Running head: THE RELEVANCE OF IRRELEVANT

Truth Table Tasks: The Relevance of Irrelevant

Aline Sevenants, Walter Schroyens, Kristien Dieussaert, Walter Schaeken and Géry d' Ydewalle

University of Leuven

Corresponding author:

Aline Sevenants

Aline.Sevenants@psy.kuleuven.be

University of Leuven, Laboratory of Experimental Psychology

102 Tiensestraat, B-3000 Leuven, Belgium

Tel: +32 (0)16/32.60.39

Fax: +32 (0)16/32.60.99

Abstract

Two types of truth table tasks are used investigating mental representations of conditionals: a possibilities-based and a truth-based one. In possibilities tasks, participants indicate whether a situation is possible or impossible according to the conditional rule. In truth tasks, participants evaluate whether a situation makes the rule true or false, or is irrelevant with respect to the truth of the rule. Comparing the two-option version of the possibilities task with the truth task in Experiment 1, the possibilities task yields logical answer patterns whereas the truth task yields defective patterns. Adding the irrelevant-option to the possibilities task in Experiment 2 leads to a considerable amount of defective patterns in the possibilities task, but still to more logical patterns in the possibilities task than in the truth task. Experiment 3 shows that directionality matters since rule-to-situation tasks yield more logical answer patterns than do situation-to-rule tasks. We conclude that both task types are not comparable as such since wording, number of options and directionality influence the results.

Keywords: *conditionals, truth table tasks, mental models theory, suppositional theory*

Acknowledgments

This research was carried out with the financial support of the National Council for Scientific Research – Flanders, Belgium (FWO grant G.0320.05) and the Odysseus Type 1 project granted to Prof. Dr. I. Douven. We thank the editor Prof. Dr. V. Thompson and the three reviewers for their helpful comments on this manuscript.

Truth Table Tasks: The Relevance of Irrelevant

The interest in the linguistic, psychological and logical meaning of ‘if’ has provided us with a long history of research on thinking and reasoning about conditionals. By conditionals, we mean conditional sentences of the form ‘*If A then C*’, with *A* being the antecedent and *C* the consequent. Conditional statements occur very frequently in everyday discourse and this in various contexts. We use them explicitly in promises or threats, but conditionals are also widely present in an implicit way: we know that if we are thirsty we have to drink and that if we cross the street without paying attention, we might get run over. Many studies have been designed in order to externalize people’s understanding and mental representation of conditionals. It is important to know how we represent and use the information we acquire. For example, how do we get to a conclusion on the basis of that knowledge? And what information serves as a confirmation or as a falsifying counterexample for that conclusion?

For many decades, standard propositional logic has been the starting point for research on conditional reasoning. This framework is based on the assumption that logic provides the correct normative account of rational reasoning. One frequently used methodology investigating the mental representation of conditional sentences is the truth table task. In this paradigm, participants are asked to evaluate, with respect to a given rule, the possibility or truth of the four logically possible cases produced by permuting the truth values of the antecedent and the consequent. For instance, given the rule ‘*If the letter is a B, then the number is an 8*’, four different situations or cases arise:

- ‘*a B*’ and ‘*an 8*’ signify a true antecedent and a true consequent (TT)
- ‘*a B*’ and ‘*not an 8*’ signify a true antecedent and a false consequent (TF)
- ‘*not a B*’ and ‘*an 8*’ signify a false antecedent and a true consequent (FT)
- ‘*not a B*’ and ‘*not an 8*’ signify a false antecedent and a false consequent (FF)

Table 1
Truth Table for Conditional Statements

Logical Truth Tables				Defective Truth Tables	
A	C	Material Implication	Material Equivalence	Defective Implication	Defective Equivalence
T	T	T	T	T	T
T	F	F	F	F	F
F	T	T	F	I	F
F	F	T	T	I	I

Truth tables are used in logic to determine whether an expression is true or valid. According to standard logic, the connective ‘if’ follows the truth table for the *material implication* (see Table 1), meaning that only the TF case falsifies the conditional. Therefore, the rule ‘*If B then δ*’ is falsified only when there is *a B*, but *not an δ* (TF). An alternative logical possibility for the meaning of the connective ‘if’ is the *material equivalence*: ‘*C if and only if A*’, the situation in which A implies C and C also implies A. According to this truth table, not only the case TF, but also FT falsifies the rule. So the conditional ‘*If B then δ*’ is falsified both when there is *a B* but *not an δ* (TF), and also when there is *not a B* but there is *an δ* (FT). Material implication and material equivalence are the two truth tables for conditionals recognized by classical logic and therefore referred to as ‘logical truth tables’ in the remainder of this paper.

A wealth of research, however, has questioned whether classical logic is to be considered as an adequate normative system for conditional reasoning. Psychologically, there is evidence that, next to true or false, people make use of a third truth value absent in classical logic, i.e. irrelevant or indeterminate (e.g. Evans & Over, 1996, 2004). Wason (1966, 1969) was the first to introduce the notion of ‘defective truth tables’, in which false antecedent cases (FT and FF) are considered to be irrelevant rather than true. In the defective truth table view, people judge that false-antecedent cases have nothing to do with the truth or falsity of a conditional and are therefore labelled as ‘irrelevant’. This is referred to by Evans and Over (2004) as a ‘truth value

gap' for the false-antecedent cases. For example, the FF case *not a B* and *not an 8* would be interpreted as irrelevant with respect to the truth or falsity of the conditional rule '*If B then 8*' since there is no B. This defective truth table representation of conditionals has been replicated on a number of occasions (e.g. Newstead, Ellis, Evans & Dennis, 1997).

Throughout psychological reasoning literature, one can broadly discern two types of truth table tasks: a possibilities-based and a truth-based variant. In the possibilities task, people have to indicate, for each of the four possible antecedent-consequent combinations, whether that specific case is either possible or impossible with respect to the given rule. In the truth task, participants are asked to indicate for each of the four cases whether the combination makes the given rule true, false or is irrelevant with respect to the truth of the rule. There is quite a lot of evidence that the possibilities task and the truth task do not yield the same pattern of results. With their possibilities task, Barrouillet and Lecas (1998) demonstrated that false antecedent cases are often judged to be possible with respect to the rule, yielding logical answer patterns. This contrasts with the defective answer patterns reported in studies making use of the truth task (for a review, see Evans, Newstead & Byrne, 1993). Two major theories of conditional reasoning, the mental models theory and the suppositional theory, claim support for their account, each from one version of the task but not the other: the mental models theory from the possibilities task and the suppositional theory from the truth task.

The mental models theory provides an account of the logical answer patterns yielded by the possibilities task (Johnson-Laird & Byrne, 1991; Johnson-Laird, Byrne & Schaeken, 1992). According to the 'truth principle' of the mental models theory, people construct mental models of the possibilities compatible with the premises, but they initially and by default do not represent what is false. Therefore, their conclusion is based on the initial model:

[A] C

...

Square brackets are the notation for an exhaustive representation. [A] C means that the antecedent is represented exhaustively. Individuals do not represent what is false by default, but under certain circumstances they make ‘mental footnotes’ about the falsity of clauses (represented by the ellipsis). If they are able to retain these footnotes, reasoners can flesh out the implicitly represented information into fully explicit models, which represent clauses even when they have false antecedents (the symbol $\neg$ denotes an abstract mental symbol representing negation).

A C

$\neg$ A C

$\neg$ A $\neg$ C

These possibilities correspond to the three rows of the truth table in which the material implication is true, including the false-antecedent cases FT and FF. This explicit representation in turn leads to logical answer patterns.

The suppositional theory (Evans, Over & Handley, 2003; Evans & Over, 2004; Evans, Handley, Neilens & Over, 2007) provides a detailed account of the defective truth tables yielded by the truth task. According to the suppositional theory, people evaluate conditionals by means of the Ramsey test. That is, they “hypothetically add p to their stock of knowledge and evaluate their degree of belief in q given p ” (Ramsey, 1931/1990). So they first estimate the probability of the consequent and the antecedent occurring together (the TT case), and then estimate the probability of the antecedent together with the non-occurrence of the consequent (the TF case). The combination of these two stages then leads to an estimation of the occurrence of the consequent, given the antecedent. As a consequence of this Ramsey test, participants disregard

the false-antecedent cases and only focus on those cases in which the antecedent is true, resulting in a defective truth table pattern.

In this context, Evans and Over (2004, p. 36) state: “We are a little suspicious of the ‘possibilities’ form of the truth table task that is exclusively used by followers of the mental models theory and seems to us to obscure a distinction that the standard task reveals.” They refer to the truth task as the ‘standard task’ and argue that with the dichotomy possible/impossible, used in the possibilities task, one cannot point out the difference between true and irrelevant responses as one is able to in the truth task.

In the psychological reasoning literature, many experiments using the truth table task methodology are reported, each of them administering a version of either the possibilities task or the truth task. It is clear that both tasks must yield different results since a defective answer pattern is not obtainable with the possibilities task in which ‘irrelevant’ is not an answer option. Dugan and Revlin (1990) and Thompson (2000) already showed that the interpretation of conditionals is task-specific, so one can’t just make hard claims about the mental representation of conditionals, based on the comparison of results obtained by two different tasks. In the present paper, we bring together the two separate methodologies of the possibilities task and the truth task in a series of three large-scale experiments. In the first experiment, we aim to make a direct comparison of both task types in their classical format, eliminating differences in instructions, administration format, participant age and population that compromise comparisons between studies. In Experiments 2 and 3, the goal is to systematically eliminate obvious differences between the tasks, such as the number of answer alternatives and task directionality, in order to investigate whether controlling for these variables eliminates differences in performance between both tasks. In the General Discussion section of the paper we discuss the theoretical interpretation of the data and how they relate to the mental models theory and the suppositional theory.

Experiment 1

The psychological reasoning literature contains a wealth of truth table based experiments, but large variability exists between these studies. The truth table experiments reported in literature differ on a number of variables, each with their own effects: not only possibilities versus truth-based, but also the nature of the conditionals (content-neutral, content-rich or abstract), the nature of the negations (implicit versus explicit), the task-format (evaluation versus construction), the specific nature of the instructions, the language of administration, the age of the participants (adult-performance versus developmental studies), the population from which the participants are recruited,...

In order to be able to draw conclusions from the differences in results obtained by the possibilities task and the truth task, it is crucial to control for all those variables influencing the results. A direct comparison between the possibilities task and the truth task in their most commonly used formats, i.e. the evaluation version of the possibilities task and the truth task as described in the introduction, within the same experiment, with subjects from the same population, using exactly the same instructions and administration format, has never been subject to an experimental study. Since the comparability of the tasks themselves is a crucial factor in drawing conclusions from the comparison of the results, it is our aim in this first experiment to compare the response patterns yielded by the possibilities task and the truth task, controlling for other differences that might influence the results.

Method

Participants

Two hundred first-year Psychology undergraduate students at the University of Leuven (17-23 years of age, $M = 18$) took part in this experiment in partial fulfilment of course requirements.

None of the participants had ever taken a course in logic. One hundred participants received the possibilities task, while the other 100 participants completed the truth task.

Design, Materials and Procedure

Participants were run in two groups, with one group performing the possibilities task and the other group the truth-based variant. Participants were randomly assigned to the task type. Both groups received the same instructions, appearing on the computer screen and explaining that the purpose of the experiment was to examine how people reason with conditionals. The instructions also contained the description of a machine producing cards with a letter on the front and a number on the back, always doing so following a certain rule, for example '*If there is an A on the front, there is a 2 on the back of the card*'. Participants could read that in the upcoming task they were going to see four cards produced by that machine, and that per card they had to evaluate the compatibility of the card with the card-producing rule. Participants were then provided with a concrete example of a conditional rule, as well as with an example of an item in the actual task (no correct answers were provided). The instructions were followed by one practice trial.

In both task-type conditions, all participants were successively presented with four items (see Appendix A). Each item consisted of the abstract conditional rule followed by one of the four combinations of occurrence and non-occurrence of A and C. Only explicit negations were used. This means that all participants were presented with each of the following situations:

- Rule: *if the letter is a B, then the number is a 5*
Situation: 'a B' and 'a 5'
- Rule: *if the letter is a B, then the number is a 5*
Situation: 'a B' and 'not a 5'

- *Rule: if the letter is a B, then the number is a 5*
Situation: 'not a B' and 'a 5'

- *Rule: if the letter is a B, then the number is a 5*
Situation: 'not a B' and 'not a 5'

In order to keep the possibilities task as similar as possible to the truth task, we chose for the evaluation format of both truth table task types. In the possibilities task, participants had to evaluate for each of the four situations whether that situation was either possible or impossible according to the rule. In the truth task, participants had to evaluate for each of the four antecedent-consequent combinations whether the situation made the given rule either true or false, or whether it was irrelevant with respect to the truth of the rule. No feedback was provided. For each item, the rule followed by one of the four situations appeared on the screen. Each item appeared on a different screen and presentation order of the four items was randomized.

Tasks were constructed with 'E-prime' software (Psychological Software Tools, Pittsburgh, PA) and presented to the participants on individual standard PCs in a self-paced manner. Responses were given with the arrow-keys on an AZERTY keyboard. The experiment lasted between 5 and 10 minutes. All parts of the experiment were presented in Dutch.

Results

Given the focus of this study on the nature of the mental representation of conditionals (logical or defective), we first examined the individual answer patterns, that is the combination of judgments per individual on the four different situations. The 'logical' answer patterns include both the material implication and the material equivalence responses, whereas 'defective' answer patterns include the defective implication and the defective equivalence patterns. A Chi-square test

revealed that the proportion of logical answer patterns in the possibilities task was higher than the proportion of logical answer patterns in the truth task ($\chi^2(1) = 3.88, p < .05$). In the truth task, 42% of the participants responded according to a defective truth table and the X-pattern (TFIT), first observed by Newstead et al. (1997), was given by 3% of the participants. Both the defective answer patterns and the X-pattern are not observable in the possibilities task, since in the original format of that task ‘irrelevant’ is not an answer option. The conjunctive answer pattern finally was yielded equally often by the possibilities task and by the truth task. Each individual pattern within the ‘other’ group was shown by less than 5 % of the participants and therefore considered negligible.

Table 2

Response Patterns (%=n=100) for the Possibilities Task and the Truth Task in Experiment 1

	Possibilities Task	Truth Task
Material Implication (TFFT)	36	4
Material Equivalence (TFFT)	37	20
Defective Implication (TFII)	/	17
Defective Equivalence (TFFI)	/	25
Conjunctive Pattern (TFFF)	4	3
X-pattern (TFIT)	/	3
Y-pattern (TFTI)	/	0
Other	23	28
	100	100

In addition to the answer patterns, we examined the total number of judgments per situation. Table 3 summarizes the responses relating to the four situations presented in the possibilities task (‘possible’, ‘impossible’) and the responses of the 100 participants who completed the truth task (‘true’, ‘false’ or ‘irrelevant’). Analyzing the data, we focused on the false-antecedent cases of both tasks, since it is for those cases that the mental models theory and the suppositional theory predict different results. Regarding the proportion of logically correct judgments according to the material implication truth table, we performed a Chi-square test for

two independent samples. We compared the proportion of ‘possible’ vs. ‘impossible’ judgments in the possibilities task with the proportion of ‘true’ vs. ‘false’ plus ‘irrelevant’ judgments in the truth task, and this for both false-antecedent cases (FT and FF)¹. We observed a significantly larger proportion of ‘possible’ judgments in the possibilities task than of ‘true’ judgments in the truth based task ($\chi^2(1) = 86.7, p < .01$).

Table 3

Truth Table Judgments (%=n=100) for the Possibilities Task and the Truth Task in Experiment 1

		TT	TF	FT	FF
Possibilities Task	Possible	91	19	52	87
	Impossible	9	81	48	13
Truth Task	True	84	15	8	38
	False	5	76	63	8
	Irrelevant	11	9	29	54

Discussion

The present study aims to provide an explicit comparison between the two formats of the truth table task: the possibilities task and the truth task in an evaluation format. The most striking result occurs within the false-antecedent cases: There seems to be a major shift from ‘possible’ to ‘irrelevant’. This means that people judge false-antecedent cases to be irrelevant with respect to the truth of the conditional rule rather than judging them to make the rule true, if they have the opportunity to give that answer. This finding supports a defective truth table representation: The truth of the conditional is decided by true-antecedent cases, and false-antecedent cases are classified as irrelevant.

¹ We tested whether the proportion of ‘possible’ judgments in the possibilities task is larger than the proportion of ‘true’ judgments in the truth task, even though we acknowledge that the baseline probabilities of the answer options differ. For the possibilities task, the category other than ‘possible’ is ‘impossible’, while in the truth task there is more than one category other than ‘true’, namely ‘false’ and ‘irrelevant’.

The ‘other’ category of the answer patterns in this experiment is surprisingly large (almost 30%). This category mainly consists of participants that clearly did not perform the task as they were asked to: Most of them gave the same judgement for all presented situations. We attribute this ‘noise’ to the fact that it was a computerized version of the truth table task in which no justification for the chosen answer option was asked.

Within the present experiment, we want to make a direct comparison between the possibilities task and the truth task. And since the two-option format of the possibilities task is most frequently used within the present research literature, this is the format we used. It is problematic, however, that the possibilities task only has two answer alternatives (possible and impossible), while the truth task has three (true, false, irrelevant): Since ‘irrelevant’ is not an option in the possibilities task, the results yielded by both tasks are not fully comparable. Adding the option ‘irrelevant’ to the possibilities task would resolve this problem.

This leads us to a second issue: If we focus on the meaning of ‘irrelevant’, the high proportion of defective truth tables observed in the truth task of this first experiment should be put into perspective. The question in the possibilities task ‘Is the following situation possible or impossible with respect to the rule?’ is much more straightforward than the question in the truth task ‘Does the following combination make the rule true, false or is it irrelevant with respect to the rule?’. How do people interpret the phrase ‘to make the rule true’, since Johnson-Laird (1990) argues that reasoning about truth is more difficult than reasoning about possibility? Only if participants were to respond ‘irrelevant’ to the straightforward question ‘Is the situation possible, impossible or irrelevant according to the rule?’, could one conclude that they did not choose this alternative in the present experiment due to a lack of comprehension. It is not unthinkable that if participants do not know exactly how to reason with the truth-question, they might choose the response ‘irrelevant’ as a synonym for ‘in fact, I don’t know’. And that is not the meaning an

‘irrelevant’ judgment is supposed to have. This explanation can be ruled out in an experiment that compares the truth task with a possibilities task that also provides participants with three answer options i.e. ‘possible’, ‘impossible’ and ‘irrelevant’.

Experiment 2

In the second experiment we compare the results of the possibilities task and the truth task as we did in Experiment 1, but now ‘irrelevant’ is one of the three answer options in either task. This is the only way an explicit comparison between the results yielded by both truth table tasks can be made, since the addition of ‘irrelevant’ as a third answer alternative to the possibilities task (referred to as the ‘extended possibilities task’) allows for a defective answer pattern in both tasks, and not only in the truth task, as was the main issue in the previous experiment.

We add ‘irrelevant’ as an option to both types of truth table tasks in order to make them as comparable as possible, but we acknowledge that ‘irrelevant’ has not exactly the same status in the possibilities task than it has in the truth task. In the truth task on the one hand, the three answer alternatives map onto distinctions made in three valued logical systems that include indeterminate as a third truth value, in addition to true and false. Some situations make the rule true, other situations make it false and still some other situations do not provide any information about the truth of the conditional. So the three response options are exclusive. Possible, impossible and irrelevant on the other hand do not really map onto exclusive response sets in the same way as in the truth task. The fact that a situation is possible according to the rule doesn’t really exclude it to be irrelevant according to that same rule.

According to Evans and Over (2004), the classical possibilities task conflates the answer alternatives ‘true’ and ‘irrelevant’. Hence, it is hypothesized that adding ‘irrelevant’ to the

possibilities task - everything else being equal - will eliminate the difference in results between the two task types (see also Handley, Evans & Thompson, 2006). So, if the absence of the answer alternative ‘irrelevant’ in the original possibilities task is the major cause of the observed shift from ‘possible’ to ‘irrelevant’ for the false-antecedent cases in Experiment 1, participants are expected to choose the answer alternative ‘irrelevant’ rather than ‘possible’ in the possibilities task, as they now have the opportunity. The alternative hypothesis suggested in the discussion of Experiment 1, however, i.e. that participants might use the answer alternative ‘irrelevant’ as a synonym for ‘I don’t know’, also needs to be taken into account. In that case, the irrelevance option should be chosen far less in the straightforward possibilities task than in the truth task.

In order to pinpoint the meaning that people ascribe to ‘irrelevant’ and to rule out the alternative hypothesis that ‘irrelevant’ means ‘I don’t know’, we are interested in the justifications that participants give for their judgments. Allowing them to describe in their own words why, for instance, they judge a situation to be irrelevant with respect to the rule, may shed light on these questions. Likewise, the justifications allow us to check how participants interpret the presence of ‘irrelevant’ in the possibilities task and whether the meaning they ascribe to irrelevant in this task differs from the interpretation they describe in their justifications of irrelevance answers in the truth task.

Method

Participants

One hundred and six last-year high-school students (17-19 years of age, $M = 17,7$) participated on a voluntary basis. No participants had ever taken a course in logic. Fifty-five participants

received the extended possibilities task, while 51 participants completed the truth task. Students were randomly assigned to the task type.

Materials and Procedure

Participants were run in two groups, with one group evaluating the four items of the extended possibilities task and the other group evaluating the four items of the truth task (see Appendix A). The tasks were presented in printed booklets, which participants completed in a self-paced manner. The experiment lasted between 5 and 10 minutes.

The instructions were the same as in Experiment 1 and appeared on the first page of the booklet. In the extended possibilities task, participants had to evaluate for each of the four situations whether that situation was possible, impossible or irrelevant according to the rule. In the truth task, as in Experiment 1, participants had to evaluate for each of the four possible antecedent-consequent combinations whether the combination made the given rule true, false or was irrelevant with respect to the truth of the rule. No feedback or correct answers were provided and the order of the four different situations was randomized. For both task types, participants were successively presented with four pages in random order, containing both the conditional rule and one of the four combinations of the occurrence and non-occurrence of A and C. They were asked to tick the one answer that they thought was correct. In addition to these instructions similar to those in Experiment 1, participants were informed that they were expected not only to choose the correct answer, but also to justify their judgments in the box at the bottom of each page.

Results

Table 4 shows the answer patterns yielded by the four presented situations (TT, TF, FT and FF). As was the case in the previous experiment, the logical answer patterns include the material implication and the material equivalence responses, whereas the defective patterns include the defective implication and the defective equivalence pattern. Chi-square tests revealed that the proportion of logical answer patterns in the extended possibilities task was higher than the proportion of logical answer patterns yielded by the truth task ($\chi^2(1) = 3.88, p < .05$). Moreover, the truth task yielded a higher proportion of defective answer patterns than did the extended possibilities task ($\chi^2(1) = 4.72, p < .05$). Both tasks did not differ regarding the amount of conjunctive patterns, X-patterns (TFIT) and TFTI patterns, which we name the Y-pattern. Each of the other answer patterns was shown by less than 5 % of participants and therefore considered negligible.

Table 4

Response Patterns (% and (n)) for the Possibilities Task and the Truth Task in Experiment 2

	Extended Possibilities Task	Truth Task
Material Implication (TFTT)	20 (11)	6 (3)
Material Equivalence (TFFT)	36 (20)	31 (16)
Defective Implication (TFII)	2 (1)	24 (12)
Defective Equivalence (TFFI)	18 (10)	16 (8)
Conjunctive Pattern (TFFF)	5 (3)	2 (1)
X-Pattern (TFIT)	4 (2)	8 (4)
Y-Pattern (TFTI)	9 (5)	4 (2)
Other	6 (3)	9 (5)
	100 (55)	100 (51)

Table 5

Truth Table Judgments (% and (n)) for the Possibilities Task and the Truth Task in Experiment 2

		TT	TF	FT	FF
Extended Possibilities Task	Possible	96 (53)	2 (1)	31 (17)	62 (34)
	Impossible	2 (1)	96 (53)	62 (34)	7 (4)
	Irrelevant	2 (1)	2 (1)	7 (4)	31 (17)
Truth Task	True	96 (49)	0 (0)	10 (5)	47 (24)
	False	2 (1)	96 (49)	57 (29)	8 (4)
	Irrelevant	2 (1)	4 (2)	33 (17)	45 (23)

Table 5 shows the judgments ('possible', 'impossible', 'irrelevant') of the four situations presented in the extended possibilities task and also summarizes the responses ('true', 'false' or 'irrelevant') relating to the truth task. Focusing on the false-antecedent cases, a Chi-square test revealed that the possibilities task yielded a lower proportion of irrelevance-answers than did the truth task ($\chi^2(1) = 10.5, p < .01$).

Analyzing the justifications, we focused on how participants paraphrase an irrelevance-judgment in both the possibilities task and the truth task. Moreover, we determined whether they indicate choosing 'irrelevant' when they do not know the correct answer. Irrelevance answers occurred almost solely with the false-antecedent cases (see Table 5). Most importantly, none of the justifications mentioned that 'irrelevant' was chosen as a synonym for 'I don't know'. Rather, the data revealed two other kinds of justifications for these irrelevance-judgments. The first type of account, given in 57% of the irrelevance-answers, was one in terms of a truth-value gap (Evans, Newstead & Byrne, 1993; Evans 2006)

. So, for example, for the situation *not a B* and *a 7*, it was said that 'when the antecedent is absent, the rule has nothing to say about the consequent'. This truth-value gap justification was

observed in 55% of the irrelevance-judgments in the extended possibilities task and in 58% of the irrelevance-judgments of the truth task. The second type of account for ‘irrelevant’, next to the truth-value gap, was one in terms of necessity. In 23% of the irrelevance-answers, participants indicated that it is possibly, but not necessarily the case that a situation is possible according to the given rule (in the possibilities task, 25%) or makes the given rule true (in the truth task, 20%). Actually, participants literally wrote down: “this is possibly but not necessarily the case”, both for the possibilities and the truth task and thus irrespective of the wording of the task.

Discussion

In the present experiment, we add the answer option ‘irrelevant’ to the possibilities task in order to make a direct comparison of the results yielded by both task types. We observe that approximately one third of the participants chooses this answer option now that they have the opportunity to do so. However, based on Experiment 1, we would have expected more than one third of the participants to judge the false-antecedent cases as irrelevant with respect to the rule, if the only reason for the absence of defective answer patterns in the possibilities task was the lack of ‘irrelevant’ as an answer alternative. Thus, adding ‘irrelevant’ to the possibilities task does not seem sufficient to bridge the gap between the two task types.

The extended possibilities task yields fewer irrelevance answers than the truth task. Still, there is a considerable amount of irrelevance answers, not only in the truth task but also in the extended possibilities task, which indicates that irrelevance answers mean more than ‘I do not know’. Concerning the answer patterns, we observe more logical answer patterns in the extended possibilities task than in the truth task and more defective patterns in the truth task than in the extended possibilities task.

What we can conclude from the justifications is that ‘irrelevant’ means more than ‘I don’t know’, since the majority of the participants formulate their justification in truth-value gap terms: The rule has nothing to say about the consequent, since the antecedent is not present. So we can reject our alternative hypothesis for the defective patterns, i.e. that irrelevant is considered as a synonym for ‘I don’t know’. The fact that the truth-value gap justification of ‘irrelevant’ occurs equally frequent in the possibilities task than in the truth task gives us an indication of the fact that participants have a similar interpretation of ‘irrelevant’ in both tasks. Moreover, none of the participants in the extended possibilities task giving an irrelevance judgement mentioned that the situation was irrelevant, but at the same time possible according to the rule. Likewise, none of the participants remarked that he/she for instance chose for ‘possible’, but that the situations was at the same time irrelevant with respect to the rule.

Of course, the meaning of ‘irrelevant’ in both variants of the truth table task is debatable: Saying that a situation is ‘irrelevant according to a given rule’ does not presuppose the same reasoning as judging a situation to be ‘irrelevant with respect to the truth of a given rule’. And this leads us to the next point: The difference in directionality between the two task types has to be taken into account. The direction is from rule to situation in the possibilities task but from situation to rule in the truth task, and this difference is the one we aim to resolve in Experiment 3. It could be the case that the observed difference in results between the (extended) possibilities task and the truth task is due to the difference in directionality and dilutes when this difference in directionality is controlled for.

Experiment 3

Despite their high degree of resemblance, the two task types classically used thus far differ not only regarding their number of answer alternatives, but also regarding their directionality: The truth task concerns the evaluation of the given rule on the basis of situations, while the possibilities task concerns the assessment of situations with respect to the given rule. Nevertheless, this is the format in which the tasks have been administered in the conditional reasoning research tradition for many years.

Barrouillet, Gauffroy and Lecas (in press) refer to this directionality difference as “reasoning about possibilities given the truth of assertions” versus “reasoning about the truth of assertions given possibilities”. They claim that the distinction between possibilities and truth values delineates two different kinds of reasoning. In the possibilities task, people start reasoning from the rule they consider to be true, and try to find out what must, can, or cannot occur given this rule. In the truth task, people start from a situation that is presented as existing, and they judge whether the given rule is made true or false in this case. Hence, there is a clear distinction between situations that are possible according to the conditional and situations which make the conditional true. This is of importance because there is ample evidence that the two kinds of tasks do not produce the same patterns of results, as demonstrated in the two first experiments of this study (for a review, see also Evans et al., 1993).

In this third experiment we make use of the three option version of both tasks, again in order to make the tasks as comparable as possible. Although, as we discussed in the introduction of Experiment 2, the status of ‘irrelevant’ is not exactly the same in both tasks, the results of that experiment suggests that participants’ interpretation of ‘irrelevant’ is not that different. We observe a truth value gap in the possibilities task as well as in the truth task and the truth value

gap justification of ‘irrelevant’ occurs equally frequent in the possibilities task and the truth task. Moreover, none of the participants mentions something about the fact that ‘possible’ and ‘irrelevant’ are not exclusive.

The aim of Experiment 3 is to assess whether participants’ answer patterns depend on the difference in directionality when the difference in number of answer alternatives is controlled for, by presenting both the extended possibilities task and the truth task in both directions, i.e. from rule to situation and from situation to rule.

Method

Participants

Three hundred and three last-year high-school students (17-20 years of age, $M = 17,9$), all unfamiliar with the field of logic, participated on a voluntary basis. None of these students was a participant in Experiment 2. Eighty-five participants received the three-option possibilities task in its original directionality-format from rule to situation (referred to as R-S possibilities task or RS-PT), while 76 participants completed the ‘reversed’ possibilities task, i.e. from situation to rule (S-R possibilities task or SR-PT). In addition, 72 participants completed the truth task with its original directionality from situation to rule (S-R truth task or SR-TT), while finally 70 participants received the reversed truth task with a rule-to-situation directionality (R-S truth task or RS-TT). Task type was a between subjects variable to which participants were randomly assigned.

Materials and Procedure

Participants were run in four groups, respectively completing the R-S possibilities task, the S-R possibilities task, the R-S truth task and the S-R truth task (see Appendix A). Administration was the same as in Experiment 2: The four items of the tasks were presented in booklets, which participants completed in a self-paced manner. The experiment lasted between 5 and 10 minutes. The same instructions as in the two previous experiments appeared on the first page of the booklet.

In the *R-S possibilities task*, participants had to evaluate for each situation whether that combination was possible, impossible or irrelevant according to the rule. In the *S-R possibilities task*, they had to evaluate for each of the four antecedent-consequent combinations whether the combination made the given rule either possible or impossible, or whether it was irrelevant with respect to the possibility of the rule. Concerning the *S-R truth task*, for each of the four combinations participants had to judge whether the combination made the given rule either true or false, or whether it was irrelevant with respect to the truth of the rule. For the *R-S truth task* finally, participants had to evaluate whether each of the four possible situations was true, false or irrelevant according to the rule.

Again participants in all conditions were successively presented with four pages in random order, each page containing both the conditional rule and one of the four combinations of the occurrence and non-occurrence of A and C. They had to tick the one answer they thought that was correct. Next, similar to Experiment 2, participants were asked to account for their judgments, by adding a justification for each answer in the box at the bottom of each page.

Results

Regarding the answer patterns (see Table 6), Chi-square tests revealed that the possibilities tasks yielded a higher proportion of logical patterns than the truth tasks ($\chi^2(1) = 9,51, p < .05$), while the truth tasks yielded a higher proportion of defective answer-patterns than the possibilities tasks ($\chi^2(1) = 17,44, p < .01$). The logical answer patterns are the material implication and the material equivalence responses, the defective answer patterns are the defective implication and the defective equivalence patterns. There was no difference between the tasks regarding the amount of conjunctive and X patterns. With respect to the Y-pattern (TFTI), it was more frequently observed in the possibilities tasks than in the truth tasks ($\chi^2(1) = 11,19, p < .01$).

Table 6

Response Patterns (% and (n)) for the Possibilities Tasks and the Truth Tasks in Experiment 3

	RS-PT Possibilities Task	SR-PT Possibilities Task	RS-TT Truth Task	SR-TT Truth Task
Material Implication (TFTT)	29 (25)	11 (8)	1 (1)	3 (2)
Material Equivalence (TFFT)	25 (21)	25 (19)	30 (21)	22 (16)
Defective Implication (TFII)	15 (13)	11 (8)	24 (17)	39 (28)
Defective Equivalence (TFFI)	11 (9)	17 (13)	19 (13)	18 (13)
Conjunctive Pattern (TFFF)	5 (4)	4 (3)	3 (2)	3 (2)
X-Pattern (TFIT)	6 (5)	7 (5)	14 (10)	4 (3)
Y-Pattern (TFTI)	7 (6)	12 (9)	0 (0)	1 (1)
Other	2 (2)	13 (11)	9 (6)	10 (7)
	100 (85)	100 (76)	100 (70)	100 (72)

Table 7 shows the judgments about the four situations presented in the possibilities tasks and the truth tasks. Concerning the judgments about the situations of interest to this paper, i.e. the false-antecedent cases, Chi-square tests revealed that, as in the previous experiments, the

possibilities tasks (RS-PT and SR-PT) yielded a lower proportion of irrelevance answers than the truth tasks (SR-TT and RS-TT) ($\chi^2(1) = 23,34, p < .01$). Moreover, there was also an effect of directionality: The rule-to-situation tasks (RS-PT and RS-TT) yielded a higher proportion of logical answer-patterns than the tasks with a direction from situation to rule (SR-PT and SR-TT) ($\chi^2(1) = 5,85, p < .05$). Likewise, the tasks with a direction from situation to rule (SR-PT and SR-TT) yielded a higher proportion of defective answer-patterns than the tasks with a direction from rule to situation (RS-PT and RS-TT), but this trend failed to reach significance. No difference between the rule-to-situation tasks and the situation-to-rule tasks was observed by means of Chi-square tests for the conjunctive patterns, the X-patterns and the Y-patterns. As for the false antecedent cases (FT and FF), a lower proportion of irrelevance answers was given in the rule-to-situation tasks (RS-PT and RS-TT) than in the tasks with the opposite direction (SR-PT and SR-TT) ($\chi^2(1) = 3,56, p = .059$).

Table 7

Truth Table Judgments (% and (n)) for the Four Truth Table Tasks in Experiment 3

		TT	TF	FT	FF
R-S	Possible	99 (84)	1 (1)	38 (32)	60 (51)
	Impossible	1 (1)	99 (84)	42 (36)	5 (4)
	Irrelevant	0 (0)	0 (0)	20 (17)	35 (30)
S-R	Possible	97 (74)	3 (2)	29 (22)	49 (37)
	Impossible	0 (0)	92 (70)	49 (37)	11 (8)
	Irrelevant	3 (2)	5 (4)	22 (17)	41 (31)
R-S	True	99 (69)	0 (0)	3 (2)	49 (34)
	False	0 (0)	96 (67)	56 (39)	6 (4)
	Irrelevant	1 (1)	4 (3)	41 (29)	46 (32)
S-R	True	97 (71)	0 (0)	5 (4)	36 (26)
	False	3 (2)	95 (69)	48 (35)	4 (3)
	Irrelevant	0 (0)	5 (4)	47 (34)	60 (44)

Finally we compared the tasks when they are made as comparable as possible (i.e. RS-PT to RS-TT and SR-PT to SR-TT). Regarding the answer patterns, Chi-square tests revealed more logical patterns in the R-S possibilities task than in the R-S truth task ($\chi^2(1) = 8,03, p < .01$) and more defective answer patterns in the R-S truth task than in the R-S possibilities task ($\chi^2(1) = 4,96, p = .026$). Comparing SR-PT to SR-TT, we observed more logical patterns in the S-R possibilities task, but this trend was not significant. There were more defective answer patterns in the S-R truth task than in the S-R possibilities task ($\chi^2(1) = 13,05, p < .01$) and there were no differences regarding the amount of conjunctive patterns and X-patterns. Concerning the Y-pattern, it was more frequently observed in the RS-PT than in the RS-TT ($\chi^2(1) = 5,14, p < .05$) and more frequently in the SR-PT than in the SR-TT ($\chi^2(1) = 6,41, p < .05$). With respect to the false-antecedent cases (FT and FF), Chi-square tests revealed that a higher proportion of irrelevance answers was yielded by the R-S possibilities task than by the R-S truth task ($\chi^2(1) = 8,58, p < .01$) and by the S-R truth task than by the S-R possibilities task ($\chi^2(1) = 14,56, p < .01$).

If we take a closer look at the justifications for the irrelevance-answers in the false-antecedent cases, half of the irrelevance answers were phrased as a truth-value gap: Since the antecedent is not present, the rule has nothing to do with the consequent and is therefore irrelevant with respect to the situation. This goes for both the possibilities tasks (RS-PT, 56% and SR-PT, 58%) and the truth tasks (SR-TT, 49 % and RS-TT, 36 %). The justification that it is possible, but not necessary that the situation is possible/true with respect to the given rule and that the rule is therefore irrelevant, accounted for one third of the justifications in the possibilities tasks (RS-PT, 28 % and SR-PT, 24 %) as well as in the truth tasks (SR-TT, 35 % and RS-TT, 46 %). Again, in none of the justifications participants referred to ‘irrelevant’ as an alternative for ‘I don’t know’ or mentioned something about the fact that possible and irrelevant are not exclusive.

Discussion

Regarding the difference between the possibilities tasks and the truth tasks, the results of previous experiments are replicated: Fewer irrelevance answers are yielded by the possibilities task than by the truth task. As for the answer patterns, more logical answer patterns are observed in the possibilities task than in the truth- tasks, and more defective answer patterns are observed in the truth tasks than in the possibilities tasks. However, there is a considerable number of defective answer patterns to be found in the possibilities tasks, while logical answer patterns are not only observed in the possibilities tasks but also in the truth tasks.

Comparing the tasks with the most similar format, i.e. the S-R possibilities task with the S-R truth task and the R-S possibilities task with the R-S truth task, the difference between the possibilities tasks and the truth tasks continues to exist: More logical patterns are yielded by the possibilities tasks than by the truth tasks, and more defective patterns by the truth tasks than by the possibilities tasks. With respect to the false antecedent cases, a higher proportion of irrelevance answers is observed in the truth tasks than in the possibilities tasks. This shows that the difference in results between the possibilities tasks and the truth tasks, as observed in the previous experiments, is not just an artefact of directionality, since it persists when the difference in directionality is controlled for.

On top of the effect of possibility versus truth however, task directionality does influence the results. When we look at the difference between RS-PT and RS-TT on the one hand and SR-PT and SR-TT on the other hand, we observe the following: When the direction is from rule to situation (RS-PT & RS-TT; i.e. Is the situation possible/true according to the rule?), more logical answer-patterns are given than when the direction is from situation to rule. When the direction is from situation to rule, however (SR-PT & SR-TT; i.e. Does the situation make the rule

possible/true?), more defective answer-patterns are observed than when there is a rule-to-situation directionality, although the latter trend was not significant. It seems to be more natural and intuitive for participants to evaluate a situation based on a rule, than to evaluate a rule based on a situation, and this also shows in the justifications.

General Discussion

In a series of three experiments, we wanted to make a direct comparison of the possibilities task and the truth task. We did so controlling for differences in participant population and administration format in Experiment 1. In Experiments 2 and 3 we manipulated respectively the number of answer alternatives and task directionality. The goal was to investigate the influence of these variables on the observed difference in results between the two task types. The general observation is that the possibilities task and the truth task yield different results: More logical answer patterns are observed in the possibilities tasks than in the truth tasks, and more defective patterns occur in the truth tasks than in the possibilities tasks. Where does the difference between these two task types come from?

Firstly, the fact that the original possibilities task has only two answer alternatives, ‘possible’ and ‘impossible’, whereas in the truth task ‘irrelevant’ is an option next to ‘true’ and ‘false’, accounts for a major part of the differences between the two tasks as observed in the literature. Since ‘irrelevant’ is not an option in the possibilities task, a defective pattern is not observable. Adding irrelevant as a third answer alternative to the possibilities task could therefore resolve the difference between the two tasks. And indeed, when participants have the opportunity to judge the false antecedent cases to be irrelevant with respect to the rule, almost one third of the participants does so. Still, the difference between both tasks persists: The majority of the

participants in the possibilities task gives a logical answer pattern whereas the truth task yields more defective answer patterns.

Next to the unequal number of answer alternatives, both tasks differ regarding their directionality. The classical possibilities task has a directionality from rule to situation, the classical truth task from situation to rule. Presenting both task types in both directions, we observe that rule-to-situation tasks lead to more logical answer patterns than do the tasks with a directionality from situation to rule. But again, irrespective of the task directionality, we observe the same difference between the possibilities tasks and the truth tasks: There are more logical answer patterns in the possibilities tasks than in the truth tasks, and there are more defective answer patterns in the truth tasks than in the possibilities tasks.

The observation that logical answer patterns are mainly yielded by the possibilities task and defective patterns by the truth task leads us to the interpretation, also suggested by Johnson-Laird (1990) and by Barouillet et al. (in press), that reasoning about truth or falsity is more difficult and requires a higher level of cognitive development than reasoning about possibilities, since reasoning about truth requires the understanding of the meta-linguistic meaning of ‘true’ and ‘false’. A working memory load study and further developmental studies, in which a three-option version of the possibilities task and the truth task is presented to children with differing levels of cognitive development, could shed light on this account. Irrespective of their degree of difficulty however, both task types are asking a different question, eliciting a different kind of representation of information: Asking participants to make a judgment of truth recruits the type of information that the suppositional theory refers to, whereas asking for a judgment of possibility recruits the type of information that the mental models theory refers to.

According to Evans’ suppositional theory, a majority of defective patterns might be expected, since false-antecedent cases are not considered and judged to be irrelevant. We indeed

observe a large number of defective answer patterns, both in the possibilities task and the truth task. The suppositional theory provides a detailed account for the evaluation of a situation as making a conditional rule true, false or as being irrelevant with respect to the truth of the rule (as in the truth tasks). According to this account, people think about conditionals by hypothetically supposing p and then running a mental simulation evaluation p . In other words, they perform the Ramsey test (Evans et al, 2007). In this Ramsey test, only the ‘ p situations’ are considered, not the ‘not- p situations’. It is not completely clear to us however what the predictions of the suppositional theory are when participants have to evaluate possibilities (as in the possibilities tasks). Do participants only make use of the Ramsey test in the truth task and are there other factors involved when reasoning about possibility? Because it is not specified precisely how participants running the Ramsey test would end up with a logical answer pattern in the possibilities task, if not- p situations are not considered. So the suppositional theory should provide a more detailed account of exactly what factors and processes are involved when people are presented with a possibilities task and are asked to consider what situations are possible given a true conditional.

The suppositional theory emphasizes the defective representation of conditionals, but is able to justify, however, the logical material equivalence answer patterns and the defective equivalence patterns if converse and inverse implicatures are taken into account (Evans and Over, 2004; Evans, Handley, Neilens & Over, 2008). Combining the evaluations for the conditional and its converse (see Appendix B) leads to a ‘false’ judgment on the TF case. This yields the so-called *defective equivalence truth table/interpretation: TFFI*. The implications of the inverse implicature are comparable. The FF case denotes the TT contingency for <if not- A then not- C >, while <not- A _ C > captures the TF contingency for this inverse implicature. The resulting pattern of evaluations is the so-called *material equivalence truth table: TFFT*. According to Evans and

Over (2004), however, with abstract conditionals, as presented in our experiments the converse implicature is more likely than the inverse implicature. The yielded defective equivalence truth table (TFFI) is indeed frequently observed in our experiments. The material implication answer patterns in the possibilities tasks are an important problem for the suppositional theory: Even when the implicatures are added, the suppositional theory cannot account for that part of the logical answer patterns in a truth task. In our data however, only a very low rate of material implication answer patterns was observed in the truth tasks, so the suppositional theory is able to account for our results.

The mental models theory is challenged by this overall low rate of material implication patterns and the large proportion of defective patterns, especially in the possibilities tasks. The mental models account of the large number of irrelevance-answers in the truth task is as follows (Johnson-Laird, 2006): When participants are asked, as in the possibilities task, which combination is possible given a conditional rule, they enumerate fully explicit models. The most salient possibility compatible with the rule is the one corresponding to the model explicitly mentioned in the premises (thus, $A \supset C$). But the conditional allows for the antecedent to be absent, so with a little thought most of the participants can think of two further possibilities besides the most salient one ($\neg A \supset C$ and $\neg A \supset \neg C$), especially when this is exactly what is asked for in a task like the possibilities task.

According to Johnson-Laird (2006) however, people make a different kind of judgment when they are asked to evaluate the truth or falsity of the same conditional. To list the possibilities, all they have to do is understand a conditional and think of what is possible, so they enumerate the complete models of the conditional. To evaluate whether a conditional is true or false, however, they have to compare it with a state of affairs that they see, but they also have to

be able to understand the meta-linguistic meaning of true and false. They are more likely in this case to rely on mental models rather than on an enumeration of the possibilities.

The mental models of the conditional are the explicit model $A \supset C$, and the implicit models (the false-antecedent cases) denoted by the ellipsis ($\neg A \supset C$ and $\neg A \supset \neg C$). Hence, according to Johnson-Laird (2006), any situation in which the antecedent is true is judged as making the conditional true or false, depending on whether or not the situation matches the explicit mental model ($A \supset C$). So, TT is evaluated as true and TF as false. States of affairs in which the antecedent is false (FT or FF) are judged as irrelevant to the truth or falsity of the rule, because these situations correspond to a model without explicit content (...), leading to the conclusion that nothing seems to follow from the premises and that the correct answer is 'irrelevant'.

The mental models theory is therefore able to explain the defective implication pattern (TFII), if it is assumed that people base their answer solely on their initial model: $[A] \supset C$. This initial model undoubtedly supports the 'true' judgment of the TT case. The TF case is judged to be false since there are no further models in which there is an A. The 'irrelevant' judgments for the FT and the FF cases can be explained on the basis of the fact that in this initial model, the false-antecedent cases are not explicitly represented. The defective equivalence pattern (TFFI) however is more challenging for the mental models theory. In order to account for this pattern, it has to be assumed that those material equivalence reasoners base their answers solely on the initial model $[A] [C]$, that is, with both the antecedent and the consequent exhausted by the initial model. This leads to a true judgment for TT, a false judgment for TF, a false judgment for FT since the C cases are exhausted and an irrelevance judgement for FF since this doesn't match with any explicit content. The $[A] [C]$ initial model was described in Johnson-Laird and Byrne (1991), but in more recent writings (Johnson-Laird et al. 1992 and Johnson-Laird & Byrne, 2002) the square brackets around the A but also around the C are dropped.

The present series of experiments shows that task characteristics such as wording, number of answer alternatives and task directionality influence participants' answer patterns. The main methodological conclusion we can draw from this is a major caveat against making hard claims about the mental representation of conditionals, in favour of one or the other theory, based on answer patterns yielded by two tasks that clearly differ.

References

- Barrouillet, P., & Lecas, J. F. (1998). How can mental models theory account for content effects in conditional reasoning? A developmental perspective. *Cognition*, 67(3), 209-253.
- Barrouillet, P., Gauffroy, C., & Lecas, J. F. (in press). Mental models and the suppositional account of conditionals. *Psychological Review*.
- Dugan, C. M., & Revlin, R. (1990). Response options and presentation format as contributors to conditional reasoning. *Quarterly Journal of Experimental Psychology*, 42, 829-848.
- Evans, J. St. B. T., Over, D., (2004). *If*. Oxford University Press.
- Evans, J. St. B. T., Newstead, S. E., & Byrne, R. M. J. (1993). *Human reasoning: The psychology of deduction*. Hillsdale, NJ: Erlbaum.
- Evans, J. St. B. T., & Over, D. E. (1996). Rationality in the selection task: Epistemic utility versus uncertainty reduction. *Psychological Review*, 103, 356-363.
- Evans, J. St. B. T., Over, D. E., & Handley, S. H. (2003a). A theory of hypothetical thinking. In D. Hardman & L. Maachi (Eds.), *Thinking: Psychological perspectives on reasoning, judgement and decision making* (pp. 3-22). Chichester: Wiley.
- Evans, J. St. B. T., Handley, S. H., Neilens, H., & Over, D. E. (2007). Thinking about conditionals: A study of individual differences. *Memory & Cognition*, 35, 1722-1784.
- Evans, J. St. B. T., Handley, S. H., Neilens, H., & Over, D. E. (2008). Understanding causal conditionals: A study of individual differences. *Quarterly Journal of Experimental Psychology*, 61, 1291-1297.

- Handley, S. J., Evans, J. St. B. T., & Thompson, V. (2006). The negated conditional: Litmus test for the suppositional conditional? *Journal of Experimental Psychology: Learning, Memory and Cognition*, 13, 378-395.
- Johnson-Laird, P. N. (1990). The development of reasoning. In P. Bryant & G. Butterworth (Eds.), *Causes of development*. Hemel Hempstead, Hertfordshire, England: Harvester-Wheatsheaf.
- Johnson-Laird, P. N. (2006). *How we reason*. New York: Oxford University Press.
- Johnson-Laird, P. N., & Byrne, R. M. J. (1991). *Deduction*. Hillsdale, NJ: Erlbaum.
- Johnson-Laird, P. N., & Byrne, R. M. J. (2002). Conditionals: A theory of meaning, pragmatics, and inference. *Psychological Review*, 109, 646-678.
- Johnson-Laird, P. N., Byrne, R. M. J., & Schaeken, W. (1992). Propositional reasoning by model. *Psychological Review*, 99, 418-439.
- Johnson-Laird, P. N., & Tagart, J. (1969). How implication is understood. *American Journal of Psychology*, 2, 367-373.
- Newstead, S. E., Ellis, M. C., Evans, J. St. B. T., & Dennis, I. (1997). Conditional reasoning with realistic material. *Thinking and Reasoning*, 3, 49-76.
- Oberauer, K., Geiger, S., Fisher, K., & Weidenfeld, A. (2007). Two meanings of 'if'? Individual differences in the interpretation of conditionals. *Quarterly Journal of Experimental Psychology*, 60, 790-819.
- Ramsey, F. P. (1990). *General propositions and causality* (original publication, 1931). In D. H. Mellor (Ed.), *Philosophical papers* (pp. 145-163). Cambridge: Cambridge University Press.
- Thompson, V. A. (2000). The task-specific nature of domain-general reasoning. *Cognition*, 76, 209-268.

Wason, P. C. (1966). Reasoning. In B. M. Foss (Ed), *New horizons in psychology, Vol. I*. Harmandsworth, UK: Penguin.

Wason, P. C., & Johnson-Laird, P.N. (1969). Proving a disjunctive rule. *Quarterly Journal of Experimental Psychology*, 21, 14-20.

Appendix A

Tasks presented to the participants in the different experiments

Conditional Rule	If the letter is a B, then the number is a 5
4 situations	There is: 'a B' and 'a 5' 'a B' and 'not a 5' 'not a B' and 'a 5' 'not a B' and 'not a 5'
Experiment 1	
Possibilities Task (R-S)	The situation is possible according to the rule. The situation is impossible according to the rule.
Truth Task	The situation makes the rule true. The situation is irrelevant with respect to the truth of the rule. The situation makes the rule false.
Experiment 2	
Extended Possibilities Task (S-R)	The situation is possible according to the rule. The situation is irrelevant according to the rule The situation is impossible according to the rule.
Truth Task	The situation makes the rule true. The situation is irrelevant with respect to the truth of the rule. The situation makes the rule false.
Experiment 3	
R-S Possibilities Task	The situation is possible according to the rule. The situation is irrelevant according to the rule The situation is impossible according to the rule.
S-R Possibilities Task	The situation makes the rule possible. The situation is irrelevant with respect to the possibility of the rule. The situation makes the rule impossible.
R-S Truth Task	The situation is true according to the rule. The situation is irrelevant according to the rule The situation is false according to the rule.
S-R Truth Task	The situation makes the rule true. The situation is irrelevant with respect to the truth of the rule. The situation makes the rule false.

Appendix B

Defective Truth Table Judgments for the Conditional and for the Pragmatic Implicatures of this Conditional

1 Conditional 'if A then C'		2 Converse 'if C then A'		3 Inverse 'if not-A then not-C'		1+2	1+3
Situation	Judg	Situation	Judg	Situation	Judg	Judg	Judg
TT	<u>T</u>	TT	T	FF	I	T	<u>T</u>
TF	<u>F</u>	FT	I	FT	I	F	<u>F</u>
FT	I	TF	F	TF	<u>F</u>	F	<u>F</u>
FF	I	FF	I	TT	<u>T</u>	I	<u>T</u>