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Monotonicity and the Theory of Relation Changes in LFG

1 Early LFG

LFG was one of the first theories of grammar designed in accordance with both computational and linguistic constraints. *Monotonicity* is the most fundamental computational constraint imposed on its design, *universality* the most important linguistic constraint. 'Monotonicity' refers to the mapping from the set S of strings of words of a language into the set F of structures representing the grammatical relations of those strings according to a grammar G: as the length of any string increases, so does the information contained in the structure(s) assigned to that string according to the rules of G.[1]

Relation changes pose a particular problem for the theory, because the linguistic and computational constraints appear to come into conflict in this domain. If relation changes necessarily replace the syntactic attributes of arguments (as the passive replaces an object by a subject, for example), how can they be analyzed monotonically by a simple syntax interpreter? Information would be lost or deleted from the string if the initial analysis of the subject of a passive sentence, such as *the theorem* in *The theorem was proved by the woman*, were changed to make it the object of the verb.

Lexical-functional grammar originally achieved monotonicity by removing all relation changes from the syntax into the lexicon and lexical morphology, where they can be "precompiled" for syntactic analysis. This move is possible because all relation changes, like the active-passive relation, are local to verbs (and other predicators), affecting only lexically related arguments, and the choice among alternative lexical forms involves only bounded computation.

This idea requires that both the active and passive forms of verbs be provided by the lexicon and lexical morphology, through lexical redundancy

[1] See Bresnan, "Lecture Notes for LFG," Fall 1990, No. 4; distributed at the Tutorial on Linguistic and Computational Constraints on Grammar—An LFG Approach, Seoul International Conference on Natural Language Processing, Seoul, Korea, November 21–24, 1990.

rules as in (1) and (2) (Bresnan 1982):

(1)

$$\begin{array}{ccc} \text{active} & & \text{passive} \\ \mathrm{R} < \begin{array}{cc}\theta_1 & \theta_2 \\ | & | \\ \text{S} & \text{O}\end{array} > & \Longleftrightarrow & \mathrm{R} < \begin{array}{cc}\theta_1 & \theta_2 \\ | & | \\ (\text{OBL}) & \text{S}\end{array} > \end{array}$$

(2)

$$\begin{array}{ccc} \text{active} & & \text{intransitive} \\ \mathrm{R} < \begin{array}{cc}\theta_1 & \theta_2 \\ | & | \\ \text{S} & \text{O}\end{array} > & \Longleftrightarrow & \mathrm{R} < \begin{array}{cc}\theta_1 & \theta_2 \\ | & | \\ \text{OBL} & \emptyset\end{array} > \end{array}$$

Relation changes as illustrated in (1) and (2) are viewed as redundancy rules yielding alternative lexical relations for the same verb.

In essence, the grammar is factored into relation-changing lexical regularities like (1)–(2) and relation-preserving syntactic regularities. The latter consist of word order principles and principles for associating surface structures with syntactic functions. The syntactic functions serve to abstract away from variations in the structural expression of arguments.

It was thought to be a consequence of this LFG architecture that relation changes must be largely invariant across languages, while the surface structural changes associated with them may vary radically across languages (Bresnan 1982: pp. 8ff). This is so because relation changes are defined on predicate argument structures and grammatical functions, both of which abstract away from language-particular grammatical properties, while the associations of functions with surface structures are variable within and across languages.

Thus, in a nutshell, in LFG the lexical analysis of relation-changes allows for monotonicity in the syntax, and the abstraction to grammatical functions allows for universality.

2 Problems with the Theory

There are, however, serious linguistic problems with this theory of relation changes.

2.1 No Substantive Theory of Lexical Relations

First, while the theory does constrain relation changes by limiting them to redundancies on lexical relations, as in (1)–(2), it provides no substantive theory of the lexical relations themselves. Apart from very general formal conditions on lexical relations, there are no limitations on associating functions with semantic roles. For example, an agent and patient could just as well be associated with an OBJ and SUBJ, respectively, as the reverse. Hence it would be just as easy to write the lexical rule in (3) as the passive rule in (1).

(3) $$\mathrm{R} < \begin{array}{cc}\theta_1 & \theta_2 \\ | & | \\ \mathrm{S} & \mathrm{O}\end{array} > \quad \Longleftrightarrow \quad \mathrm{R} < \begin{array}{cc}\theta_1 & \theta_2 \\ | & | \\ \mathrm{O} & \mathrm{S}\end{array} >$$

Rule (3) simply reverses the grammatical functions SUBJ and OBJ, which in turn induces reversal in the possible syntactic positions of the arguments. Thus examples like *The woman proved the theorem* and **The theorem proved the woman* would be systematically related. But such relation changes are vanishingly rare in natural language, while the active-passive relation change is widespread. This and many other such gaps are not explained by the theory.

2.2 Insufficient Generality of Lexical Rules

Second, it is true that each lexical rule abstracts away from language-particular surface structures, and so provides an invariant characterization of a relation change for languages that share the rule. But the rules themselves lack generality as universal characterizations of the relation changes. For example, the lexical rule of passive in (1) captures the invariance of passive across English and other structurally different languages that share this rule. But only some of the abstract properties of passivization across languages are captured by the rule.

Consider the existence of symmetric passivization. In Standard American English, only the first object of a ditransitive verb can become the passive subject, as illustrated in (4):

(4) a. Both parents cooked the children supper.

b. The children were cooked supper by both parents.

c.*Supper was cooked the children by both parents.

This is asymmetric passivization, and it can be accounted for by assuming the passive rule in (1) and analyzing the examples in (4) as having one OBJ function (the NP adjacent to the verb) and one OBJ$_2$ function (the second NP); only the OBJ function will be replaced by SUBJ by rule (1). However, in other languages either of the two objects of ditransitive verbs can become the passive subject; for example, Bresnan and Moshi (1990) give grammatical examples in Kichaga corresponding to both (4b and c). This is symmetric passivization.

There are two ways that symmetric passivization might be analyzed consistently with (1). One way is to assume that both objects have the same syntactic function Then the passive rule (1) will apply to either object:

(5)

$$\begin{array}{ccccc}
 & \text{active} & & & \text{passive} \\
\mathrm{R} < & \begin{array}{ccc}\theta_1 & \theta_2 & \theta_3 \\ \mathrm{S} & \mathrm{O} & \mathrm{O}\end{array} & > \quad \Longleftrightarrow & \mathrm{R} < & \begin{array}{ccc}\theta_1 & \theta_2 & \theta_3 \\ (\mathrm{OBL}) & \mathrm{S} & \mathrm{O}\end{array} > \text{ or:} \\
 & & & \mathrm{R} < & \begin{array}{ccc}\theta_1 & \theta_2 & \theta_3 \\ (\mathrm{OBL}) & \mathrm{O} & \mathrm{S}\end{array} >
\end{array}$$

Howevever, there are both empirical and theoretical problems with this solution.[2]

The other analysis consistent with the universality of (1) assumes that the ditransitives are covertly asymmetric, in that they are functionally ambiguous as to which argument is the passivizable object (OBJ) and which is the unpassivizable object (OBJ$_2$). Then either object argument can undergo the passive relation change in (1). This analysis is shown in (6):

(6)

$$\begin{array}{ccccc}
 & \text{alternative actives} & & & \text{alternative passives} \\
\mathrm{R} < & \begin{array}{ccc}\theta_1 & \theta_2 & \theta_3 \\ \mathrm{S} & \mathrm{O} & \mathrm{O}_2\end{array} & > \quad \Longleftrightarrow & \mathrm{R} < & \begin{array}{ccc}\theta_1 & \theta_2 & \theta_3 \\ (\mathrm{OBL}) & \mathrm{S} & \mathrm{O}_2\end{array} > \\
\mathrm{R} < & \begin{array}{ccc}\theta_1 & \theta_2 & \theta_3 \\ \mathrm{S} & \mathrm{O}_2 & \mathrm{O}\end{array} & > \quad \Longleftrightarrow & \mathrm{R} < & \begin{array}{ccc}\theta_1 & \theta_2 & \theta_3 \\ (\mathrm{OBL}) & \mathrm{O}_2 & \mathrm{S}\end{array} >
\end{array}$$

Unlike (5), this analysis predicts that either of the two object roles of a ditransitive verb can be a passivizable object (OBJ), but only one at a time can be. This prediction, too, is empirically false (Bresnan and Moshi 1990).

In sum, there is evidence that passivization of ditransitives across languages is incompatible with the universality of the passive rule (1). Within

[2] See Bresnan and Moshi (1990) and the references cited there for discussion.

the framework of the early LFG theory, a second passive rule must be formulated, allowing OBJ$_2$ to be replaced by SUBJ:

(7)
$$\begin{array}{ccccccccccc}
 & & \text{active} & & & & & & \text{second passive} & & \\
\mathrm{R} < & \theta_1 & \theta_2 & \theta_3 & > & \Longleftrightarrow & \mathrm{R} < & \theta_1 & \theta_2 & \theta_3 & > \\
 & | & | & | & & & & | & | & | & \\
 & \text{S} & \text{O} & \text{O}_2 & & & & (\text{OBL}) & \text{O} & \text{S} &
\end{array}$$

This discussion shows that the passive rule itself is not invariant across languages, but requires the stipulation of several variations. Various notational devices for collapsing rules such as (1) and (7) into a single schema can be devised, but they simply mask the disjunctions of stipulations which indicate that the theory itself is insufficiently abstract.

2.3 Covariation of Relation Changes

The third problem for the theory is the covariation of relation changes across languages. We have just seen that several different versions of the passive rule are required for different languages. The same is true of other relation changes as well, such as intransitivization in (2). Intransitivization can apply only to passivizable objects—to OBJs, but not to OBJ$_2$s, as illustrated by the contrast in (8):[3]

(8) a. We'll cook for Thanksgiving.
(= We'll cook something for Thanksgiving.)

b. *We'll cook the children for Thanksgiving.
(= We'll cook the children something for Thanksgiving.)

But in a symmetric passive language, Bresnan and Moshi (1990) show that intransitivization can apply to the OBJ$_2$—even when the OBJ has been passivized as in (9):

(9) *The children will be cooked for Thanksgiving.
(= The children will be cooked something for Thanksgiving.)

[3]Bresnan and Moshi (1990) establish this point by contrasting two Bantu languages which differ minimally in the syntax of their ditransitives. English has a property which provides an overlapping explanation of the ungrammaticality of (9): no intransitive verb in English can take a dative NP object (cf. *We danced *(for) them*).

What this means is that not only must a second passive rule be formulated, as in (7), but a second intransitive rule must also be formulated, as in (10):

(10)

$$\begin{array}{ccccccccccccc} & \text{active} & & & & & & & \text{second intransitive} & & & \\ R < & \theta_1 & \theta_2 & \theta_3 & > & \Longleftrightarrow & R < & \theta_1 & \theta_2 & \theta_3 & > \\ & | & | & | & & & & | & | & | & \\ & \text{S} & \text{O} & \text{O}_2 & & & & \text{S} & \text{O} & \emptyset & \end{array}$$

What is not explained by this approach is the covariation in such relation-changing rules across languages.

3 A New Theory of Relation Changes

These are other problems are resolved by the new theory of relation changes in LFG referred to as the lexical mapping theory (Bresnan and Kanerva 1989) or the theory of a(rgument)-structures (Bresnan and Zaenen 1990).[4] This theory provides principles constraining the mappings between the semantic roles in lexical relations and the syntactic functions in f-structures.

3.1 The Theory of A-structures

The grammatically significant participant-role relations in the structure of events are represented by a-structures. An a-structure consists of a predicator with its argument roles, an ordering that represents the relative prominence of the roles, and a syntactic classification of each role indicated by a feature. Examples are given in (11) and (12):[5]

(11)

$$\begin{array}{ccccc} \textit{pound} & < & ag & pt & > \\ & & [-o] & [-r] & \end{array}$$

(12)

$$\begin{array}{cccc} \textit{freeze} & < & th & > \\ & & [-r] & \end{array}$$

The relative prominence of the roles is indicated by their left to right order and reflects a thematic hierarchy. The ordering is the one proposed in Kiparsky (1987), Bresnan and Kanerva (1989), and elsewhere, and might

[4]The description of the theory given here is taken from Bresnan and Zaenen (1990).

[5]The thematic labels *ag(ent), th(eme)* are used here as abbreviations for a finer-grained semantic analysis. Cf. Dowty (1987) and Pinker (1989).

be derived from semantic primitives along the lines of Dowty (1987): *agent* $<$ *beneficiary* $<$ *experiencer/goal* $<$ *instrument* $<$ *patient/theme* $<$ *locative*. Thus the most prominent role of *pound* is the agent, the most prominent role of *freeze* is the theme. The notation $\hat{\theta}$ designates the most prominent role of a predicator.

Although the agent of (11) and the theme of (12) are the most prominent roles in the respective argument structures, there are important syntactic differences between them. These are captured by the syntactic features of the a-structure. The a-structure features $[\pm o]$ and $[\pm r]$ constrain the way in which the roles are mapped onto syntactic functions in f-structures. The syntactic functions are grouped into natural classes as shown in (13):

(13)

$$\begin{array}{ccc} -r & \text{S} & -o \\ & & \\ \text{O} & & \text{OBL}_\theta \\ & & \\ +o & \text{O}_\theta & +r \end{array}$$

The feature $[-r]$ refers to an *unrestricted* syntactic function, the kind of function which is not restricted as to its semantic role. Only subjects and objects are $[-r]$; obliques and restricted objects are $[+r]$. The feature $[-o]$ refers to a *nonobjective* syntactic function, the kind of function which complements intransitive predicators such as N or A. Only subjects and obliques are $[-o]$; objects and restricted objects are $[+o]$. Not all languages make use of all these possibilities. Many languages lack restricted objects; this is one difference between Romance and Germanic, for example. However, we assume that all languages have subjects.[6] In our representation, the minus features define the less marked syntactic functions; the subject is least marked, and the restricted object is most marked. Thus (13) can be read as a markedness hierarchy of syntactic functions, descending from top to bottom.

It follows from this classification that a $[-o]$ role cannot be mapped onto an object, and a $[-r]$ role can be mapped onto a subject or object:

(14)

$$\begin{array}{lcc} \text{a-structure:} & \theta & \theta \\ & [-o] & [-r] \\ & \not| & | \\ \text{f-structure:} & \text{O} & \text{S/O} \end{array}$$

[6] This assumption is not uncontroversial. See Foley and Van Valin (1984) and Andrews (1985) for discussion.

The basic principles for determining the unmarked choice of syntactic features in the a-structure (ignoring cases of lexical idiosyncrasy) are simple and general across languages:

(15) patientlike roles: $\begin{array}{c}\theta \\ [-r]\end{array}$

secondary patientlike roles:[7] $\begin{array}{c}\theta \\ [+o]\end{array}$

other roles: $\begin{array}{c}\theta \\ [-o]\end{array}$

The a-structure allows us to define notions akin the those of external and internal argument as used e.g. in Levin and Rappaport (1986): an internal argument has one of the object features ($[-r]$ or $[+o]$), and the external argument is a $\hat{\theta}$ which is $[-o]$. Note that a-structures may have empty argument roles that have no semantic role content; these can only be $[-r]$, by definition of the unrestricted feature.

Conditions can be imposed on the a-structure. In some languages more than one semantic role can be associated with $[-r]$ whereas in others this association is limited to just one. Bresnan and Moshi (1990) argue that the classical typological differences between symmetrical (so-called 'double object') languages and asymmetrical ones follows from this parameter and illustrate this with a comparison of Chicheŵa and Kichaga. English is another language in which this constraint on a-structures, stated in (16), holds, as noted above:

(16) $$* \begin{array}{cc}\theta & \theta \\ | & | \\ [-r] & [-r]\end{array}$$

When, in an asymmetrical language, there are two patientlike roles (such as a recipient object and a theme, for example), $[+o]$ will be assigned to the secondary one. In English this is always the lower role on the hierarchy.

[7] Verbs may have multiple patientlike roles, as with ditransitives. Which roles count as secondary appears to be a parameter of variation. See Alsina and Mchombo (1989), Bresnan and Moshi (1990), Huang (1990), and Alsina (1990) for further discussion.

The lexical stock of a-structures in a language can be extended by morphological means.[8] For example, the a-structure of a passive verb differs from the active in that the most prominent role cannot be mapped onto a syntactic argument in the f-structure (though it may be linked to an argument adjunct such as the by-phrase in English). This is called 'suppression'. The notation is given in (17):

(17) Passive:
$$\begin{array}{c} \hat{\theta} \\ | \\ \emptyset \end{array}$$

The intransitivization rule is also a suppresion operation on a-structure:

(18) Intransitivization:
$$\begin{array}{c} th/pt \\ | \\ \emptyset \end{array}$$

Suppressions can affect only unmarked roles in a-structures (Alsina 1990), that is, only negatively specified roles.

In sum, the a-structures of words contain the minimal lexical information needed for the projection of semantic roles onto surface syntactic functions. A fundamental generalization embodied in them is that patientlike roles may alternate between subject and object while other roles such as agent and e.g. locatives alternate between the nonobject functions. This captures a pervasive typological pattern across languages. (See Bresnan and Kanerva, 1989, pp. 25–26.)

3.2 Principles Mapping A-structures to Syntactic Functions

The basic syntactic principles for mapping a-structures to surface grammatical functions are simple.[9] The underspecified roles are freely mapped onto all compatible grammatical functions subject to a few general constraints: if available, the 'external' argument (as defined above) has to be mapped onto the subject; if there is no external argument, an internal argument

[8]—and possibly also by syntactic means such as phrasal composition of a-structures in certain cases of complex predicates. Syntactic relation changes were precluded in early versions of LFG because relation changes involved nonmonotonic attribute changes (e.g. OBJ $\rightarrow$ SUBJ). The present theory is monotonic and compatible with the syntactic composition of complex predicates under certain conditions.

[9]For a formally equivalent system, see Alsina (1990).

is mapped onto the subject. All other roles are mapped onto the lowest compatible function on the markedness hierarchy (14).

(19) **Mapping Principles:**

a. Subject roles:

(i) $\underset{[-o]}{\hat{\theta}}$ is mapped onto SUBJ; otherwise:

(ii) $\underset{[-r]}{\theta}$ is mapped onto SUBJ.

b. Other roles are mapped onto the lowest compatible function on the markedness hierarchy (14).

There are other constraints on the mapping, such as Function-argument Biuniqueness:[10]

(20) *Function-argument biuniqueness:* Each a-structure role must be associated with a unique function, and conversely.

Multiple restricted objects and obliques are possible because these functions are further individuated by their semantic roles (see Bresnan and Kanerva, 1989, p. 25 for discussion).

3.3 Examples

The active form of *cook* has an agent role and a patient role. These are respectively assigned a $[-o]$ and a $[-r]$ feature by the a-structure principles given above. The $[-o]$ argument is also the most prominent argument, given the thematic hierarchy, so it is the 'external argument'. The a-structure is as given in (21):

(21) $\textit{cook} \quad < \quad \underset{[-o]}{\textit{ag}} \quad \underset{[-r]}{\textit{pt}} \quad >$

[10]For cases not discussed in this paper, we also need the Subject Condition, according to which every (verbal) predicator must have a subject. This condition may need to be parameterized so as to hold only for some types of languages (see Bresnan and Kanerva, 1989; Mohanan, 1990).

According to the a- to f-structure mapping principles in (19), the 'external' argument role will be mapped onto the subject (19a(i)); the other argument role will be mapped to the unrestricted object function, the most marked function compatible with the $[-r]$ a-structure feature:

(22) TRANSITIVE:

$$\begin{array}{lllccll} \text{a-structure:} & \textit{cook} & < & \textit{ag} & \textit{pt} & > & \\ & & & [-o] & [-r] & & \\ & & & | & | & & \\ \text{f-structure:} & & & \text{S} & \text{O} & & \text{((19a(i)) and (20))} \end{array}$$

In the passive a-structure, $\hat{\theta}$ is suppressed and an internal role is mapped onto the subject function by (19a(ii)):

(23) PASSIVE:

$$\begin{array}{lllccll} \text{a-structure:} & \textit{cooked} & < & \textit{ag} & \textit{pt} & > & \\ & & & [-o] & [-r] & & \\ & & & \emptyset & | & & \\ \text{f-structure:} & & & & \text{S} & & \text{((19a(ii)))} \end{array}$$

In the active intransitive a-structure, it is the patient role that is suppressed:

(24) TRANSITIVE:

$$\begin{array}{lllccll} \text{a-structure:} & \textit{cook} & < & \textit{ag} & \textit{pt} & > & \\ & & & [-o] & [-r] & & \\ & & & | & \emptyset & & \\ \text{f-structure:} & & & \text{S} & & & \text{((19a(i)) and (20))} \end{array}$$

The ditransitive of *cook* has an added beneficiary role, which is a patient-like 'internal argument'. It is thus assigned the $[-r]$ feature and, because English allows only one such internal role by the asymmetrical object parameter discussed above, the lower patient role must then receive the secondary $[+o]$ classification. The a-structure is as given in (25):

(25)
$$\begin{array}{llcccl} \textit{cook} & < & \textit{ag} & \textit{ben} & \textit{pt} & > \\ & & [-o] & [-r] & [+o] & \end{array}$$

Applying the mapping principles to this argument structure, we find that the agent will be mapped onto the subject as external argument; the beneficiary will be mapped onto the object as the most marked function compatible with the $[-r]$ feature; and the patient will be mapped onto the restricted object as the most marked function compatible with the $[+o]$ feature:

(26) DITRANSITIVE:

a-structure:	*cook*	<	*ag*	*ben*	*pt*	>	
			$[-o]$	$[-r]$	$[+o]$		
			|	|	|		
f-structure:			S	O	O_θ		((19a(i)) and (20))

In the corresponding passive a-structure, $\hat{\theta}$ is suppressed and an internal role is mapped onto the subject function:

(27) PASSIVE OF DITRANSITIVE:

a-structure:	*cooked*	<	*ag*	*ben*	*pt*	>	
			$[-o]$	$[-r]$	$[+o]$		
			Ø	|	|		
f-structure:				S	O_θ		((19a(ii)))

However, if we try to apply intransitivization to either the active ditransitive argument structure or to the passive version, it will fail. Suppressions may apply only to unmarked roles, that is, those that are negatively specified:

(28) DITRANSITIVE:

a-structure:	*cook*	<	*ag*	*ben*	*pt*	>
			$[-o]$	$[-r]$	$[+o]$	
					Ø	
					*	

This accounts for examples (8)–(9) above.

4 Solutions

The problems posed for the earlier theory of relation-changes are solved by the new theory of argument structures. Consider first the problem of co-variation. A symmetric passive language will differ from English is allowing more than one $[-r]$ internal role in the a-structure. Either of two such roles can be mapped onto the subject function by the mapping principles, and suppressions such as intransitivization will have more possible roles to apply to. The covariation in these properties flows from the same single factor: how many 'internal' argument roles are allowed in the a-structure.

Next consider the problem of generality of relation changes. Under the new theory the formulation of a-structure operations such as passive and intransitivization is maximally simple: these simply suppress roles. (Other relation-changes may add or fuse argument roles (Alsina 1990).) What had to be expressed in the earlier theory by variations in the formulation of rules, follows in the new theory from a single variation in a condition on a-structures. The rules are now invariant.

Finally, consider the problem of lack of a substantive theory of lexical relations. Without such a theory we could not explain the absence of rules that simply reverse the associations of agent and patient with subject and object. According to the new theory, the agent (being the least patient-like role) is intrinsically characterized as nonobjective ($[-o]$); it cannot be mapped onto an object. Hence unwanted relation changes between examples like *The woman proved the theorem* and **The theorem proved the woman* are excluded in principle.

Observe, however, that subject-object reversals are allowed by the principles of the new theory in cases where two *internal* roles occur in the same a-structure:

(29) $$\begin{array}{lccccc} verb & < & \theta_1 & \theta_2 & > \\ & & [-r] & [-r] & \end{array}$$

In such a case, the mapping principles will allow either role to be mapped onto the subject function, and the other will be mapped onto the object. It also follows that languages exhibiting such reversals should show symmetrical passivization as well. Joshi (1990) demonstrates that Marathi, an Indo-European language spoken in India, is just such a language. She shows that Marathi allows subject-object reversals with a class of perception verbs, which have two internal argument roles, and it also allows symmetric passivization.

In conclusion, I have argued that the nonmonotonic theory of lexical relation-changes assumed in early LFG failed to satisfy the linguistic requirements of universality. The new theory solves the empirical linguistic problems of universality posed here, and also shows that the computational requirement of monotonicity can be met even in the domain of relation changes.

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