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The Semantics of 'unless' Conditionals: Evidence from 'unless' and Disjunctive Inferences

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We report the results of an experiment investigating conditional inferences from conditional assertions such as 'Juan won't go to León unless Nuria goes to Madrid' and 'Either Nuria goes to Madrid or Juan won't go to León'. This experiment addresses Dancygier's claims about the semantics of 'unless' by examining inferential endorsements of 'not-A unless B' and 'Either B or not-A' in the canonical order, presenting the categorical premise after the conditional assertions, and in the inverse order, presenting the categorical premise before the conditional assertions. The results of the experiment confirm that the representation of 'unless' includes two possibilities, although as Dancygier holds one of the possibilities may not be complete. The implications of the results are discussed in the context of the strategic nature of conditional reasoning and recent convergent theories of linguistic processing.
Keywords: conditionals, mental models, reasoning.

Se presentan los resultados de un experimento en el que se investigaron las inferencias realizadas a partir de enunciados condicionales como 'Juan no irá a León a menos que Nuria vaya Madrid' y 'O Nuria va a Madrid o Juan no irá a León'. En este experimento se abordan las concepciones de Dancygier sobre la semántica de 'a menos que' mediante el estudio de las inferencias que se extraen de 'no-A a menos que B' y de 'o B o no-A', en el orden canónico, al presentar la premisa categórica después de la afirmación condicional; y en el orden inverso, presentando la premisa categórica antes que la afirmación condicional. Los resultados confirman que la representación de 'a menos que' incluye dos posibilidades aunque, como Dancygier sostiene, una de las posibilidades puede no ser completa. Las implicaciones de los resultados se discuten en el contexto de la naturaleza estratégica del razonamiento condicional y de las teorías convergentes recientes sobre el procesamiento lingüístico.
Palabras clave: condicionales, modelos mentales, razonamiento.

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Our aim is to examine Dancygier's hypothesis about the meaning of 'unless' conditionals by using a conditional inference task. Our global theoretical framework is mental model theory; it will allow us to make precise predictions in order to check Dancygier's hypothesis. We outline a mental model theory of conditional reasoning and consider the possibilities people keep in mind to understand 'unless' and disjunctive conditionals.

A warning, frequently repeated in Spain during the Winter of 2010, expressed as a 'not- A unless B' assertion, was as follows:

> "President Zapatero will not win the 2012 election unless he achieves clear economic growth"

This assertion has an illocutionary force which focuses on the desirability of the protasis (to achieve an economic growth). This sentence may be interpreted in terms of two possibilities: the first asserts a probable outcome: 'President Zapatero will not win the 2012 election' (not-A); the second the unique, exceptive situation in which President Zapatero might win: by achieving clear economic growth (B and A). Hence, the meaning of 'unless' is interpreted in a way similar to an exclusive disjunctive assertion, as follows:

> "Either President Zapatero achieves clear economic growth or he will not win 2012's election"

In English and Spanish, as in many other languages, this kind of disjunctive assertion conveys a conditional meaning (see, for Spanish, Montolío, 1999, p. 3697). This assertion maintains the warning while also stressing the illocutionary force of 'achieving clear economic growth'. The interpretation of this disjunctive assertion also implies, from the outset, the construction of two possibilities or models.

We report an experiment that compares reasoning from 'not-A unless B' and 'Either B or not-A' sentences. Our aim is to advance understanding about representing and reasoning with 'unless' conditionals.

During the last four decades a great deal of psychological research has been devoted to propositional reasoning, particularly to conditionals. The study of how people reason from conditional statements has become the main concern of research in deductive reasoning (see, Evans, Newstead & Byrne, 1993). Four main theories have been posited in propositional reasoning. One view is that reasoners rely on abstract rules of inference that operate in virtue of their form (e.g., Braine & O'Brien, 1998; Rips, 1994), and a second view is that reasoners rely on domain-specific rules of inference (e.g., Fiddick, Cosmides, & Tooby, 2000; Holyoak & Cheng, 1995). A third view is that reasoners rely on imagining possibilities or models (Johnson-Laird & Byrne, 1991; Johnson-Laird & Byrne, 2002; see also Evans, 1993). A fourth view claims that reasoners must deal not just with possibilities, but with models that attach knowledge and probabilities to these possibilities. According to the latter approach, these new kind of models are not semantic but epistemic models (Evans & Over, 2004; Evans, Over, & Handley, 2005). That is, this suppositional theory asserts that reasoners consider the probability of conditional statements and think about the closest possibility in which the antecedent holds.

A great deal of psychological work on conditionals has centered on evaluating reasoners' abilities by using the inferential rules task. This task requires participants to construct or evaluate conclusions from the application of four conditional rules: 'modus ponens' (MP), 'denial of antecedent' (DA), 'affirmation of the consequent' (AC) and 'modus tollens' (MT). The studies reported here have been carried out from the perspective of mental model theory and are aimed at validating its capacity to explain how people understand and reason from unless conditional assertions. We will present some new empirical data using the inferential rules task to compare people's ability to reason with two different conditional linguistic formulations.

Mental model theory (Johnson-Laird & Byrne, 1991, 2002) holds that reasoning depends on the semantic processes of constructing and manipulating possibilities (i.e., models of sentences). Mental model theory of conditional reasoning (Johnson-Laird & Byrne, 2002) holds that people's reasoning may be explained according to two main principles. First, the principle of truth affirms that people keep in mind true possibilities or models, e.g., 'A and B' and 'not-A and not-B', but not false possibilities, e.g., 'A and not-B'. The second principle maintains that in order not to overload working memory, people explicitly represent as little information as possible (Johnson-Laird & Byrne, 1991; Johnson-Laird, Byrne, & Schaeken, 1992). Thus, when reasoning from a conditional assertion such as 'if and only if A then B', people keep in mind at the outset just the possibility mentioned in the conditional, 'A and B'. If required, people may flesh out the representation of conditionals in order to make all the possibilities fully explicit:

A B
not-A not-B

Mental model theory has precise predictions for the four rules of inference that are traditionally posited from conditional and biconditional assertions (Johnson-Laird & Byrne, 1991; 2002; see also Evans, 1993). The MP and AC rules of inferences may be drawn from the initial possibility 'A and B'; on the contrary, MT and DA require fleshing out the representation in order to be drawn. The MP rule of inference states that from the conditional statement 'if and only if A then B' and the categorical premise:

There is an A

The conclusion "there is a B" may be drawn. The situation represented in the categorical premise corresponds with the possibility people keep in mind initially when they interpret 'if and only if then' conditional assertions. In the 'affirmation of consequent' (AC) rule, the categorical premise is:

There is a B

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And the conclusion, "there is an A", may be also drawn from the first explicit model.

In the MT rule of inference, the categorical premise is:

There is not a B

And yields the conclusion "there is not an A." The categorical premise eliminates the initial possibility and demands a full fleshing out of models. MT inferences will obviously be harder than MP since they require the extra cognitive work of fleshing out the models.

With the 'denial of antecedent' (DA) the categorical premise is:

There is not an A

And then the conclusion "there is not a B" requires one to flesh out the models, as in MT inferences. Hence mental model theory predicts that people will draw more AC inferences than DA ones. AC and DA inferences are valid only for biconditional interpretations of conditionals that include only the two symmetric models 'A and B' and 'not-A and not-B'. In the one-way interpretation of conditionals ('If A then B'), people represent a third model 'not-A and B' that falsifies the AC and DA inferences and makes the 'nothing follows' conclusion logically valid.

'Unless' is a negative conditional connective directly related to 'if not' (see Quine, 1972; Reichenbach, 1947). Following Geis (1973), however, linguists offer compelling arguments against the identification of 'unless' with 'if not' (see, Dancygier, 1998, 2002; Declerck & Reed, 2000). Geis holds that the meaning of 'unless' is more similar to 'except if' than to 'if not' (see also von Fintel, 1991). In a similar way, Fillenbaum (1976, 1986), in trying to explain both the intimate relationship between 'unless' and 'if not' and their differences, proposed 'only if' as the preferred understanding of 'unless' sentences. Other psychologists and linguists agree on the tight relationship between 'only if' and 'unless' conditionals (see for instance, Clark & Clark, 1977; Montolío, 1999; Wright & Hull, 1986, 1988).

Following Fillenbaum's proposals, García-Madruga et al. have confirmed the semantic similarity between 'unless' and 'only if' (Carriedo, García-Madruga, Gutiérrez, & Moreno, 1999; García-Madruga, Carriedo, Moreno, Gutiérrrez, & Schaeken, 2008; García-Madruga, Moreno, Quelhas, & Juhos, 2008). However, these authors found that solving conditional inferences with 'unless' was harder than with 'only if'. These authors proposed that people represent 'not A unless B' by constructing from the outset two complete possibilities: 'not-B and not-A' and 'B and A'. This two-model initial representation allows drawing the four inferences and therefore no relevant differences among inferences are predicted. However, the results of these studies at times show that reasoners tend to draw fewer DA inferences than MT inferences. This result is unstable and slight, and is probably dependent on the complexity of the task reasoners have to do.

A second main result from the studies on 'unless' conditional reasoning is its special difficulty. This difficulty comes mainly from the trend in producing asymmetric conclusions in problems with 'unless'. As an example of these kinds of asymmetric responses, some people gave the incorrect response 'B' to the following set of premises: 'Not-A unless B', and 'not-A' (DA inference). These authors maintain that these reasoners were using a shortcut strategy, produced by the asymmetry of the 'unless' assertions, that consists of matching the two terms that appear in the statement (Not-A unless B).

Likewise, García-Madruga et al. (García-Madruga, Gutiérrez, Carriedo, Luzón, & Vila, 2007) have shown the importance of working memory in 'unless' reasoning. These authors claim that applying this superficial matching strategy does not consume cognitive resources and will hence be mainly used by people with low working memory span. This prediction has been confirmed: Asymmetric responses for 'unless' conditionals were indeed given more by participants with low working memory. In this paper we will use a different perspective in studying the role of working memory in 'unless' reasoning: we will try to increase working memory load by changing the order of premises.

There is a more recent hypothesis about the meaning of 'unless' proposed by Dancygier (1998; see also Traugott, 1997). Dancygier maintains that 'not-A unless B' is interpreted as including two different statements: one claiming 'not-A' and the other expressing the unique, exceptive circumstances (B) under which 'A' might occur. Dancygier and Sweeter (2005) have reanalyzed the meaning of 'unless' assertions within the general framework of Mental Spaces Theory (Fauconnier, 1985 [1994]). Dancygier and Sweeter's Mental Spaces theory of conditionals has obvious similarities with Mental Models theory: "an if-clause sets up a mental space … [that is,] a partial or local model of some aspect of mental content, in this case very possibly a model of some situation in the world, or (as we shall see) of some speech-act interaction or some reasoning process" (Dancygier & Sweeter, 2005, p. 29).

According to these authors, the main feature of a predictive conditional warning such as "President Zapatero will not win the 2012 election unless he achieves clear economic growth" is its exceptive meaning highlighted first by Geis (1973); that is, Zapatero is to lose the election *except if* he is able to achieve economic growth. This exceptive meaning accounts for the preferences quite opposite from 'if' with respect to clause order: 'unless'-clauses most commonly follow main clauses. Compare the clause order of this 'unless' conditional with its logically equivalent, but not exceptive, 'if not' assertion: 'If President Zapatero does not achieve clear economic growth, he will not win the 2012 election'.

Moreover, as a result of its exceptive nature, comprehension of the above 'unless' sentence implies to built of two alternative scenarios or models. One that asserts that, probably, 'Zapatero will not win the 2012 election'

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(not-A), without explicitly identifying the space to which we are adding to it, that is, that 'Zapatero doesn't achieve clear economic growth' (not-B). The other, on the contrary, is the space or model in need of a complete identification, that is, the exceptive "unless" space in which both components 'Zapatero achieves clear economic growth and wins the election' (A and B) have to be identified (pp. 183-4). Dancygier and Sweeter also maintain that it is this inherent alternativity of 'unless' constructions that accounts for its biconditional reading (p.187).

In sum, according to Dancygier's hypothesis, people interpret 'not-A unless B' in a biconditional way, by keeping two alternative possibilities or models in mind: one that claims only 'not-A' and the other that claims 'A and B' (see Table 1). As we can observe, Dancygier's and our mental model interpretation of Fillenbaum's ideas propose a two-model initial representation. However, according to Dancygier, one of the models or possibilities is now not complete; it now claims only 'not-A' instead of 'not-B and not-A' (see Table 1).

The alternativity of the 'not- A unless B' representation is emphasised by its semantic similarity with disjunctive assertions such as 'Either B or not-A'. According to mental model theory, the interpretation of a disjunctive assertion implies the construction from the outset of two incomplete possibilities or models (see Johnson- Laird & Byrne, 1991; Johnson- Laird, Byrne, & Schaeken, 1992).

The aim of this paper is to test Dancygier's ideas about the meaning of 'unless' by using a conditional inference task. The following Experiment addresses the hypothesis that two possibilities are initially represented by comparing people's reasoning ability to use 'unless' with their ability to use disjunctive conditional assertions. Likewise, the Experiment manipulates the order of presentation of the categorical premise. It will be presented either in the canonical order, after the conditional assertions (for example, using an 'unless' sentence: 'not-A unless B', 'not-B', What can you conclude?), or in the inverted order, presenting the categorical premise before the conditional assertions (for example, 'not-B', 'not-A unless B', What can you conclude?). We expect the inversion will impair participants' performance by increasing working memory load, as instead of serving to eliminate one of the already-constructed models, the categorical premise now needs to be held in working memory during model construction.

Experiment

In this experiment we manipulated two main independent variables, the linguistic form of conditionals and the order of the presentation of premises. The third variable was the four conditional inferences. In order to test the two initial possibilities hypothesis, we compared people's inferential ability on 'not-A unless B' assertions with that of 'Either B or not-A' (see table 2).

According to mental model theory, the interpretation of 'Either B or not-A' implies the construction from the outset of two incomplete possibilities or models as follows (see Table 1):

B
not-A

In a similar way, the representation of 'not-A unless B' will lead from the outset to the construction of two possibilities, the first either being incomplete (Dancygier's hypothesis) or complete as follows:

(not-B) not-A
B A

Both initial representations of 'Either B or not-A' and 'not-A unless B' may be fleshed out to construct the same complete representation:

B A
not-B not-A

That matches the truth conditions of 'if and only if A then B' (see Table 2). Our hypothesis is that participants will go through the process of reasoning out both statements from the same two models. Likewise, given that 'not-A unless B' and 'Either B or not-A' are both asymmetric, we expect asymmetric responses to both assertions. The Experiment also attempts to check Dancygier's hypothesis about the

Table 1
The initial and complete possibilities reasoners keep in mind when they interpret both linguistic conditional formulations. The two possibilities of the initial representation of 'unless' can either be complete (including not-B) or incomplete (without not-B: Dancygier's hypothesis)

	Initial	Complete Final
Not-A unless B	(not-B) and not-A B and A	not-B and not-A B and A
Either B or not-A	B and and not-A	B and A not-B and not-A

Note. The full set of true possibilities for each of the two linguistic forms is the same: 'A and B', 'not-A and not-B'.

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Table 2
*The truth conditions for 'If and only if A then B', 'Not-A unless B' and 'Either B or not-A', and the four inferences from them.**

	If and only if A then B	Not-A unless B	Either B or not-A
Truth conditions			
A and B	True	True	True
not-A and not-B	True	True	True
not-A and B	False	False	False
A and not-B	False	False	False
Inferences			
MP	A.·.B	A.·.B	A.·.B
AC	B.·.A	B.·.A	B.·.A
MT	not-B.·.not-A	not-B.·.not-A	not-B.·.not-A
DA	not-A.·.not-B	not-A.·.not-B	not-A.·.not-B

Note. Naming the four inferences for 'unless' is difficult and we have been guided by the form of the minor premise and conclusion, as well as by the possibilities that are true and false. As Table 2 shows, for 'Not-A unless B' and 'Either B or not-A', the two true possibilities are 'A and B' and 'not-A and not-B'; that is, the same as for 'if and only if A then B'. Therefore, the inferences MP, MT, DA and AC are the same as for 'if and only if A then B'. We accept that at first sight it may seem odd to use 'MP' to refer to the inference 'Not-A unless B, A therefore B' or 'Either B or not-A, A therefore B'. Other naming schemes run into difficulties, however, and so we opt for this one.

meaning of 'unless' by changing the order of presentation of the categorical premise. Following mental model theory, the effect of premise order may be explained by the crucial role working memory plays in reasoning (see, García-Madruga, Moreno, Carriedo, Gutiérrez, & Johnson-Laird, 2001; Girotto, Mazzoco, & Tasso, 1997; Legrenzi, Girotto, & Johnson-Laird, 1993; Johnson-Laird & Bara, 1984).

Girotto et al. (1997) showed that the presentation order of the categorical premise in conditional inference tasks may affect people's performance. These authors found that the presentation of the categorical premise 'not-B' before 'if A then B' (MT inference) increased the percentage of valid 'not-A' responses, whereas MP inferences were unaffected with the presentation of categorical premise before the conditional (see, however, Evans, Handley, & Buck, 1998). According to these authors, because reasoners represent MT inferences when the categorical premise is presented first, they do not have to represent the model of the conditional in which the antecedent and consequent are true. They are more likely to flesh out the other models of the conditional, and hence reach the valid conclusion; in other words, the presentation of the categorical premise in MT inference allows reasoners to simplify their task and skip directly to the construction of the 'not-A and not-B' model. In our opinion, this facilitation effect for MT inferences is possible because the initial representation of 'if A then B' includes a single explicit possibility: 'A and B'. This facilitation effect is not expected in our experiment since 'unless' and disjunctive assertions lead from the outset to the construction of two possibilities.

However, changing the presentation order of the premises can affect reasoners' performance in a different way. García-Madruga et al. (2001) showed that presentation order influenced reasoners' ability to solve Rips's problems that include either a conjunction, or a disjunction and two conditionals (Conjunctive problems: 'A and B', 'if A then C, 'if B then C'; Disjunctive problems: 'A or B', 'if A then C', 'if B then C'). When a conjunction or disjunction followed the two conditional premises (Conjunctive problems: 'if A then C', 'if B then C', 'A and B'; Disjunctive problems: 'if A then C', 'if B then C', 'A or B'), conjunctive problems were easier than disjunctive problems independently of the kind of task used: evaluation or construction. This may be because the one model only interpretation of the conjunction (A and B) is more easily connected with the modelling of the two previous conditional assertions. On the other hand, the interpretation of the disjunction requires reasoners to construct two models while their working memory is already preoccupied by the two explicit models of the conditionals.

The presentation of the categorical premises before 'unless' and disjunctive assertions may similarly affect people's performance. According to our hypothesis, the representation of the conditional assertions 'not-A unless B' and 'Either B or not-A' will lead from the outset to the construction of two possibilities (Table 1). When the categorical premise is presented in the usual order, reasoners have already interpreted the conditional premise, and the categorical information permits the elimination of one of the models and allows one to infer the conclusion from the complete model that matches it. When the categorical premise is presented prior to the conditional premise, on the other hand, the reasoning process may be impaired. The understanding of 'not-A unless B' and 'Either B or

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not-A' assertions is already a hard task that cannot be simplified, and the prior presentation of categorical premises will probably only negatively affect the reasoning process: Now reasoners have to cope with a multiple-model assertion that demands the construction from the outset of two models while their working memory is preoccupied with the information in the categorical premise.

According to the complete initial representation hypothesis the increase in difficulty should be similar for the diverse inferences. According to Dancygier's hypothesis, in the 'unless' semantic representation, the first model lacks the token that permits the DA inference:

not-A
B A

When reasoners receive the not-A categorical premise that matches the token of the first model they don't have the second token that allows them to directly draw the not-B inference. Therefore, the increase in difficulty should be particularly apparent when reasoners receive the not-A categorical premise before 'not-A unless B'. In other words, if Dancygier is right, the manipulation of order will yield a decrease of DA inferences and they will now be harder than MT ones.

In a similar way, according to mental model theory, the representation of 'Either B or not-A' will lead from the outset to the construction of two possibilities as follows:

B
not-A

When the categorical premise is presented in the usual order, reasoners have already interpreted the disjunctive premise, and the categorical information permits the elimination of one of the models and allows one to infer the conclusion from the complete model that matches it. When the categorical premise is presented prior to the conditional premise, the reasoning process may be impaired because reasoners have to cope with a multiple-model premise, while their working memory is preoccupied by the information in the categorical premise.

The two initial models of disjunctions lack the token that permits the AC inference (the B categorical premise) and the DA inference (the not-A categorical premise). Therefore, the increase in difficulty should be particularly apparent when reasoners receive the B categorical premise and the not-A categorical premise first. In other words, the inversion of order will yield a decrease in AC and DA inferences and they will be harder than MP and MT ones, respectively.

Summarizing, our hypotheses are:

1. When the categorical premise is presented after the conditional assertion, the pattern of results for 'unless' and disjunctive conditionals will be similar, that is we don't expect any differences among the four inferences.
2. When the categorical premise is presented before the conditional assertion, there will be a decrease in inferential endorsements and the pattern of results for 'unless' and disjunctive conditionals will be different. For disjunctive conditional assertions we expect differences between AC and MP inferences, and DA and MT inferences. For unless assertions, following Dancygier's hypothesis, as the initial representation is incomplete, we expect differences between DA and MT inferences.
3. As in previous studies, we expect a relevant percentage of asymmetric responses in 'unless' assertions and also in disjunctive conditional assertions.

In this experiment participants will be asked to generate their conclusions and write them down in a booklet without any time restriction. The task was particularly simple because each group of participants was asked to solve only one kind of conditional expression.

Method

Design

Participants were randomly assigned to four different conditions: Group 1 and 2 (canonical order) first received the 'not-A unless B' or 'Either B or not-A' conditionals, respectively, and then they received the categorical premise; Group 3 and 4 (inverted order) received the categorical premise first and then the 'not-A unless B' and 'Either B or not-A' conditionals, respectively. Each subject had to do 16 conditionals problems, 4 in each conditional inference: MP, AC, MT and DA. Thus a 2 x 2 x 4 (form x order of presentation x inference) design was used. The first two variables were between-subject and the third within-subject.

Participants

Participants were 115 students from a psychology class at the 'Universidad Nacional de Educación a Distancia' (UNED) and the 'Universidad Autónoma' of Madrid that voluntarily participated in the experiment. The participants had received no training in logic and had not been previously tested in any experiment on reasoning. The number of participants in each group was: group 1 = 26, group 2 = 30, group 3 = 28 and group 4 = 31.

Materials

The content of the problems concerned people and cities. The experiment was carried out in Spanish, and here is an example of one the problems that use 'unless' conditionals (translated into English):

Carlos won't go to Madrid, unless Marta goes to Sevilla [Carlos no irá a Madrid a menos que Marta vaya a Sevilla]
Marta goes to Sevilla [Marta va a Sevilla]
What can you conclude?
Conclusion: .....

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An example of one of the disjunctive conditional problems is:

Either Marta goes to Sevilla or Carlos won't go to Madrid [O Marta va a Sevilla o Carlos no irá a Madrid]

Marta goes to Sevilla [Marta va a Sevilla]

What can you conclude?

Conclusion: .....

We devised 4 sets of different content sets, each containing the names of people and places, and rotated them over the 4 inferences in order to construct 16 versions of the problems. Each participant was assigned at random to one of the versions of a task.

Procedure

The participants were tested together in a single group. The instructions and the problems were assembled into booklets, which were assigned to the participants at random. The instructions on the first page of the booklet explained the nature of the task. Participants were told that they had to state what, if anything, followed necessarily from each set of premises, i.e., what must be true given that the premises are true. If the participants considered that nothing followed from the premises, then they had to write that "nothing follows". There were two examples with 'if then' assertions, one based on MP and one based on AC, which were used to illustrate the meaning of "necessarily true". The participants were told that they could take as much time as they needed on a problem, but that they should not return to a problem once they had provided a response.

Results and discussion.

We analysed the results in an ANOVA with linguistic form ('unless', 'or'), order (canonical, inverted), and inference (MP, MT, AC and DA) as factors, with repeated measures on the last factor. It showed a main effect of form, $F(1,111) = 20.00$, $MSE = 5009.9$, $p < .001$, and inference, $F(3,109) = 4.71$, $MSE = 456.48$; $p < .0031$; the effect of order was only marginally significant, $F(1,111) = 3.6$, $MSE = 5009.9$, $p = .06$. Form interacted with inference, $F(3,109) = 3.30$, $MSE = 456.48$, $p = .02$, but not order, $F(1,111) = .05$, and order interacted with inference, $F(3,109) = 3.41$, $MSE = 456.48$, $p = .018$. The three way interaction was not reliable, $F(3,109) = .24$. As we can see, the overall percentage of endorsements of 'not-A unless B' (78%) was reliably higher than in the 'Either B or not A' condition (48%). Likewise, as predicted, the overall percentage of endorsements when the presentation of premises was canonical (70%), was higher than when inverted (57%), although the difference was only marginally significant ($p = .06$).

The percentages of endorsements for each inference can be observed in Table 3. To test our predictions we carried out a series of planned comparisons:

In the canonical order, when the conditional premise is presented first, the differences among the four inferences were not reliable for any of the two conditional assertions: 'not-A unless B', $F(3,23) = 1.09$, $MSE = 255.4$, $p = .36$, and 'Either B or not-A', $F(3,27) = 1.38$, $MSE = 505.2$, $p = .25$.

In the inverted order, when the categorical premise is presented first, there were differences among the four inferences for the two conditional assertions: 'not-A unless B', $F(3,25) = 3.69$, $MSE = 566.9$, $p < .016$, and 'Either B or not-A', $F(3,28) = 4.24$, $MSE = 613$, $p < .008$. As predicted by Dancygier's hypothesis, for 'not-A unless B' there was a lower percentage of endorsements for DA inferences than for MT inferences $F(1,27) = 6.25$, $MSE = 4464.28$, $p < .019$; likewise, as predicted, for 'Either B or not-A', there was a lower percentage of endorsements for DA inferences than for MT inferences $F(1,30) = 5.77$, $MSE = 4032.25$, $p < .023$; and, there was a lower percentage of endorsements for AC inferences than for MP inferences, although this

Table 3
Percentages of conclusions endorsed by participants in the Experiment. Asymmetric responses are between brackets

	MP A.·.B	AC B.·.A	MT notB.·.notA	DA notA.·.notB
Canonical Order (Conditional assertion first)				
Not-A unless B	86 (9)	89 (8)	82 (9)	84 (11)
Either B or not-A	59 (32)	49 (40)	54 (29)	53 (33)
Inverted order (Categorical premise first)				
Not-A unless B	71 (12)	78 (17)	77 (20)	59*(17)
Either B or not-A	52 (19)	39*(30)	48 (26)	32*(29)

Note. * indicates the figure is significantly different from the one on the left.

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difference was only marginally significant $F(1,30) = 3.80$, $MSE = 2913.30$, $p = .06$.

The percentage of asymmetric responses for 'Either B or not-A' (30%) was higher than for 'not-A unless B' (13%), $F(1,111) = 8.67$, $MSE = 962.1$, $p < .004$. There were no differences in the percentage of asymmetric responses among the four inferences, neither for the 'not-A unless B' conditionals, $F(3,51) = .73$, nor for the 'Either B or not-A' conditionals, $F(3,58) = 2.05$, $MSE = 504.5$, $p = .11$.

The results seem to bear out the predictions: Participants seem to reason from 'not-A unless B' and 'Either B or not A' in a similar way, by using a two model representation. When the presentation of premises is canonical, there are no differences among the four inferences for any of the two conditional assertions. In the inverted order, the presentation of the categorical premise first impairs reasoners' performance and a difference among the endorsements for the four inferences appears. As predicted, for the disjunctive conditional there is a difference between DA and MT inferences and AC and MP inferences. For unless assertions, the results refute our prior hypothesis based on Fillenbaum's ideas and confirm Dancygier's hypothesis: there is a difference between DA and MT inferences. These results confirm the mental model analysis of 'unless' and 'or', which predicts that both assertions lead from the outset to the construction of two possibilities or models. In canonical order, participants reason from the complete representation of two possibilities, whereas in the inverted order participants reason from an incomplete representation of the two possibilities.

There is also a relevant result concerning the difficulty of disjunctive inferences. We have shown in prior experiments that 'not-A unless B' conditionals are hard, but the results of this experiment show that 'Either B or not A' are even harder. The differences in difficulty between both conditional assertions are shown not only in the diverse percentage of endorsements but also in the percentage of asymmetric responses that, as we have proposed, may occur due to the activation of a kind of superficial strategy. This superficial strategy, as García-Madruga et al. (2008) holds, might consist of matching the two terms that appear in the statement; for example, from 'Either B or not-A' and 'B' (AC inference), some people give 'not-A' as an answer.

General Discussion

We have tested Dancygier's hypothesis about the mental representations and processes underlying inferring with 'unless' conditionals. According to model theory, 'if ' conditionals are understood initially by keeping in mind a single possibility, corresponding to the true possibility whose elements are mentioned in the conditional. 'If A then B' and 'if and only if A then B' are understood by initially keeping in mind the possibility 'A and B' (Johnson-Laird & Byrne, 2002). On the other hand, we suggested that 'unless' conditionals are understood by keeping in mind two possibilities, corresponding to the true possibility whose elements are affirmative, and the true possibility whose elements are negative. The elements mentioned in the 'unless' conditional are one negative (not-A) and the other affirmative (B).

According to model theory, the difference between Dancygier and the complete two model representation hypothesis about 'unless' would mainly affect DA inferences. Following Fillenbaum's claim we proposed that people represent 'not A unless B' by constructing the two complete possibilities: 'B and A' and 'not-B and not-A'. From this representation we shouldn't expect a relevant difference between the endorsement of DA and the other inferences for 'unless'.

The experiment presented in this work checks an alternative hypothesis that may account for the 'peculiarity' of DA in 'unless' assertions from Dancygier's hypothesis. The incomplete representation of the negative possibility Dancygier claims might explain what happens to DA inferences, as we analysed in the introduction. This hypothesis was evaluated by comparing people's inferential performance with 'not-A unless B' and 'Either B or not-A', by presenting the premises in two different orders: the usual canonical order (categorical premise after the conditional assertion) and the inverse order (categorical premise before). We claimed that this inverse order should increase the problem's difficulty because of the increase in participants' working memory load. In canonical order, we did not expect any differences among the four inferences, neither for 'unless' nor for 'or'. In inverted order, however, according to Dancygier hypothesis 'unless' participants should have more difficulties in searching for the response to DA inference, due to the absence of one token in the negative possibility, the token that directly allows making the inference. Likewise, for 'or', participants should have more difficulties in searching for the response to DA and AC inferences, due to the absence of one token both in negative and affirmative possibilities. The results of the experiment clearly support these hypotheses:

1. In the canonical order, there were no differences among the four inferences, neither for 'not-A unless B' nor for 'Either B or not-A'.
2. In the inverted order of presentation of premises, for 'not-A unless B', DA inferences were harder than MT inferences; and for 'Either B or not-A', DA inferences were harder than MT inferences and AC inferences were harder than MP inferences.
3. Inverted order problems were harder than canonical order problems. This tendency was only marginally reliable, but the four inferences in the two conditions decreased in the inverted order.

The experiment in this paper bears out the difficulty of 'unless' assertions. However, our results show that conditional 'Either B or not-A' inferences are even harder than 'not-A unless B' ones: Reasoners make fewer inferences and more

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asymmetric responses. This result is not completely unexpected. It has been previously shown (see Johnson-Laird, Byrne & Schaeken, 1992; see also, Evans et al., 1993; Evans, 2007) that disjunctive inferences are quite difficult, harder than conditional inferences, particularly if they include a negative.

The results of the experiment highlight the strategic nature of human deductive reasoning. Reasoners do adopt different strategies and these strategies depend on the task (see e.g. Byrne & Handley, 1997, García-Madruga, Moreno, Carriedo, & Gutiérrez, 2000; García-Madruga et al., 2001). The use of strategies in cognition and reasoning is based on the cognitive-economy principle: Strategies are aimed at satisfying a goal in the simplest, quickest and most economical way possible. There is a second related principle that determines the use of strategies in reasoning: The adaptive character of thought. This principle holds that strategies are adapted to the particular task reasoners face: A minor change in the problem-solving task, namely, in our experiment, the presentation order of premises, may lead to a relevant alteration in the way reasoners will treat it and therefore may also directly affect the results they will draw from their mental processes. As we have seen in this paper, the change in the presentation order of premises in conditional inferences does affect reasoning performance. When the categorical premise is presented after the 'unless' and 'or' conditionals, given that the task is simple and without time restrictions, reasoners show no differences in difficulty when drawing the four inferences from the two model representation of both conditional assertions: they construct the two complete models. On the other hand, when we introduce a tiny modification in the task, a change in the order of premises, some people find their working memory overloaded. The effect of overloading working memory appears in those very inferences that demand the extra cognitive work of completing absent tokens, that is: DA inferences for 'unless' and DA and AC inferences for 'or'. This interpretation of our results holds that the initial representation of 'unless' and 'or' is always incomplete: Some models lack a token, but the incompleteness of representation is not apparent when the reasoning task and process at hand are simple. However, there is an alternative, though tightly related, interpretation of the results of our experiment: The representation that people construct depends not only on the kind of assertion used and participant's working memory, but also on the complexity and difficulty of the task they face. According to this interpretation, when the reasoning task and process are simple, as in the canonical order condition, people tend to construct complete representations of 'unless' and 'or' assertions; on the other hand, when the reasoning task and process are harder, as in the inverted order condition, people have to economize cognitive resources and they tend to construct incomplete representations of 'unless' and 'or' assertions.

There is convergent support for our results from the linguistic processing perspective, namely the 'good enough' approach to language comprehension, formulated by Ferreira et al. (Ferreira, Ferraro, & Bailey, 2002; Ferreira & Patson, 2007). These authors argue the language comprehension system is not always going to deliver an accurate and detailed representation of the speaker's utterance; on the contrary, the representations created during language comprehension are just 'good enough': 'the system's responsibility is to create representations that are suitable for the task that the listener wants to perform with the help of the linguistic input' (Ferreira & Patson, 2007, p. 71). In the same line, Sanford and Graesser (2006) hold that a key concept in normal language comprehension is that of 'underspecification': 'a precise and complete semantic analysis is rarely constructed by the comprehender because the information explicitly offered in the text is incomplete or because a precise complete interpretation would not be worth the processing effort' (p. 3). According to these perspectives, the results of our experiment show that when participants are faced with a task that demands more processing effort (presenting the categorical premise first), they tend to build only a "good enough", but incomplete, representation of both conditional assertions. As we can see, both theoretical frameworks, the analysis of the reasoning process from a perspective based on the strategies used by individuals and the 'good-enough' approach to language processing, highlight the key role working memory resources play in the construction and integration of the meaning of the premises of reasoning. Nevertheless, the role of working memory in sentence processing and hence in the reasoning process is an open question. Some authors have formulated resource-limitation theories that analyse in depth how working memory operates during the processing of language (see, for instance, Gibson, 1998; Lewis &Vasishth, 2005), whereas other authors have claimed the crucial role of expectations in sentence processing, such as one finds in 'surprisal' theory (see, Levy, 2008). Therefore, although working memory is a clear candidate, some other variables such as the expectations and the frequency of the input might also account for our results. This issue may indeed be deserving of new research that controls participants' WM and thus analyses its role in comprehension and reasoning processes. Our experiment provides further evidence regarding the way people think about 'unless'. People usually express warnings and threats using 'unless' assertions. However, until recently psychologists have not paid attention to 'unless' conditionals. The assertion 'you won't pass the exam unless you work harder', conveys subtly different information from the assertion, 'If you don't work harder then you won't pass the exam'. We suggest that reasoners keep one possibility in mind initially to understand the latter but not the former. Likewise, following Dancygier, we claim that the meaning of 'you won't pass the exam unless you work harder' is more similar to 'either you work harder or you won't pass the exam'. In both cases, people keep in mind two possibilities. For 'unless', we claim that these possibilities are: one conjecture about 'working harder

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and passing the exam' and another about the probable result of 'not passing the exam'. Our results seem to confirm that in at least some circumstances, for 'unless', this second possibility or model may be incomplete, whereas for 'or' conditionals both possibilities may be incomplete. As we have seen, this idea corresponds well with a 'good enough' approach to language comprehension, as well as the cognitive-economy principle in mental model theory, which claims that people represent as little information as possible explicitly (Johnson-Laird & Byrne, 1991; Johnson-Laird, Byrne, & Schaeken, 1992).

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