An Approach to Anaphora Based on Mental Models

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Abstract. Structural approaches to anaphora try to solve it at the level of the formal language used for representing the meaning of sentences. But we believe that it must be approached by referring to the extension of the sentences. In this paper, we show that Johnson-Laird's Mental Models provide an adequate tool for coping with extensional representations and anaphora in a cognitively plausible way.

1 Introduction

Anaphora is a complex phenomenon. It has proven difficult to analyze at a syntactic level, so that structural approaches as DRT [6] or semantic ones as Dynamic semantics [3] enriched the formal language used to represent the meaning of sentences. However, no approach is completely satisfactory and, often, they appear to adopt *ad hoc* solutions to widen their coverage. We believe that most anaphors can be resolved in a more natural way by making direct reference to *extensional* representations [4]. In other words, the representation of the context where the anaphora must find its referent should put at disposal all elements of the situation which the anaphora could refer to (we do not consider here *generic* readings).

An extensional approach which has been shown to be cognitively plausible is the one of *mental models* [5]. With respect to anaphora, let's consider a simple example. In the following pairs, the first sentence introduces the context where the anaphora must be solved. In the first pair there is number agreement between the (intended) referent and the pronoun, while no agreement is enforced in the second pair. However, acceptability is guaranteed just for the non-agreeing pair:

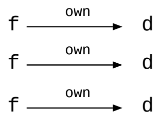

Fig. 1. *Every farmer owns a donkey.*

[1] **Every farmer owns a donkey. It is pink.*

[2] *Every farmer owns a donkey. They are pink.*

A mental model contains a finite number of tokens (placeholders for individuals, here farmers f and donkeys d) and relations among tokens. In particular, the first sentence of the two pairs appears as shown in Fig.1.

Given the model shown below, which donkey, out of the represented ones, can we relate to the singular *it*, appearing in the second sentence of [1]? On the contrary, the plural pronoun in [2] can be interpreted as referring to the set of donkeys appearing in the model, without the need of any choice.

2 The interpretation of logical connectives

As a starting point, we must recall the mental model representation of logical connectives. A negation is represented by means of an horizontal line, which keeps apart the items appearing in the model. For instance, Fig.2 represents the sentence:

[3] *John does not own a car.*

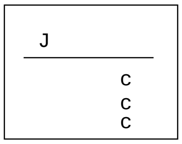

Fig. 2. Negation.

Conjunction is simply represented by inserting the representations of the conjoined sentences in the same subplane. As the last connective, we consider disjunction[1]; it involves the construction of two distinct models, one for each disjunct. The two models are alternative, so the two disjuncts are taken into account separately. Each of them is incomplete because, as all mental models, it includes only the focused information. But, when necessary, a model can be extended (*fleshed out*) with more information, provided that it is compatible with the existing one. So, in

[4] *John went to the restaurant or to the cinema.*

we get one model where John went to the restaurant and a second, distinct, model where John went to the cinema. But if one considers all possible extensions of the two original models, the three classical interpretations of logical *inclusive or* come out: (1) [restaurant + cinema] (2) [restaurant + not cinema] (3) [not restaurant + cinema].

Another important point concerns indefinites: when an indefinite expression is encountered, only one token is introduced: it represents an entity with the given property, but it is marked (with three dots) to represent the fact that, if needed, more tokens of the same type may be introduced.

Let's now see how the mental models representation of logical connectives affects the analysis of anaphors. The first example involves negation:

[5] **No farmer has a car. It is red.*

Examples as this one present some difficulties for other representation frameworks (in particular, DRT), because the main verb (*has*) does not include an explicit negation (which appears just in the subject NP), so that the object NP still constitutes a potential antecedent. In the mental models approach, the first sentence produces a model where farmers appear in the subplane of existing entities and owned cars in the other subplane, so that no referent for 'a red thing' can be found in the subplane of existing entities.

Another interesting anomaly is related to conjunction and disjunction:

[6] *John owns a car$_i$ and Fred washes it$_i$*

[7] **John owns a car$_i$ or Fred washes it$_i$*

In the two examples above, the syntactic structure is identical, but the acceptability is not. Since the mental model representation of a conjunction involves the inclusion in the same model of the conjoined sentences, no problem arises with [6]. But disjunction requires the construction of two *separate* models, and in the second model there is no available referent for the pronoun. When an error (e.g. impossibility of understanding a sentence) occurs, the model can be fleshed out; when applied to the second model,

[1] In this paper we do not discuss implication because of space constraints.

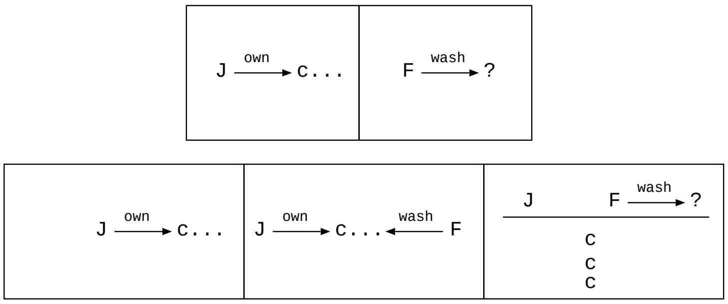

Fig. 3. Implicit and explict models of sentence [7].

this process could produce two alternatives: John owns a car, or he does not. The first extension seems to solve the problem: John owns a car and Fred washes it. In Fig.2 the lower part shows the three resulting models where the second one includes the first and the third is discharged However, from any disjunction at least two distinct models must be constructed, and that none of them must be included in the other: otherwise, the common part of the two models would be necessarily true and according to Grice, the speaker should not have use a disjunction to express such a meaning.[2].

3 Donkey sentences

Donkey sentences, so called after the example:

[8] *Every farmer who owns a donkey beats it*

are difficult to interpret in standard approaches, because of some problems associated with the scoping of the quantifiers. In principle, the NP *Every farmer who owns a donkey* can be interpreted (as we did) with the universal having wider scope than the existential or with reversed scope. In this example this second reading is excluded by pragmatic principles (the same donkey cannot be owned by different farmers). So, it is the preference for the wide-scope reading of the universal, and the plurality of donkeys implied by that reading, which makes [8] acceptable and *Every farmer owns a donkey. *It is pink* unacceptable. Then, it is the absence of any connection between the predicate in the second sentence and the universal quantifier that blocks the interpretation process.[3]

When faced with [8], the procedure first interprets the subject phrase, thus obtaining, in the wide-scope reading of the universal, the representation on the left side of Figure 4; then it extends the representation by searching a referent through each complex token

[2] An example that supports the previous analysis is: *John does not own a car or he washes it* In this case, there are two separate non-overlapping models. In the first one John does not own a car, while the second one can be fleshed out to put at disposal the required car (which he washes).

[3] Pragmatics can enter into play by establishing the bridge between different sentences. In *Every farmer owns a donkey. He needs it for carrying heavy loads*, the antecedent of *he* is *a farmer*; because of the rhetorical relation of "justification" between the two sentences, *it* can be assumed to refer to *the donkey of that farmer* [7].

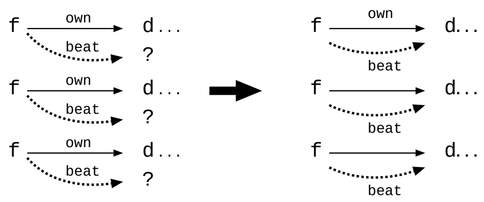

Fig. 4. Resolution of anaphoric pronouns

$f \to d$; so, for each farmer, a different referent for *it* is found, i.e. the donkey owned by him. The possible antecedent satisfies the restriction carried by the singular number (cfr. **Every farmer who has two donkeys beats it*). So, the sentence is interpreted successfully, as shown in Fig.4.

4 Conclusion

Mental models are a cognitively plausible model of human reasoning; so, they can be useful in finding an explanation of linguistic phenomena (see [2] and [1]). In this paper we have shown that a mental model approach to anaphora is not only plausible from a cognitive point of view, but provides also a general and elegant explanation to some complex anaphoric phenomena.

Some problems remain open. We want to mention here just intensional anaphora, as exemplified by *The leopard is difficult to see. It is a shy animal*. Since, as we have shown, the phenomena discussed in the paper are best faced from an extensional point of view, it is clear that some different machinery is required here. However, the basic logical framework on which the mental models construction process is based already accounts for the difference. It is another piece of research to verify that mental models are also suited to cope in a perspicuous way with intensional entities.

References

1. G. Boella, R. Damiano, and L. Lesmo. Beating a donkey: a mental model approach to complex anaphorical phenomena. In *Proc. of European Congress of Cognitive Science of ECCS'99*, Pontignano, 1999.
2. G. Boella, R. Damiano, and L. Lesmo. Mental models and pragmatics: the case of presuppositions. CogSci99 Conference, 1999.
3. G. Chierchia. Anaphora and dynamic binding. *Linguistics and Philosophy*, 15:111–183, 1992.
4. D. A. H. Elworthy. A theory of anaphoric information. *Linguistics and Philosophy*, 18:207–332, 1995.
5. P.N. Johnson-Laird. *Mental Models*. Cambridge University Press, Cambridge, 1983.
6. H. Kamp. A theory of truth and semantic representation. In P. Gardenfoers, editor, *Formal Methods in the Study of Language*. Mathematisch Centrum, Amsterdam, 1981.
7. J. Moore and C. Paris. Planning texts for advisory dialogues: capturing intentional and rethorical information. *Computational Linguistics*, 19(4):651–695, 1993.