LOGICAL FORMS LINKED TO CERTAIN A PRIORI FALSE CONDITIONALS

Miguel LÓPEZ-ASTORGA

Abstract

According to a study carried out by Quelhas, Rasga, and Johnson-Laird in 2017, it seems that people tend not to understand false conditionals in the way expected by standard logic, that is, following the material interpretation of the conditional. In their paper, among other types of sentences, they used a priori false conditionals and the responses given by their participants appeared to suggest that, when considering conditionals of that kind, individuals often think about possibilities or scenarios other than those that classical logic regards as the correct ones when a conditional is negated. However, I try to argue here that such responses did not really reveal that the way their participants denied the conditionals included in the study cannot be captured by classical logic, but only that the logical forms of such denied sentences do not correspond to the one of the conditional, as well as the actual formal structures relating their antecedents and their consequents that can be built. To do that, I resort to a methodology similar to that of López-Astorga in previous works.

Keywords: conditional; logic; logical form; material interpretation; negation.

1. Introduction

A current theory, the mental models theory,[1] claims that human reasoning does not work in accordance with standard logic. Following it, the human mind mainly takes the semantic meaning corresponding to the words in the sentences into account, looks for the possibilities that can be related to that semantic meaning, and thus reasoning is basically analyzing such possibilities.

However, what is interesting to this paper is not what the mental models theory is really about, but simply the fact that, by trying to confirm its predictions and theses, it

[1] E.g., Hinterecker, Knauff, & Johnson-Laird (2016); Johnson-Laird (2010, 2015); Johnson-Laird, Khemlani & Goodwin (2015); Khemlani, Orenes & Johnson-Laird (2012, 2014); Orenes & Johnson-Laird (2012); Quelhas & Johnson-Laird (2017); Quelhas, Rasga, & Johnson-Laird (2017); Ragni, Sonntag & Johnson-Laird (2016).

sometimes tends to argue that the phenomena it can explain cannot be accounted for from other theories or frameworks, for example, the theories or frameworks based on logic. In this way, I will focus here on one of its arguments in this regard, which is to be found in the paper authored by Quelhas et al.,[2] in which the theory is called "the unified theory of mental models",[3] By means of that argument, Quelhas et al.[4] attempt to prove that the way people understand an a priori false conditional is very different from the way that very conditional can be interpreted from classical logic, which, as it is well known, assumes the material interpretation of the conditional. Nevertheless, my intention in this paper is to try to show that their argument, which appears to be supported by experiments included in their study, does not really lead to the rejection of the idea that logic is an important part of the human mental activity. And this is so because the results obtained by Quelhas et al.[5] can also be consistent with a framework admitting that the inferential processes are linked to formal schemata akin to those indicated by, for example, Gentzen[6] or Deaño.[7] In particular, I will resort to an approach such as that of López-Astorga[8] to argue in favor of this last idea.

To achieve this aim, I will firstly explain what the argument raised by Quelhas et al.[9] that will be analyzed below is actually. As it will be described, that argument is essentially based on three examples of conditional sentence that are clearly a priori false and that, nonetheless, from their perspective, individuals tend not to consider exactly in the same way as standard logic deems false conditionals. Secondly, I will comment on López-Astorga's framework, that is, the framework from which the three aforementioned examples will be reviewed again in this paper. Finally, I will deal with each of the examples separately in order to show that the results reported by Quelhas et al.[10] can be coherent with this last framework as well, and what such results can mean from that very framework. So, I begin by the argument and the examples proposed by Quelhas et al.

[2] Quelhas et al. (2017).

[3] *Ibid*, p. 1006.

[4] *Ibid*, p. 1003-1030.

[5] *Ibid.*

[6] Gentzen (1934); Gentzen (1935).

[7] Deaño (1999).

[8] E.g., López-Astorga (2015); López-Astorga (2016).

[9] Quelhas et al. (2017).

[10] *Ibid.*

2. The unified theory of mental models and false conditionals

As said, this paper is intended to exam no thesis of the mental models theory in detail. Only one particular aspect of it is relevant here. That aspect is the one corresponding to Quelhas et al.'s[11] argument, and refers to the idea that one of the points that make the unified theory of mental models superior to any approach claiming that the human mind follows logic is that standard logic understands the falsehood of the conditional in a very limited way. Indeed, given a sentence such as $p \rightarrow q$ (where '$\rightarrow$' denotes conditional relationship), propositional logic only accepts three possible situations in which that sentence can be true:

[I] $v(p) = 1$ and $v(q) = 1$
[II] $v(p) = 0$ and $v(q) = 1$
[III] $v(p) = 0$ and $v(q) = 0$

(Obviously, '$v(\alpha)$' here means 'truth value of α', '1' stands for 'truth', and '0' indicates 'falsehood').

In this way, the remaining scenario is the only one in which $p \rightarrow q$ can be false, or, in other words, $\neg(p \rightarrow q)$ (where '$\neg$' is negation) can only be true in this case:

[IV] $v(p) = 1$ and $v(q) = 0$

As it is well known, this is the material interpretation of the conditional. However, what the mental models theory states in this regard is that [IV] is not the only possible scenario that can be thought by people given a false conditional. Thus, based on the general theses of the theory, on previous works authored by proponents of it, and on their experiments, Quelhas et al.[12] claim that, while [IV] seems to be, in principle, the most probable circumstance that can be related to a false or denied conditional, the human mind can modulate the possibilities and remove this last scenario or add one or several of the other three possible situations. That modulation action works by virtue of pragmatics and semantics, and is clearly linked to factors such as the context or what the words in the sentences exactly mean.

As it can be checked in several of the references cited above, the idea of modulation is an old concept of the theory, and not firstly introduced by Quelhas et al.[13] Neverthe-

[11] *Ibid.*

[12] *Ibid.*

[13] *Ibid.*

less, they do appear to be the first writers that apply it to the case of false conditionals. Indeed, the general structure of some of their experimental conditions consisted of presenting evidently false conditionals sentences with the form $p \rightarrow q$ to their participants, and asking them to indicate to which of the possibilities p and q, p and $\neg q$, $\neg p$ and q, and $\neg p$ and $\neg q$ they referred. So, an important finding was that the participants not always linked a false $p \rightarrow q$ sentence to the scenario p and $\neg q$, and that, in various cases, they preferred or also included other options. All of this can be seen in a clearer way if some of the examples used in their argumentation are considered. One of them is as follows:

"If Mary has the flu, then she is healthy".[14]

Evidently, this is an a priori false conditional, since nobody can have the flu and be healthy at the same time. Nevertheless, [IV] is not the only scenario that it admits. [II] and [III] are also possible, as these three situations can be thought:

[II] Mary does not have the flu and Mary is healthy
[III] Mary does not have the flu and Mary is not healthy
[IV] Mary has the flu and is not healthy

The only circumstance that is not possible is, as said, that Mary has the flu and she is healthy [I].

A second example is this one:

"If Ricardo has a daughter, then he is a mother".[15]

According to Quelhas et al., the problem with this conditional is that, because 'Ricardo' is a man's name, although he has a daughter, Ricardo cannot be a mother. Nonetheless, This does not mean that [IV] is the only possibility here either. In this case, [II] is also valid, since these two situations can be supposed:

[III] Ricardo does not have a daughter and Ricardo is not a mother
[IV] Ricardo has a daughter and Ricardo is not a mother

[14] *Ibid*, p. 1026, Table 6.

[15] *Ibid*, p. 1026, Table 6.

Thus, the impossible scenarios are two now: Ricardo has a daughter and he is a mother [I], and Ricardo does not have a daughter and he is a mother [II].

Finally, a third example can be the following:

"If Ricardo is a mother, then he has a child".[16]

As mentioned, 'Ricardo' is a man's name, and this fact eliminates the possibilities in which the antecedent or if-clause is true, that is, the possibilities [I] and [IV]. So, the acceptable possibilities for this example are the other two situations:

[II] Ricardo is not a mother and Ricardo has a child
[III] Ricardo is not a mother and Ricardo does not have a child

Indeed, these are the only scenarios that can be considered. It is not relevant that Ricardo has a child in [I] and he does not in [IV]. However, as indicated, it is so that he is a mother in both of them.

Therefore, there are at least three cases in which, following Quelhas et al.'s[17] account, the falsehood of the conditional does not refer to [IV], or, as in the two first examples, just to [IV]. For this reason, it can be thought that this inconsistency with standard logic prevents them from being interpreted based on this last logic. Nevertheless, in my view, this conclusion is not correct. The framework provided in works such as, for example, those of López-Astorga[18] allows understanding those three conditionals from the perspective of logic and this will be shown below. However, before that, that framework is described in the next section.

3. A framework linking possibilities and logical forms

Actually, López-Astorga's approach is not the only possible alternative to the explanation offered by Quelhas et al.[19] That is only an example, the example that will be considered in this paper. Nonetheless, other responses to their arguments are possible. For instance, they cite Braine and O'Brien's[20] as a work presenting a proposal that is

[16] *Ibid*, p. 1026, Table 6.

[17] *Ibid*, p. 1003-1030.

[18] E.g. López-Astorga (2015); López-Astorga (2016).

[19] Quelhas et al. (2017).

[20] Braine & O'Brien (1998a).

not able to face facts such as those explained in the previous section. However, this is questionable. The book edited by Braine and O'Brien in 1998 proposes a theory of reasoning, the mental logic theory, which has been developed for decades,[21] and that theory, while it claims that there is a logic in the human mind, it clearly states that that logic is not standard logic too. In fact, in several of the works supporting the theory, its proponents explicitly point out that they reject the material interpretation of the conditional. As far as this last connective is concerned, they only admit that human beings use two rules related to it: Modus Ponendo Ponens ($p \rightarrow q, p \therefore q$ —where '$\therefore$' means that the left formulae enable to derive the right formula) and the conditional introduction rule ($q \therefore p \rightarrow q$).[22] So, the criticism that the mental logic theory cannot respond to arguments against the material interpretation of the conditional does not seem suitable, since, as said, that is not the way the mental logic theory understands the conditional.

On the other hand, in previous studies based on the mental models theory, which is, as indicated, essentially the framework assumed by Quelhas et al.,[23] very interesting results have been obtained. That is, for example, the case of Khemlani, et al.'s paper.[24] The research reported in this last paper showed that, when a conditional does not have an a priori truth value, individuals can deny it not as $\neg(p \rightarrow q)$, but as $p \rightarrow \neg q$. In particular, one of their experimental conditions revealed that 59% of their participants did that in the case of a conditional of this last kind. This is interesting because it is obvious that the cases in which a conditional such as $p \rightarrow \neg q$ can be true are [II], [III], and [IV], that is, exactly the same cases in which the first conditional used as an example by Quelhas et al.,[25] i.e., 'if Mary has the flu, then she is healthy', is true.

Certainly, $p \rightarrow \neg q$ is true when

[IV] $v(p) = 1$ and $v(q) = 0$
[III] $v(p) = 0$ and $v(q) = 0$
[II] $v(p) = 0$ and $v(q) = 1$

And it can only be false if

[I] $v(p) = 1$ and $v(q) = 1$

[21] See, e.g., O'Brien (2014).

[22] See, e.g., Braine & O'Brien (1998b); O'Brien (2014).

[23] Quelhas et al. (2017).

[24] Khemlani et al. (2014).

[25] Quelhas et al. (2017).

Thus, from a formal perspective, it can be thought that the key to explain Quelhas et al.'s[26] results is related to the thesis that the expressions in natural language do not have a direct, automatic, and clear translation into the formal language of logic, and that, therefore, a false conditional does not have to refer to the logical form $\neg(p \rightarrow q)$, or, if preferred, $p \wedge \neg q$ (where '$\wedge$' represents conjunction). In this way, it can also be assumed that, while the responses given by the participants in Khemlani et al.'s study[27] indicate that people often interpret the negation of a conditional as $p \rightarrow \neg q$, other logical forms different from that and $\neg(p \rightarrow q)$ are possible as well, especially when the conditional is of a type other than that used by Khemlani et al.

This is the direction taken in papers such as those of López-Astorga.[28] Indeed, they are based on the assumption that there is no an unequivocal correspondence between natural language and logical formulae, which is an idea that, as it is well known, is not new.[29] However, what does seem to be new in his proposal is that it presents a mechanism to recover the real logical forms of the sentences, and a very important point in this way is that it ignores neither the findings reported in the literature on the mental models theory nor the methodology of this last framework (which, as explained, is focused on the identification of possibilities). Thus, being aware that semantics and pragmatics are the aspects prioritized by the mental models theory, López-Astorga tries to link such aspects to another one that is explicitly rejected in that theory: syntax. True, although the proponents of the mental models theory usually claim that syntax, and hence logical forms, plays no role in thinking,[30] in López-Astorga's view, they often make analyses of possibilities that lead to the hidden logical forms of certain sentences, which in turn enables to deem semantics, pragmatics, and syntax as three relevant aspects of human language and intellectual activity at the same time.

In this manner, López-Astorga's general proposal refers to two phases: in the first one, the semantic possibilities are detected from the meanings of the words present in the sentences and the action of pragmatics, that is, in a way similar to that shown above for the three examples used by Quelhas et al.[31] considered. After that, truth tables are constructed by paying attention to the situations in which the sentences can be true, which leads to logical forms consistent with such situations and to which schemata

[26] *Ibid.*

[27] Khemlani et al. (2014).

[28] E.g., López-Astorga (2015); López-Astorga (2016).

[29] See, e.g., Deaño (1999).

[30] See especially, e.g., Johnson-Laird (2010), p. 203-204, where proposals clearly akin to that of López-Astorga and, therefore, to the one of this paper are criticized.

[31] Quelhas et al. (2017).

such as those of propositional calculus can be applied. Nevertheless, all of this can be better described by means of an example. In López-Astorga's work in 2015,[32] disjunctions such as the following, which is taken from Orenes and Johnson-Laird,[33] are reviewed in accordance with the previous phases:

"...Lucia wore the bracelet or she wore jewelry".[34]

In principle, one might think that the logical form of this sentence is obvious: $p \vee q$ (where 'p' represents that Lucia wore the bracelet, 'q' that she wore jewelry, and '$\vee$' is disjunction). Nonetheless, it can be easily noted that this is not so if we pay attention to the semantic possibilities that would be assigned to it from the framework of the mental models theory:

[I] The bracelet is worn and jewelry is worn
[II] The bracelet is not worn and jewelry is worn

Evidently, one more scenario is necessary to attribute the form $p \vee q$ to 'Lucia wore the bracelet or she wore jewelry'. That scenario is [IV], and the reason is that, as reminded by López-Astorga,[35]

$v(p \vee q) = 1$ in these cases:

[I] $v(p \wedge q) = 1$
[IV] $v(p \wedge \neg q) = 1$
[II] $v(\neg p \wedge q) = 1$

And this is so because disjunction is only false when

[III] $v(\neg p \wedge \neg q) = 1$

However, [IV] is not possible here, since a bracelet is jewelry and wearing a bracelet necessarily implies wearing jewelry. According to the mental models theory, what happens with this example is that modulation removes [IV]. Nevertheless, López-Astorga[36]

[32] López-Astorga (2015).

[33] Orenes & Johnson-Laird (2012).

[34] *Ibid*, p. 363; see also, e.g., López-Astorga (2015), p. 145.

[35] López-Astorga (2015), p. 146.

[36] López-Astorga (2015), p. 141-149.

claims that other account is possible. In his view, it can be thought that, in spite of the presence of 'or' in the sentence, it is not a real disjunction. Thus, he tries to recover the logical form that truly corresponds to it from [I] and [II], that is, from the possibilities in which the sentence can be true, the result being obvious: he raises that formulae such as $(p \vee \neg p) \rightarrow q$ or q can be those that represent the actual formal structure of 'Lucia wore the bracelet or she wore jewelry'.[37] Clearly, the reason of this is that both

$v[(p \vee \neg p) \rightarrow q] = 1$ and $v(q) = 1$ if and only if $v[(p \wedge q) \vee (\neg p \wedge q)] = 1$

So, there is no doubt that logical forms can be identified from the possibilities linked to the sentences by the mental models theory, and this can be made, of course, not only in the case of disjunction, but also in that of any logical connective, including, evidently, the conditional. Therefore, it can be said that the possibilities indicated by Quelhas et al.[38] to the three examples of a priori false conditional analyzed above also allow recovering their actual logical forms. The next section shows this for each of those examples.

4. The logical forms of the three a priori false conditionals

As accounted for, the denial of the conditional 'if Mary has the flu, then she is healthy' can be related not only to the possibility [IV], but also to the possibilities [II] and [III]. Hence, based on the approach commented on in the previous section, that means that that denial is not true just when

$v(p \wedge \neg q) = 1$

But when

$v[(\neg p \wedge q) \vee (\neg p \wedge \neg q) \vee (p \wedge \neg q)] = 1$

Which in turn enables to think that its real logical form is not $\neg(p \rightarrow q)$, but, for example, $\neg(p \wedge q)$ or, in a way consistent with the results achieved by Khemlani et al.,[39] $p \rightarrow \neg q$. Indeed, both

$v[\neg(p \wedge q)] = 1$ and $v(p \rightarrow \neg q) = 1$ if and only if $v[(\neg p \wedge q) \vee (\neg p \wedge \neg q) \vee (p \wedge \neg q)] = 1$

[37] *Ibid*, p. 146-147.

[38] Quelhas et al. (2017).

[39] Khemlani et al. (2014).

And formal structures such as $\neg(p \wedge q)$ or $p \rightarrow \neg q$ make sense for the negation in natural language of 'if Mary has the flu, then she is healthy', as they reveal that it is impossible that Mary has the flu and Mary is healthy at the same time.

As far as the a priori false conditional 'if Ricardo has a daughter, then he is a mother' is concerned, the possibilities are, as also pointed out, [III] and [IV], which leads one to assume that the logical form of its negation is not $\neg(p \rightarrow q)$ either, but a formula that is true when $v[(\neg p \wedge \neg q) \vee (p \wedge \neg q)] = 1$. Nevertheless, it is very easy to find formulae fulfilling that requirement as well. Two of them can be, for example, $(p \vee \neg p) \rightarrow \neg q$ and $\neg q$, since, undoubtedly,

Both $v[(p \vee \neg p) \rightarrow \neg q] = 1$ and $v(\neg q) = 1$ if and only if $v[(\neg p \wedge \neg q) \vee (p \wedge \neg q)] = 1$

And, again, these underlying logical forms make sense here too, as they show that, whether or not Ricardo has a daughter, he is not a mother $[(p \vee \neg p) \rightarrow \neg q]$, or, if preferred, that he is not absolutely a mother $(\neg q)$.

Lastly, in connection with the example 'if Ricardo is a mother, then he has a child', as also indicated, its possibilities are [II] and [III]. And this means that the logical form to which its denial refers is clearly not $\neg(p \rightarrow q)$ here either, but a formula that has to be accepted when $v[(\neg p \wedge q) \vee (\neg p \wedge \neg q)] = 1$. Nonetheless, actually, two easy formulae can be taken into account in this case too: $(q \vee \neg q) \rightarrow \neg p$ and $\neg p$. Certainly, there is no doubt that both

$v[(q \vee \neg q) \rightarrow \neg p] = 1$ and $v(\neg p) = 1$ if and only if $v[(\neg p \wedge q) \vee (\neg p \wedge \neg q)] = 1$

Furthermore, these two formulae detected also seem to be suitable here, as they provide that, whether or not Ricardo has a child, he is not a mother $[(q \vee \neg q) \rightarrow \neg p]$, or, if preferred, again, that he is in no way a mother.

5. Conclusions

So, it can be thought that the three examples of a priori false conditional are sentences that, although they include words such as 'if' and 'then', they cannot be denied as $\neg(p \rightarrow q)$. As shown, it can be said that the logical forms that can be assigned to their denials do not correspond to that structure, and this can explain why people can consider them not to have to be related to [IV] or only to [IV].

In this way, my conclusions here continue to follow the same direction as, for example, works such as those of López-Astorga cited above. According to that direction, it is evident that the mental models theory, or, if preferred, the unified theory of mental

models, has made important achievements to which it is necessary to pay attention. This last theory has revealed relevant intellectual processes in the human mind that cannot be ignored. However, such achievements also need to be complemented with the syntactic dimension that logical forms give, which cannot be forgotten either. In this regard, the fact that it is possible to find logical formal structures underlying for the sentences in natural language shows that pragmatics and semantics may not be the only factors that play a role in reasoning. Thus, as also indicated in papers such as those mentioned, this is a point that requires further exploration.

Hence, the general idea would be similar to that of papers such as the ones of López-Astorga[40] as well. Following that idea, it can be stated that, as explained, pragmatics and semantics only work in the first moment of information processing, that is, in the moment in which the translation from natural language into formal language happens. As also described, that translation starts by identifying possibilities, and, then, building truth tables from such possibilities, logical forms are recovered. As pointed out above too, this would allow making inferential processes relating those logical forms or formulae and applying formal rules such as those of standard calculus to them.

Nevertheless, there is still work to do in this regard. It is necessary to check whether or not all of this applies to all the achievements of the mental models theory, which are many. Therefore, it is required a longstanding research activity to review all the experimental results reported by proponents of the mental models theory in the specialized literature. The goal of that activity would be to confirm that such results can be accounted for by means of the logical forms built from the possibilities linked to the sentences used in the experiments. And, obviously, a confirmation of that kind would be only obtained if the logical forms recovered led, by derivation and using formal schemata of logic, to the responses given by the participants.

Clearly, this seems to be the main task to do with respect to this issue, since perhaps it is the only way to verify the adequacy of the methodology used in this paper. In any case, it is also evident that the studies based on the mental models theory will continue in the future. Consequently, if it is wanted to relate that theory to syntax, works such as the one carried out here must continue as well.

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Miguel LÓPEZ-ASTORGA
Institute of Humanistic Studies "Juan Ignacio Molina"
University of Talca, Chile
milopez@utalca.cl

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