Flexible Boolean Semantics: Coordination, Plurality and Scope in Natural Language

Summary of the Dissertation

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This dissertation is based on the compositional modeltheoretic approach to natural language semantics that was initiated by Montague (1970) and developed by subsequent work. In this general approach, coordination and negation are treated following Keenan and Faltz (1978,1985) using *Boolean Algebras*. As in Barwise and Cooper (1981), noun phrases uniformly denote objects in the boolean domain of *Generalized Quantifiers*. These foundational assumptions, although elegant and minimalistic, are challenged by various phenomena of coordination, plurality and scope. The dissertation solves these problems by developing a *flexible* process of meaning composition, as first proposed by Partee and Rooth (1983). Flexible interpretation involves semantic operations without any phonological counterpart, which participate in the interpretation process and change meanings of overt expressions. The dissertation introduces a novel flexible system where a small number of operations describe the behaviour of complex phenomena like "non-boolean" *and*, the scope of indefinites and the semantics of collectivity with quantificational NPs.

The proposed theory is based on distinguishing between two features of meanings in natural language:

1. The *semantic category* feature, which describes the distinction between *quantificational* denotations and *predicative* denotations.

2. The *semantic number* feature, which distinguishes between denotations ranging over *atoms* and denotations ranging over *sets of atoms*.

We can describe these features using the notation $\pm$Q and $\pm$S. Flexibility operators shift meanings between the four kinds of denotations that these two features describe.

The boolean theory of coordination The basic fact about coordination in many languages is its *cross-categorial* behaviour: morphemes like *and* and *or* can appear in coordinate structures of many different categories, as (partly) illustrated by the following simple sentences.

(1) Mary sang and/or Sue danced.

(2) Mary and/or Sue sang.

(3) Mary sang and/or danced.

Early versions of Transformational Grammar assumed that this property of coordination could be explained by assuming that at deep structure coordinators are sentential only, like the connectives of first order logic. A *Conjunction*

Reduction transformation was assumed to relate phrasal coordinations at surface structure to sentential coordinations at deep structure. However, it was soon observed that this mechanism, in addition to its ill-founded assumption that first order logic is a linguistically relevant representational tool, also fails to describe many intricate facts about the semantics of coordination. For instance, while conjunction reduction correctly expects sentence (4a), with VP coordination, to be equivalent to the sentential coordination (4b), it falsely predicts equivalence also between sentences (5a) and (5b). The pattern of correct predictions and false predictions reverses in (6) and (7).

(4) a. Every woman danced and sang.
b. Every woman danced and every woman sang.

(5) a. Some woman danced and sang.
b. Some woman danced and some woman sang.

(6) a. Every woman danced or sang.
b. Every woman danced or every woman sang.

(7) a. Some woman danced or sang.
b. Some woman danced or some woman sang.

We conclude that conjunction reduction is too crude in being sensitive neither to the identity of the coordinator nor to the identity of the quantifier.

In opposition to the conjunction reduction rule, Boolean Semantics assumes that coordination can apply in *all* semantic domains, not only in the sentential domain of truth values. Thus, the "logical form" of coordination in boolean semantics can be identical to its surface structure. The reason coordinators like *and* and *or* apply in different semantic domains is that all these domains have something in common: they are all *boolean algebras*. This means (among other things) that they are all ordered in a similar way. For instance, the sentential domain of truth values is ordered by *implication*: truth is "greater than" falsity, or $1 > 0$. The domain of (intransitive) predicates is similarly ordered by *set inclusion*: any set is "greater than" its proper subsets. Such different order relations are all manifestations of one and the same relation: the *domination* order of boolean algebras. Similarly, the coordinators *and* and *or* denote the boolean operators *meet* and *join*, which apply in all the boolean domains. Keenan and Faltz's boolean semantics of coordination accounts for semantic relations between sentences as in (4)-(7) above in a remarkably elegant way.

The flexible boolean approach to "non-boolean" *and* One of the main challenges for the boolean treatment of coordination (as well as for conjunction reduction) comes from the "collective" interpretation of NP conjunctions as in the following simple sentence.

(8) Mary and John met.

The standard boolean treatment incorrectly predicts (8) to be equivalent to the unacceptable sentence *Mary met and John met.*

Many previous works, notably Hoeksema (1983,1988), conclude that the purely boolean treatment of *and* is incorrect, and propose that *and* also has a "non-boolean" denotation. This assumption, unlike the Keenan and Faltz system, is rather stipulative: it does not explain why conjunctive coordinators like *and* show collective behaviour in striking regularity across different languages of the world. Moreover, as reported in Payne (1985:17-8), no language was found where other coordinators (e.g. parallel to English *or*) show a "non-boolean" behaviour. Another general drawback of non-boolean accounts of conjunction is that they do not give a clear picture of the boolean/non-boolean variation in the meaning of *and* across coordinations of different categories. For instance, it is unclear why predicate conjunctions like *big and new* do not show a "non-boolean" meaning equivalent to *partly big and partly new.*

One of the main observations of the dissertation is that the boolean analysis of *and* has in fact a mathematical property that allows to treat also "collective" effects as in (8) without any change in the boolean semantics of coordination. A conjunction like *Mary and John* is standardly treated as a boolean coordination of generalized quantifiers. This is a quantificational denotation that ranges over atoms (+Q −S). However, the set of Mary and John, which is responsible for the collective interpretation of the NP, is in fact present in this "distributive" quantifier: it is its *minimal set.* By applying a minimum operator, the noun phrase denotation is shifted to a quantifier over this set (a +Q +S denotation). This procedure accounts for the collective meaning of sentences like (8) without any postulation of a special meaning for *and.* The difference between *and* and *or* in such contexts follows directly from their boolean treatment and the formal definition of the proposed operator.

The choice function analysis of indefinites A surprising semantic property of indefinites, observed by Fodor and Sag (1982) among others, is their exceptionally free scopal behaviour when compared to other NPs. For instance, while sentence (9a) can be interpreted as in (9b), this is not the case in the infelicitous sentence (10a), which cannot have the interpretation of (10b). We say that the *some* indefinite in (9a) and the *every* noun phrase in (10a) contrast with respect to their ability to take scope over the conditional.

(9) a. If some woman I know gave birth to John then he has a nice mother.

b. For some woman I know x, if x gave birth to John then he has a nice mother.

(10) a. #If every woman I know gave birth to John then he has a nice mother.

b. For every woman I know x, if x gave birth to John then he has a nice mother (=if one of the women I know is John's mother then she is nice).

No standard mechanism (e.g. Quantifier Raising, Cooper Storage) for treating wide scope effects can account for such clear contrasts. Moreover, if a movement

rule like Quantifier Raising (QR) were responsible for "wide scope" interpretations like (9b) for sentences with indefinites, then this rule must have violated island constraints on movement (e.g. the adjunct island introduced by the conditional in (9a)). Such behaviour would contradict all that is known about movement operations in other domains.

Reinhart (1992,1997) proposes a novel account of the exceptional wide scope interpretation of indefinites. While not introducing any change in the island restricted operation of QR, Reinhart proposes that indefinites should be interpreted using *choice functions*. These are functions that pick an element from every non-empty set. Wide scope readings of indefinites as in (9a) are analyzed as follows.

(11) For some choice function f, if the entity picked by f from the set of women I know gave birth to John, then he has a nice mother.

Under this formulation, there is no need to modify the QR rule, as existential quantification in (11) ("for some f") is obtained using the standard existential closure operator assumed in Discourse Representation Theory, which is independent of the position of the indefinite.

The dissertation shows that also the more complex scopal behavior of *plural* indefinites like *three women* can be correctly treated using choice functions. It is argued that these NPs show two different scope effects: the scope of *distributivity* of plural indefinites is independent of their *existential* scope and must be captured by a separate distributivity mechanism. A central piece of evidence for this claim comes from the interpretation of sentences like the following.

(12) If three workers (in our staff) have a baby soon then we will have to face some hard organizational problems.

   a. *There is* a set A of three workers such that *if each* x in A has a baby soon we will have to face some hard organizational problems.
   there is $>$ **if** $>$ **each** – an available scope relation

   b. *There is* a set A of three workers such that for *each* x in A, *if* x has a baby soon we will have to face some hard organizational problems.
   there is $>$ **each** $>$ **if** – an unavailable scope relation

As in Ruys (1992), it is shown that (12b), where distributivity ("each") takes scope over the conditional ("if"), is not an available interpretation of sentence (12). Moreover, the acceptable interpretation in (12a) directly shows two distinct scope positions for the indefinite: one is the scope of the existential quantifier ("there is"), which escapes the conditional island; another is the scope of distributivity, which is restricted to remain within the island. Both this "double scope" behaviour and the island restricted nature of distributivity are straightforwardly accounted for in the proposed analysis of choice functions and distributivity.

The dissertation makes two other contributions to the theory of choice functions in natural language:

1. The formal semantics of choice functions is defined within the boolean framework in a way that solves a central problem for this approach: the interpretation of indefinites with an empty N' denotation, as in *some intelligent unicorn*.

2. The choice function mechanism is introduced as a *general* existential flexibility mechanism from predicative NPs to quantificational NPs. In the flexibility scheme that emerges, this is the inverse operator to the minimum operator responsible for the interpretation of "non-boolean" conjunction.

The atom/set distinction and plural quantifiers Consider the following contrasts between the (a) and (b) sentences:

(13) a. All the/exactly five girls gathered in the hall.
b. *Every/exactly one girl gathered in the hall.

(14) a. All the/exactly five girls gathered in the hall. (=(13a))
b. *All the/exactly five girls are the team that won the cup.

(15) a. The (five) girls are the team that won the cup.
b. *All the/exactly five girls are the team that won the cup. (=(14b))

Each of these pairs illustrates another factor that affects the possibility to get a collective reading with quantificational NPs. The pair in (13) illustrates the necessity of plural number in order to get a collective reading. The pair in (14) illustrates the observation in Dowty (1987), where it was pointed out that there are two kinds of collective predicates: predicates such as *gather*, that allow collectivity with *all* and other plural quantifier, and predicates like *be the team that won the cup*, which resist collectivity in such contexts. The pair in (15) exemplifies a distinction between "referential" NPs and "quantificational" NPs with respect to the availability of collective interpretations.

The dissertation proposes a general account of such complex patterns, which is based on the following principles:

1. Flexibility operations that shift a denotation ranging over atoms to a denotation ranging over sets are allowed only with *morphologically plural* expressions.

2. With respect to the semantic number feature $\pm$S, there are two kinds of predicates in natural language: predicates of feature $-$S like *sleep* or *be the team that won the cup*, which range over atoms, and $+$S predicates like *meet* or *gather* that range over sets of atoms. This new "atom/set" typology is independent of the traditional distributive/collective distinction among predicates.

3. "Referential" plural NPs like *the (five) girls* have an "atom reading" following Landman (1996).

It is shown how these principles allow us to obtain a more general theory of plural quantification that develops existing treatments in the generalized quantifier school (Scha (1981), van der Does (1993)).

Additional topics Three other main topics are treated in detail within the framework of the dissertation:

1. The status of distributivity operators in semantic theory. It is argued that these operators are *unary* (apply to only one argument of the predicate at a time) and *atomic* (range over atoms rather than on arbitrary sets of atoms).

2. The apparent "non-boolean" behaviour of *and* in *predicate* conjunctions, as in the sentence *the books are old and new*, which is not equivalent to *the books are old and the books are new*. It is shown how such effects are handled using a generalization of the *strongest meaning hypothesis* on reciprocals proposed in Dalrymple et al. (1998).

3. The "wide scope" interpretation of coordination as in sentences like *every man and woman*. Such cases are treated using a revision of the boolean treatment, which assumes that *and* (unlike *or*) is meaningless, and its semantic function of boolean *meet* is carried by a (universal) grammatical operation.

References

Barwise, J. & and R. Cooper (1981). Generalized quantifiers and natural language. *Linguistics and Philosophy* 4, 159–219.

Dalrymple, M., M. Kanazawa, Y. Kim, S. Mchombo, & S. Peters (1998). Reciprocal expressions and the concept of reciprocity. *Linguistics and Philosophy* 21, 159–210.

Van der Does, J. (1993). Sums and quantifiers. *Linguistics and Philosophy* 16, 509–550.

Dowty, D. (1987). Collective predicates, distributive predicates and *all*. *Proceedings of the Eastern States Conference on Linguistics, ESCOL3*.

Fodor, J. D. & I. Sag (1982). Referential and quantificational indefinites. *Linguistics and Philosophy* 5, 355–398.

Hoeksema, J. (1983). Plurality and conjunction. *Studies in Modeltheoretic Semantics*, edited by A. ter Meulen. Dordrecht: Foris.

Hoeksema, J. (1988). The semantics of non-boolean *and*. *Journal of Semantics* 6, 19–40.

Keenan, E. & L. Faltz (1978). *Logical Types for Natural Language*. UCLA Occasional Papers in Linguistics 3, Department of Linguistics UCLA.

Keenan, E. & L. Faltz (1985). *Boolean Semantics for Natural Language*. Dordrecht: D. Reidel.

Landman, F. (1996). Plurality. *The Handbook of Contemporary Semantic Theory*, edited by S. Lappin. Blackwell.

Montague, R. (1970). English as a formal language. *Linguaggi nella Società e nella Technica*, edited by B. Visentini et al. Milan: Edizioni di Comunità. Reprinted in *Formal Philosophy: selected papers of Richard Montague*, edited by R. Thomason (1974). New Haven: Yale.

Partee, B. & M. Rooth (1983). Generalized conjunction and type ambiguity. *Meaning, Use and Interpretation of Language*, edited by R. Bauerle, C. Schwarze & A. von Stechow. Berlin: De Gruyter.

Payne, J. (1985). Complex phrases and complex sentences. *Language Typology and Syntactic Description*, Vol. 2, *complex constructions*, edited by T. Shopen. Cambridge: Cambridge University Press

Reinhart, T. (1992). Wh-in-situ: an apparent paradox. *Proceedings of the eighth Amsterdam Colloquium.*

Reinhart, T. (1997). Quantifier scope: how labor is divided between QR and choice functions. *Linguistics and Philosophy* 20, 335–397.

Ruys, E. G. (1992). *The Scope of Indefinites.* Doctoral dissertation, Utrecht University.

Scha, R. (1981). Distributive, collective and cumulative quantification. *Formal Methods in the Study of Language*, edited by J. Groenendijk, M. Stokhof, & T. M. V. Janssen. Amsterdam: Mathematisch Centrum.

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