So, we need rules that would express, for example, that when a predicate has the feature « conditional mood », an implicit test is to be supposed. The logic-like nature of our representation allows a very natural way to express such relations, by rules of the form :

[Tense, Sem., conditional](A1)...(An) — —> if *condition* then [Tense, Sem.](A_1)...(A_n)

where Tense, Sem, A_1 (for *argument*)... and A_n are to be considered as variables unifiable (in the Prolog sense) with any value of the corresponding features of the predicates or of the noun phrases (like in C-Prolog, we note them with a first capital letter), whereas « conditional » imposes a value to the feature, which should be instanciated by all the formulas of the state (or by the structure which is at the header of the state). The nature of the *condition* depends on the context. It is a Boolean condition which can be expressed as a first-order predicate logic formula.

This kind of rewriting rules can be called *cognitive axioms.*

In the example in 2.1; the features selected are not enough to infer that the common point between « buy » and « steal » is the *acquisition* process. Here, a more traditional semantical representation would be necessary.

We expect to deduce from the analysis of large corpuses the necessary cognitive axioms to be introduced in a complete computable analyzer. This is why this part of our study has still not been as developed as it should be. But our model provides a unified mean to express very different kind of such axioms. With these *cognitive axioms*, we expect to automatically rebuild the algorithmic structure of decision expressed in the text.

4. Detailed analysis of a real corpus

The hypothesis of regularities in texts by the same author and the algorithmic nature of mental structures is being tested through a real corpus, obtained through the « explicitation interview » procedure (2.2). We have analyzed the documents produced with our model.

4.1. Detailed analysis of a Text

Here is one of these texts (translated from French), relating how the speaker has chosen her last pair of trousers :

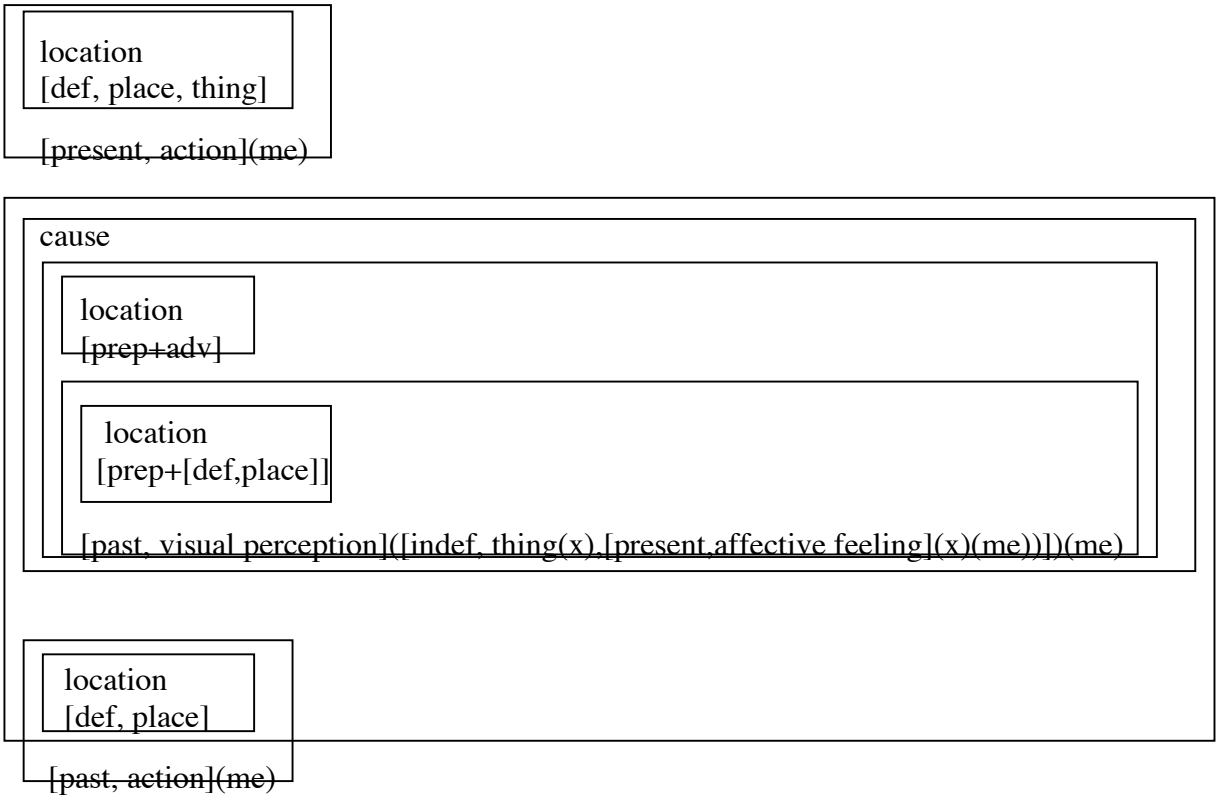
> *I come into the clothes shop. I have come into it because from outside I had seen in the shop window some clothes I like. I have seen the trousers, I have rushed forward them, I*

have touched them to see the textile, I immediately wanted them. I tried them on and as I looked at myself in the mirror I was convinced that I wanted them.

The sequence of formulas obtained from the systematic translation of the propositions of this text is the following :

[[location, [def, place, thing]], [present, action](me)].
[[cause, [[location, prep+*adv*],
  [[location, prep+[def, place]],
    [past, visual perception]([indef, thing(x),[present, affective feeling](x)(me))])(me)]]],
      [[location, [def, place]], [past, action](me)].
[past,visual perception]([def,material thing])(me) & [[location,prep+them], [past,action](me)]
& [[purpose, [visual perception]([def, material thing])(me)], [past, tactile action](them)(me)]
& [[time,*adv*],[past,want](them)(me)].
[past, action](them)(me) &
[[time,[[location, prep+[def,thing]],[past, visual perception](myself)(me)]],
  [past, mental state([past,want](them)(me))](me)]].

This representation is not readable enough. It is possible to make it clearer if the sub-structures are included into boxes, as in the following schema (for the first two sentences) :



Now, the problem is : what are the different cognitive states expressed in this text and what are their respective characteristic features ?

Observing a large number of texts relating decision processes, we have noticed that most (if not all) of them could be divided into three parts : an « exposition » part where the general circumstances of the decision to be taken are exposed, the « heart » of the decision, where it is explicitly taken, and the « consequences », which can be either a final validation or confirmation

procedure or a simple exposition of some results. This observation is just a common sense expectation, and it has also be noticed by psychologists ([Weil-Barais 93]).

The text we have considered can actually be divided into three sections :

<u>exposition :</u>

I come into the clothes shop. I have come into it because from outside I had seen in the shop window some clothes I like.

<u>decision :</u>

I have seen the trousers, I have rushed forward them, I have touched them to see the textile, I immediately wanted them.

<u>consequence (confirmation) :</u>

I tried them on and as I looked at myself in the mirror I was convinced that I wanted them.

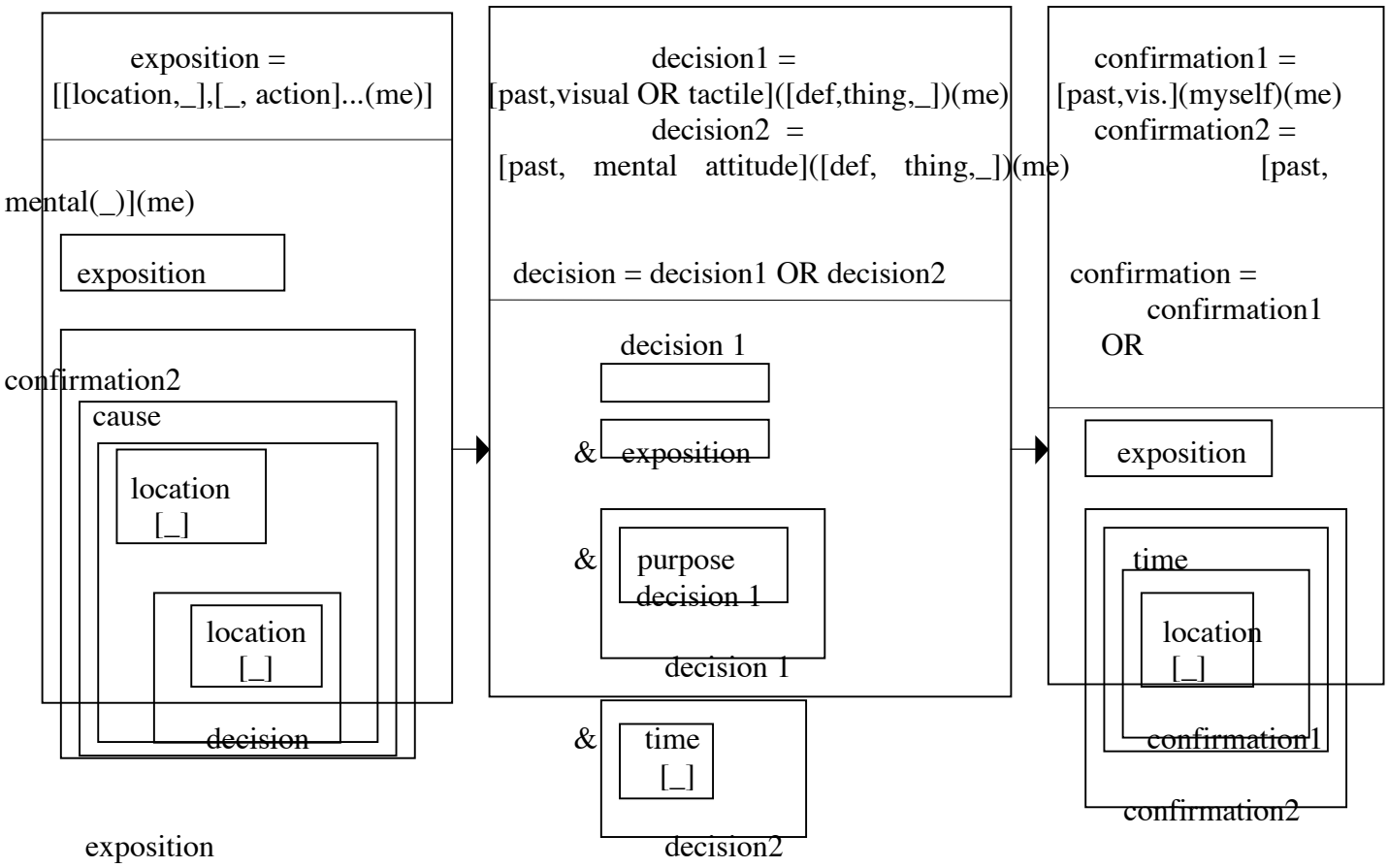
Here, the limits of the sections coincide with the end of sentences; in fact the relevant boarders are those of propositions (corresponding to formulas). It could happen that different propositions belonging to the same sentence are classified into different parts. We want to show that each of these sections correspond to a different cognitive state in our sense, that is to say that they can be identified by relevant structures and that the nature of these structures depend on the individual and not on the domain. They will lead us to the cognitive style of this individual.

Considering the sequence of formulas we have obtained for each section, we can notice that :

- the first two formulas can be unified relatively to the feature *action* of the main predicate, to the grammatical subject *me* and to the presence of an adverbial complement of *location* . We will say that these features characterize the « exposition state » of the narrator. A typical proposition of this state has thus the structure :
  [[location, _],[_, action]...(me)] ;
- these features are also present in another formula : the one that translates *I have rushed forward them.* which, although included into the « decision section » can actually be considered as also belonging to the « expositive state ». So it is possible either to unify it with the first state or to consider it as « the exposition part of the decisive state ». The latter option is the one we have chosen.
- the formulas translating the decision section of the text (except the one previously treated) share several features : the grammatical tense *past*, the subject *me*, the semantic aspect which is either a *visual perception* or a *tactile action* (to describe how the narrator extract information from the environment) or a *propositional attitude* (*want*, to express the decision itself) and the direct object which is always a *definite material thing*. The corresponding typical structure is thus :
  [past, visual perception OR tactile]([def, material thing, _])(me)
  OR [past, mental attitude]([def, material thing, _])(me)
  It can be noticed that this structure also fits for the formula translating the proposition *I had seen in the shop window some clothes I like,* belonging to the « expositive state » (because it is an adverbial complement of a main proposition of this state) but relating a minor decision (how the narrator *decided* to come into the shop) and so explaining « the decision part of the exposition state ».
- finally, the last section of the text, which relates the « confirmation process » of the decision is characterized by a mixture of the previously used features. The formula that translates the proposition *I tried them on* fits with the main predicate of the typical structure of exposition (the adverbial complement of location can be considered as optional). This

« confirmation section » is a kind of sum-up of the elements introduced before. The formulas have a structure of the form :
[past, visual](myself)(me) OR [past, mental(_)](me)

This example shows that the representation we have extracted from the text (the sequence of formulas), in which a lot of information have been disregarded, is nevertheless precise enough to perform a non trivial analysis of this text. This analysis allows us to represent the whole text as a sequence of three cognitive states :



This representation is a condensed version of the « formulas-in-boxes » one, where the names of each state of the decision process put as headers of this state are used as abbreviations of the corresponding typical structures inside the boxes. Mutual calls between formulas inside each of the three global boxes and the headers of the others are possible (this introduces a new possible level of recursivity) but the header of a box should characterize the majority of the formulas it contains. It is a more flexible version of the cognitive states than the one presented in 3.4. The headers are chosen so as to sum-up a maximal number of formulas. There is no uniqueness of choice and so this representation is not the only possible one.

This representation is called a *cognitive plan*. It is very abstract, it gives no indications on the semantics of the text analyzed but it pretends to display a *correspondence* between an *intention to communicate* (an exposition, a decision or a confirmation state) and *the grammatical and semantic structures* used to express it. Moreover, an « exposition » or a « confirmation » is more than an intentional state. It is the result of a *filtering* of all the information available in the environment to put forward the ones that have really been taken into account for the decision

process. This is the reason why we can say that our features, structures and plan are cognitive ones.

4.2. Another text

Let us recall that we are mostly interested in the research of redundancies. It is then necessary to compare the results of this first analysis with the analysis of other texts by the same narrator.

The representation of the previous section was for a large part built manually because at the beginning we had no idea of which relevant typical structures could be defined. But, now that we have a first definition of them, these structures can be used to automatically *filter* other formulas extracted from these other texts.

So, let us consider another text by our interviewed individual. In opposition to what one could expect from an analogy with the beginning of this article, the decision related here does not deal with the stealing of a car but with the composition of a breakfast :

> *I got up. Passing by the cereals box, I though that there was cold milk in the fridge, I imagined what would be a bowl of cereals and I thought that it was pleasant, good for health, quick and easy. I took one.*

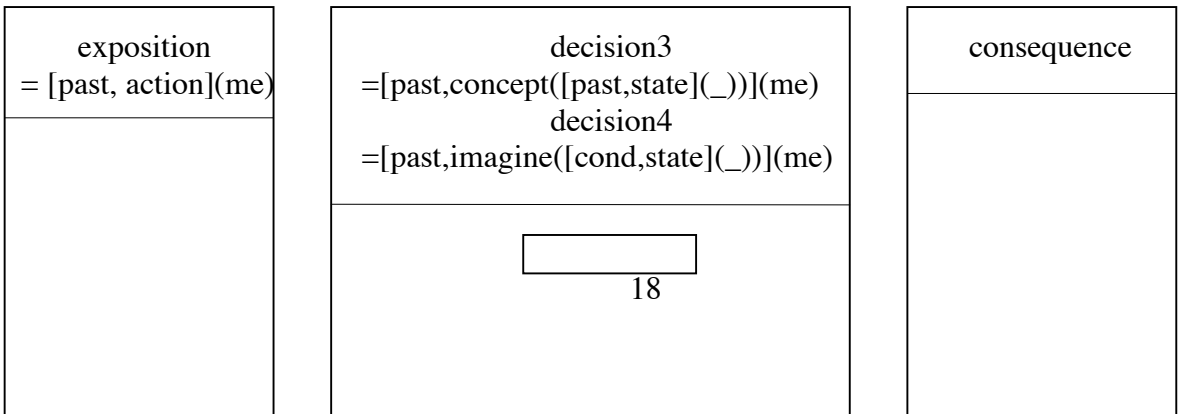
The sequence of formulas translating this text is :

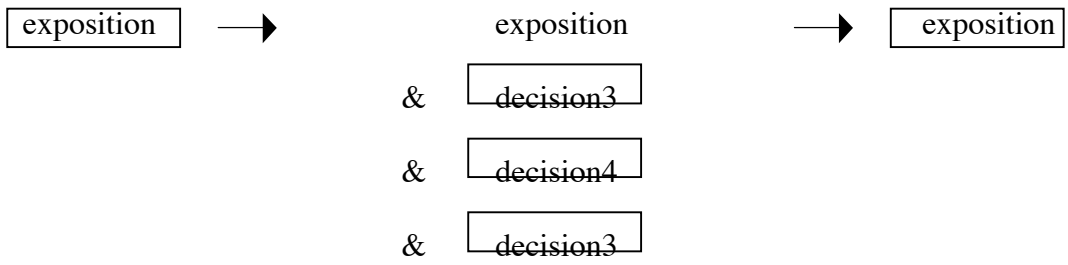
[past, action](me).
[[location, [def, material thing, natural thing]], [action](me)]
  [past, conceptualization([[lieu, [def, thing]], [past, state]([def, thing, feeling])]](me)
  & [past, imagine([conditional present, state]([def, thing, thing])]](me)
  & [past, conceptualization([past, state(feeling & value & time & comfort)])(it)]](me).
[past, action](one)(me).

This text is composed of three sentences corresponding with the three cognitive states we are looking for. A closer look at them allows us to notice that :

- the typical structures extracted from the analysis of the first text allow us to recognize that the first two propositions belong to the « exposition state » ;
- the three following ones have a common structure :
  [past, conceptualization ([past, state](_))](me)
  OR [past, imagine([conditional present, state](_))](me).
  The « imagine » feature is probably close to a perceptive feature (the individual may build a mental image) but we prefer defining a distinct one.
- finally, the last proposition, which expresses the consequence of the decision, has the same structure as an exposition.

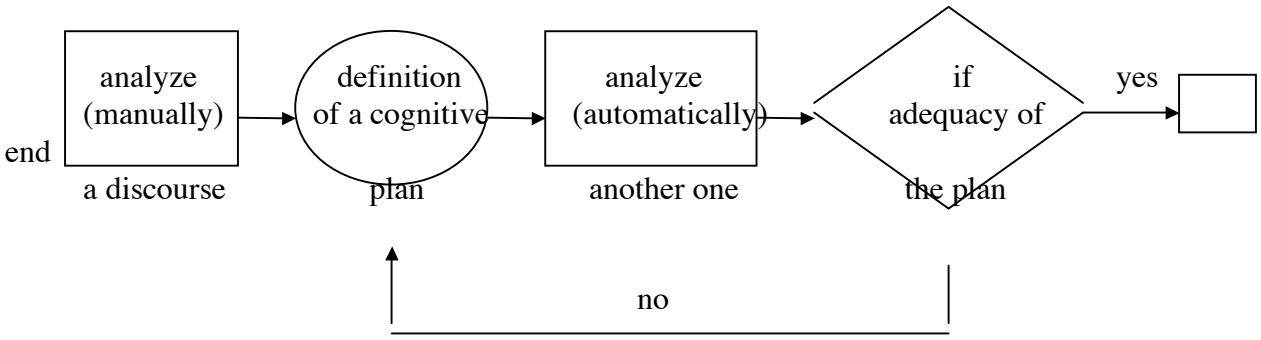
The final cognitive plan extracted from this text is thus :





The common points between the two texts (not easy to notice without the tools we have provided) are already obvious by comparing this representation with the previous one. They are confirmed by further analysis of other texts (that we won't give here). Not only the features and the typical structures associated with the states are redundant but also some characteristics of the general construction of the texts: for example the fact that the decision itself (the central cognitive state) is performed in three steps (it contains three « little decisions ») and that the consequence always contains an « exposition ».

These observations let us think that at the discourse level as well, redundancies are to be expected and that a unification between cognitive plans as the ones we have built to represent the two texts should be defined, in order to display the most general structure of all decision processes of the author of the texts. The suggested method to perform such a unification will (not surprisingly) be the following one :



An automation of the analysis process is then possible.

4.3. Towards a cognitive style

Finally, the different levels of redundancies present in the texts we have analyzed are all relevant to characterize a « style » :

- the level of features is the domain of the morpho-lexical choices : the individual who has written the texts analyzed in the previous section tend to privilege verbs of action or of perception and noun phrases related to material things ;
- the functional level expressed by the formulas is the domain of the syntactic choices : whereas all the sentences in the texts analyzed here have « I » as grammatical subject, some other texts studied use more diverse grammatical constructions (for example, the exposition section can be constituted by a description starting with « there is/are »...), the most frequently used adverbial complements vary also from one individual to another.
- the cognitive level, defined by sequences of cognitive states is the domain of the discourse organization : the order in which some kinds of formulas appear can obey to individual regularities.

What seems specific to the decision process is the distinction between three states. But, what is specific to each interviewed individual is the link between each of these states and their linguistic structure (for the three levels just noticed), displayed in boxes as the ones we have proposed.

The first two levels of choices are globally represented by syntactico-semantic formulas. The redundancies of typical structures (that are abstractions over these formulas) associated with the intentions they communicate define the *linguistic style* of the individual. They are expressed by the headers of our cognitive states.

The redundancies of the sequences and of the internal organizations of the cognitive states which constitutes a cognitive plan define the *cognitive style* of the individual.

This definition may still seem dependent on the linguistic style, but the cognitive states considered correspond to cognitive processes. For example, an « exposition » is the result of a cognitive analysis of a situation. The fact that the individual we have studied systematically uses action verbs to relate them means that she feels an *active actress* of the decision she has to take. Someone else gave us texts which always started with the modality « I have to », and this is the sign of a fundamental different cognitive approach where the decision is viewed as a duty or a constraint. Using concrete or abstract nouns also reveals different cognitive abilities. Another example is given by the way the « consequence » is related. For some individuals, it always deals with a test where a qualifying as « good enough», « comfortable » is present, as if a kinesthetic feeling of well-being was necessary to confirm a decision. These characteristics are not only linguistic ones.

We are not at the moment able to give a classification of the different possible styles most frequently encountered and to give a correspondences between these classes and different other cognitive abilities (for example the different cognitive styles defined in [Daniel & alii 92] , which deal with some « inductive » or « deductive » ways of reasoning). Statistical tools should be necessary to go further in our definitions.

5. Conclusion

With the tools provided in section 3 (plus the syntactic analysis that we cannot make clear here, but that will be detailled in our PhD to appear in 1996) it is possible for reasonably simple texts to generate the representation we have given as example in section 2.1., where only the headers of the cognitive states were taken into account. In fact, our representation is even far richer than the one presented in this example, as it displays the logical structure of the propositions and the global organization of the discourses. The main purpose was to present a new model and to show how the structure proposed was computable.

This model is a very abstract and general one. It allows a filtering of lexico-semantic features and of propositional and structural properties of texts. Although simple to define, it has a high power of expression because at every level considered, we make the most of recursivity. Each level defined is supported by the preceding one and a unified methodology is used at each step of the construction.

With this formal model, we try to characterize some aspects of the linguistic *performance* and of the *cognitive style* of individuals. The final representation defined extracts the *skeleton* of the decision related by the speaker. The first studies of corpuses done allow us to assume that this skeleton (including the features preferred, the typical structures most frequently used and the instanciated cognitive plan) is specific to the individual and in most cases independent from the domain of the decision. These first results are to be confirmed by further investigations, where quantifiable statistics could support qualitative observations.

Of course, this model may not be adapted to all kinds of texts. We are aware that the results of this study are conditioned by the « sincerity » of the individuals writing their texts. They should

not be concerned with writing « beautiful » texts, where the linguistic effects are desired. Moreover, a lot of classical linguistic problems appearing in texts analysis, as the treatment of anaphors or pragmatic inferences, which may need a model of the world to be correctly understood, are, at the moment, abandoned.

To reach more general conclusions, we first have to go on our study on larger corpuses and then to extend it to the study of the expression of other intentional attitudes. It is now well known that an intention is under-determined by its linguistic form. It is possible that, to determine the right class an ambiguous intention belongs to, one does not need to know more about the « circumstances » of the locution but on the « cognitive style » of the narrator, who will tend to express the same intention with the same typical structure.

This approach seems promising as we point out some cognitive aspects of the language that have been deserted by traditional semantical representations only focusing on truth conditions. Instead of considering texts as representing *states of the world* (what is assumed in semantical studies), we consider them as indications about the *states of mind* of the narrator. This work can thus also be considered as a contribution to a computational definition of mental states, based on linguistics indications. Our approach is certainly still rudimentary, but we think that it is worth going further in this direction.

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