Positions of Words and Logical Forms

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There is no doubt that it is hard to give a systematic procedure to find logical forms from sentences in natural language. However, we try to offer one. Our framework is based on the theory of mental models, a psychological approach that, precisely, proposes that logical forms should be ignored in reasoning. In this way, López-Astorga's framework still needs to be improved in certain aspects. This paper is intended to do that by considering a particular point: the order of some words, expressions, or noun phrases in sentences. Thus, it follows some of L. Talmy's arguments in order to show that, indeed, the position of certain elements in a sentence can have an influence on its logical form.

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Introduction

As it is well known, to find a systematic method to recover logical forms from expressions in natural language is a difficult task. Nevertheless, there have been some attempts. One of them is that in papers such as those of López-Astorga (e.g., López-Astorga 2019a; 2020). Perhaps the main characteristic of this approach is that it is based on a reasoning theory coming from psychology, the theory of mental models (e.g., Khemlani – Johnson-Laird 2019), which, curiously, tends to reject logical form (e.g., Johnson-Laird 2010).

But, beyond its essential foundations, proposals such as the one of López-Astorga (2019a; 2020) are just general frameworks that need to be qualified and deepened regarding some details and certain uses of language. In this way, this paper will focus on an important aspect related to those problems: the place in which words, expressions or noun phrases

appear in sentences. In particular, it will follow some examples given from Cognitive Linguistics by Talmy (2007), and its main aim will be to show that different positions of some elements in sentences can lead to relevant changes in their logical forms, at least, if procedures akin to those described in López-Astorga (2019a; 2020) are taken into account.

To do that, first, it will be shown what the procedure proposed by López-Astorga (2019a; 2020) is exactly. Next, some examples offered by Talmy (2007), as well as the explanation he presents to argue that their sense can be modified if the order of the words composing them is altered, will be considered. Lastly, it will also be described how, from methodologies such as that of López-Astorga (2019a; 2020), changes in the order of the words such as those in Talmy's (2007) examples cause their logical forms to be different.

Syntactic logical forms from iconic semantic possibilities

As said, frameworks such as the one of López-Astorga (2019a; 2020) are based on the theory of mental models (see also, e.g., Byrne – Johnson-Laird 2020). In particular, they take its idea that linguistic expressions refer to different semantic models that iconically stand for alternatives of possible realities (see also, e.g., Quelhas – Rasga – Johnson-Laird 2019). An example of the case of the conditional can be enlightening enough in this way:

(1) If you eat shrimps, then you eat seafood.

This sentence can be correct in three possible situations: when you eat shrimps and, therefore, you eat seafood, when you do not eat shrimps but you eat another kind of seafood, and when you eat neither shrimps nor seafood. These three scenarios can be expressed, following the theory, as follows (see also, e.g., Khemlani – Byrne – Johnson-Laird 2018):

(2) Possible (shrimps & seafood) & possible (not-shrimps & seafood) & possible (not-shrimps & not-seafood)

Thus, each of the conjuncts in (2) is a model or 'iconic possibility', and the set of the three ones reveal that the only alternative reality that is not possible is that you eat shrimps and do not eat seafood, since, as it is well known, shrimps are seafood.

One might think that what (2) expresses is just the rows in which the conditional is true in its truth table in classical logic (see, e.g., Jeffrey 1981). However, there are important differences between the scenarios of the theory of mental models and the truth tables in classical logic. First, as

pointed out, the theory indicates that the scenarios are iconic in the sense Peirce (1931-1958) understands this adjective (see also, e.g., Johnson-Laird, Khemlani, & Goodwin 2015). This means that they are not simple cases in a table, but mental representations of reality. When they refer to the same sentence, only little changes distinguish the iconic possibilities. For instance, the two first conjuncts in (2) stand for the same scenario with only a modification: in the second one, you do not eat shrimps. Nevertheless, the rest of the world keeps being the same in both scenarios. Obviously, the third conjunct introduces one more change: seafood is not eaten in it either.

Nonetheless, there are more characteristics differentiating the theory of mental models from classical logic. (1) and (2) do not describe the only possible behavior of all the conditionals in natural language. The case of this one is really different:

(3) If she is British, then she is English.

Now, the models change and are these ones:

(4) Possible (British & English) & possible (British & not-English) & possible (not-British & not-English)

The second conjunct in (4) is the opposite to the second conjunct in (2). While in the second conjunct in (2) the antecedent of the conditional (1) is negated, in the second conjunct of (4) is the consequent of the conditional (3) what is negated. This is another element moving the theory of mental models from classical logic. The option allowed in (4) and forbidden in (2) is the one in which the conditional is false in classical logic. But, as it can be checked, (4) enables it. Under the theory, this happens by virtue of the action of modulation (see also, e.g., Quelhas – Johnson-Laird 2017). Modulation occurs when pragmatics or semantics has an influence on the possibilities. In this particular case, semantics removes the scenario in which the antecedent does not hold and the consequent is true because of the meanings of 'British' and 'English' (no one can be English without being British). However, at the same time, a new situation is considered: the one in which the antecedent is true and the consequent does not hold (it is possible to be British without being English). This is important, since, as pointed out, that possibility is incorrect from the perspective of classical logic. Nevertheless, it can be acceptable following the theory of mental models.

The cases of (1) and (3) are only examples. From the theory, the different sets of models or possibilities that can be attributed to a conditional

are ten and have been studied in detail (e.g., Johnson-Laird – Byrne 2002). Nevertheless, what is important for this paper is that, as it is evident in classical logic, (1) and, hence, (2) refer to the situations in which the conditional is true in its truth table, and (3) and, accordingly, (4) are linked to different situations. This is not a problem for the theory of mental models. It claims that people never consider logical forms. In its view, individuals only resort to iconic possibilities such as those in (2) and (4) to think, reason and make inferences (e.g., Johnson-Laird 2010).

Nonetheless, there are approaches such as that of López-Astorga (2019a; 2020) trying to reconcile the theory of mental models and logic. This is made by assigning to sentences the logical forms corresponding to the cases in which they can be true in their truth tables, regardless of the literal words used in them. Thus, although the proponents of the theory of mental models insist on that the iconic possibilities cannot be compared to rows in a truth table (e.g., Johnson-Laird – Ragni 2019), in proposals such as the one of López-Astorga (2019a; 2020) the potential of that comparison is explored. The result of that exploration is that, beyond the theses of the theory of mental models about logical form, its way to analyze possibilities can be deemed, paradoxically, as a method to identify the particular logical forms of sentences. (1), (2), (3) and (4) allow seeing this clearly. If the possibilities in (2) are taken as rows in a truth table in which (1) is true, (5) is the logical form of (1):

(5) $(p \land q) \lor (\neg p \land q) \lor (\neg p \land \neg q)$

(Where '$\land$' represents logical conjunction, '$\lor$' stands for logical inclusive disjunction, and '$\neg$' denotes negation).

Logical form (5) corresponds to the conditional in classical logic (it can also be expressed as '$p \rightarrow q$', where '$\rightarrow$' stands for conditional relation) and is formula [XXVI] in López-Astorga (2020). It is different, in its second disjunct, from (6), which is the formula that can be attributed to (3) if (4) is taken into account.

(6) $(p \land q) \lor (p \land \neg q) \lor (\neg p \land \neg q)$

Logical form (6) is formula [XXVII] in López-Astorga (2020). In papers supporting the theory of mental models such as that of Johnson-Laird and Byrne (2002), the names 'conditional' and 'enabling' are also attributed to sentences with combinations of models such as, respectively, (2) and (4). In addition, in works such as Johnson-Laird (2010), methodologies similar to the one of López-Astorga (2019a; 2020) are explicitly rejected.

However, perhaps what is more important now is that, although this explanation is based on simple examples, it is, as far as the goals of this paper are concerned, illustrative enough to understand López-Astorga's (2019a, 2020) framework. More complex accounts of that very framework can also be found both in these last papers and in, for example, other works cited in them.

Then, the present paper moves forward to the inputs Talmy (2009) gives from Cognitive Linguistics, since those inputs can help improve this methodology. They can show the information related to models, and hence logical forms, which certain linguistic elements, such as the order in which words are presented in sentences, can offer. The inputs are described in the next section.

The order of words in sentences

Actually, to provide comparisons between Talmy's (2007) approach and the theory of mental models is not uncommon. In fact, in López-Astorga (2019a), the framework presented, which, as indicated, to a large extent follows the theory of mental models, is related to other linguistic theory: the government-binding theory (for a description, see, e.g., Hornstein 1995). Thus, López-Astorga (2019a) tries to link the theory of mental models, which, as indicated, ignore logical forms, to another framework in which logical form is relevant (the government-binding theory). The bridge between the two approaches is offered by the methodology indicated above and assumed in papers such as López-Astorga (2019a; 2020). This is because that methodology can be related to both the government-binding theory (by virtue of logical form) and the theory of mental models (by virtue of the assumption that sentences refer to possible scenarios).

Furthermore, there are also papers linking Cognitive Linguistics, which, as it is well known, is the approach proposed by Talmy (2007), to the theory of mental models. For example, in López-Astorga (2019b), concepts such as those of 'Figure' and 'Ground' (Talmy 1978; Verhagen 2007), as well as the one of 'Perspective' (Verhagen, 2007) or that of 'Mental Space' (e.g., Fauconnier 1985), are compared to the iconic possibilities of the theory of mental models. In this way, López-Astorga (2019b) reviews the differences between morphological and sentential negations, mainly focused on Verhagen's (2007) idea that, while sentential negations can refer to two mental spaces, morphological ones can only correspond to one. And his essential conclusion is that, given that, from the theory of mental models, it can be said that sentential negations often have models with two iconic possibilities and that the models of morphological negations

usually only include one iconic possibility, there is a clear parallel between certain concepts of Cognitive Linguistics and the general thesis of the theory of mental models.

Thereby, the present paper can offer another opportunity: it can also allow tying one more framework independent from logical form, that is, Cognitive Linguistics, with classical logic. The aim of this paper is to improve the methodology proposed by López-Astorga (e.g., 2019a; 2020). However, if that methodology is linked to the theory of mental models, and this last theory is in turn linked to Cognitive Linguistics, correspondences between the latter approach and logical form can be established as well. In any case, this section deals with the arguments given by Talmy (2007) about the changes of sense modifications in the order of expressions in sentences can lead to. His basic example is the following:

(7) "I can't stand this kind of music right now" (Talmy 2007, 275).

Sentence (7) reveals the speaker's mood regarding a very particular fact: listening to certain type of music at the moment. Nevertheless, if just its two last words are changed and placed at the beginning of the sentence, one point is highlighted:

(8) "Right now I can't stand this kind of music" (Talmy 2007, 275).

Indeed, (8) seems to indicate that the most important information transmitted by it is that the problem is the present time, and that perhaps the speaker could listen to that very music in other occasion.

But more changes in the positions, and, accordingly, in the sense, are possible. That can be seen with this new modification:

(9) "This kind of music I can't stand right now" (Talmy 2007, 275).

Now, what (9) appears to basically express is that maybe another type of music could be accepted by the speaker at this time.

Obviously, from the perspective of the theory of mental models, this Talmy's (2007) account seems to show that the differences between (7), (8), and (9) imply changes in the models or iconic possibilities. So, from the point of view of frameworks such as the one of López-Astorga (2019a; 2020), the differences must also mean different logical forms.

Logical forms and the positions of words
In principle, one might think that a methodology such as the one of López-Astorga (2019a; 2020) is not suitable for sentences such as (7), (8), and

(9). These sentences indicate facts that do not seem to be linked by means of logical operators and to which it would be very hard to apply truth tables. However, to analyze them can be really a valuable contribution to López-Astorga's approach. That could allow looking into the internal structure of sentences in a deeper manner, which, evidently, in turn would enable to move from forms of propositional logic to forms of first-order predicate calculus.

Certainly, (7) just refers to one model or possibility (it is simply a fact):

(10) Possible (not-this kind of music right now)

Thus, its logical form is absolutely clear from the propositional logic point of view. Given that it corresponds to just a fact, it could be as follows:

(11) ¬p

Nonetheless, it is possible to move forward to first-order predicate logic, which can allow capturing the nuances and the different senses of (7), (8), and (9). So, a more detailed and descriptive logical form for (7) could be this one:

(12) ¬Sab(T0)

(Where 'S' means 'to stand', 'a' represents the speaker, 'b' signifies the particular type of music to which (7) refers, and 'T0' represents, in a similar way as in temporal logics, a moment in time, and, in this particular case, the current time).

Of course, the formula can be even more complex. For example, that 'b' is a type of music can be explicitly mentioned, and therefore, this form, which is completer and more accurate, can be built for (7):

(13) Mb ∧ [¬Sab](T0)

(Where, obviously, 'M' stands for 'to be a kind of music').

However, (12), as it can be checked below, can be enough to show the point of this paper.

As far as (8) is concerned, as stated, its more relevant information is that maybe the music could be listened to in other moment. Hence, its model could be:

(14) Possible (not-this kind of music right now & this kind of music in other time)

Based on (12), the additional information of (8) can lead to a logical form such as this one:

(15) [¬Sab](T0) ∧ [Sab](Tn)

(Where T0 ≠ Tn).

Evidently, (15) could also be more elaborated and include a predicate such as 'M' in (13), but, as in the previous case, that is not absolutely necessary to develop the account in this section.

Finally, the information emphasized by (9) allows thinking about a different model too:

(16) Possible (not-this kind of music right now and another kind of music right now)

And this model, keeping following (12), is coherent with a formula such as this one:

(17) [¬Sab](T0) ∧ [Vx (x ≠ b ∧ Sax)](T0)

(Where 'V' is the existential quantifier).

Once again, a predicate such as 'M' could be used in (17). Nevertheless, perhaps what is more important now is that the previous explanation can already be useful by itself to broaden frameworks such as that of López-Astorga (2019a; 2020). As stated, this analysis enables to incorporate forms from first-order predicate calculus in that framework, and, accordingly, better formulae describing sentences.

Nonetheless, the real input given by this account to approaches such as the one of López-Astorga (2019a; 2020) can be noted if more complex sentences are considered. For instance, one might think about more extensive sentences including simple sentences such as (7), (8), and (9). For the case of (7), one of such sentences could be:

(18) If I cannot stand this kind of music right now, then you should not play it.

Because (18) is a conditional, in principle, its models should be as follows:

(19) Possible (not-this kind of music right now & not-to be played right now) & possible (this kind of music right now & not-to be played right now) & possible (this kind of music right now & to be played right now)

There is no doubt that (19) is the set of iconic possibilities corresponding to (18), since modulation does not appear to play a role in this case. So, from (19), the logical form of (18) is obvious:

(20) $[\neg Sab](T0) \rightarrow [\neg Pcb](T0)$

(Where 'P' means 'to play' and 'c' stands for the listener).

Of course, the consequent in (18) can be considered as a pragmatic inference. So, one could ask about its relation to a logical form. But the answer is given above: because it takes part in a conditional, that is, (18), its iconic possibilities can be deployed, in (19). If necessary, those possibilities already capture the pragmatic and semantic aspects having an influence on the sentence. Thus, given that, following López-Astorga (2019a; 2020), it is possible to go from those possibilities to logical forms, the result is (20).

However, if the antecedent of (18) is replaced with (8), the sentence would be:

(21) If right now I cannot stand this kind of music, then you should not play it.

And, as the model of (8) is not exactly the one of (7), the iconic possibilities of this new sentence would be:

(22) Possible (not-this kind of music right now & not-to be played right now & this kind of music in other time) & possible (this kind of music right now & not-to be played right now & this kind of music in other time) & possible (this kind of music right now & to be played right now & this kind of music in other time)

The role of modulation does not seem possible here either. Nevertheless, an important point with (22) is that each of its iconic possibilities has three conjuncts: the two that are present in the possibilities of (19) plus one more conjunct referring to the information underscored by the sentence. In this way, regarding its logical form, it can be claimed that in each possibility there is a clear conditional relation between the two first conjuncts,

and that is evident by virtue of (19) and (20). But the third conjunct in each of them, which corresponds to the second conjunct in (15), has to be in the formula as well. Therefore, a logical form that can be deemed as suitable in this case can be, for instance, this one:

(23) $\{[\neg Sab](T0) \rightarrow [\neg Pcb](T0)\} \wedge [Sab](Tn)$

And, undoubtedly, something similar would happen if the antecedent were replaced again with (9). In that situation, the sentence in entirety would be:

(24) If this kind of music I cannot stand right now, then you should not play it.

Which, of course, would lead to these models:

(25) Possible (not-this kind of music right now & not-to be played right now & another kind of music right now) & possible (this kind of music right now & not-to be played right now & another kind of music right now) & possible (this kind of music right now & to be played right now & another kind of music right now)

Modulation does not have an influence on (25) either and, again, it can be said that, in each iconic possibility, the two first conjuncts have a conditional relation. Furthermore, the third conjunct in each possibility, which refers to the second conjunct in (17) now, reveals here the information outlined as well. Therefore, in view of all that, a logical form for (24) can be:

(26) $\{[\neg Sab](T0) \rightarrow [\neg Pcb](T0)\} \wedge [Vx \ (x \neq b \wedge Sax)](T0)$

In this way, all these models and formulae make it absolutely clear that arguments such as those of Talmy (2007) analyzed above can help develop to a larger extent approaches such as the one of López-Astorga (2019a; 2020).

Conclusions

Indeed, as shown, Talmy's (2007) arguments with regard to the changes of sense modifications in the order of expressions in sentences can cause are very strong. The changes can refer to different aspects, for instance, time (8) or an object (9).

However, if this is the case, it can be stated, in a similar way as in López-Astorga (2019b), that the relations that can be provided between those arguments and the theory of mental models can benefit both this last theory

and Cognitive Linguistics. Certainly, the particular cases analyzed here reveal that Talmy's (2007) approach can lead some processes of detection of models, indicating the elements that must be highlighted in them. But, in the same way, the theory of mental models can contribute to Talmy's (2007) framework. It can be thought, for example, that sentences emphasize different facts because they are linked to different models. Accordingly, from this point of view, the task of relating proposals from Cognitive Linguistics to the theory of mental models can be very fruitful, since, as pointed out, both approaches can be complemented and improved by each other.

Nevertheless, if Talmy's (2007) arguments from Cognitive Linguistics can be useful for the theory of mental models and this theory can offer tools to enhance those arguments, the same can be stated about frameworks such as the one of López-Astorga (2019a; 2020). As claimed, those frameworks are essentially based on the theory of mental models. So, on the one hand, Talmy's (2007) explanations, by revealing how the real models of certain sentences should be, also show how their logical forms should be built. On the other hand, an approach such as that of López-Astorga (2019a; 2020) enables, in the same way, to account for the differences between (7), (8), and (9) from a more syntactic perspective: it can be said that, although they are very similar, their logical forms can be very different, as made it evident in the previous section.

Therefore, there is no doubt that it can be interesting to continue to provide comparisons between frameworks such as those indicated. In the literature, works relating to Cognitive Linguistics and the theory of mental models are already to be found (e.g., López-Astorga 2019b). Nonetheless, this paper, which mainly focuses on a particular idea given by Talmy (2007), moves forward to a more formal approach and extends the relation from the theory of mental models to a framework, such as the one of López-Astorga, in which syntax has more important status.

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