

FORMAL INFERENCE AND THEIR RELATIONS TO KNOWLEDGE ACQUISITION: MENTAL MODELS AND SEMANTIC LINKS

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Abstract. The mental model theory is an approach with clear psychological, linguistic, and cognitive consequences. This paper delves into some of the epistemological conclusions that can be drawn from it. In particular, it addresses the process why knowledge acquisition can modify the inferences people tend to make. That process is described by means of an example based on a well-known logical schema related to the conditional: Modus Tollendo Tollens.

Key Words: Inference • knowledge acquisition • mental model • Modus Tollendo Tollens • semantics

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1. Introduction

A very important cognitive proposal is nowadays the mental model theory (e.g., Bucciarelli & Johnson-Laird 2019; Khemlani & Johnson-Laird 2019; Khemlani, Byrne & Johnson-Laird 2018; Khemlani, Hinterecker & Johnson-Laird 2017; López-Astorga 2019; Quelhas & Johnson-Laird 2017; Torres-Bravo & Gairín 2019). The literature shows that this approach mainly focuses on reasoning and language. However, its assumptions lead to epistemological consequences too. In fact, such assumptions describe the mental processes that happen when an individual acquires knowledge or accesses to new information.

This paper aims to comment on the nature of those processes by means of an example. Thus, first of all, it will offer a brief account of some of the general theses of the mental model theory about the conditional, which will be the connective the paper will deal with. Then, it will explain how, based on the previous theses, different kinds of conditionals can have different behaviors even when inferences of the same type are made. The case that will be considered here will be the one of



Modus Tollendo Tollens. Lastly, several reflections about the way all of this has an influence on knowledge, as well as some of its epistemological consequences, will be also included.

2. Some theses of the mental model theory about the conditional

Following most of the works cited in this paper, it can be claimed that a key concept in the mental model theory is that of iconic possibility or model. The theory states that people think by means of revisions and comparisons of the iconic possibilities that can be attributed to each piece of information. The problem is that individuals are not always able to discover all the models corresponding to an assertion (see also, e.g., Johnson-Laird 2012).

An easy way to see this can be to take into account an example given by Byrne and Johnson-Laird (2009). That is the following conditional sentence:

- (1) “If he spoke then she laughed” (Byrne & Johnson-Laird 2009, p.282).

According to the framework, given (1), individuals will tend to only consider one iconic possibility, which is that with its two clauses occurring. In a manner similar to the one used in papers such as that of López-Astorga (2019), which will be the manner that will be used in all the examples here as well, that possibility can be represented as follows:

- (1.a) He spoke & she laughed.

Of course, there are other two possibilities that can be linked to (1): the one in which only the second clause happens and the one in which no clause occurs. These last two possibilities can be stood for in this way:

- (1.b) He did not speak & she laughed.
(1.c) He did not speak & she did not laugh.

But, as indicated in papers such as that of Byrne and Johnson-Laird (2009), to be aware that (1.b) and (1.c) are also real possibilities for (1), it is necessary the action of working memory. The theory indicates that this implies to assume a dual-process framework akin to the one described in, for example, Stanovich (1999). Thus, it can be said that (1.a) is obtained by intuition, and (1.b) and (1.c) by deliberation (see also, e.g., Khemlani; Byrne & Johnson-Laird 2018). However, semantic or pragmatic factors can cause all the iconic possibilities to be noted in a simple and quick way. This is because of processes that modulate the possibilities (see also, e.g., Orenes &

Johnson-Laird 2012). (2) allows one to think about an example in which semantics has an influence.

(2) If this is a triangle, then it is a geometric figure.

As (1), three iconic models correspond to (2) too:

(2.a) This is a triangle & this is a geometric figure.

(2.b) This is not a triangle & this is a geometric figure.

(2.c) This is not a triangle & this is not a geometric figure.

Nevertheless, the difference between (1) and (2) can be that, while, as pointed out, for an average person, identify (1.b) and (1.c) as possibilities related to (1) is a difficult activity requiring the action of working memory, for that very person, to note that (2.b) and (2.c) are linked to (2) can be very easy. As also mentioned, semantics is the key here. An average individual knows the meaning of words such as ‘triangle’, ‘geometric’, and ‘figure,’ and hence she also knows that, if something is a triangle, that very thing has to be a geometric figure (2.a), that there are things that are geometric figures but not triangles (2.b), and that there are also things that are neither triangles nor geometric figures (2.c). So, it can be thought that an average person has the three models, (2.a), (2.b), and (2.c), at her disposal, since they are available in her mind without need for mental effort of any kind. And, of course, this is not the case in (1), because the semantic relation between to speak and to laugh are not that clear.

(1) and (2) only provide a limited example of how the mental model theory works. They only consider one connective (the conditional) and the action of semantics. In the literature on the theory, much more examples are to be found. There are examples addressing other connectives, analyzing both semantic and pragmatic modulations, and dealing with even gender stereotypes (see, e.g., Torres-Bravo & Gairín 2019). Nonetheless, (1) and (2) suffice for the goals of this paper.

The next section will take a particular case into account as well. It will be devoted to just one of the possible schemata that can be logically accepted. It is Modus Tollendo Tollens and has been chosen because it can be applied to conditionals such as (1) and (2) and it is illustrative enough too.

3. Modus Tollendo Tollens and the mental model theory

The formal structure of Modus Tollendo Tollens is well known. It is that indicated in (3).

(3) If p , then q .

Not- q .
Not- p .

Although (3) is correct from the perspective of classical logic, it raises a very relevant cognitive problem, since people derive its conclusion from its premises only at times (see, e.g., Byrne & Johnson-Laird 2009). However, the mental model theory has an account to explain this.¹

The problem is that, to apply a schema such as (3), it is necessary to detect the three possibilities that usually can correspond to the conditional, or, at least, the third one, that is, the one in which none of the two clauses happen (see, e.g., in addition to Byrne and Johnson-Laird 2009, Johnson-Laird 2006). Accordingly, in the case of an inference in which, for instance, the first premise is (1) and the second one is:

(4) “She didn’t laugh” (Byrne & Johnson-Laird 2009, p.282).

People will be unlikely to infer a conclusion such as ‘he did not speak.’ To do that it is necessary to note that (1.c), that is, the only possibility in which she did not laugh, is a model that can be related to (1). Only in this way an individual can deduce that, when she does not laugh, which only occurs in (1.c), and neither in (1.a) nor (1.b), the only possible situation is that he does not speak either. However, as shown, to identify (1.c) as a model for (1) can be hard.

Nevertheless, the situation is different in the case of a conditional such as (2). If it is supposed an inference in which the first premise is (2) and the second one is:

(5) This is not a geometric figure.

Individuals are highly likely to come to a conclusion such as ‘this is not a triangle.’ It keeps being necessary to note the third possibility, which in this case is (2.c), since it is the only possibility in which this is not a geometric figure. And this is that way because, in a similar manner as in the previous case, they have to be aware that, when this is not a geometric figure, which only happens in (2.c), and neither in (2.a) nor in (2.b), the only possible circumstance is that this is not a triangle either. Nonetheless, as claimed, to identify (2.c) given (2) is easier than to identify (1.c) given (1). Hence, to obtain the correct conclusion when the premises in (3) are (2) and (5) has to be easier than when they are (1) and (4).

Therefore, the mental model theory can explain why Modus Tollendo Tollens is in some cases harder than in other cases. The key is in the facility or difficulty to deploy the iconic model in which the two clauses are negated in each case. Several works supporting the theory (among them, of course, Byrne & Johnson-Laird 2009; Johnson-Laird 2006) contribute to this point. However, the most interesting consequences of all of this for this paper can be the epistemological or cognitive ones.

4. Conclusions

The reason why Modus Tollendo Tollens is easier to apply in the case of (2) is that it is not hard to display all its models. This deployment is not difficult because of semantics. The meanings of the word ‘triangle’ and the expression ‘geometric figure’ aid that. However, this fact implies that certain models are, in general, difficult to identify, and that they can become easy to note only if the particular individual knows the meanings of certain words or expressions. Thus, a person who does not know such concrete words or expressions should tend not to come to the correct conclusions in many inferences including those very words or expressions.

Accordingly, both the arguments above and the overall literature on the mental model theory allow stating that knowledge acquisition modifies the conclusions people tend to derive whenever faced to inferences. In fact, such modifications can reveal the real knowledge a particular person has and whether his or her knowledge is increasing or not. The example of Modus Tollendo Tollens enables to see this without difficulties. The greater is an individual’s knowledge, the higher her tendency to find the adequate conclusion in Modus Tollendo Tollens is, at least, when the meanings of the clauses in the conditional are related in any way.

So, beyond the fact that, as indicated, the cases reviewed above are only examples focused on just a connective (the conditional), a logical schema (Modus Tollendo Tollens), and the action of semantics, it can be said that the mental model theory can also provide interesting inputs to epistemology. It can reveal the exact manner certain cognitive processes occur.

There is no doubt that one might think that much of what has been proposed in this paper is not new. For example, probably, almost all the cognitive theories, and not only the mental model theory, would accept the idea that knowledge acquisition can modify our inferences or make them more correct. In the same way, the topic of the relations that can exist between the two clauses in a conditional sentence has already been addressed from ancient times (see, e.g., O’Toole & Jennings 2004) to recent years (see, e.g., Douven *et al.* 2018). However, what seems to be an absolutely relevant input in this regard is that, from its general framework, the mental model theory offers, as pointed out, a description of how knowledge acquisition really has an influence on human inferences in an exact manner and in detail.

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Notes

¹Actually, the difficulties of Modus Tollendo Tollens are much more than those that will be indicated below. As shown by, for example, Bosley (1979) and Yalcin (2012), when modality or concepts such as the ones of probability or likelihood are implied in the conditional, the application of Modus Tollendo Tollens can be specially complicated. However, beyond the fact that the mental model theory can also deal with probability (see, e.g., Hinterecker; Knauff &

Johnson-Laird 2016), a simple explanation such as that given in this section can absolutely suffice to make the point of this paper.

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