THE CATEGORY OF THE CONJUNCTION IN CATEGORIAL GRAMMAR

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In this work a categorial type for conjunctions (and, or, etc) is proposed within the Categorial Grammar formalism. First of all, I present three main characteristics that have to be accounted for in any analysis of conjunction. Secondly, I explain the different contributions that have been made within this formalism to find a category for conjunction that allows us to account for natural language phenomena. All those proposals are commented on with regard to the three properties to be explained. Next, a categorial type for conjunctions is proposed which can account for those characteristics. This category introduces a new n-tuple operator which is also useful for analysing other natural language phenomena.

INTRODUCTION

This paper is organized in two parts that can be read separately. The first one is an introduction to the Categorial Grammar formalism, so people who are familiar with this linguistic paradigm can directely pass to the second part of the paper. In the second part, I discuss what is the categorial type that should be assigned to conjunctions (and, or).

I. A GENERAL INTRODUCTION TO CATEGORIAL GRAMMAR

In this section I shall expose the main features of Categorial Grammar to allow people who do not know anything of this formalism to understand the objective of the second part of this paper.

Catalan Working Papers in Linguistics (CWPL) 1991: 301-341
Universitat Autònoma de Barcelona

A Categorial Grammar is formed by a set of Categories, a set of Operators and a set of Operations.

1. Categories

The categories are the formulae assigned to lexical entries. Every lexical item in the lexicon has a category. Categories can be basic or functor (slashed). The basic ones are S (Sentence) and N (Noun) and all the other categories in the grammar are formed by combining these basic categories by means of operators. The categories that have operators in their composition are functor categories. A functor category is a function (a mathematical function) and is formed by a functor, an argument and a direction where the functor is looking for the argument. For instance: A category which looks for a Noun on its right to give a Noun Phrase is a Determiner, a category which looks for an NP on its right to give a category which looks for another NP on its left to give a Sentence is a transitive verb.

The formal definition of the set of categories is:

(i) If A is a basic category, then A belongs to CAT (the set of categories).

(ii) If A and B belong to CAT, then A/B belongs to CAT, where '/' is any member of the set of operators.

The clause (i) specifies the set of basic categories and the clause (ii) allows the grammar to generate the set of functor categories by means of the set of operators.

In this way, from S and N we have to be able to generate all the categories (formulae) of natural language grammatical categories. The categories which bear operators are functor categories which seek arguments to be cancelled.

2. Operators

The set of operators that are used to form new functor categories has gradually been made bigger as Categorial Grammar has been applied to natural language phenomena. The first operator is the slash of Forward Application, which is the operator that marks that the argument has to be sought forward, on the right side of the functor category:

(1) *Forward Application Operator*:

/ X/Y Y --> X

Ex. Det = NP/N

The second operator is the Backward Application. This is similar to the Forward one but the direction of the search changes. In this case the argument has to be looked for on the left:

(2) *Backward Application Operator:*

\ Y X\Y --> X

Ex. Intransitive Verb = S\NP

The third operator is the Bidirectional one. Then, the argument can be sought either on the right or on the left of the functor category.

(3) *Bidirectional Operator:*

| X|Y Y --> X , Y X|Y --> X

Ex. An extended class of sentencial modifiers: S|S

The fourth operator in pure Categorial Grammar is the product. This operator joins two adjacent categories.

(4) *Product Operator:*

* X*Y

This operator could be useful in some languages where some lexical items always appear concatenated, for instance, the two objects of ditransitive verbs in English, although it would be a category specifically proposed for such languages, since in other languages these two objects do not always appear adjacent . Moreover, in the second part of this work we shall see a new use of this operator.

This is the set of operators that were defined by Lambek (1958) in his Calculus, and has been widely adopted by most people who work in Categorial Grammar. The Lambek Calculus is a Formal System that allows us to deduce the operations of the grammar as theorems of the System. This Formal System has been studied in depth by Michael Moortgat (1988) and is the basis of the Generalized Categorial Grammar.

3. Operations

Operations apply to categories. There are two types of operations or rules: One place Operations and Two Place Operations. One place operations apply to a category to give another one. Two place operations apply to two categories to give one.

3.1. One Place Operations

They apply to a category of any type (in (5), T is any other category):

(5) *Forward Type Raising:*

$$X \dashrightarrow_{T>} T/(T\backslash X)$$

It means that if you have a category NP, for instance, you can change it to get S/(S\NP). This kind of operation, in any of its possibilities, is very useful. In fact, it permits us to change an argument category into a functor category. In the example given we have changed the category of an NP into a category which needs to find on its right another category which needs to find on its left that NP. What is this category? This category is the category of a NP subject. Recall that a VP will be a category that needs to find a NP on its left, (S\NP), then the category resulting from the type raising is the one that needs to find a VP on its right, namely a NP subject.

(6) *Backward Type Raising:*

X -->$_{T<}$ T\(T/X)

An interesting example could be the raised category of an object NP. This time T = S\NP, then the resulting category is (S\NP)\(S\NP)/NP. This category says that in order to form a VP -(S\NP)- we need to find on the left a transitive verb, which has the category (S\NP)/NP as it has already been explained.

3.2. Two Place Operations

They apply to two categories if their form matches with the variables.

(7) *Forward Functional Application:*

X/Y Y -->$_{>}$ X (>)

This operation corresponds to the Forward Application Operator. If we have a functor category whose argument is Y and we find this argument to the right, then we can derive the functor. For instance:

```
(8)  the     boy
     NP/N    N
     ------------>1
         NP
```

(9) *Backward Functional Application:*

Y X\Y -->$_{<}$ X (<)

This rule corresponds to the Backward Application Operator. This time the argument is found to the left of the functor category:

```
(10)  Mike   runs
      NP     S\NP
      ----------------<
          S
```

The intransitive verb seeks a NP on its left to give a Sentence.

(11) *Forward Functional Composition:*

X/Y Y/Z -->$_{C>}$ X/Z

This is the typical composition of mathematical functions. This is useful in linguistics, among other reasons, because it allows an analysis from left to right. Let us compare two derivations with and without Functional Composition, respectively:

```
(12)  Mary   eats        apples
      NP     (S\NP)/NP   NP
             ---------------------->
                  S\NP
      --------------------------------<
                  S
```

```
(13)  Mary   eats        apples
      NP     (S\NP)/NP   NP
      ------T>
      S/(S\NP)
      ------------------C>
             S/NP
      -------------------------------->
                 S
```

In (12), the analysis begins in the middle of the sentence while in (13) we strictly go from left to right.

There is also the backward version of composition:

(14) *Backward Functional Composition:*

$$Y\backslash Z \ X\backslash Y \dashrightarrow_{C<} X\backslash Z$$

The rule of introduction of the product operator:

(15) *Product Formation:*

$$X\ Y \dashrightarrow_{*} X{*}Y$$

This rule is used to concatenate adjacent elements. It takes two adjacent categories and gives a new category formed by the concatenation of both. It is an operation with a long tradition in Mathematics and Logic.

(16) *Product Deconstruction:*

$$X{*}Y \dashrightarrow X\ Y$$

This is the inverse of (15). It is used to break a product category into two adjacent categories.

These are some of the operations that can be derived from the Lambek Calculus. Moreover other authors, mainly Steedman, add new operations in order to give more descriptive and explanatory power to the grammar. Some of these are Forward and Backward Substitution and Crossed or Disharmonic operations:

(17) *Forward Substitution:*

$(X/Y)/Z \ Y/Z \longrightarrow_{>S} X/Z$

(18) *Backward Susbtitution:*

$Y\backslash Z \ (X\backslash Z)\backslash Z \longrightarrow_{<S} X\backslash Z$

All the operations seen until now are harmonic in the sense that the direction of their operator is the same. Disharmonic operations have the direction of operators crossed. One category is forward and the other is backward. These operations are proposed by Steedman (Combinatory Categorial Grammar) in order to account for some linguistic phenomena related with crossed dependencies:

(19) *Forward crossed Composition:*

$X/Y \ \ Y\backslash Z \longrightarrow_{>Bx} X\backslash Z$ [2]

(20) *Backward crossed Composition:*

$Y/Z \ \ X\backslash Y \longrightarrow_{<Bx} X/Z$

(21) Ex:

```
I     shall       buy    today  and   cook   tomorrow    the mushrooms
NP    (S\NP)/VP   VP/NP  VP\VP  CONJ  VP/NP  VP\VP       NP
                  -----------<Bx      ----------------<Bx
                    VP/NP                VP/NP
                  -----------------------------------&
                               VP/NP
                  ------------------------------------------------------>
                                    VP
      ------------------------------------------------------------------>
                               S\NP
------------------------------------------------------------------------<
                               S
```

(22) *Forward crossed Substitution:*

(X/Y)/Z Y\Z -->$_{>Sx}$ X\Z

(23) *Backward crossed Substitution:*

Y/Z (X\Y)/Z -->$_{<Sx}$ X/Z

(24) Example of analysis of a Parasitic gap:

```
(..the articles) that        the    boss  kept        without           reading
        N|N/(S/NP)           NP/N   N     (S\NP)/NP   (S\NP)\S\NP/GER   GER/NP
                             ------------>            ---------------------------C>
                                NP                        (S\NP)\(S\NP)/NP
                             ------------------T>  --------------------------------<Sx
                                   S/(S\NP)               (S\NP)/NP
                             ------------------------------------------------------C>
                                            S/NP
      ---------------------------------------------------------------------------->
                                      N|N
```

With crossed operations of Combinatory Categorial Grammar I end the exposition of operations.

II. THE CATEGORY OF CONJUNCTION

In this section I would like to discuss the category that should be attached to a copula. The resolution of this problem is previous to any account for coordination in Categorial Grammar.

As we have seen in the previous section, every lexical category has a categorial formula assigned to it. Normally, a categorial formula is found by considering its possibilities as being defined by a composition of diferent functions. So, the categorial type associated with a transitive verb is a function.of two arguments First of all, we have to find a NP object on the right. After cancelling this argument we have to find another NP on the left in order to lead to the final result, the sentence. Similarly, we have to find a formulation of conjunctions in these terms.

To get it, I will firstly explain some of the characteristics that any treatment of conjunction should include. After that, I shall comment on some proposals which have been made in the Categorial Grammar literature. Next, a new categorial type will be proposed and some examples of its application to natural language phenomena will be shown.

1. Some Characteristics of Conjunction

I would like to expose three main features of conjunctions. They are its prepositional nature, its infix location and the type of categories it combines with.

1.1. Prepositional Nature

This property was firstly pointed out by Ross (1967). He says that a natural language conjunction does not take its two arguments at the same time but it firstly takes the right argument and forms a constituent and after that it takes the left argument to get the final constituent. So, conjunctions are like prepositions since they combine on the right (although prepositions only have one argument). Many syntactic observations can be brought to support such a hypothesis.

In questions like (25), we can easily find answers like (26):

(25) Has Mary arrived yet?

(26) and Joan too.

(27) Mary has already arrived and Joan too.

And sentences like (28) can be paraphaseable like (29) but cannot be like (30):

(28) John left, and he did not even say goodbye

(29) John left. And he did not even say goodbye

(30) * John left and. He did not say goodbye

More evidence is provided by the 'textual' copula. These examples should be understood as coordinated with all the previous text. Thus, this conjunction joins two texts:

(31) And God said: (...)

In Latin, there was an enclitic copula ('-que') which was always attached to the last constituent of the coordination.

(32) Caius militesque vinxerunt

Caius soldiers-and won

Caius and his soldiers won

(33) * Caiusque milites vinxerunt

A last reason I shall show here is that the conjunction always appears with the second constituent when this constituent can move:

(34) Even Mary scolded him, and she is his best friend

(35) Even Mary, |and she |is his best friend, scolded him

|who |

All these points prove the rightness of the assumption that the conjunction forms a constituent with the second argument. And it should be accounted for by an analysis of coordination.

1.2. Infix Location

It will also be clear that the conjunction always appears between the two constituents that coordinates. Sentences like (36) and (37) cannot be right:

(36) *and John looks at Mary Peter kisses her

(37) *John looks at Mary Peter kisses her and

What is more, the conjunction not only appears between two constituents but also it takes both consecutively. We should propose a category that firstly takes the right argument and after that must take the left one. So, it would not be right to give an analysis where the conjunction joins the right constituent and the remnant of the sentence combines with the first conjunct.

1.3. The Type of Combinable Categories

It seems to me that the unmarked case and the more general one is when the two constituents the conjunction coordinates are of the same type. Let's look at some examples:

(38) [Peter]$_{NP}$ and [Mary]$_{NP}$

(39) [John buys the chicken]$_{S}$ and [Peter cooks it]$_{S}$

(40) [slowly]$_{ADV}$ and [smoothly]$_{ADV}$

(41) Peter [sings]$_{VP}$ and [dances]$_{VP}$

In all these sentences the constituents coordined are of the same type. There are some other examples that apparently join two constituents of different type:

(42) Harry eats beans and Barry potatoes (gapping phenomena)

(43) Bill is [a sensible man]$_{NP}$ and [waiting for being elected]$_{VP}$

(44) George is either [silly]$_{AP}$ or [an idiot]$_{NP}$

(45) Harry is [clever]$_{AP}$ and [receiving a good education]$_{VP}$

(46) Bill is [nervous]$_{AP}$ and under [pressure]$_{PP}$

(47) Bill has become [a manager]$_{NP}$ and [rich]$_{AP}$

(48) George comes [tomorrow]$_{ADV}$] and [on Monday]$_{PP}$

(49) Harry sings in the Royal theatre [this evening]$_{NP}$ and [on Saturday]$_{PP}$

In the example (42), I shall assume an analysis of the sort proposed in Steedman (1990). This author shows an analysis of gapping phenomena as constituent coordination. The reader interested in this proposal is suggested to consult the literature since I am not explaining it in detail because it would separate us from the matter of this paper.

The explanation of how we can account for examples in (43)-(49) is shorter and easier and we shall show how we can treat these examples as constituent coordination using Categorial Grammar.

In conclusion, we have to look for a category which conjoins like constituents as it can be shown that all coordination is constituent coordination.

2. The Categories Proposed

In this section, I shall expose some of the treatments of the categorial type of conjunctions (and, or...) that have been proposed in the Categorial Grammar literature. At the same time, I will comment on the adequacy of these proposals with regard to the characteristics of conjunctions which have just been explained.

2.1. Ajdukiewicz's Category

Ajdukiewicz assigned the type (50) to the conjunction:

(50) S|SS

($\frac{S}{SS}$ in his terminology, like a fraction)

This category says that in order to form an S we need to find on the right or on the left two Sentences. This category applies as follows, if we assume an analysis from left to right:

```
(51)  Peter eats apples   and      Beth drinks water

           S              S|SS            S

      -------------------------<

             S|S

      ------------------------------------------------>

                          S
```

It should be said that Ajdukiewicz mainly applies his analysis to formal languages. So, the comments we can make on this analysis are always relative as Ajdukievicz did not pretend to account for natural language phenomena. But, as his grammar has widely applied to natural language, we should consider his proposal for the conjunction. Moreover, this category has recently been used by Flynn (1983).

To begin with, the categorial type (50) is only for Sentential coordination, and it should be generalized to coordination of any categorial type. Secondly, the analysis outlined in (51) does not meet the prepositional property. As the direction of the first combination is not specified, we can combine it with the left constituent. But, more generally, this categorial type overgenerates due to this underspecification. In fact, we could derive sentences like (52) and (53).

(52) *and John eats apples Mary drinks water

(53) *John eats apples Mary drinks water and

which do not find the infix property.

In addition, it is not clear what kind of category forms 'SS', given the set of operators given above ({\,/,|,*}).

2.2. Lambek's Category

Lambek (1958,1961, 1988) proposed the following categorial type for conjunctions:

(54) (X\X)/X

It means that the conjunction is a category such that it has to combine with a category of any type, say X, on its right to give another category that has to combine with a category of type X on its left to give a category of type X. X is a variable which ranges over any possible category. So, let X be equal to NP:

```
(55) John    and       Mary
      NP   (X\X)/X    NP
           ------------------>
                 NP\NP
      -------------------------<
                 NP
```

This analysis obviously has the prepositional property since the conjunction first combines with the constituent on its right. On the other hand, it seems to be infix because it seeks one argument on its right and another on its left but there is a problem. The problem is there is nothing that forbids us from forming the first constituent NP\NP and, after that, combining it with the left constituent by means of a different operation from application, in a way that violates the third characteristic, the conjunction of like categories.

For instance, an ungrammatical sentence like (56) could be wrongly predicted by this categorial type in combination with backwards composition. Ajdukievicz's categorial type has this problem too.

```
(56) * (A man) who          walks   and      he talks
           N\N/(S\NP)[3]    S\NP  (X\X)/X    S
                                   ------------------>
                                           S\S
                            ----------------------------<C
                                          S\NP
```

Thus, as we can combine the category resulting from the conjunction plus the right conjunct with the left conjunct by means of backward composition, we have a wrong prediction. Intuitively, what we learn is that we have to compel an analysis where the operations that apply are forward and backward application on categories of the same type.

2.3. Steedman's Category

Steedman has treated in depth the problem of coordination in many papers and his categorial type for conjunction has been changing throughout. I will only comment on the last one but the criticisms are valid for his past accounts.

Steedman (1990) proposes a syntagmatic rule attached to conjunction. This rule has two parts:

(57) *Forward Coordination Rule (>&)*

conj X --> $[X]_{\&}$

Steedman (1990) pg. 223.

By this rule he combines the conjunction with the category of the second conjunct to get a new category which is the same as the second conjunct but he has added a '&' feature. This rule accounts for the prepositional property.

The second rule of coordination is:

(58) *Backward Coordination Rule (<&)*

X $[X]_{\&}$ --> X

ibid. pg. 223.

The second rule wipes the constituent marked with the feature '&' by combining it with another constituent with the same category. The resulting category is of the same type as the other two. It allows him to account for the infix property and conjunction of like categories. This rule allows him to avoid the problem of Ajdukievicz's and Lambek's category which was shown in (56).

In my opinion these rules have at least two problems. The first one is intratheoretic. As we have seen, a Categorial Grammar does not have any syntagmatic rule. Its derivations are produced by lexical categories and general operations over categories. Adding syntagmatic rules would be ad-hoc within the categorial grammar mechanism.

The second one concerns the nature of the rules themselves. Let us assume that we accept these syntagmatic rules, although we should not by the reasons alluded to. Then, we cannot admit such rules which introduce ad-hoc features in their application. Recall that Steedman needs a feature to mark the second constituent of the coordination. This mark allows him to recognize this second constituent to combine with the first one by means of the second rule. It forbids the application of another rule like backward combination in (56).

For these reasons I think a lexical category must be found for coordination within a categorially-based approach to coordination.

2.4. Geach and Wood's Category

I will comment on these two proposals together because they are very similar. Geach (1971) suggested the category (59):

(59) :x(2x) (in his terminology)

This category says that in order to form a category of type X, we have to find two categories of the same type X. Morover it says that the connective takes both arguments at the same time, as Geach has not contemplated the linguistic data exposed above to defend the prepositional character of conjunctions.

> "...'and', 'or', the connective is felt to be joining two clauses, not going with one rather than another"
>
> Geach (1971), pg 131.

To express this idea more properly Wood (1988) introduces a new operator. This is the infix operator 'I' which indicates that a functor appears between the elements of its argument. This operator can only be used when the argument is formed by a product:

> "as only will it have two elements for the functor to appear between, at the position in the string parallel to that of the * connective in the product category."
>
> Wood (1988) pg 90.

The infix operator allows us to cancel one argument on the left and another on the right. The product operator indicates that two arguments form a single unit, and draws the place where the lexical conjunction appears in a real sentence. Then the categorial type for conjunctions suggested by Wood is:

(60) $XI(X^{+}*X)$

where the superindex + means one or more occurrences of the category X (it is the asterisk of Kleene). It is useful for cases of multiple coordination like:

(61) Mary, Beth and Peter

The Kleene + allows us to conjoin all these coordinated categories and the product symbol (*) points out the place where the conjunction lexical item appears, in the last but one position.

This category has the infix property since it cancels both categories together, one on its left and the other on its right and it conjoins only like categories . One problem is that it does not account for the prepositional nature as it treats the two conjuncts as forming one single constituent with the conjunction.

An additional problem of this proposal is the use that Wood makes of the product operator. This operator is an old one within the categorial grammar literature and has a very well defined syntax and semantics. It was first introduced by Lambek (1958) as an operator of his Calculus. After that it was resumed by Moortgat (1988) and it is defined in the following terms:

> "An expression belongs to a product category (X*Y) if it is the concatenation of an expression of category X and an expression of category Y, in that order."
>
> Moortgat (1988)

With this, it seems to be clear that the interpretation that should be given to a category of type X*Y is a concatenation of two adjacent categories.

Nevertheless, when Wood proposes the category $XI(X^{+}*X)$ as associated with conjunctions, it seems that she does not use the product operator in this sense but instead '*' points to the place where the conjunction appears in the sequence of categories. Then:

> " ...the category assignment as $XI(X^{+}*X)$. * may be any conjunction is infixed before the final conjunct."
>
> Wood (1988), pg. 171.

It will be clear that if we interpret the sign '*' as the product operator defined by Lambek, we should interpret the category $XI(X^{+}*X)$ as one that looks for two or more items of the same category which are adjacent. But the interpretation given in Wood (1988) is that the product is parallel to the conjunction, in fact it is a draw of the conjunction. We can gloss this by saying that the conjunction would be an operator which appears between two categories that would otherwise appear concatenated. But, in fact, they are not concatened and the product operator does not describe the situation faithfully.

Wood's use of product operator seems to confuse the algebraic operator with the natural language one. Whenever we use an operator of Categorial Grammar, we are not referring to any operator of natural language. This is clear in the use of the product operator which also appears in Wood (1988). She says that a ditransitive verb is a category which has to combine with a product of two NP to get a VP (S\NP): (S\NP)/NP*NP. Here, the product operator only means adjacency, it is not drawing the place where a lexical operator of natural language appears.

There are two different uses of the product operator in Wood's work and I think that it should be clear that what corresponds to the classical definition of this operator does not give lexical reality to an algebraic operator. The product operator means adjacency; therefore, as we cannot identify it with a natural language operator, it seems that it is not the operator that joins the two (or more) constituents that enter coordination and that are cancelled by the infix operator.

Then, if product cannot join the coordinated constituents, which categorial operator does join the constituents coordinated by conjunction?.

2.5. *The Proposal*

As we have seen, the product operator has some problems as a categorial operator joining the constituents coordinated by conjunction. Moreover, Wood's category has the problem of not accounting for the prepositional property. On the other hand, Steedman's category does so but is not a lexical category as it is the claim of Categorial Grammar. I will try to give a lexical category which meets the three properties described above for conjunctions.

I shall adopt the infix operator. The infix operator is a function of two arguments, namely: F(x,y). This formula suggests that the two arguments are cancelled at the same time. But a function of two arguments can also cancel its arguments in two steps: F'y(x). I will adopt this second way of cancelling arguments to enable this operator to meet the prepositional property of the conjunction. This move is linguistically motivated, since both are formally equivalent.
To express this operator in Categorial Grammar formalism I will define it as an operator which seeks each argument in a different direction. It is an operator of double directionality. The first

argument is looked for on the right and the other argument on the left. In Categorial Grammar terminology it is a concatenation of operators of forward and backward application. Then:

(62) $\mathrm{I} = /,\backslash$

But I not only want to express that arguments have to be sought on the right and on the left, sucessively. I also want to express that they are to be cacelled by means of backward and fordward application rules. No operation in Categorial grammar has been defined for operators of two arguments. So we have to build an operation of cancellation of the infix operator, in the same way that there is one (or more) for using product or functional application operators. The operation which cancels the infix operator is:

(63) *Rule of infix operator:*

$$[Z\mathrm{I}(X,Y) \quad Y \text{-->} Z\backslash_{<}X] \cdot [X \quad Z\backslash_{<}X \text{-->} Z]$$

So the use of the infix operator is equivalent to the concatenation of fordward and backward application. The sign "$\backslash_{<}$" is not a new operator. It only expresses the intermediate step of the application of the infix operator. It reminds us that the second argument has to be looked for on te left and cancelled by backward application.

It is different from Wood´s infix operator, since (63) is an operation of two steps. It does not join its two argument at the same time: rather it firstly joins the right one and, immediately after that, the left one.

But the question is how to formally represent the set of arguments that the infix operator has to cancel. In fact, the two constituents that the conjunction joins form an ordered sequence. First comes the left constituent and then the right one, but they are not adjacent. Then, they form an ordered sequence, not a product.

In Mathematics and Logic, the idea of ordered pair and, generalizing, of n-tuple has been used fruitfully. I think it would be very useful to introduce a tuple operator in order to solve many empirical linguistic problems. Intuitively it represents an ordered sequence of elements.

Formally, it can be defined inductively:

(64) <x1,...xn>=<<x1...xn-1>,xn>, i.e., the n-tuple <x1...xn> is the ordered pair whose first element is the (n-1)-tuple <x1...xn-1> and whose second element is xn.

By introducing it as an operator of categorial grammar, we need a rule of construction:

(65) *N-Tuple Formation:*

X,...,Y --> ...,<X,Y>

This means that two categories which are in some order in a sentence can be grouped in a sequence or n-tuple of categories. A n-tuple is an ordered set of a concrete number of elements.

Correspondingly:

(66) *Tuple deconstruction:*

...,<X,Y> --> X,...,Y

Then, having this operator we can define the set of arguments that the infix operator needs to find as <X,X>. So the category that is proposed for the conjunction is:

(67) X I <X,X>

The infix operator will be taking its two arguments from the tuple from right to left until it is empty by means of forward and backward application.

Then, having in mind the syntax of the infix operator and the operator tuple, the derivation of a coordinated phrase would be:

```
(69)  John    and        Mary
       NP    XI<X,X>     NP
            ------------------->
               NP\<<NP>
        -------------------------<
                 NP
```

The category proposed, XI<X,X>, is equivalent to Lambek´s (X\X)/X category, but excluding the problem mentioned above as the infix operator forces the categorial engine to cancel both argument consecutively by means of forward and backward application. Even this categorial type is very similar to Ajdukiewicz´s, although it specifies the procedure of combination in more detail.

This category observes the prepositional property since it firstly joins the right conjunct. Moreover, it meets the infix property and it observes the like categories property. Finally , it is a unary category as it always asks for one category.

To allow this category to account for multiple coordination, we have only to add a Kleene asterisc[4]. Then:

(70) XI <X^{+},X>

Recall that with this category we need not stipulate the place where the conjunction appears as it runs directly from definition. In addition, with this formulation we maintain infix operator's characteristic of being diadic.

Recall that the only operator that can take elements from a tuple is the infix operator since the other operators only take one argument. Then if a n-tuple appears in a category with a slash operator {\,/,|}, the n-tuple must be cancelled as a whole. This kind of operation will be useful in providing analysis for some interesting phenomena of natural languages but I shall not treat these applications here.

The main difference between Wood's proposal and what has been outlined above refers to the application of the infix operator. Wood's infix operator takes both arguments in a single step as she unifies the product operator with the conjunction and its two arguments with the two constituents that conjunction joins. With the category proposed here the application of the infix category runs step by step, taking first the right argument and after that the left one as has been shown in (63).

3. Some Examples

In this section I would like to show some analysis using the categorial type proposed in section 2.5 to prove its correctness. I will distinguish between "constituent coordination" and "non-constituent coordination".

3.1. Constituent Coordination

To begin with, I would like to note the easiness of analysing the coordination of every categorial type by means of this category. There is no problem in analysing a coordination of NP, VP, or any category.

Then, two intransitive verbs coordinated:

```
(71) She     sings     and          dances

      NP      S\NP     XI<X+,X>  S\NP

      ---T>

      S/(S\NP)

                        ------------------>

                        (S\NP)\<(S\NP)[5]

              ------------------------------<

                            S\NP

      ---------------------------------------->

                        S
```

Two transitive verbs, and so on:

```
(72) Beth   buys        and          reads          a newspaper

      NP    (S\NP)/NP   XI<X+,X>  (S\NP)/NP      NP

      ---T>

      S/(S\NP)          ---------------------------->

                        (S\NP)/NP \< (S\NP)/NP

              ---------------------------------------<

                            (S\NP)/NP

      --------------------------------------------------C>

                        S/NP

      ------------------------------------------------------------------------->

                                    S
```

It can also be applied to modifiers of verb phrase:

```
(73)  always              or              often
   (S\NP)\(S\NP)[6]    XI<X+,X>     (S\NP)\(S\NP)
                        ------------------------------>
                          (S\NP)\(S\NP)\<(S\NP)\(S\NP)
   ----------------------------------------------------<
                         (S\NP)\(S\NP)
```

or to sentential modifiers:

```
(74)  today   and          tomorrow
        S\S   XI<X+,X>       S\S
               --------------------->
                (S\S) \< (S\S)
       --------------------------------<
                      S\S
```

And with nominal modifiers:

```
(75)  Many     green    and         blue    T-shirts
       NP/N     N/N    XI<X+,X>    N/N     N
                        -------------------->
                        N/N)\<(N/N)
                  --------------------------<
                              N/N
                  --------------------------------------->
              N
      ---------------------------------------------------<
                        NP
```

Let us try with a bit more difficult sentences, like the following:

```
(76) Beth said        that Peter  bought t    the chicken   and        Bill   cooked        it
      NP (S\NP)/S' S'/S   NP    S\NP)/NP  NP     X|<X+,X>   NP   (S\NP)/NP   NP
     --T>
    S/(S\NP)
      ---------C>
        S/S'
     --------------C>   --T>                                      --T>
         S/S           S/(S\NP                                    S/(S\NP)
                        . ------------C>                            -----------C>
                               S/NP                                    S/NP
                         ----------------------------->             ------------------------>
                                       S                                    S
                                                               ------------------------------>
                                                                         S\S
                         --------------------------------------------------------------------<
                                                           S
      ------------------------------------------------------------------------------------------>
                                       S
```

But:

```
(77) *Beth said     Harry  bought   the newspaper and        that  Peter   read      it
      NP (S\NP)/S' NP   (S\NP)/NP  NP     XI<X+,X> S'/S  NP    (S\NP)/NP  NP
     --T>
     S/(S\NP)
      ---------C>  --T>
          S/S'    S/(S\NP)
                   ------------C>
                        S/NP
                   ----------------------->                 --T>
                          S                              S/(S\NP)
                                                         ----------C>
                                                         S'/(S\NP)
                                                         --------------------C>
                                                                S'/NP
                                                         ---------------------------->
                                                                S'
                                              ------------------------------------------>
                                                             S'\<S'
                  *-----------------------------------------------------------------*
```

Moreover, with this categorial type, the derivation of sentence (56) is predicted ungrammatical. Sentence which was a problem for Lambek's proposal:

```
(78) * (A man) who        walks    and        he talks
             N\N/(S\NP)  S\NP  XI<X+,X>     S
                                 ------------------->
                                        S\<S
                           *----------------------------*
```

While:

(79) (A man) who walks and talks

N\N/(S\NP) S\NP XI<X^+,X> S\SN

--------------->

(S\NP)\<(S\NP)

----------------------------<

S\NP

-->

N\N

We can also see an example of multiple coordination:

(80) John sings, Beth dances and Mary jumps

S S XI<X^+,X> S

-------------------------->

S\<<S^+>

---<

S

But we cannot derive the ungrammatical coordination (81) because of the position of Kleene´s asterisc[7]:

(81) *John sings and Beth dances, Mary jumps

S XI<X^+,X> S S

------------------------->

S\<S

------------------------------------<

S

3.2. Non-Constituent Coordination

We have already commented on the fact that that coordination does not always seem to be like type coordination. In this section we shall show that coordination is always constituent coordination. To begin with, let us remember the cases shown above:

(43) Bill is [a sensible man]$_{NP}$ and [waiting to be elected]$_{VP}$

(44) George is either [silly]$_{AP}$ or [an idiot]$_{NP}$

(45) Harry is [clever]$_{AP}$ and [receiving a good education]$_{VP}$

(46) Bill is [nervous]$_{AP}$ and under [pressure]$_{PP}$

(47) Bill has become [a manager]$_{NP}$ and [rich]$_{AP}$

(48) George comes [tomorrow]$_{ADV}$] and [on Monday]$_{PP}$

(49) Harry sings in the Royal theatre [this evening]$_{NP}$ and [on Saturday]$_{PP}$

In all these cases, it seems to be a coordination of constituents of unlike type. But, in fact, the categorial type assigned to the constituents in each case is the same. I shall explain it in detail.

Most of the sentences that allow non-constituent coordination are copulatives, like (43)-(46). Following Wood (1988), in all sentences with a copulative verb it is convenient to unify the type of the atribute. The categorial type attached to the copulative verb is '(S\NP)/N/N'. This category says that a copulative verb needs to combine with a category which can function as a modifier of a Noun (an adjective, an NP in aposition, a PP, a gerund phrase...)[8]. Then, the categorial type asociated with an atribute is N/N, independently of its traditional category. So, an NP can be of categorial type N/N if it is an atribute or a modifier of NP. Some examples:

```
(82) George    is           an       idiot
      NP    (S\NP)/N/N  (N/N)/N   N
     --T>
     S/(S\NP)
     ---------------------C>   -------------->
         S/(N/N)                   N/N
     ----------------------------------------->
                      S
```

Thus, the derivation of (44) is:

```
(83) George is            either   silly     or          an       idiot
      NP  (S\NP)/N/N   X/X     N/N  XI<X+,X>    (N/N)/N     N
      --T>
      S/(S\NP)
     ----------------C>
         S/(N/N)                                      --------------->
                                                          N/N
                                               ---------------------------->
                                                     (N/N) \< (N/N)
                                  -----------------------------------------<
                                                     N/N
                          ------------------------------------------------->
                                                  N/N
     -------------------------------------------------------------------------->
                                     S
```

The derivation of (45):

```
(84) Harry     is          clever   and        receiving     a   good   education

       NP  (S\NP)/N/N  N/N    XI<X+,X>    (N/N)/NP NP/N N/N       N

     --T>

     S/(S\NP)

      -----------C>

        S/(N/N)

                                                              ------------------>

                                                                      N

                                                           --------------------->

                                                                         NP

                                               ---------------------------------->

                                                                  N/N

                                       ------------------------------------------->

                                                            (N/N)\<(N/N)

                                 -------------------------------------------------<

                                                           N/N

     ------------------------------------------------------------------------------>

                                                  S
```

Or (46):

```
(85) Bill    is           nervous   and          under        pressure

      NP   (S\NP)/N/N   N/N   XI<X+,X>   (N/N)/NP     NP

     --T>

     S(S\NP)

     ------------C>                              ------------------>

      S/(N/N)             N/N

                                     -------------------------------->

                                             (N/N)\<(N/N)

                           ---------------------------------------------<

                                          N/N

     ------------------------------------------------------------------->

                                        S
```

With regard to the other kind of sentences that allow non-constituent coordination from (47) to (49), I shall show that they have the same categorial type as they occupy the same argumental place. So, in Categorial Grammar an Adverb and a PP modifiing a VP both have the same categorial type '(S\NP)\(S\NP)'. Then the derivation of sentence (48) is straightforward:

```
(86) George   comes   tomorrow          and            on Monday
      NP       S\NP   (S\NP)\(S\NP)   XI<X+,X>  (S\NP)\(S\NP)
     ---T>
    S/(S\NP)
                                      ------------------------------->
                                   (S\NP)\(S\NP)\<(S\NP)\(S\NP)
                           ------------------------------------------------<
                                       (S\NP)\(S\NP)
                 ------------------------------------------------------------<
                                     S\NP
     ---------------------------------------------------------------------C>
                                 S
```

And (49):

```
(87) Harry   sings   in the Royal theatre  this evening    and         on Saturday
      NP     S\NP    (S\NP)\(S\NP)        (S\NP)\(S\NP)  XI<X+,X>    (S\NP)\(S\NP)
    ---T>
  S/(S\NP)
             -------------------------<               ---------------------------->
                     S\NP                           (S\NP)\(S\NP)\<(S\NP)\(S\NP)
                                      ----------------------------------------------<
                                                         (S\NP)\(S\NP)
            --------------------------------------------------------------------------<
                                          S\NP
     --------------------------------------------------------------------------------C>
                                       S
```

Categorial Grammar allows all these derivations in a simple way, by studying the argumental possibilities of constituents. In this way, there is no non-constituent coordination. As shown, all coordination is constituent coordination.[9]

4. Conclusions

In this paper, I have proposed a categorial type for conjunction. This category meets three important observational characteristics of natural language conjunctions, prepositional nature, infix location and like type coordination.

We have considered other possibilities such as Ajdukiewicz's, Lambek's, Steedman's, Geach's and Wood's. The categorial type proposed here is lexically based, which attunes with the general basis of Categorial Grammar. It joins its arguments by means of applications, avoiding the empirical problems that Lambek's proposal has. Moreover, it uses an adaptation of the infix operator firstly pointed out by Wood (1988). This new version allows us to account for the prepositional property of the conjunction, first indicated by Ross (1967).

Finally this categorial type introduces a new operator within Categorial Grammar formalism. The tuple operator will permit us to solve other intricate problems which natural language presents that will be treated in the future. In this work, I use it to indicate that the set of arguments that a conjunction must cancel are not adjacent but consecutive. In this sense, it leads to better results than the product operator, which has been used in the literature, and picks up the true spirit of Ajdukiewicz's proposal.

•The author is indebted to support from the General Department of Education of Catalonia.

Notes

[1] Every step of a derivation has a symbol which says which operation has been applied.

[2] The symbol 'B' to mark the composition is usually used by Steedman in all his works because this is the symbol of the Combinator of Combinatory Logics equivalent to Lambek's Composition.

[3] This category corresponds to a relative pronoun of subject. It is a category which needs to find a VP on its right to give a Nominal modifier.

[4] Notice that the Kleene asterisk could be rewritten as an n-tuple of like type arguments.

[5] This can be written in this way by the equivalence shown above. The Kleene asterisk should also be written, as in derivation (80) below, but we will not write it for the sake of simplicity when the coordination is not multiple.
So the formally strict category should be: $(S\backslash NP)\backslash\langle(S\backslash NP)^{+}\rangle$.

[6] This categorial type is associated with verb phrase modifiers. It only says that in order to form a category of type verb phrase (S\NP), it needs to find a verb phrase on its left. Every VP modifier will have this categorial type. So, a preposition which would modify a VP will have the categorial type: '(S\NP)\(S\NP)/NP'.

[7] Of course, if we apply this categorial type to languages where word order is different we should change the direction of operators in the syntax of infix operator and, perhaps, the position of the Kleene asterisk.

[8] The direction of the operator of a modifier is very variable. As I am not giving a theory for modifiers I will not treat this point , although.the direction will change parametrically between languages and occasionally in a language. These variations should be studied in depth.

[9] For further details of gapping phenomena treated as constituent coordination, see Steedman (1990).

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