PRAGMATIC FACTORS IN CONDITIONAL REASONING*

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INTRODUCTION

One of the questions that has generated most interest in the last decade is the role that pragmatic knowledge has in the reasoning process (see Valiña, 1996, for a revision of the theoretical approaches towards pragmatic reasoning).

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The objective of this experiment is, precisely, to determine in what way the subjects' knowledge of the real world modulates their performance in a conditional reasoning task.

In a previous experiment, carried out by the authors, the subjects were presented with the three versions of Wason's selection task (Wason, 1966, 1968), with three types of content (abstract, thematic-permission and thematic-obligation). The results of this experiment showed the importance of factors related to knowledge in executing a metainference task, such as the task of selecting four cards. Indeed, this effect cannot be understood as a mere facilitation of concrete content, faced with the abstract content of the rule. In fact, a better performance was registered in the versions which included a *deontic relation*, both in abstract and thematic content. Besides, the worst results were obtained with the rule, with a thematic content,

which expressed a relation of possibility.

This improvement in reasoning could be explained by the proposals of the Theory of Pragmatic Reasoning Schemas (Cheng and Holyoak, 1985, 1989; Cheng, Holyoak, Nisbett & Oliver, 1986; Holyoak and Cheng, 1995). From this perspective, in the two tasks which register a higher number of correct answers, the subjects would be using a schema similar to that of "Obligation". However, it is difficult to explain other results by way of this theoretical proposal, such as the differences in performance registered between the two thematic versions, with both being similar to a pragmatic schema, either of obligation ("thematic-2") or of permission ("thematic-1").

However, using the Theory of Mental Models (Johnson-Laird 1983; Johnson-Laird and Byrne, 1991), it is possible to predict and explain the differences in performance between conditionals

which express a deontic relation, of "*necessity"* and conditionals which present a mere "*possibility"*. In this respect, as Johnson-Laird and Byrne indicated (1992; Byrne and Johnson-Laird, 1992), the *"deontic framework"* or *"epistemic"* of the conditional relation may be modulating the subjects' reasoning.

Also, the results of Valiña and colleagues (1996) only allow us to verify the influence of the character of "*necessity"* of a conditional relation, when the subjects are reasoning about a metainference task, such as the selection task. However, is this an influence that may be generalised to other conditional inference tasks?. We designed this experiment to answer this question.

Our interest in this experiment is not, therefore, to analyse the influence of the content (abstract vs. thematic) on the subjects' conditional reasoning, as this has been dealt with previously by the authors (Seoane

and Valiña, 1988). In fact, we only used conditional arguments, with thematic content, as experimental material. In our opinion, questions relating to the possible effect of thematic facilitation have generated abundant experimental investigation in the last twenty years, but is now a theme that is practically exhausted, given that, as we previously indicated, the influence of knowledge on pragmatic reasoning is more complex than that of a mere facilitation of thematic versus abstract content.

In this experiment we tried to determine, precisely, the importance of the variable which we refer to as *"the probability of empirical frequency"* on conditional reasoning (see Valiña and colleagues, 1992a, b). This refers to the frequency with which the expressed relation between antecedent and consequent in conditional statements, occurs in the real world. This offers three levels, which refer to the grade of empirical occurrence: "*deterministic"*,

"probabilistic" and *"without relation"*. In this respect, we consider the *deterministic* relation similar to a relation of *"empirical necessity"* (the relation expressed in the conditional statement always happens), while the "*probabilistic"* relation presents a character *of "empirical possibility"* (which only happens sometimes in the real world).

If, as is proposed from the theory of mental models, subjects reason by elaborating analogical representations of the real world, it would be expected that reasoning with conditional statements in which "*empirical possibilities"* are expressed will be different from the reasoning involved with statements which imply "*empirical necessities"*. More precisely, and in agreement with Johnson-Laird's proposals (Johnson-Laird and Byrne, 1992; Byrne and Johnson-Laird, 1992), reasoning about a "*necessary"* argument requires the elaboration of a unique, explicit mental model of the situation.

However, if the situation is of a "*probable"* conditional statement, that may or may not occur in the real world, then it would be necessary to elaborate an explicit mental model and an implicit model. It may therefore be expected that the subjects will manifest more correct reasoning with conditional statements, that they express a *necessary (deterministic)* relation, than if the relation is *possible (probabilistic).* In the latter case the number of mental models necessary to produce the conclusion will be greater, which will lead to an increase in the load on operative memory, and will definitively mean an increase in the number of errors.

We have also manipulated another two variables: the *"type of conditional rule"* and the *"availability"*. The first offers four levels which correspond to the four types of conditional inference rules proposed by propositional logic.

The manipulation of the "*type of rule"* variable

will allow us to check how our results support the predictions of the theory of mental models (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991), or those of its revised version (Evans, 1993), developed within the framework of Evan's theory of heuristic-analytical processes.

Based on the theory of mental models, the following is predictable: 1) the Modus Ponens rule is produced more often than Modus Tollens, 2) Modus Ponens and the rule of Affirmation of the Consequent will occur with the same frequency, 3) the rule of Affirmation of the Consequent will be produced more often than the rule of Denial of Antecedent, and 4) the rules of Modus Ponens and Affirmation of Consequent will be more frequent than those of Modus Tollens and Denial of Antecedent.

Evans (1993) indicated that the predictions offered by Johnson-Laird (1983; Johnson- Laird &

Byrne, 1991) do not always fit the data. He developed a "revised version" of the theory of mental models, with the intention of being able to explain some of the empirical results registered in experimental investigation about conditional inference, that are not justified by the original version of the theory of mental models. Some of the empirical predictions proposed by Evans, with regard to the generation of the four modalities of conditional inference, coincide with or differ from those proposed by Johnson-Laird (1983; Johnson-Laird & Byrne, 1991). These are the following: 1) The MP rule is produced more frequently than MT, 2) the MP rule is generated more often, being even more frequent than the AC rule, 3) the AC and DA rules will occur with approximately the same frequency, and 4) the MP and AC rules will occur more often than those of MT and DA.

Finally, the third variable manipulated was

the *"availability"*. Our objective is to study up to what point the accessibility of a scenario is a sufficient condition (as proposed by Pollard, 1982) to provoke an improvement in subjects' reasoning, or if, as Evans proposed (1984, 1989), it may be a necessary condition, but not enough so to influence reasoning.

Based on our theoretical proposals, we conceive the following empirical expectations:

1. We consider that the reasoning process is modulated by factors related to the subjects' previous knowledge. In this respect, the greater the possibility of activating knowledge by the subjects, the easier the task will be. As Johnson-Laird & Byrne (1992; Byrne & Johnson-Laird, 1992) proposed, reasoning from a deontic relation implies the elaboration of a unique mental model. Consequently, we hope to obtain the highest number of correct answers and greatest certainty of answer when the subjects reason about "deterministic" statements. In the same way,

the worst performance and lowest levels of certainty will be registered in statements “without relation”, where it is not possible to access the subjects' conceptual system.

2. In our opinion, the subjects reason by elaborating mental models or scenarios of the situation. However, the use of accessible scenarios is not enough to improve performance in a reasoning task. In this respect and bearing in mind that the availability of the scenario presented was limited to including available professions in decontextualised arguments, we do not expect to register significant principal effects of this variable on the number of correct answers. More specifically, we do not expect better performance when the subjects reason about arguments which include available professions, compared to those which present non-available professions.

3. We consider that availability, in itself, is not a sufficient factor to improve performance, and agree with Pollard and Evan's proposal (1987) when they indicate that variables of content-context are those which modulate human reasoning. In this respect, we expect to register lower number of correct answers and less certainty of answer when the probability of empirical occurrence expressed in the arguments is null ("without relation" condition), if the subjects reason about non-available scenarios. Also, subjects will tend to reject the task more often (which will be reflected in the increase in the percentage of selections of the non-propositional alternative). However, when the subjects reason about deterministic statements presented in available contexts, we expect to register the highest number of correct answers and greatest certainty of answer. Here, access to the conceptual system is being facilitated, and the activation of relevant knowledge will definitively facilitate the elaboration of a mental

framework to reason about.

EXPERIMENT

Method

Subjects

54 college students participated voluntarily in this experiment (26 females and 28 males, average age 17 years 6 months), from La Coruña, Spain.

Design

A 3 x 2 x 4 design was used (probability of occurrence in the real world x availability x type of rule), with repeated measurements in the three factors.

The first factor manipulated was *probability of empirical occurrence* of the relation expressed between the antecedent and the consequent of each conditional statement. This relation could occur always in the real world (deterministic), sometimes

(probabilistic) or there could be no specific relation between antecedent and consequent (without relation).

The second factor was *Availability*, with two levels (Available and Non-Available). This refers to the type of profession included in the problem, that in one case was available for the subjects (for example, a singer), while in the other case it was non-available (for example, a soprano).

Finally, the third factor was the *Type of Rule*, which corresponds to the four types of conditional inference, proposed by propositional logic: Modus Ponens (MP), Modus Tollens (MT), Affirmation of the Consequent (AC) and Denial of the Antecedent (DA).

As Dependent Variables, we used the Number of Correct Answers according to logic and Certainty which the subjects offered in their answers.

Materials and Procedure

Two booklets were used, produced by ourselves. Each contained one page of instructions and a total of 48 problems of conditional inference (two on each page). 16 of them expressed *deterministic* relations, which always occur in the real world (for example, *"if the nun looks at herself in the mirror, then she sees herself reflected"),* 16 contained statements which happen sometimes, or *probabilistic* (for example, *"if the miner smokes a lot, then he will have lung cancer")* and, finally, 16 items which contained conditional statements where there is *no specific relation* between the antecedent and the consequent (for example, *"if the sculptor cuts his hair, then he will get married").* The conditional statements were taken from a previous normative study, elaborated by the authors (Martín, 1992; Martín and Valiña, 1993).

The degree of *availability* of the content was manipulated, selecting the professions of the people in it, that were included in the premises. These people could have an *available* profession for the subjects (for example, *"if the workman falls from the tenth floor he will hurt himself),* while in the other eight items a non-available profession was presented (for example,*"if the plasterer falls from the tenth floor, then he will hurt himself).*

We have used with conditional arguments, people with available professions (eg. singer, clown, philosopher, biologist, workman etc.), and non-available (eg. soprano, axiologist, tightrope walker, malacologist, plasterer, etc.), selected from a previous standardising study carried out by one of the authors. In previous studies these had been used in a series of experiments based upon the study of syllogistic reasoning, with quantifiers of natural language, including syllogisms in narrative texts

(Valiña 1985, 1988; Valiña & De Vega, 1988).

Finally, two problems of each rule of propositional logic were included for both types of content (2 Modus Ponens, 2 Modus Tollens, 2 Affirmation of the Consequent, and 2 Denial of the Antecedent).

The problems were randomised and their order of presentation in the booklets was random and inverse random.

The experimental paradigm used was an answer selection paradigm. The task the subjects faced was to select the conclusion that was logically deduced from the premises. Also, they had to mark with a cross in a seven point scale, the degree of certainty that they had in the correction of their choice. This scale went from "not at all certain" to "completely certain", with an intermediate step for "undecided".

The experiment was carried out in a single experimental session, in the class where the students normally have

lessons. Half of the subjects, randomly selected, received the booklet with the items presented in random order, and the other half received another booklet with the items in inverse random order.

Once the instructions had been read out loud and any problems resolved, the subjects carried out the task without a time limit.

RESULTS

The data from 6 subjects was eliminated for carrying out the analysis as they had not completed the task.

A) Type of Answer

The paradigm used in this experiment was, as previously noted, an answer selection paradigm. The task was to select the conclusion or conclusions that they considered possible to logically deduce from the premises. Three conclusions were presented for each item. The “type 1" answer corresponded to the

affirmative conclusion, “type 2" to the negative conclusion and "type 3" to the non-propositional, meaning it was not possible to deduce any conclusion.

In relation to the percentage of subjects who selected each of the three possible alternatives for each type of rule, in each experimental condition, the most frequently selected answer in the Modus Ponens rule was the affirmative conclusion, which is logically correct. This percentage is reduced in line with the probability of empirical occurrence between antecedent and consequent of the conditional statement. More precisely, the highest percentages of selection of the correct answer was registered in the “deterministic” condition, while a lower frequency of selection of the correct answer appeared in the “without relation” condition. In this case, the subjects were not able to establish any particular link between the events mentioned in the rule and the real world. A higher frequency of rejection of the

problem was registered in this task, which is reflected in an increase in the selection of the non-propositional alternative.

In the case of the Modus Tollens rule, the most selected answer was the conclusion which in this case is correct. However, the percentage of subjects who reached the logically correct answer is less than in the Modus Ponens rule. Despite this, the decreasing progression remains the same, throughout the three conditions of empirical occurrence: deterministic-probabilistic-without relation. Therefore, in Modus Tollens the deterministic condition is also that which registered a greater percentage of subjects who selected the correct answer, followed by the probabilistic condition. Nonetheless, the percentage of subjects who selected the non-propositional alternative increased with the problems of the "without relation" condition. This increase is greater than that registered in the same condition with the Modus Ponens rule.

Accordingly, the correct answer is that which is selected most with the Modus Ponens and Modus Tollens rules, in agreement with the criteria of formal logic (an affirmative conclusion for MP and a negative conclusion for MT).

In the rules of Affirmation of the Consequent and Denial of the Antecedent, the condition where the greatest percentage of correct selections occurs ("type 3" answer) was in “without relation”. However, when the empirical occurrence was deterministic or probabilistic, there was an increase in the tendency to make biconditional interpretations of the statement, which was reflected in an increase of the selection of “type 1” and “type 2” answers, respectively.

Therefore, when the subjects reasoned about AC or DA rules, where there was no empirical relation between the antecedent and the consequent, they mainly selected the answer that showed that no

conclusion could be deduced from the premises, being the correct alternative, according to logic. However, when the statement expressed a deterministic or probabilistic empirical relation, there were differences between both rules (AC and DA) with regard to the type of answer most frequently selected. When the subjects had to reason about AC problems, they most frequently selected the “type l” answer, while with DA problems they mainly tended to select “type 2”. This may indicate that the increase in the empirical frequency of the content of the rules is accompanied by an increase in the subjects' tendency to carry out biconditional interpretations of the premises, while in the case of conditions “without relation”, this tendency is "blocked", and as a consequence the subjects considered that it was not possible to deduce any conclusion. Indeed, it is precisely the choice of this answer in the “without relation” condition which raises the percentage of correct answers with AC and DA rules.

In relation to the percentage of subjects who selected the “type 3” answer ("no conclusion deduced") was greater in the non-logical rules than in the logical rules. In turn, this alternative was that which was most selected when the subjects reasoned about statements where there was no relation between their elements.

B) Number of Correct Answers

The number of correct answers which each subject had in his booklet was added up, following the criteria of formal logic.

An ANOVA 3 x 2 x 4 was made (probability of occurrence x availability x type of rule), using the number of correct answers as a dependent variable. In this analysis a significant effect was registered of the *type of rule* variable ($F(l.64, 77.26)=14.14$; $p< .0001$; $\varepsilon =.54797$), with relation to the number of correct answers. The highest number of correct answers

were registered when the subjects reasoned about Modus Ponens problems (M_{MP}=82.82%), followed by those obtained with Modus Tollens problems (M_{MT}=62.85%) and Denial of the Antecedent (M_{DA}=50.86%). Finally, the lowest percentages of logical successes were obtained with Affirmation of the Consequent problems (M_{AC}=43.23%). The corresponding contrasts carried out afterwards indicated that there were significant differences in the selection of correct answers between Modus Ponens and Modus Tollens ($t=19.14$; $p<.0001$), as well as between these two rules with regard to the Affinnation of the Consequent rule ($t= 18.465$; $p<.001$). However, no significant differences were registered between the number of correct answers with the Affirmation of the Consequent and Denial of the Antecedent rules.

Similarly, a significant interactive effect was registered between probability of empirical occurrence x type of rule ($F(3.58, 168.42)$; $p< .0001$; $\varepsilon= .59724$).

As may be seen in Figure 1, with the Modus Ponens rule, when a deterministic relation was presented, the highest number of correct answers was obtained. Specifically, the following decreasing progression was registered in the number of logically correct answers, between experimental conditions: deterministic (96.35%), probabilistic (81.25%) and without relation (70.85%).

The same progression is maintained with the Modus Tollens rule, even if the number of correct answers in the three levels of empirical occurrence is lower than in the MP rule (70.33% - 62.5% - 55.73%, respectively). However, in the rules of Affirmation of the Consequent and Denial of the Antecedent, this progression was different. More specifically, in the Affirmation of the Consequent rule, the decreasing progression with regard to the number of correct answers was the following: without relation (54.18%), deterministic (38.53%) and probabilistic (36.98%). The Denial of the Antecedent

rule followed the same progression, although higher number of correct answers was registered than in the AC rule: without relation (60.93%) - deterministic (46.35%) - probabilistic (45.30%).

ANOVAs 3 x 2 x 2 were also carried out in both, in which the two first variables were the same factors of analysis that have been referred to (probability of empirical occurrence x availability), while the third variable only had two levels, which corresponded either to the two “types of logical rules” or with the two “non-logical rules”.

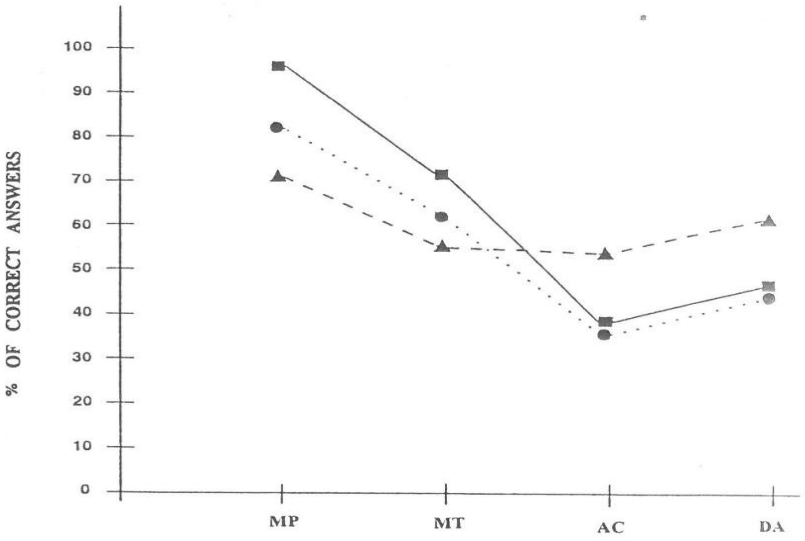

Figure 1: INTERACTIVE EFFECTS OF THE PROBABILITY OF EMPIRICAL OCCURRENCE AND THE TYPE OF RULE IN THE PERCENTAGE OF CORRECT ANSWERS

■ Deterministic ● Probabilistic ▲ Without Relation

B.l. Number of correct answers (logical rules)

The results of the ANOVAS 3 x 2 x 2 (probability of

empirical occurrence x availability x logical rule) indicated that the probability of empirical occurrence significantly influenced this dependent variable ($F(2,46)=9.894$; $p<.0001$). There were significant differences between the deterministic condition, where the highest levels of correct answers were registered, and the other two ($t = 19.638$; $p< .0001$).

Significant differences were also obtained in the type of logical rule variable ($F(1,47)= 16.49$; $p < .0001$). Specifically, when the subjects reasoned about Modus Ponens rules, the percentage of correct answers was higher (82.82%) than when they reasoned about Modus Tollens rules (63.89%).

B.2. Number of Correct Answers (non-logical rules)

The results of ANOVAs, where the number of correct answers in non-logical rules was considered as a variable, once again showed that the probability of empirical occurrence significantly influences the

number of logically correct answers (F(l.39, 65.38; p < .04; ε =.659). When the subjects reasoned about statements without a relation between their elements, they offered a higher number of correct answers (57.55%), and the lowest percentage appeared when they reasoned about probabilistic statements (41.14%). Later contrasts showed significant differences between the "without relation" condition and the other two (t= 2.661; p< .028).

The type of non-logical rule also significantly influenced this dependent variable (F(l ,47)= 5.05; p < .029), with a higher percentage of correct answers being registered with the Denial of the Antecedent rule (50.86%) than with the Affirmation of the Consequent rule (43.23%).

C) Certainty

The subjects had to indicate for each of the items the certainty with which they selected the conclusion

which, in their opinion, could be deduced from the premises. Each one of the answers was marked on a scale which went from l (not at all certain) to 7 (completely certain).

An ANOVA 3 x 2 x 4 was made (probability of empirical occurrence x availability x type of rule). In this case, differences with regard to availability were registered. The subjects appeared more certain about the correction of their answer, when they reasoned about available content (M_{Av}=6.21), than when they did so with non-available content ($M_{Non\text{-}Av}$=6.13). Despite the fact that the values of the averages between both conditions appeared to be undetectable, the results of the analyses indicate that the differences were statistically significant ($F(l,47)= 4.96$; $p< .031$).

Similarly, as with the number of correct answers, significant differences were registered in certainty of answer with regard to the type of rule variable

(F(2.70, 126.67)= 11.48; p< .0001; ε= .898). Once the corresponding contrasts were carried out afterwards, significant differences were noticed between the MP rule with relation to MT (t= 17.45; p<.0001), so that the subjects feel more confident with their answers when they reasoned about Modus Ponens problems than with Modus Tollens rules. Furthermore, the subjects were more confident when they reasoned about any of these arguments (MP and MT) than with arguments of Affirmation of the Consequent (t = 10.991; p<.002). Finally, there were significant differences in the certainty of answer when the subjects reasoned about MP, MT and AC rules compared to Denial of the Antecedent rules (t = 7.677; p< .001).

The probability of empirical occurrence also significantly influenced the certainty of answer (F(l.44, 67.63) = 5.17; p< .015; ε= .719). When the subjects reasoned about deterministic statements, meaning that they always happened in the real world, they

showed themselves to be more certain about their answers (M_{DET}=6.27) than when they reasoned about statements that only occur with certain frequency, or that were probabilistic (M_{PROB}=6.18). Finally, arguments where there is no empirical relation between antecedent and consequent are those which provoked less certainty in the subjects' reasoning (M_{WR}=6.06). Subsequent contrasts showed differences in the deterministic condition compared to the other two ($t = 6.533$; $p < .014$).

DISCUSSION

Significant differences were registered in the number of correct answers, with regard to the *type of rule.* Correct performance resulted from the following decreasing progression, by way of the four rules: Modus Ponens-Modus Tollens-Denial of the Antecedent-Affirmation of the Consequent. The best performance was obtained, therefore, when the

subjects reasoned about Modus Ponens rules, followed by Modus Tollens rules, as is predicted by the original and revised version of the Theory of Mental Models.

For Johnson-Laird (1983; Johnson-Laird and Byrne, 1991), these results are due to the fact that, in the case of Modus Ponens, the subjects generate the correct answer directly from the explicit model that they originally elaborate in order to reason. When the subjects reason about MP problems they only elaborate an explicit and implicit model, that represents possible alternative models that are not developed at first. From the minor premise of a MP argument, the subjects do not need to develop this implicit model. Therefore, they will focus their attention on the initial explicit model, and from there will generate the conclusion immediately.

In turn, Modus Tollens is less frequent than Modus Ponens, as the conclusion cannot be directly

generated from the explicit model, but instead by developing the possible implicit models. Regarding the minor premise of MT, reasoning with this rule requires the elimination of the explicit model, as the subjects cannot reason about a premise that is not included in this model. Consequently, they will have to develop alternative implicit models. If they make a conditional interpretation of the statement, then MT will be generated through the elaboration of three models, whereas if the subjects interpret the relation as biconditional, then two models will be developed. In any case, the number of mental models necessary in MT is greater than in the MP rule. This implies that the load on operative memory will be greater, and accordingly, performance will be worse.

Evans (1993) coincides with Johnson-Laird's theory in predicting a higher frequency of problems with Modus Ponens than with Modus Tollens, but he considers that in the original version there is no clear

explanation of how the models are elaborated, when they have to reason about Modus Tollens problems. In the revised version of the Theory of Mental Models, the author proposes that the subjects start elaborating an initial representation, that includes the exhaustive representation of the affirmative values, but implicit representation of the negative values. According to the author, *"subjects may draw inferences if either the premise is exhaustively represented in the current model, or if all models in wich it occurs are explicity represented"* ("P1" principle, Evans, 1993, p. 7). MP inference adjusts to the previous principle, but not that of MT. In this sense, MP may be generated immediately from the initial representation, as "p" is exhaustively represented, but MT is not, as the premise "not q" is not totally represented. The revised version of the theory also proposes that when a subject has to reason about a premise that is not included in the explicit model, he or she will try to develop an implicit model. However, this may be

successful or not, and so may generate the correct inference or fail.

Similarly, as well as the number of correct logical answers, we have used as a dependent variable certainty of answer. The greater complexity of reasoning with MT and importantly, the greater load on operative memory, explain the lesser certainty registered in MT with regard to MP. In the same way, the non-propositional alternative was selected with greater frequency in the MT rule than in the MP. This result could be explained within the framework of the Theory of Mental Models, bearing in mind that in reasoning about a MT the explicit model is eliminated, and subjects only have the implicit model on hand, that they will have to develop to be able to generate the correct inference. However, on occasions this model is not developed, with the direct conclusion that "it is not possible to deduce any conclusion". In the MP, the percentage of

subjects who selected the non-propositional alternative is less, as in this case the subjects are reasoning directly from the initial explicit model.

Our results also show that the MP and MT rules were more frequently developed than those of AC and DA. These results do not support either of the two versions of the theory, according to which the MP and AC rules occur more often than those of MT and DA. On one hand, the original version of the theory predicts the higher occurrence of MP and AC with regard to the explicit representation in the initial model of the affirmative values, and not of the negative. For Evans, the higher frequency of MP and AC was due to the fact that: *"inferences will be more often made if the conditions for inference are met in the initial implicit representation and less often if fleshing out is required"* (P2 principle, formulated by Evans, 1993, p. 7).

Unlike the original version of the theory, which

predicts a similar frequency in the production of MP and AC, and supporting the prediction of the revised version, we registered a higher frequency in the production of MP with regard to AC. While Johnson-Laird and Byrne (1991) justify their prediction by pointing out that a conditional may be initially represented by a model where "p" is not exhaustively represented, for Evans an inference is only produced if the premise is exhaustively represented in a model, or if all the models have been developed (the P1 principle, proposed by the author). For this reason, only MP is directly produced, and AC needs to be produced in a biconditional interpretation of the statement.

The results obtained with the "type of rule" variable partially support the Theory of Mental Models, and, more so, the revised version of the theory. To sum up: a) MP takes place more often than MT, as is proposed by both versions, b) MP is more frequent than the AC rule, and, in turn, the AC rule is produced with a similar

frequency to the DA rule; both results support the predictions of the revised version of the theory, and do not confirm the predictions of the original version, and c) the MP and AC rules are produced more often than the MT and DA rules. This prediction, from the two versions of the theory, is not confirmed by our results.

The results of this investigation confirm our empirical expectations regarding the importance of knowledge about reasoning, in line with results from previous investigations (Valiña and colleagues, 1992a, b). We registered a significant interactive effect on the number of correct answers between the type of rule and probability of empirical occurrence of the statements. Thus, just as Johnson-Laird and Byrne (1992); Byrne and Johnson-Laird (1992) proposed, the difficulty in the production of the four rules of inference is modulated by the *necessary* or *probable* character of the relation which they express. According to the authors, when subjects reason about a *deontic* or

necessary relation (which we have called deterministic), they only need to elaborate an explicit model of the situation to produce the correct inference. However, when they reason about a *probabilistic* relation, they have to contemplate at least two alternative possibilities, given that the relation may or may not occur. Therefore, they will have to elaborate an explicit model, from the information mentioned in the rule, and an implicit model.

The results of our experiment support this previous proposal. Effectively, the best performance with Modus Ponens and Modus Tollens rules was registered with statements which expressed a deterministic relation. However, as previously shown, with MT problems performance was worse, as the structure of the rule means that the subjects are not able to reason directly from a single initial explicit model. Furthermore, in the Modus Tollens rule, worse reasoning was observed with probabilistic

relations. In this case, added to the inherent difficulties in the formal structure of MT, was the fact that the probabilistic relation means that the subject had to contemplate various alternative models in order to produce the conclusion.

Similarly, Byrne and Johnson-Laird (1992, experiment 3), observed that the presence of a *probabilistic* modal verb in statements converted the relation into a fact that may or may not occur. As a consequence, in order to reason, the subjects had to elaborate an explicit model (that reveals the event occurrence mentioned in the rule) and an implicit model (that represents the potential possibility that an event may not occur). However, the presence of a deontic modal verb indicated to the subjects that there was no possible alternative to the event mentioned in the statement. In this respect, the determinism in the relation guided the subjects towards the construction of a single explicit model that expressed the occurrence of

the relation. In short, as Byrne and Johnson-Laird (1992) pointed out, while a modal verb with a probabilistic character requires the elaboration of a series of alternative models which are intrinsically hypothetical, the modal verb which expresses a relation of necessity brings about the construction of a single simple factual model.

Furthermore, the interactive effect registered between the probability of empirical ocurrence and the type of rule revealed that in the AC and DA rules, the lower the possibility of activating empirical knowledge, then performance with both rules was more correct. These results may be explained through the existence of a bias towards non-propositional conclusions, that would lead the subject towards a correct conclusion. In this respect the subjects could be selecting the correct alternative simply because the absence of empirical relation between the elements of the rule would lead them to

reject the task more often, and, consequently, to point out that it was not possible to come to a conclusion.

Stevenson and Over (1995, experiment 4), analysed the effect of the "quality" of premises on the production of the AC and DA rules. The authors observed that as the lack of certainty increased in the conditional relation, reasoning with the AC became difficult, while it had no effect upon the DA rule. Our results in the "without relation" condition, with AC and DA rules, support those of Stevenson and Over. Effectively, the lack of empirical relation between the antecedent and the consequent make performance more difficult with AC rules than with DA problems. In general, these authors explain their results within the framework of the Theory of Mental Models, indicating that: *"the epistemic weights of mental models of the premises in*

an inference would help determine the weights of the mental models of the conclusion, which would fix how probable or improbable the conclusion was thought to be" (Stevenson & Over, 1995, p. 640).

Similarly, other authors (Cummins, Lubart, Alksnis and Rist, 1991) underlined the importance of the *content* of conditional statements on the production of inference rules. The authors designed an investigation which analysed the influence of the *form* and *content* of the statements on the subjects' reasoning with decontextualised conditional arguments. As in our experiment, the authors presented the subjects with problems of the four rules of conditional inference, with thematic content, that expressed cause-effect relations and varied with regard to the number of "alternative causes" and "possible causes" that could be derived from the conditional. The authors also registered an interactive effect between form and

content, which lead them to characterise human reasoning as a fundamentally *pragmatic* type of reasoning: "*the tendency to interpret a statement as a conditional or a biconditional may exist on a continuum, varying with the size of the pool of alternatives that characterize the situation described by the conditional"* (Cummins, Lubart, Alksnis & Rist, 1991, p. 275).

If a parallelism is established with the probability of empirical occurrence variable which we used, the "deterministic" level may be assimilated with the condition in which the authors suggest a narrow relation between antecedent and consequent, so that there are no possible "altemative causes" in the conclusion that is presented. On the contrary, it would be possible to assimilate the "probabilistic" level with the condition where the content of the argument is flexible towards the possible existence of "incapacitating conditions" that make the presented statement more

relative (or probable). In this respect, and according to the authors, the greater the number of possible causes which the subjects may produce by activating their knowledge, then the lesser the probability of the subjects making a biconditional interpretation of the statements. In conditionals whose consequence is probable, the subjects will produce MP and MT rules less often than in "deterministic" statements. The AC and DA rules will be produced with deterministic statements, as they are more interpreted as biconditionals. According to the authors, the less "alternative causes" the subject is able to elaborate, the better the production of MP, MT, AC and DA rules.

These authors, in agreement with their own predictions, found a similar interactive effect to that which we obtained between form and empirical frequency. The results of Cummins and colleagues (1991) confirm that the type of inference produced is modulated by factors related to the activation of

knowledge, particularly to the possibility of activating "alternative causes" or "incapacitating conditions" from the statements. In our case, this influence of knowledge upon reasoning was reflected in the possibility of activating empirical knowledge from the frequency of the statements which were presented. These variables determine the search for plausible conclusions elaborated from empirical knowledge, and not from logical or necessary conclusions, elaborated through the activation of formal rules.

Moreover, our empirical expectations with regard to availability were confirmed. As Evans (1984) proposed, availability is not enough to facilitate the production of a conditional inference task, as opposed to Pollard's (1982) point of view. Our results show that the mere inclusion of available professions in decontextualised arguments does not improve the subjects' performance regarding the inclusion of non-available professions. However, the subjects' level of

certainty in their answers increased.

Nonetheless, one of the predictions made regarding availability of the scenario was not confirmed. In line with Pollard and Evans (1987), where the influence of context-content variables on reasoning was proposed, we expected to register a significant interactive effect between the empirical frequency of the statements and availability of the scenario where they were included. We hoped to obtain a higher number of correct answers and greater certainty of answers when the subjects reasoned about deterministic relations, presented in accessible contexts. Similarly, the worst degree of performance and lowest certainty of answer would be registered when the subjects reasoned about statements "without relation", in non-avaible contexts. However, these predictions were not confirmed, as we did not register the expected interactive effect.

In spite of this, in the context of this experiment, when we refer to “available scenarios”, we are simply referring to conditional arguments which include available professions. Perhaps the way of manipulating this variable and the type of task presented may explain the absence of significant effects of this factor on correct performance. It will be important to undertake new investigations in the future to study if the effect of this variable on reasoning is greater when conditional arguments included in texts are used, that allow the subjects to elaborate a “mental framework that is actively transformed, with the intention of deriving its factual and plausible consequences from the "mental simulation" mode” (Valiña and De Vega, 1988, p. 58).

REFERENCES

Byrne, R.M.J., & Johnson-Laird, P.N. (1992). The spontaneous use of propositional connectives. *Quarterly Journal of Experimental Psychology, 44A*, 89-110.

Cheng, P.W. & Holyoak, K.J. (1985). Pragmatic reasoning schemas. *Cognitive Psychology, 17*, 391-416.

Cheng, P.W., & Holyoak, K.J. (1989). On the natural selection of reasoning theories. *Cognition, 33*, 285-313.

Cheng, P. W., Holyoak, K.J., Nisbett, R.E., & Oliver, L.M. (1986). Pragmatic versus syntactic approaches to training deductive reasoning. *Cognitive Psychology, 18*, 293-328.

Cummins, D.D., Lubart, T., Alksnis, O., & Rist, R. (1991). Conditional rensoning and causation. *Memory and Cognition, 19*(3), 274-282.

Evans, J. St.B.T. (1984). Heuristic and analytic processes in reasoning. *British Joumal of Psychology, 75*(4), 451-468.

Evans, J. St. B. T. (1989). *Bias in Human Reasoning: Causes and Consequences*. Hove, UK: Erlbaum.

Evans, J. St. B. T. (1993). The Mental Models Theory of Conditional Reasoning: Critical Appraisal and Revision. *Cognition*, *48*(1), 1-20.

Holyoak, K.J., & Cheng, P.W. (1995). Pragmatic Reasoning About Human Voluntary Action: Evidence for Wason's Selection Task. In S.E. Newstead, & J.St.B.T. Evans (Eds.). *Perspectives on Thinking and Reasoning. Essays in Honour of Peter Wason* (pp. 67-89). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Johnson-Laird, P.N. (1983). *Mental Models. Towards a cognitive science of language, inference and consciousness*. Cambridge, England: Cambridge University Press.

Johnson-Laird, P.N. (1983). *Mental models. Towards a cognitive science of language, inference and consciousness*. Cambridge, England: Cambridge University Press.

Johnson-Laird, P.N., & Byrne, R.M.J. (1991). *Deduction*. Hove, UK: Lawrence Erlbaum Associates.

Johnson-Laird, P.N., & Byrne, R.M.J. (1992). Modal reasoning, models, and Manktelow and Over. *Cognition*, *43*(2), 173-182.

Martín, M. (1992). *Una aproximación experimental al razonamiento pragmático en tareas de inferencia condicional.* Unpublished Master Thesis. University of Santiago de Compostela.

Martín, M., & Valiña, M.D. (1993). *Procesos de inferencia condicional. Una aproximación al razonamiento cotidiano.* Santiago de Compostela: Tórculo.

Pollard, P. (1982). Human reasoning: Some possible effects of availability. *Cognition, 12*(1), 65-96.

Pollard, P., & Evans, J. St. B.T. (1987). Content and context effects in reasoning. *American Joumal of Psychology, 100*(1), 41-60.

Stevenson, R.J. , & Over, D.E (1995). Deduction from uncertain premises. The *Quarterly Journal of Experimental Psychology. Human Experimental Psychology, 48A*(3), 613-643.

Seoane, G., & Valiña, M.D. (1988). Efecto del contenido y microgénesis de la tarea en inferencia condicional. *Cognitiva, 1*(3), 271-298.

Valiña, M.D. (1985). *Una exploración del razonamiento cotidiano con lenguaje natural: silogismos con cuantificadores probabilísticos.* Unpublished Doctoral Dissertation. University of La Laguna, Tenerife.

Valiña, M.D. (1988). Efecto del contenido y rnicrogénesis de la tarea en razonamiento silogístico con cuantificadores probabilísticos: Un estudio cronométrico. *Cognitiva*, *1*(2), 199-212.

Valiña, M.D. (1996, in press). Razonamiento Pragmático. In M. Carretero & M. Asensio (Eds.). *Psicología del Pensamiento.* Madrid: Alianza.

Valiña, M.D., Seoane, G., Gehring, S., Ferraces, M.J., & Fernández-Rey, J. (1992a). Conditional reasoning: Scenario or context effects. In *Abstracts of the Fifth Conference of the European Society for Cognitive Psychology. ESCOP* (p. 120). September, 12-16, Paris, France.

Valiña, M.D., Seoane, G., Martín, M., Fernández-Rey, J., & Ferraces, M.J (1992b). The role of content and context in pragmatic reasoning. In *Abstracts of the Fifth Conference of the European Society for Cognitive Psychology. ESCOP* (p.120). September, 12-16, Paris, France.

Valiña, M.D., Seoane, G., Ferraces, M.J, & Martín, M. (1996). *Wason's selection task: Content effect, instruction effect or both?*. Paper presented at the Third International Conference on Thinking. Symposium Pragmatic Factors in Reasoning and Decision Making. British Psychological Society. Cognitive Psychology Section. University College London. August, 29-31, London.

Valiña, M.D., & Vega, M. de (1988). Un estudio experimental del razonamiento cotidiano en tareas de silogismos: una aproximación pragmática. *Cognitiva, 1*(l), 33-62.

Wason, P.C. (1966). Reasoning. In B.M. Foss (Eds.). *New horizons in Psychology* (pp. 135-151). Hardsmondsworth: Penguin.

Wason, P.C. (1968). Reasoning about a rule. *Quarterly Joumal of Experimental Psychology, 20,* 273-281.