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Initial Models in Conditionals: Evidence from Priming

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We examined the comprehension of different types of conditionals. We measured the reading time of sentences primed by different types of conditionals (Experiments 1 and 2). We found that the participants read *not-p and not-q* faster when it was primed by the conditional form *p if q* and they were slower to read *p and q* when it was primed by the conditional form *p only if q*. This effect disappeared in the second experiment, where the order of the elements was reversed (*q and p* and *not-q and not-p*). These results suggest that the conditional form *p if q* elicits an initial representation "from p to q" with two possibilities, while the conditional form *p only if q* elicits a reverse representation with only one possibility. The third experiment showed that there were effects of the order only for the conditional *if p then q,* which confirms the reverse representation hypothesis. We discuss the implications of these results for different theories of conditional comprehension.
Keywords: lexical conditional reasoning, priming, suppositional theory, mental model

Examinamos la comprensión de diferentes tipos de condicionales. Medimos el tiempo de lectura de frases facilitadas por diferentes tipos de condicionales (experimentos 1 y 2). Encontramos que los participantes leían *no-p y no-q* más rápidamente cuando era facilitada por la forma condicional *p si q* y que eran más lentos leyendo *p y q* cuando era facilitada por la forma condicional *p sólo si q.* Este efecto desapareció en el segundo experimento, donde el orden de los elementos se invirtió (*q y p* y *no-q y no-p*). Estos resultados sugieren que la forma del condicional *p si q* elicita una representación inicial "desde p a q" con dos posibilidades, mientras que la forma condicional *p sólo si q* elicita una representación inversa con una sola posibilidad. El tercer experimento mostró que había efectos de orden sólo para el condicional *si p entonces q,* lo cual confirma la hipótesis de la representación inversa. Se comentan las implicaciones de estos resultados para las diversas teorías de comprensión condicional.
Palabras clave: razonamiento condicional, priming, teoría suposicional, modelo mental

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A conditional is a declarative sentence in which two propositions are joined by the connective *if ... then*. For example, the sentence *if p, then q* is a conditional, where *p* is the antecedent and *q* is the consequent. As displayed in Table 1, there are four inferences that can be obtained from a conditional: Modus Ponens (MP), Affirmation of Consequent (AC), Denial of Antecedent (DA) and Modus Tollens (MT). In a conditional sentence, MP and MT are correct inferences whereas DA and MT are fallacies. Research on conditional inference has shown that MP is more frequently accepted as a correct inference than MT, and a substantial number of reasoners accept the fallacies DA and CA as correct inferences (see Evans, Newstead, & Byrne, 1993, for a review).

For some time, research interest has been focused on the conditional form *if p then q*. Recently, however, more attention is being given to other ways of formulating the conditional. Research has been conducted on the conditional form *p only if q* and *p if q*. From the logical view, *p only if q* can be converted directly into *if p then q*, whereas *p if q* is equivalent to *if q then p* (Luckhardt & Bechtel, 1994).

There are several theories of conditional reasoning that differ in the ways they account for an individual's understanding of conditionals and the inferences made from these. The formal-rule theories (Braine & O'Brien, 1991; Rips, 1994) postulate that when people read a conditional sentence they make a syntactic representation by bringing to light the underlying logical form. Suppositional theory (Evans & Over, 2004; Evans, Over, & Handley, 2005; Over & Evans, 2003) proposes that people interpret everyday conditionals in naturals languages by means of the *Ramsey test*. According to Ramsey (1931), people who are arguing with a conditional sentence *if p then q* are "hypothetically adding p to their stock knowledge and arguing on that basis about q." Suppositional theory predicts that when people read a conditional, such as *if p then q*, the "use of if causes rapid and automatic focus on the p-possibilities for all conditionals" (Evans & Over, 2004, p. 155). Others possibilities, such as not p-possibility, are irrelevant for the conditional. From this point of view, the conditional *if p then q* will activate the following mental representations:

p and q
p and not-q

but not the following possibilities:

not-p and q
not-p and not-q

From the suppositional theory, we should predict that people will have equal access to the possibility *not-p and not-q* or *not-p and q* for different form of conditional (such as *p if q, only if p then q, p only if q* and *if then q*). This theory predicts that the possibility *not-p and not-q* is no considered in conditional reasoning.

On the other hand, the model theory (Johnson-Laird & Byrne, 1991) posits that reasoners understand a conditional sentence by constructing mental models based on keeping different possibilities in mind. From the model-theory point of view, there are two main principles for propositional reasoning (Johnson-Laird & Byrne, 2002). The first principle states that people keep in mind the true possibilities of the conditional. For example, for the conditional *if p then q* people might construct the following true possibilities:

p q
not-p q
not-p not-q

The second principle affirms that participants try to represent initially as few possibilities as they can. Consequently, the model theory postulates that initial representations for the conditionals *p and q*, *p only if q*, and *p if q* are different (these are summarized in Table 2). Other authors such as Baurrouillet and Lecas (1998) have proposed different initial representations for these conditionals.

The mental representations that participants construct for these kinds of conditionals have been inferred from two phenomena: the directional effect and the valence effect. The directional effect shows that the percentage of forward inferences (MP and NA) or backward inferences (AC and MT) that participants make depends on the conditional form.

Table 1
Four Inferences in Conditional Sentence

Modus Ponens (MP)	Modus Tollens (MT)
If p, then q	*If p, then q*
P	*not q*
Therefore*: q*	Therefore*: not p*
Affirmation Consequent (AC)	**Denial of Antecedent (DA)**
If p, then q	*If p, then q*
q	*not p*
Therefore*: p*	Therefore*: not q*

Table 2
Initial Models Proposed by Johnson-Laird and Byrne (1991) and Barrouillet and Lecas (1998, 2003) for the Conditional Connectives if p then q, only if p then q, *and* p if q

	Type of conditional		
	if p then q	*p only if q*	*p if q*
Johnson-Laird & Byrne	p q …	p q not-p not-q …	p q …
Barrouillet & Lecas	Hp → q …	p ← Hq …	p ← Hq …

In the conditional rule *if p then q* participants make more forward (MP and DA) than backward inferences (AC and MT), whereas for the conditional form *p only if q* participants make more backward than forward inferences (Evans, 1977, 1993; Evans & Beck, 1981; Evans et al., 1993). Moreover, other studies have shown that reasoners take a different amount of time to endorse backward or forward inferences for different conditional forms (Grosset & Barrouillet, 2003; Santamaría & Espino, 2002). Different hypotheses have been offered to explain this result. Evans suggested the "focus hypothesis," which postulates that people "are inclined to focus attention on the part of the rule—antecedent or consequent—which is modified by the *if* and reason from that component to the other" (Evans, 1993, p. 9). This hypothesis predicts that for the conditional form *if p then q* reasoners should make more forward than backward inferences because in this conditional form *p* is modified by *if*. However, this hypothesis predicts that for the conditional form *p only if q* or *p if q* that people will make more backward than forward inferences, because *q* is modified by the *if*. Grosset and Barrouillet (2003) and Barrouillet and Lecas (1998) have postulated a "hypothetical value" to explain the directionality effect. This hypothesis is similar to Evans's hypothesis; the only difference is that Grosset and Barrouillet explain the nature of the focus hypothesis by assuming that reasoners use a mental footnote to indicate the hypothetical nature of the antecedent. However, they predict the same pattern of results as Evans's model.

Johnson-Laird (1995) explains the directionality effect in the same terms as the figural effect in syllogistic reasoning. The figural effect suggests that people tend to frame conclusions in the same order in which the information has been entered into working memory. Johnson-Laird postulates: "there is now known to be a marked 'figural effect' in propositional reasoning-that is, individuals tend to frame conclusions in the same order as the information in the entered working memory (p. 131)." He also predicts that people prefer to reason from *p to q* for the following conditional forms: *if p then q*, *p only if q* and *p if q*. However, this point of view cannot explain why people produce more backward inferences (from *q* to *p*) than forward inferences (from *p* to *q*) with the conditional *p only if q*.

The valence effect shows that people make more affirmative inferences (MP and AC) than negative inferences (DA and MT). Moreover, it takes more time to endorse negative rather than affirmative inferences (Grosset & Barrouillet, 2003; Santamaría & Espino, 2002). Evans (1993), Grosset and Barrouillet and Johnson-Laird and Byrne (1991) have suggested that participants make fewer negative than affirmative inferences because the negative inferences require a fleshing-out process, whereas the affirmative inferences do not require this process. However, whereas Evans and Grosset and Barrouillet postulate that the conditional forms *if p then q*, *p only if q* and *p if q* require a fleshing-out process to make negative inferences, Johnson-Laird and Byrne consider that this fleshing-out process is only necessary for the conditional form *if p then q* and *p if q*. The model theory (Johnson-Laird & Byrne, 1991) suggests that the conditional form *p only if q* would lead people to include the negative contingency, yielding two explicit models right from the start:

p *q*
no p *no q*
. . .

whereas the conditionals *if p then q* and *p if q* elicit the following initial representation:

p *q*
. . .

In the conditional *p only if q* the possibility *not-p and not-q* is part of the initial representation, whereas in the conditionals *if p then q* and *p if q* the possibility *not-p and not-q* is not represented. In this case, people have to flesh out the information present in the implicit model (…) to reach the possibility *not-p and not-q*. A plausible explanation for this prediction of the model theory would be that the construction of an additional model for *p only if q* would be predicted from the pragmatic implications of the word *only* which directly refers to the exclusion of a possibility. It could be considered to be general in language (not

exclusive of conditional statements). For example, if someone says, "I only have ten euros," this person is directly denying the possibility of having more than ten euros, whereas if this person says, "I have ten euros," no such implication is directly present in the statement. In the case of conditionals, a statement like "I can go to dinner only if I have more than ten euros" implies a direct rejection of the possibility of going to dinner with less than ten euros.

A problem with this line of research is that the mental representation during comprehension is indirectly apprehended from the inferences that participants produce or the time they take to make those inferences. Our aim is to obtain more direct evidence about the mental representation that participants have in mind while they understand different kinds of conditionals. In our study we use a comprehension task to infer what kind of possibilities people keep in mind when they understand conditional sentences. We make use of a priming methodology (see Santamaría & Espino, 2002; Santamaría, Espino, & Byrne, 2005) to find out what kinds of mental representations people have in mind when they read different conditionals.

Conditionals as Primes

We gave our participants a scenario and a question to read of the following sort:

> Pedro was going to a sports-store with his sister. She told him that in this store, if there are rackets then there are rucksacks. When they arrived at the store they saw that there were rackets and rucksacks. Pedro tried on some sport shoes. Did Pedro try on some sport shoes?

Our interest was in the length of time it takes participants to understand the conjunction, *there were rackets and there were rucksacks*. The conditional *if there are rackets then there are rucksacks* can act as a prime for the conjunction, so we expect that participants who have understood the conditional keep in mind the true possibility in which there are rackets and rucksacks. When they read the conditional, their understanding should prime the affirmative possibility, but it should not prime the negative possibility *there were no rackets and there were no rucksacks.* The length of time it takes to understand an assertion can provide information on what is kept in mind. Of course, the negative possibility contains more words and negation may require additional processing time, and so our key predictions concern the efficacy of different conditionals as primes for the same conjunction. Our claim is that different conditionals require people to keep in mind different possibilities, and we will test this claim by comparing different conditionals as primes for different conjunctions.

This research had third main goals. First (Experiment 1), it aimed to examine whether the conditional *p if q* primes the conjunction *not p and not q* as compared to the conditionals *if p then q*, *only if p q* and *p only if q*. Some authors (e.g., Braine, 1978; O'Brien, Dias, & Roazzi, 1998) have observed that *p if q* leads to a biconditional-like response pattern in conditional syllogism tasks. It could be that people understand this kind of conditional as a biconditional. In that case, we should expect that this conditional form will prime people to read the negative possibility *not p and not q* more quickly, compared to other conditionals (*if p then q*, *only if p q* and *p only if q*). Suppositional theory (Evans & Over, 2004: Evans et al., 2005; Over & Evans, 2003) predicts that people will have equal accessibility the possibility *not-p and not-q* or *not-q and p* for different forms of conditional (*p if q*, *only if p then q*, *p only if q*, *if then q*) because this possibility is not considered when people think with conditional.

The second purpose (Experiment 1 and Experiment 2) was to examine whether the conditionals *if p then q*, *p if q* and *only if p q* prime the conjunction *p and q* compared to the conditional *p only if q*. Some authors (Barrouillet & Lecas, 1998; Evans, 1993; Santamaría & Espino, 2002) postulate that the conditional *p only if q* produces a mental representation from *q to p*. Other authors (Johnson-Laird & Byrne, 1991) postulate that the mental representation is from *p to q*. If the conditional *p only if q* produces a mental representation from *q to p*, we might expect people to read more slowly the affirmative possibility *p and q* after this conditional compared to other conditionals (*if p then q*, *only if p q* and *p if q*).

The third purpose (Experiment 3) was to examine a conjunction (*p and q* or *q and p*) as a prime for understanding the conditional *if p then q* or the conditional *p only if q*. If the conditional *if p then q* produces a mental representation from *p to q*, as some authors postulate (Barrouillet & Lecas, 1998; Evans, 1993; Johnson-Laird & Byrne, 1991; Santamaría & Espino, 2002), we might expect that the affirmative conjunction *p and q* will prime reading of the conditional *if p then q* compared with the affirmative conjunction *q and p*. For these authors, the conditional *p only if q* produces a mental representation from *q to p*. From this point of view, we might expect that the affirmative conjunction *q and p* will prime reading the conditional *p only if q* compared with the affirmative conjunction from *p and q*.

In this paper, we make no strong claims about which of the various versions of the model theory we have illustrated is correct. The aim of the following studies is simply to test which is most accurate.

Experiment 1

The aim of this experiment was to examine the differences in interpretation between different types of conditional. We made use of a comprehension task in which

no propositional inference was required. For this purpose, we composed paragraphs that included four types of conditional sentence of the types *if p then q*, *p only if q*, *only if p q* and *p if q*. After this sentence, the paragraphs included a conjunction that was either affirmative (*p and q*) or negative (*not-p and not-q*). This conjunction was the test sentence.

As mentioned above, several authors have proposed that people keep in mind different representations when they read the conditionals *if p then q*, *p if q*, and *p only if q* (Braine, 1978; Evans, 1993; Evans & Over, 2004: Evans et al., 2005; Grosset & Barrouillet, 2003; Johnson-Laird & Byrne, 1991, 2002; Over & Evans, 2003). In this experiment, we will check these predictions. Evans (1993) and Grosset and Barrouillet (2003) have proposed that the conditional *if p then q* produces a mental representation from *p to q*, whereas the conditionals *p only if q* and *p if q* produce a mental representation from *q to p*. From this view, it might be expected that the participants will read *p and q* faster after reading the conditional form *if p then q* than after *p if q* and *p only if q*. Moreover, it could be predicted that there will be no difference between different conditional forms when participants read the test sentence *not-p and not-q* (Evans, 1993; Evans & Over, 2004: Evans et al., 2005; Grosset & Barrouillet, 2003; Over & Evans, 2003). Johnson-Laird and Byrne (1991) have proposed that these conditionals (*if p then q*, *p only if q*, and *p if q*) produce a mental representation from *p to q*. Thus, it might be expected that there will be no differences between different conditional forms when participants read the test sentence *p and q*. However, as Johnson-Laird and Byrne (1991) have proposed that for the conditional *p only if q,* there are two models (*p and q* and *not p and not q*), we could expect from this point of view that the participants will read *not-p and not-q* faster after reading the conditional form *p only if q* than after *p if q* or *if p then q*. Braine's (1978) theory predicts that the participants will read *not-p and not-q* faster after reading the conditional form *p only if q* than after *if p then q*, as the interpretation of *p only if q* would depend on a rephrasing of the statement as *if not q then not p*. From this view, people will read *not-p and not-q* faster after reading the conditional form *p if q*, compared to the conditional *if p then q*.

Method

Participants

The participants were 40 students at the University of La Laguna, who received course credit for their participation.

Design and Materials

We constructed 48 paragraphs along the lines of the example in Table 3. The two independent variables: form of the conditional (*if p then q, only if p q, p only if q,* and *p if q*) and form of the test sentence (*p and q*, *not-p and not-q*), were manipulated within participants. The design was fully within participants and the 8 experimental conditions (4 conditionals × 2 conjunctions) were given to participants for 6 different contents, making a total of 48 trials. Each individual participant was given the 48 trials with a different content assigned at random, that is, 48 distinct contents. There were also 32 filler paragraphs in which no propositional connectives appeared (which used 32 different contents). We gave each participant the 80 trials in a different random order. One half of the questions required an affirmative response and the other half required a negative response. The questions targeted were presented at the start, middle, and end of the stories to ensure that participants read each story. None of the questions entailed a propositional inference.

Six practice paragraphs were presented before the experimental set. Four of these paragraphs matched the structure of the experimental texts and two were similar to the filler paragraphs.

Table 3
Example Paragraph from Experiment 1

Setting sentences:	Pedro was going to a sports-store with his sister. She told him that in this store,
Critical (*if p then q*):	if there are rackets then there are rucksacks.
Critical (*only if p q*):	only if there are rackets there are rucksacks.
Critical (*p only if q*):	there are rackets only if there are rucksacks.
Critical (*p if q*):	there are rackets if there are rucksacks.
Filler:	When they arrived at the store they saw that,
Test sentence *p and q*:	there were rackets and rucksacks.
Test sentence *not-p and not-q*:	there were no rackets and there were no rucksacks.
Filler:	Pedro tried on some sports shoes.
Question:	Did Pedro try on some sports shoes?

Procedure

The participants were tested individually in a quiet room and the experiment was controlled on-line by an IBM compatible computer. They were encouraged to read the paragraphs carefully at their own pace, and to answer the questions as quickly and accurately as possible. The paragraphs were presented one sentence at a time (as shown in Table 3). After reading each sentence, the participants had to press the space bar to erase the screen and display the next sentence. After reading the question, the participants responded *Yes* by pressing the right-hand key or *No* by pressing the left-hand key. The purpose of these questions was to ensure that the participants are reading and understanding the paragraphs, but they did not entail propositional inferences, so the percentages of correct responses were not analyzed. The computer recorded participants' reading times for the test sentences.

Results

Only participants who had more than 90% correct responses to the simple questions were included in the analysis and only the reading times corresponding to their correct responses were analyzed (the same criterion will be used in Experiment 2 and Experiment 3). The reading times for the test sentence (*p and q* or *not-p and not-q*) are presented in Table 4. The ANOVA with repeated measures showed a reliable main effect of type of conditional, $F(3, 117) = 6.92$, $MSE = 21911$, $p < .001$, and test sentence, $F(1, 39) = 120.49$, $MSE = 34689$, $p < .0001$. Effect for the interaction was not found, $F(3, 117) = 2.15$, $MSE = 21119$, $p = .098$.

Planned comparison showed that the participants took more time to read the *p and q* sentence after the conditional *p only if q* than for other conditional forms (the differences with *p if q* was 125 milliseconds; $t = 4.32$, $p < .001$; the differences with *only if p q* was 78 milliseconds, $t = 2.09$, $p < .05$; the differences with *if p then q* was 74 milliseconds, $t = 2.10$, $P < .05$. Planned comparison for the affirmative sentence *p and q* did not show reliable differences between the other conditional forms.

Table 4
Reading-Times (in Milliseconds) for the Test Sentence in Experiment 1 (SD in Brackets)

	Test sentence	
	Affirmative (p & q)	Negative (¬p & ¬q)
If p then q	1318 (234)	1566 (307)
only if p q	1313 (188)	1594 (306)
p only if q	1392 (304)	1561 (314)
p if q	1267 (252)	1483 (252)

Planned comparison showed that the participants took less time to read the *not-p and not-q* sentence after the conditional *p if q* than for other conditional forms: The differences with *if p then q* was 82 milliseconds, $t = 2.45$, $p < .025$; the differences with *only if p q* was 110 milliseconds, $t = 3.13$, $p < .005$; the differences with *p only if q* was 77 milliseconds, $t = 2.32$, $p < .05$. Planned comparison for the negative sentence *not-p and not-q* did not show reliable differences between the other conditional forms.

Discussion

In this experiment, we found two interesting results: Firstly, participants took more time to read the test sentence *p and q* after the conditional *p only if q* than after all the other types of conditional (*p if q, only if p q, if p then q*); secondly, participants took less time to read the test sentence *not-p and not-q* after the conditional *p if q* than after any other type of conditional (*p only if q, only if p q, if p then q*). The first result supports the idea that the conditional form *p only if q* is more difficult because the mental representation is in the reverse direction. It is consistent with the idea of a directionality effect in conditional reasoning (Evans, 1993). As we have maintained elsewhere (Santamaría & Espino, 2002), it could be considered that the conditional form *p only if q* elicits the following initial mental representation:

q p
…

This proposal can also explain why, in some experiments (Evans, Clibbens, & Rood, 1995, Experiment 1; Santamaría & Espino, 2002, Experiment 2) participants make more AC inferences with the conditional form *p only if q* than with *if p then q*. Grosset and Barrouillet (2003) have presented some results that give support to this proposal. These authors found that the latencies are longer for the backward affirmative inferences (from q to p) for the conditional *if p then q* than for the conditional *p only if q*. Santamaría and Espino demonstrated a similar result for latencies in all backward inferences (from *q to p*) and they also found that the response latencies in forward inferences (from *p to q*) are shorter for the conditional form *if p then q* than the conditional *p only if q*.

The second result showed that after reading the conditional form *p if q* participants took less time to read the sentence *not-p and not-q* than after the other conditional forms (*if p then q*, *only if p q*, *p only if q*). This results is contrary to the suppositional theory because this theory predicts that there will be no difference between different conditional forms when participants read the test sentence *not-p and not-q* (Evans & Over, 2004; Evans et al., 2005;

Over & Evans, 2003). On the other hand, this result suggests that the conditional form *p if q* elicits the following two explicit models:

p *q*
no p *no q*
…

This proposal can explain why, in some experiments (Braine & O'Brien, 1998, Table 14.4; Evans et al., 1995, Experiment 1; Grosset & Barrouillet, 2003), participants made more MT and DA inferences with the conditional form *p if q* than with the conditional form *if p then q*. Moreover, it can explain why participants make more DA inferences with the conditional form *p if q* than with the conditional form *p only if q* (see Grosset & Barrouillet, 2003). Grosset and Barrouillet found that the mean reaction time to endorse the backward negative inferences (from *not-q* to *not-p*) was higher in the conditional *if p then q* than for the conditional *p if q*. Moreover, these authors showed that the mean reaction time to endorse the forward negative inferences (from *not-p* to *not-q*) was higher in the conditional *p only if q* than in the conditional *p if q*. Therefore, the results of our Experiment 1, taken together with previous research (Braine & O'Brien, 1998; Evans et al., 1995; Grosset & Barrouillet, 2003; Santamaría & Espino, 2002) sustain the proposal that *p if q* elicits an initial model with two possibilities: *p and q* and *not-p and not-q*.

Experiment 2

The results of Experiment 1 suggest that for the conditional form *p only if q*, people build a mental representation in which the elements are in the reverse order. The aim of Experiment 2 was to test this hypothesis by presenting the elements of the test sentence in reverse order (*q and p* and *not-q and not-p*). We predicted that the reverse presentation would delay the reading of the test sentence when the mental representation was in the order *p q* as in the conditional *if p then q*. However, this delay would not occur in *p only if q* if it were the case that in this conditional form the mental representation is in the reverse order. In this case, the natural delay of a reverse presentation of the elements in the test sentence will be compensated by the coincidence with the mental representation. Consequently, the difference found in Experiment 1 between *p only if q* and the other conditional forms in the affirmative test sentences will disappear.

Method

Participants

The participants were 40 students at the University of La Laguna, who received course credit for their participation.

Design, Materials and Procedure

The design and materials were similar to those used in Experiment 1. The only difference was that the order of *p and q* in the test sentence were reversed in this experiment. Consequently, we used two different kinds of test sentences in this experiment: *q and p* and *not-q and not-p*; and four conditional forms: *if p then q, only if p q, p if q* and *p only if q*. The procedure was the same as that of Experiment 1.

Results

The reading times for the test sentence (*q and p* or *not-q and not-p*) are presented in Table 5. As in Experiment 1, only the RTs for correct responses were considered. The ANOVA with repeated measures for the factor type of conditional (*if p then q*, *only if p q*, *p only if q* and *p if q*) and the factor test sentence (*q and p* versus *not-q and not-p*) showed a main effect for the test sentence, $F(1, 39) = 182.58$ $MSE = 28293$, $p < .001$. This main effect demonstrated that the affirmative test sentence was read more quickly than the negative test sentence. No effect for the interaction, $F(3, 117) = 2.07$, $MSE = 38305$, $p = .10$, or for the type of conditional, $F(3, 117) = 2.40$, $MSE = 24352$, $p = 0.07$, was found. Planned comparison for the affirmative test sentence *q and p* did not show reliable differences between conditional forms.

A planned comparison showed that the participants took less time to read the test sentence *not-q and not-p* after the conditional *p if q* than for the conditional *if p then q* (107 milliseconds), $t = 2.64$, $p < .025$, and the conditional form *p only if q* (104 milliseconds), $t = 2.86$, $p < .01$. Although the participants took less time to read the test sentence *not-q and not-p* after reading the conditional *p if q* than the conditional *only if p q* the difference was not reliable (57 milliseconds), $t = 1.60$, $p = .12$. Planned comparisons for the sentences *q and p* and *not-p and not-q* did not show reliable differences between the other conditional forms.

Table 5
Reading-Times (in Milliseconds) for the Test Sentence in Experiment 2 (SD in Brackets)

	Test sentence	
	Affirmative (q & p)	Negative (¬q & ¬p)
If p then q	1292 (329)	1592 (358)
only if p q	1257 (279)	1542 (328)
p only if q	1319 (308)	1589 (385)
p if q	1324 (285)	1485 (334)

Discussion

Two main results were found in the second experiment. The first result showed that when the test sentence is in the reverse order (*q and p*), then the difference between the conditional form *p only if q* and the other conditional forms (*if p then q*, *only if p q*, *p if q*) disappears. The second result showed that the participants read the test sentence *not q and not p* after reading the conditional form *p if q* faster than when they read other types of conditionals (*if p then q*, *only if p q*, *p if q*). The first result suggests that when the participants read a conditional form *p only if q* they built a mental representation in which the elements of the conditional are in the reverse order (*q and p*). The results of the first experiment also supported this idea. In the first experiment, the participants always took more time to read the test sentence *p and q* after reading the conditional form *p only if q* than for other conditional forms (*if p then q*, *only if p q*, *p if q*). But in the second experiment, when they had to read the test sentence in reverse order (*q and p*) the difference disappears. As previously mentioned, we did not predict that people would take less time to read the reverse order *q and p* after reading the conditional *p only if q* than other conditional forms because for the conditional *p only if q,* there are two opposite directionality effects: one of these effects (the text effect for the conditional) is going in the direction from *p to q* and the other effect (mental representation) is going in the direction from *q to p*. Because these effects are in competition with each other, we did not predict any directional effect.

The second result shows that the participants read the test sentence *not-q and not-p* faster after reading the conditional form *p if q* than when they read other types of conditionals (*if p then q*, *only if p q*, *p only if q*). This result supports the idea that the participants built the following two models for *p if q*:

p *q*
no p *no q*
…

Although the elements of the test sentence were in the reverse order (*not-q and not-p*), the participants read this sentence more quickly after reading the conditional form *p if q* than for other conditional forms (*if p then q*, *only if p q*, *p only if q*). The reason they read *not-q and not-p* faster could be that they built the representation for the negative test sentence (*not p and not p*).

Experiment 3

Experiments 1 and 2 suggest that for conditionals of the form *p only if q* the affirmative *q and p* possibility is kept in mind, whereas for the form *if p then q*, the affirmative *p and q* possibility is kept in mind. In this next experiment, our interest was in the length of time it takes participants to understand the conditional form *if p then q* or *p only if q*, when primed by the conjunctions: *p and q* and *q and p*. The logic of this procedure is that if people has in mind one possibility that is true, it will be easier to process a propositional sentence in which the possibility is true than a propositional sentence in which the possibility is false. We predict an effect of directionality for the conditional form *if p then q*: People will take less time to read the conditional form *if p then q* after they have read *p and q* compared to *q and p*. However, we do not predict any affect of directionality for the conditional *p only if q*: People will take a similar time to read the conditional form *p only if q* after they have read *p and q,* compared to *q and p*. As previously mentioned, we predict that the directionality effect will be cancelled in the conditional form *p only if q* because there are opposite directionality effects.

Method

Participants

The participants were a different set of 40 students at the University of La Laguna, who received course credit for their participation.

Table 6
Example Paragraph from Experiment 3

Setting sentences:	Pedro was going to a sports-store with his sister. She told him that in this store,
Critical (*p and q*):	there are rackets and there are rucksacks.
Critical (q and p):	there are rucksacks and there are rackets.
Filler:	When they arrived at the store they saw that,
Test sentence *if p then q*:	if there are rackets then there are rucksacks.
Test sentence *p only if q*:	there are rackets only if there are rucksacks.
Filler:	Pedro tried on some sports shoes.
Question:	Did Pedro try on some sports shoes?

Design, Materials and Procedure

Design was within subject (2 conditionals × 2 conjunctions). Materials and procedure were all similar to that used in previous experiments. The only difference was that in this experiment the participants read first the conjunction premise (*p and q* and *q and p*) and later they read the principal premise (*if p then q* or *p only if q*). In this experiment the dependent variable was the reading time for the conditional form *if p the q* or *p only if q*. Table 6 shows an example.

Results

The reading times for the test sentence (*if p then q* or *p only if q*) are presented in Table 7. Only the RTs for correct responses were considered. The ANOVA with repeated measures for the factor type of conditional (*if p then q* and *p only if q*) and order of the terms of the conjunction (*q and p* versus *not-q and not-p*) showed a main effect for the type of conditional, $F(1, 39) = 12.09$, $MSE = 41320$, $p < .001$). This main effect demonstrated that the conditional *if p then q* was read more quickly than the conditional *p only if q*. Also, there was an effect for the interaction, $F(1, 39) = 4.58$, $MSE = 31386$, $p < .05$). This interaction showed that the participants took less time ($M = 1669$ milliseconds) to read the conditional *if p then q* after the conjunction *p and q* than the conjunction *q and p* ($M = 1780$ milliseconds), $t = 2.49$, $p < .02$. However, they take a similar amount of time ($M = 1840$ milliseconds) to read the conditional *p only if q* after the conjunction *p and q* than the conjunction *q and p* ($M = 1832$ milliseconds), $t = 0.16$, $p = .86$. No effect of the order of the terms of the conjunction was found, $F(3,) = 1.77$, MSE = 59725, $p = .19$.

Table 7
Reading-Times (in Milliseconds) for the Test Sentence in Experiment 3 (SD in Brackets)

	Test sentence	
	if p then q	*p only if q*
p and q	1669 (408)	1840 (567)
q and p	1780 (419)	1832 (445)

Discussion

The main result in Experiment 3 was the interaction found between order (*p and q* versus *q and p*) and type of conditional (*if p then q* versus *p only if q*). As we predicted, there was only an effect of directionality in the conditional form *if p then q*, but not in the conditional form *p only if q*. This result is consistent with previous research (Santamaría & Espino, 2002) and gives support to the idea that for the conditional form *p only if q* people built a mental representation in which the elements of the conditional are in the reverse order (*q and p*). Moreover, the results of Experiments 1 and 2 also support this idea. In Experiment 1, participants always took more time to read the test sentence *p and q* after reading the conditional form *p only if q* than other conditional forms (*if p then q*, *only if p q*, *p if q*). Experiment 2 showed that when participants had to read the test sentence in the reverse order (*q and p*), the difference between the conditional forms (*if p then q*, *only if p q*, *p if q*) disappears.

General Discussion

The three experiments reported here rely on a new priming methodology that directly tests predictions about the way people understand different forms of conditionals (*if p then q*, *p if q*, *only if p q*, *p only if q*). Our first experiment corroborated the suggestion that a conditional form *p if q* is understood by keeping in mind the affirmative possibility *p and q* and the negative possibility *not-p and not-q*. Participants read the conjunction *not-p and not-q* more quickly after they were primed with the conditional form *p if q*, compared to when they were primed with other conditional forms (such as *if p then q*, *only if p q*, and *p only if q*).

The first experiment suggested that a conditional form *p only if q* is understood by keeping in mind the reverse affirmative possibility *q and p*. Participants read a conjunction such as *p and q* more slowly after they were primed with a conditional form *p only if q*, compared to when they were primed with other conditional forms (*if p then q*, *p if q*, *only if p q*). This suggestion gained additional support in Experiments 2 and 3. In Experiment 2, when the order of the elements in the conjunction was reversed (participants read *q and p* and *not-q and not-p*), the participants took a similar time to read the conjunction *q and p* primed by a conditional form *p only if q*, or other conditional forms (*if p then q*, *only if p q* and *p only if q*). In other words, when the order of the elements in the conjunction is reversed, the effect of the first experiment disappears. In Experiment 3, participants first read the conjunction in a different order (*p and q* versus *q and p*) and later they read the conditional form (*if p then q* versus *p only if q*). In this experiment, we found an interaction between the order of terms in the conjunction (*p and q* versus *q and p*) and the form of the conditional (*if p then q* versus *p only if q*): People took less time to read the conditional form *if p then q* after they read the conjunction *p and q* than the conjunction *q and p*, but they took a similar amount of time to read the conditional form *p only if q* after reading the conjunction *p and q* than the conjunction *q and p*. Thus, there was a directionality effect only for the conditional form *if p then q*.

We did not predict any directionality effect in Experiment 2 nor in Experiment 3 for the conditional form *p only if q* because for this conditional there are opposite directionality factors: Firstly, the conditional form *p only if q* was presented in the text in the direction from *p to q*. Secondly, we predicted that the mental representation for the conditional form *p only if q* would produce a mental model in the direction from *q to p* (Evans, 1993; Grossett & Barrouillet, 2003; Santamaría & Espino, 2002).

The results of priming experiments such as ours have implications for different theories of conditionals (Braine, 1978; Evans, 1993; Grosset & Barrouillet, 2003; Johnson-Laird & Byrne, 1991). Although these results can be explained by the standard model theory (Johnson-Laird & Byrne, 1991, 2002), some changes are necessary. As we mentioned, the model theory suggests that the conditional form *p only if q* would lead people to include the negative contingency, yielding two explicit models right from the start:

p *q*
no p *no q*
. . .

So that it should be predicted that the participants would read the negative test sentence *not-p and not-q* more quickly after *p only if q* than after the conditional form *if p then q*. However, this proposal fails to explain the results of our Experiments 1, 2, and 3. From our point of view, the model theory can explain these results by assuming that the initial representation of the conditional form *p only if q* includes a single explicit model in the reverse direction:

q *p*
…

This kind of initial representation is consistent with our results and also with previous research (Evans et al., 1995, Experiment 1; Santamaría & Espino, 2002, Experiment 2).

A further result that is difficult to explain from the model theory is why participants read the negative test sentences *not-p and not-q* (Experiment 1) and *not-q and not-p* (Experiment 2) more quickly after reading the conditional form *p if q* than other conditional forms (*if p then q*, 'p only if', *only if p q*). The model theory suggests that the conditional form *p if q* would lead people to include a single explicit model:

p *q*
. . .

and predicts that participants will read the negative test sentence *not-p and not-q* more slowly after reading this conditional than, for example, the conditional form *p only if q*. This proposal fails to explain our results in Experiments 1 and 2. However, these results could be explained by assuming that the initial representation of the conditional form *p if q* includes the following two explicit models:

p *q*
no p *no q*
. . .

Our proposal is, then, in agreement with results both from our experiments here and with previous research (Braine & O'Brian, 1998, Table 14.4; Evans et al., 1995, Experiment 1; Grosset & Barrouillet, 2003).

The results from Experiments 1, 2, and 3 do not, however, support either Grosset and Barrouillet's (2003) or Evans' (1993) findings. Grosset and Barrouillet posited that the conditional form *p if q* elicits a single explicit model from *q to p*. However, the results from our Experiments 1 and 2 are consistent with the proposal that for the conditional form *p if q*, people build two explicit models from *p to q*. Evans suggested that there is a preference to reason from the clause following *if*. This hypothesis could explain our data for the conditional form *p only if q* but cannot explain the data for the conditional form *p if q*.

Also, these data may be particularly difficult for a theory, which predicts that people understand ordinary conditionals of the natural language by means of the Ramsey test (Evans & Over, 2004: Evans et al., 2005; Over & Evans, 2003). This test implies that people understand the ordinary conditional as conditional probabilities. In this case people needs only consider the ratio of cases in which the antecedent and consequent of conditional is true (TT) and the ratio in which the antecedent of conditional is true and the antecedent is false (TF). By applying the Ramsey test to the conditionals, the suppositional theory predicts that people should take similar time to read the false possibility (FF) after reading a conditionals (*if p then q*, *p only if q*, *p if q*, *only if p then q*). Our results (Experiment 1 and 2) showed that people took less time to read the possibility *not-p and not q* or *not-q and not-p* in the conditional *p if q* but not in others conditionals (*if p then q*, *p only if q*, *only if p then q*).

The mental logic theory (Braine, 1978) cannot explain our results. Braine proposed that the meaning of *p only if q* would be equivalent to *if not q then not p*. However, Experiments 1 and 2 failed to find that participants read *not-p and not-q* faster after reading the conditional *p only if q* than, for example, after the conditional *if p then q* as would be expected from this point of view.

Although our results are consistent with the general model theory framework, they are somewhat puzzling, and further work is needed to develop a more complete theoretical understanding of them. For example, the mental model theory should explain why there is a directional effect (forward or backward effect) for conditionals and why some conditional forms yield two initial models (for example, *p*

if q). Our results seem to support the idea that the conditional *p if q* yields the initial construction of two models in forward direction and that the conditional of the form *p only if q* is represented by oriented models from *q to p*. We suggest that there are two factors that could operate simultaneously in a forward or backward direction. The first of them is the order of the propositions in the sentence. As proposed in the field of text comprehension (see, Gernsbacher, 1990), people tend to use the first proposition in the sentence (*p* or *q*) as the foundation of the mental model, and the second proposition is appended to this model (see, Espino, Santamaría, & García-Madruga, 2000, for a demonstration of this effect in reasoning). According to this factor, in the conditionals *p only if q* and *p if q*, there is a directional effect from p to q due to the "first mention" effect (Gernsbacher, 1990). The second factor relies on the connective used. We suggest that every connective has an inherent semantic directionality (Evans, 1993; Grosset & Barrouillet, 2003; Oberauer & Wilhem, 2000). We suggest, as Evans and Grosset and Barrouillet, that the connectives *if* and *only if* have a directional bias from *q* to *p* (backward effect). Also, we suggest that in the conditional *p if q* the directional effect due to the order of the propositions in the sentence is stronger than the directional effect due to the inherent semantic directionality. For this reason there is a directional effect from *p* to *q* in the conditional *p if q*. However, we suggest that in the conditional *p only if q*, the directional effect due to the order of the term in the sentence is weaker that the directional effect due to the inherent semantic directionality because as we have noted, the addition of the word *only* stresses the next proposition in language. For this reason, there is a directional effect from *q* to *p* in this conditional. Moreover, we suggest that the conditional *p if q* yields two models because the first term *p* is not taken as a hypothetical value (as no conditional particle appears before, it might be considered categorical) whereas *q* is the hypothetical value. Consequently, *p* becomes necessary and its presence is matched with *q*, whereas its absence (*not-p*) is matched with *not-q*. Also, our results support Grosset and Barrouillet's (2003) hypothesis for the conditional *p only if q*. They suggested that variable *q* introduced by the word *if* provides hypothetical values linked to outcomes pertaining to the variable *p*. Consequently, we suggest that different conditional forms could yield different initial models.

In summary, we have used a priming methodology to obtain a more direct measure of the initial representations that people construct in order to understand different forms of conditionals. Until now, evidence about the initial representation in understanding a conditional has been indirectly inferred from the conclusions reasoners reach from these different conditionals. Our results are not only consistent with those obtained with reasoning tasks; they also have important implications for conditional reasoning theories.

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