The Importance of Pragmatic Aspects in Conditional Reasoning

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The importance of pragmatic aspects in conditional reasoning was assessed in the performance of 54 subjects (26 female and 28 male; mean age 17.6 years) on 48 conditional inference problems, using a 3 x 2 x 4 design, with repeated measurements. The independent variables were probability of empirical frequency in the real world, type of conditional rule, and scenario availability. Number of correct responses and subjects' certainty about the correctness of their responses were the dependent variables. The results showed: a) the scenario availability is not sufficient in itself to explain differences in performance, but it does affect the subjects' degree of confidence in their conclusions; b) there is an interaction between probability of empirical frequency in the real world and type of conditional rule on correct performance. The results were contrasted with the predictions made by the mental models theory and its revised version proposed by Evans (1993). These findings support the semantic theories of conditional reasoning.
Key words: pragmatic reasoning, conditional reasoning, empirical relation between antecedent and consequent, availability of the scenario

En este trabajo hemos estudiado la importancia de factores pragmáticos en razonamiento condicional, analizando la ejecución de 54 sujetos (26 mujeres - 28 hombres, cuya media de edad era de 17.6 años). Planteamos un diseño 3 x 2 x 4 de medidas repetidas en los tres factores. Las variables manipuladas fueron: la relación empírica existente en el mundo, el tipo de regla y la accesibilidad del escenario. Se utilizaron como variables dependientes el número de respuestas correctas y la seguridad de los sujetos en la corrección de sus juicios. Los resultados han puesto de manifiesto que: a) la accesibilidad del escenario no es en sí misma suficiente para explicar las diferencias en la ejecución, pero afecta al grado de seguridad de los sujetos en sus conclusiones; b) hay una interacción entre probabilidad de frecuencia empírica en el mundo real y el tipo de norma lógica sobre la ejecución correcta. Contrastamos los resultados con las predicciones de la teoría de modelos mentales y con la versión revisada (Evans, 1993). Los datos apoyan las teorías semánticas del razonamiento condicional.
Palabras clave: razonamiento pragmático, razonamiento condicional, relación empírica entre antecedente y consecuente, accesibilidad del escenario

There is now considerable empirical evidence that human reasoning with conditional sentences (e.g., *if Muzzy is a cat, then Muzzy has four legs*) is influenced by concrete or thematic content (Holyoak & Cheng, 1995a, 1995b). Specifically, previous work has established that distinct types of content evoke distinct inference patterns on the Wason selection task, the most investigated problem in the psychology of reasoning (Valiña, Seoane, Ferraces, & Martín, 1998; see Evans, Newstead, & Byrne, 1993, for a detailed review).

Comparatively few studies have investigated how people reasoned with different types of realistic content (but see Newstead, Ellis, Evans, & Dennis, 1997). The main contribution of this paper is, precisely, to investigate in more detail the effects of the subject's knowledge about problems of each rule of propositional logic *(Modus Ponens [MP], Modus Tollens [MT], Affirmation of the Consequent [AC], and Denial of the Antecedent [DA])*.

In a previous experiment (Martín, 1996; Valiña, Seoane, Ferraces, & Martín, 1996a), three versions of Wason's selection task were presented to the subjects (Wason, 1966, 1968), with three types of content (abstract, thematic-permission, and thematic-obligation). The results of this experiment revealed the importance of factors related to knowledge when executing a meta-inference task, such as the Wason selection task. This effect could not be understood as a mere facilitation of concrete content, faced with the abstract content of the rule. In fact, we registered better performance in subjects when using the versions which included a deontic relation (enunciative conditionals that contain deontic terms such as the imperative modal *must*; see Manktelow & Over, 1991), both in abstract and thematic content (e.g., *if a Wasit card has A on one side, then it must have a 3 on the other* or *If a person rides a motorbike, then he or she must wear a helmet*). Besides, we obtained the worst results with the rule, using thematic content, which expressed a relation of possibility or permission (e.g., *if a person is more than 18 years old, then he or she has the right to vote*).

The proposals of the theory of pragmatic reasoning schemas (Cheng & Holyoak, 1985, 1989; Cheng, Holyoak, Nisbett, & Oliver, 1986; Holyoak & Cheng, 1995a, b; Valiña, in press) could explain this improvement in reasoning. From this perspective, in the two tasks that registered a higher number of correct answers, the subjects used a schema similar to that of "obligation" *(if the precondition is satisfied, then the action must be carried out)*. However, this theoretical proposal does not fully explain other results, such as the differences in performance between the two thematic versions, both similar to a pragmatic schema, either of obligation ("thematic-2") or of permission ("thematic-1": *if the precondition is satisfied, then the action may be carried out)*.

However, using the theory of mental models (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991), it is possible to predict and explain the performance differences between conditionals which express a deontic relation of "necessity"

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

The results of Valiña et al. (1996a) only permitted verifying the influence of the necessity nature of a conditional relation when the subjects were reasoning about a meta-inference task, such as the selection task. However, could this influence be generalized to other conditional inference tasks? We designed this experiment to answer this question.

Our interest in this experiment was not, therefore, to analyze the influence of the content (abstract vs. thematic) on the subjects' conditional reasoning, as this has been dealt with previously (Seoane & Valiña, 1988; Valiña, Seoane, Ferraces, & Martín, 1995; Valiña, Seoane, Gehring, Ferraces, & Fernández-Rey, 1992; Valiña, Seoane, Martín, Fernández-Rey, & Ferraces, 1992). In fact, we only used conditional arguments, with thematic content, as experimental material. Questions about the possible effect of thematic facilitation have generated abundant experimental investigation in the last twenty years, but this topic is now practically spent, given that, as we previously indicated, the influence of knowledge on pragmatic reasoning is more complex than that of mere facilitation of thematic versus abstract content (Valiña, Seoane, Ferraces, & Martín, 1996b).

In this experiment, we tried to determine the precise importance of the variable that we call the probability of empirical frequency in conditional reasoning (Valiña, Seoane, Gehring, et al., 1992; Valiña, Seoane, Martín, et al., 1992). 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 degree of empirical occurrence: *deterministic, probabilistic,* and *without specific relation*. In this respect, we considered the deterministic relation similar to a relation of *empirical necessity* (the relation expressed in the conditional statement will always happen, for example: *If the docker throws a plumb into the water, then the plumb will sink)*; whereas the probabilistic relation presents an *empirical possibility* (which only happens sometimes in the real world, for example: *If the farmer gets wet, then he will catch a cold)*.

If, as posited by the theory of mental models, reasoning subjects elaborate analogical representations of the real world, then one would expect that reasoning with conditional statements in which empirical possibilities are expressed will be different from reasoning involving statements which present empirical necessities. More precisely, and in agreement with Johnson-Laird's proposals (Byrne & Johnson-Laird, 1992; Johnson-Laird & Byrne, 1992), reasoning about a *necessary* argument requires the elaboration of a unique, explicit mental model of the situation. However, if the situation concerns a *probable* conditional statement, that may or may not occur in the real world, then it would be necessary

to elaborate both an explicit and an implicit mental model. Therefore, we expected the subjects to manifest more correct reasoning with conditional statements, in which they expressed a *necessary* (deterministic) relation, than if the relation was *possible* (probabilistic). In the latter case, the number of mental models needed to arrive at the conclusion was greater, which led to an increase in the working memory workload, and, finally, an increase in the number of errors.

We also manipulated two more variables: type of conditional rule and availability. The first had four levels, corresponding to the four types of conditional inference rules from propositional logic.

The manipulation of the type of rule variable allowed us to see whether our results would 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 Evans's theory of heuristic-analytic processes (Evans, 1982, 1984, 1989). According to Johnson-Laird (1983; Johnson-Laird & Byrne, 1991), MP for conditionals requires only one explicit model and one implicit model. Subjects focus their attention on the initial explicit model and, from there, immediately generate the conclusion. On the other hand, when faced with MT problems, the subjects would not be able to generate the conclusion directly from the explicit model, but by developing the possible implicit models instead. Regarding the minor MT premise, reasoning with this rule requires the subjects to generate the conclusion by the elaboration of three models. The number of mental models needed for MT is greater than for the MP rule. This implies that the operative memory workload would be greater, and accordingly, performance would be worse.

Evans (1993) agreed partially with Johnson-Laird's theory (1983; Johnson-Laird & Byrne, 1991), but considered that in the original version, there was no clear explanation of how the subjects elaborated the models when they were required to reason about MT problems. In the revised version of the theory of mental models, this author proposed that the subjects start elaborating an initial representation, that includes a complete representation of the affirmative values, but only an implicit representation of the negative values. According to this author, "subjects may draw inferences *either* if the premise is exhaustively represented in the current model, *or* if all models in which it occurs are explicitly represented" (P1 principle, Evans, 1993, p. 7). The MP inference is adjusted to the previous principle, but not to that of MT, because the premise *not q* wasn't totally represented. Therefore, subjects would try to develop an implicit model. However, they might or might not be successful, and so, could generate or fail to generate the correct inference.

The mental models theory proposes that in MP and AC inferences, subjects reason from the initial representation, in which there is no explicit model to serve as a counter-example, to the inference. Thus, Johnson-Laird predicts that

subjects will elaborate both MP and AC inferences with equal frequency, "even if subjects represent the conditional with exhaustive categories but an implicit model" (Evans, 1993, p. 5).

Nevertheless, the revised version of the theory proposes that subjects will draw MP inferences with greater frequency than AC inferences. In this sense, in the case of MP, subjects will draw the inference both from a conditional or biconditional representation of the rule, but they only will generate the AC inferences if they adopt a biconditional representation with a higher rate of MP inferences than the AC ones.

According to the original theory, subjects made the AC inference more frequently than the DA because there is an explicit representation of affirmative, but not negative, values in the initial model. Given the minor premise of the DA argument, reasoners could accurately say that *nothing follows* simply because they couldn't combine the information in the second premise with the initial set of models (regardless of whether those models were for the conditional or biconditional interpretation). So, reasoners could arrive at the right answer for the wrong reason. The same prediction followed from the revised version of the theory, but Evans (1993, p. 9), on the basis of the results of the literature which used inferences from the affirmative conditionals, pointed out that the two inferences were made with roughly equal frequency.

Finally, the third variable we manipulated was availability. Our aim was to study whether the availability of a scenario was a sufficient condition (as proposed by Pollard, 1982) to provoke an improvement in subjects' reasoning, or whether, as Evans proposed (1984, 1989, 1995), it could be a necessary but insufficient condition to influence reasoning.

Based on our theoretical proposals, we propose the following predictions:

1. The factor related to the subject's previous knowledge modulates the reasoning process. In this respect, the greater the possibility of subjects activating knowledge, the easier the task will be. As Byrne and Johnson-Laird (1992) and Johnson-Laird and Byrne (1992, 1994) 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 about the answers when the subjects reason about deterministic statements. In the same way, the lowest performance level and lowest levels of certainty would register in statements without specific relation, where it is not possible to access the subjects' conceptual system.

2. Reasoning is based on the construction of mental models or scenarios of the situation. However, the use of accessible scenarios is not sufficient to improve performance in a reasoning task. In this respect, and bearing in mind that the availability of the scenario that we will present is limited to including available professions in decontextualized reasoning, we do not expect to register significant principal

effects of this variable (availability) on the number of correct answers. More specifically, we do not expect higher performance levels when the subjects reason about arguments which include available professions, compared to those which present unavailable professions.

3. Availability, in itself, is not a sufficient factor to improve performance, and we agree with Pollard and Evan's proposal (1987) when they state that variables of content-context modulate human reasoning. In this respect, we expect to register lower numbers of correct answers and less certainty about the answer when the probability of empirical occurrence expressed in the arguments is null (without-specific-relation condition), if the subjects reason about unavailable scenarios. Also, subjects will tend to reject the task more often (the increase in the selection of the alternative *nothing follows* will reveal this). 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 about the answer. In this case, 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.

Method

Participants

Fifty-four school students (26 females and 28 males), studying at the Rafael Dieste School (A Coruña, Spain), participated voluntarily in this experiment. The age of the students ranged from 16 to 20 years ($M = 17.6$). Subjects were randomly selected and none had any prior tuition in formal logic.

Design

We used a 3 x 2 x 4 design (Probability of Occurrence in the Real World x Availability x Type of Rule), with repeated measurements in the three factors.

The first factor was probability of empirical occurrence of the relation between the antecedent and the consequent of each conditional statement. This relation could always occur in the real world (deterministic), sometimes occur (probabilistic), or there could be no specific relation between antecedent and consequent (without specific relation).

The second factor was availability, with two levels (Available and Unavailable). This refers to the type of profession included in the problem, which in one case was available to the subjects (for example, a singer), whereas in the other, it was unavailable (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: MP, MT, AC, and DA.

As dependent variables, we used: a) the number of correct answers according to Logic and b) the certainty that the subjects expressed about their answers.

Materials and Procedure

Two booklets were made up for this investigation. Each one contained a page of instructions and a total of 48 problems of conditional inference (two per page), of which 16 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 probabilistic statements which occur sometimes (for example, *if the miner smokes a lot, then he will have lung cancer*) and, finally, 16 items which contained conditional statements where there was no specific relation between the antecedent and the consequent (for example, *if the sculptor cuts his hair, then he will get married*). We used the conditional statements from a previous normative study (Martín & Valiña, 1993).

We manipulated the degree of availability of the content, selecting the professions of the characters in it, which were included in the premises. In eight items, these characters had an available profession for the subjects (for example, *if the workman falls from the tenth floor, then he will hurt himself*), whereas in the other eight items, we presented an unavailable profession (for example, *if the plasterer falls from the tenth floor, then he will hurt himself*). We used, with conditional arguments, characters with available professions (e.g., singer, philosopher, clown, biologist, workman, etc.), and unavailable professions (e.g., soprano, axiologist, tightrope-walker, malacologist, plasterer, etc.) selected from a previous standardized study, which had been used in a series of experiments based on the study of syllogistic reasoning, with quantifiers of natural language (Valiña, 1988), including syllogisms in narrative texts (Valiña 1985; Valiña & de Vega, 1988).

Finally, we included two problems of each rule of Propositional Logic for both types of content (2 MP, 2 MT, 2 AC, and 2 DA for available, as well as for unavailable professions). The problems were randomized and their order of presentation in the booklets was random and inverse random.

The experimental paradigm used was an answer-selection paradigm. The task of the subjects was to select the conclusion that was logically deduced from the premises. Also, they had to mark with a cross, on a seven-point scale, the degree of certainty that they felt about the correctness of their choice. This scale ranged from *not at all sure* to *completely sure*, with a neutral intermediate score.

We carried out the experiment in the classroom where the students normally had lessons. All the subjects sat at separate desks and they all did the same task. We handed them written instructions and we also read these instructions aloud; afterwards, we cleared up any doubts they had.

The instructions were:

In this booklet you have a series of sentence pairs. The first are of the '*if ..., then*' type. These two sentences are always considered to be true. After each of these pairs of sentences you will find a series of three statements. Your task is to point out which of these statements, at your discretion, is deduced logically from the former ones. If you think that there is one that is logically correct, then you should circle its number. If you think that none of the sentences can be logically deduced from the former pair, then circle the number corresponding to *No conclusion is deduced*. Apart from this, you must also indicate how sure you feel about your choice. You have all the time you consider necessary for this. Make sure you understand what you have to do.

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

Once we read the instructions and we cleared up any doubts, the subjects carried out the task without a time limit. The experiment lasted just under an hour.

Results

The data from 6 subjects was eliminated before carrying out the analysis because they had not completed the task. We present the results in three sections: (a) distribution of each type of answer among the four conditional inferences; (b) analysis of the impact of experimental factors on performance; and (c) study of the influence of the above-mentioned factors on the subject's confidence.

A) Distribution of each Type of among the four Conditional Inferences

Each item offered a choice of three conclusions: *affirmative, negative,* and *nothing follows,* meaning it was not possible to deduce any conclusion. Descriptive data for all variables are shown in Figure 1.

As shown in this figure, the most frequently selected answer in the MP rule is the affirmative conclusion, which is logically correct. This percentage decreased parallel to the probability of empirical occurrence between antecedent and consequent of the conditional statement. Specifically, the deterministic condition registered the highest percentages of correct answers, whereas this frequency decreased in the without-specific-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. We registered a higher frequency of rejection of the task in this condition, which is reflected in an increase of the choice of the alternative *nothing follows.*
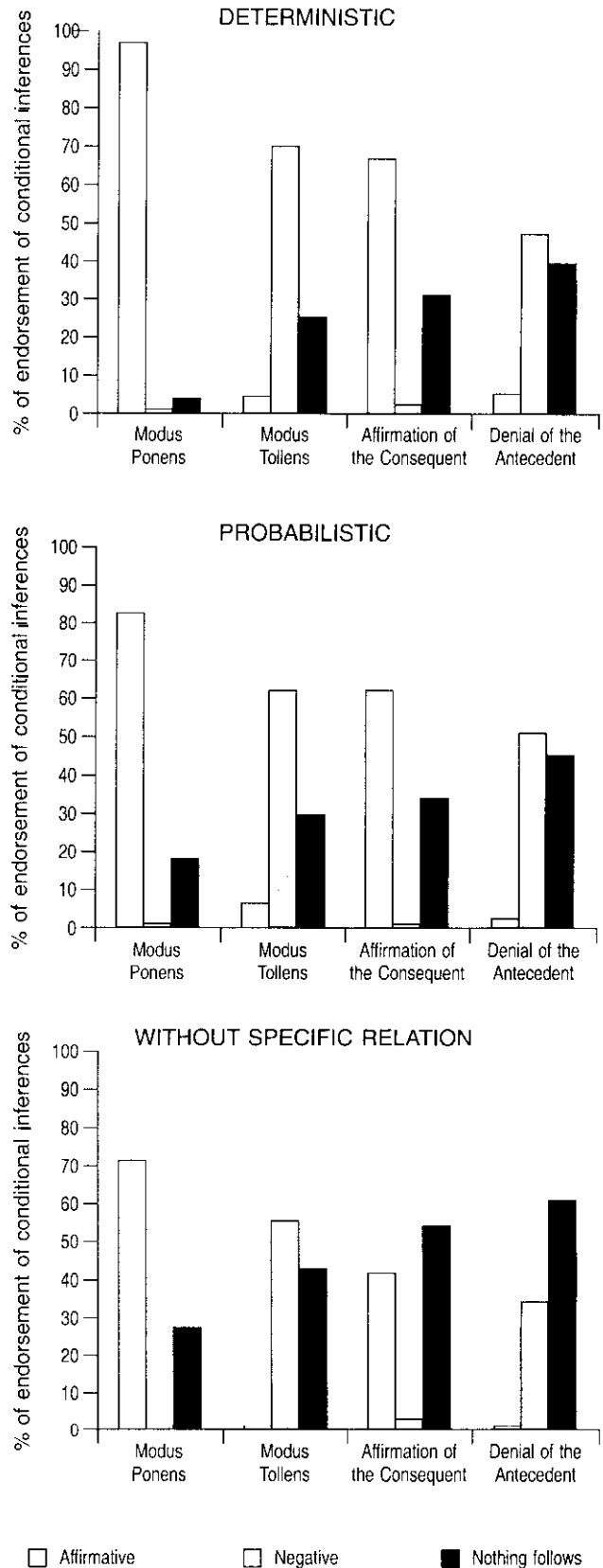

Figure 1. Frequency (%) of endorsement of conditional inferences for affirmative *If p, then q.*

In the case of the MT rule, the most frequently selected answer was the negative conclusion, which, in this case, was correct. However, the percentage of subjects who reached the logically correct answer was less than for the MP rule. Despite this, the same decreasing progression was observed throughout the three conditions of empirical occurrence: deterministic-probabilistic-without specific relation. Thus, in MT, the deterministic condition was also the one that registered a greater percentage of subjects who chose the correct answer, followed by the probabilistic condition.

The correct answer was chosen most frequently with the MP and MT rules, according to the criteria of Formal Logic (an affirmative conclusion for MP and a negative conclusion for MT).

In the rules of AC and DA, the condition where the greatest percentage of correct selections occurred was the without-specific-relation one. 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 in the choice of affirmative and negative answers, respectively. (See Figure 1.)

Thus, when the subjects reasoned about AC or DA rules, when there was no empirical relation between the antecedent and the consequent, they mainly chose the answer that stated that no conclusion could be deduced from the premises, which was 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 most frequently selected type of answer. When the subjects were asked to reason about AC problems, they most frequently selected the affirmative answer, whereas with DA problems they tended mainly to choose negative ones. This could indicate that the increase in the empirical frequency of the content of the rules was accompanied by an increase in the subjects' tendency to carry out biconditional interpretations of the premises, whereas in the case of conditions without specific relation, this tendency was "blocked", and consequently, the subjects considered that it was not possible to deduce any conclusion. Indeed, it was precisely the choice of this latter answer in the without-specific-relation condition which increased the percentage of correct answers with AC and DA rules.

In Table 1 are displayed the percentages of the *nothing follows* answers selected. In this table, it may be seen that the percentages of this alternative were greater in the nonlogical rules (AC, DA) than in the logical rules (MP, MT). In turn, this alternative was the most frequently selected when the subjects reasoned about statements with no relation between their elements.

B) Analysis of the Impact of Experimental Factors on Subject's Performance

The number of correct answers of each subject was added up, following the criteria of formal Logic. In Table 2, the percentage of correct answers is shown, for each type of rule, with regard to the availability and probability of empirical occurrence.

Table 1

Percentage of "Nothing Follows" Responses Selected

		Deterministic	Probabilistic	Without specific relation	TOTAL MEAN
Available	MP	2.10	17.75	27.10	15.65
	MT	23.95	28.15	44.80	32.30
	AC	30.20	35.45	55.20	40.30
	DA	44.80	41.65	60.40	48.90
	Mean	25.30	30.75	46.90	34.30
Unavailable	MP	4.20	16.70	30.20	17.05
	MT	28.15	35.40	41.65	35.10
	AC	32.30	38.55	53.15	41.35
	DA	33.30	48.95	61.45	47.90
	Mean	24.50	34.90	46.65	35.35
TOTAL MEAN		24.90	32.85	46.80	

Note. MP = Modus Ponens; MT = Modus Tollens; AC = Affirmation of the Consequent; DA = Denial of the Antecedent.

Table 2

Percentage of Correct Answers in each Experimental Condition

		Deterministic		Probabilistic		Without specific relation		TOTAL	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Available	MP	96.85	16.05	81.25	32.00	71.90	42.42	83.35	10.30
	MT	70.85	38.40	64.60	35.65	54.15	43.55	63.20	6.90
	AC	30.20	33.80	35.40	39.83	55.20	42.85	40.30	10.80
	DA	44.80	52.75	41.65	41.15	60.40	44.90	48.95	8.20
	Total	60.70	25.45	55.75	18.30	60.45	7.00	58.95	2.30
Unavailable	MP	95.85	17.40	81.25	33.62	69.80	40.95	82.30	10.70
	MT	69.80	56.80	60.40	42.46	57.30	39.95	62.50	5.35
	AC	46.85	93.45	38.55	40.31	53.15	43.05	46.20	6.00
	DA	47.90	94.00	48.95	39.25	61.45	42.15	52.80	6.15
	Total	65.10	20.00	57.30	15.85	60.40	6.15	60.90	3.20
TOTAL		62.90	23.00	56.40	17.10	60.40	6.60	59.90	3.00

Note. MP = Modus Ponens; MT = Modus Tollens; AC = Affirmation of the Consequent; DA = Denial of the Antecedent.

We performed a 3 x 2 x 4 *ANOVA* (Probability of Occurrence x Availability x Type of Rule), using the percentage of correct answers as the dependent variable. We obtained a significant effect of the type of rule, $F(1.64, 77.26) = 14.14$, $p < .0001$, with relation to the number of correct answers. The highest number of correct answers was registered when the subjects reasoned about MP problems ($M = 82.82\%$), followed by those obtained with MT problems ($M = 62.85\%$), and DA ($M = 50.86\%$). Finally, the lowest percentages of logical successes were obtained with AC problems ($M = 43.23\%$). The corresponding contrasts carried out subsequently indicated that there were significant differences between MP and MT in the number of correct answers, $F (1, 47) = 41.90$, $p < .0001$, as well as with regard to the AC rule, $F (1, 47) = 4.54$, $p < .001$. However, no significant differences were revealed in the number of correct answers between the AC and DA rules.

Similarly, a significant Probability of Empirical Occurrence x Type of Rule interaction was revealed, $F (3.58, 168.42) = 6.41$, $p < .0001$. As may be seen in Figure 2, with the MP rule, when we presented a deterministic relation, we registered the highest number of correct answers $F (1, 47) = 10.75$, $p < .0012$. Specifically, we registered the following decreasing progression in the number of logically correct answers in the three experimental conditions: deterministic (96.35%), probabilistic (81.25%), and without specific relation (70.85%).

The same progression occurred with the MT rule, although the number of correct answers in the three levels of empirical occurrence was lower with the MP rule
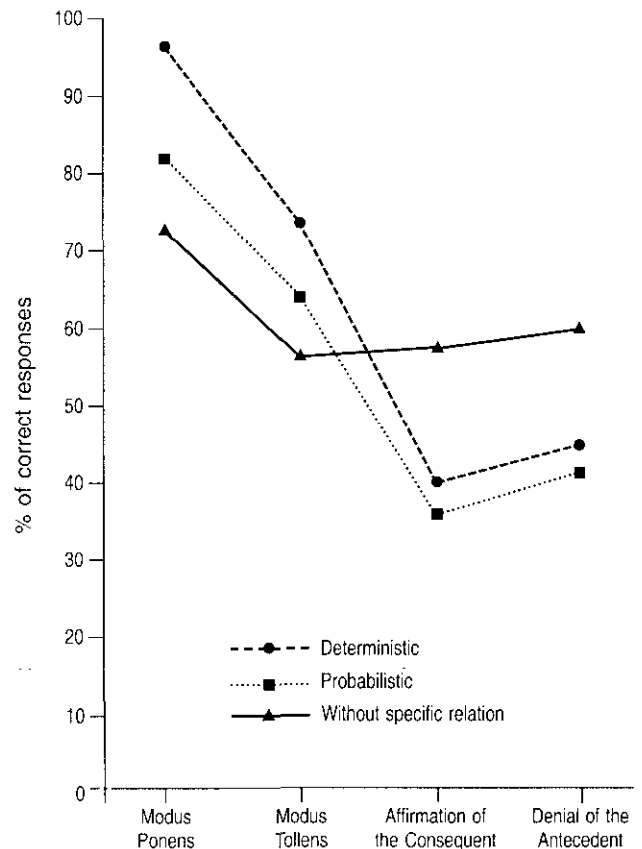

Figure 2. Interactive effects between probability of empirical occurrence and type of rule in the percentage of correct responses.

(70.33%, 62.5%, and 55.73%, respectively). However, with the AC and DA rules, this progression was different. With the AC rule, the order of the decreasing progression in the number of correct answers was the following: without specific relation (54.18%), deterministic (38.53%), and probabilistic (36.98%). The DA rule followed the same order, (although we registered a higher number of correct answers than in the AC rule): without specific relation (60.93%), deterministic (46.35%), and probabilistic (45.30%).

We also carried out 3 x 2 x 2 *ANOVAs*, in which the two first variables were the same factors (Probability of Empirical Occurrence x Availability), whereas the third variable only had two levels, which corresponded either to the logical rules or to the nonlogical rules.

B.1.) Impact of experimental factors on subjects' performance with logical rules

The results of these *ANOVAs* (Probability of Empirical Occurrence x Availability x Logical Rule) indicated that the probability of empirical occurrence significantly influenced the number of correct answers, $F(2,46) = 9.894, p < .0001$. There were significant differences between the deterministic condition, where we registered the highest levels of correct answers, and the other two, $F(1, 47) = 19.638, p < .0001$.

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

B.2.) Impact of experimental factors on subjects' performance with nonlogical rules

The results of the *ANOVAs*, using the number of correct answers in nonlogical rules as a dependent variable, once again showed that the probability of empirical occurrence significantly influenced the number of logically correct answers, $F(1.39, 65.38) = 3.83, p < .04$. When the subjects reasoned about statements without a specific relation between their elements, they chose a higher number of correct answers (57.55%), and the lowest percentage appeared when they reasoned about probabilistic statements (41.14%). Subsequent contrasts showed significant differences between the without-specific-relation condition and the other two, $F(1, 47) = 2.661, p < .028$.

The type of nonlogical rule also significantly influenced the number of correct answers, $F(1, 47) = 5.05, p < .029$, with a higher percentage of correct answers registered with the DA rule (50.86%) than with the AC rule (43.23%).

C) Influence of Experimental Factors on the Subjects' Confidence

The subjects were asked to indicate for each of the items the certainty they felt about the conclusion which, in their opinion, could be deduced from the premises. Each one of the answers was marked on a scale ranging from 1 (*not at all sure*) to 7 (*completely sure*). In Table 3 are displayed the means of the subjects' confidence for all experimental conditions.

Table 3
Subject's Confidence (Means) in each Experimental Condition

		Deterministic		Probabilistic		Without specific relation		TOTAL	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Available	MP	6.65	1.00	6.30	1.15	6.25	1.35	6.40	0.20
	MT	6.30	1.45	6.15	1.65	6.00	1.40	6.15	0.10
	AC	6.25	1.45	6.20	1.65	6.15	1.55	6.20	0.05
	DA	6.20	1.45	6.15	1.55	6.05	1.40	6.15	0.05
	Total	6.35	0.20	6.20	0.20	6.10	0.10	6.20	0.10
Unavailable	MP	6.60	1.50	6.25	1.85	6.20	1.50	6.35	0.15
	MT	6.00	1.85	6.10	1.75	6.00	1.70	6.00	0.05
	AC	6.20	1.40	6.15	1.70	6.00	1.60	6.10	0.10
	DA	6.10	1.20	6.20	2.00	5.90	2.15	6.10	0.10
	Total	6.20	0.20	6.20	0.10	6.00	0.10	6.10	0.10
TOTAL		6.20	0.15	6.00	0.10	6.00	0.10	6.15	0.10

Note. MP = Modus Ponens; MT = Modus Tollens; AC = Affirmation of the Consequent; DA = Denial of the Antecedent.

We performed a 3 x 2 x 4 *ANOVA* (Probability of Empirical Occurrence x Availability x Type of Rule). Differences with regard to availability were revealed: the subjects felt more certain about the correctness of their answer when they reasoned about available content ($M = 6.21$), than when they did so about unavailable content ($M = 6.13$). Despite the fact that the differences between the averages of both conditions appeared negligible, the results of the analyses indicated that they were statistically significant, $F(1, 47) = 4.96$, $p < .031$.

Similarly, we obtained significant differences in the certainty of the answers with regard to the type of rule, $F(2.70, 126.67) = 11.48$, $p < .0001$. Upon performing subsequent contrasts, significant differences were revealed between the MP and the MT rules, $F(1, 47) = 24.53$, $p < .0001$: the subjects felt more sure of their answers when they reasoned about MP problems than about MT ones. Furthermore, the subjects were more confident when they reasoned about any of these arguments (MP and MT) than about arguments of AC, $F(1, 47) = 10.991$, $p < .002$. Finally, there were significant differences in the certainty of the answer when the subjects reasoned about MP, MT and AC rules, as compared to DA rule, $F(1, 47) = 7.677$, $p < .001$.

The probability of empirical occurrence also significantly influenced the subjects' certainty of their answers, $F(1.44, 67.63) = 5.17$, $p < .015$. When the subjects reasoned about deterministic statements, they seemed more certain about their answers ($M = 6.27$) than when they reasoned about probabilistic statements ($M = 6.18$). Finally, statements with no empirical relation between antecedent and consequent provoked the least certainty in the subjects' reasoning ($M = 6.06$). Subsequent contrasts showed differences in the deterministic condition compared to the other two, $F(1, 47) = 6.87$, $p < .014$.

Discussion

We obtained significant differences in the number of correct answers, with regard to the type of rule. Correct performance in the four rules follows a decreasing progression in this order: MP - MT - DA - AC. We obtained the best performance, therefore, when the subjects reasoned about MP rules, followed by MT rules.

According to the theory of mental models, the MP inference is easier than the MT because in the former, the initial set of models does not need to be fleshed out to make the inference. The MT inference is more difficult because it requires fleshing out the set of models and keeping multiple models in mind. The revised version of the theory predicts the superiority of MP over MT: "inferences will be made more often 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).

Besides the number of correct logical answers, we used as a dependent variable the subjects' certainty about their

answers. The greater reasoning complexity with MT and specially, the greater load on operative memory, explain the lower degree of certainty registered in MT as compared with MP. In the same way, the subjects select the alternative *nothing follows* more frequently in the MT rule than in the MP. This result may be explained within the framework of the theory of mental models, bearing in mind that when reasoning about MT, the explicit model is eliminated and subjects only have the implicit model on hand, which they must develop to be able to generate the correct inference. However, occasionally this model is not developed, with the direct result that it is not possible to deduct any conclusion. In the MP rules, the percentage of subjects who select the alternative *nothing follows* is lower, as, in this case, the subjects are reasoning directly from the initial explicit model.

Our results also show that the MP and MT inferences are made more frequently 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 the AC occur more often than those of MT and DA.

Unlike the original version of the theory, which predicted 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 MP inference than in the AC.

In general, 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 inferences take place more often than the MT, as is posited by both versions, b) the MP occurs more frequently 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, but do not confirm the predictions of the original version; and c) the subjects produce the MP and the AC rules more often than the MT and the DA rules.

The results of this investigation confirm our predictions regarding the importance of knowledge about reasoning, following the trend revealed in previous investigations (Valiña, Seoane, Gehring, et al., 1992; Valiña, Seoane, Martín, et al., 1992). We obtained a significant interaction between the type of rule and probability of empirical occurrence of the statements. Thus, as Byrne and Johnson-Laird (1992) and Johnson-Laird and Byrne (1992) stated, the difficulty in the production of the four rules of inference is modulated by the *necessary* or *probable* character of the relation that they express. According to these authors, when subjects reason about a *deontic* or *necessary* relation (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 have to elaborate an explicit model from the information mentioned in the rule, as well as an implicit model.

The results of our experiment support this proposal. Effectively, the subjects registered the best performance with MP and MT rules with statements that expressed a deterministic relation. However, with MT problems, performance was worse, because the structure of the rule implies that the subjects could not reason directly from a single initial explicit model. Furthermore, in the MT rule, we observed poorer performance with probabilistic relations. In this case, added to the inherent difficulties in the formal structure of MT, is the fact that the probabilistic relation forces the subject 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 turned the relation into a fact that might or might 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 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, whereas a modal verb with a probabilistic character requires the elaboration of a series of alternative models that are intrinsically hypothetical, the modal verb which expresses a relation of necessity brings about the construction of a single simple factual model.

Furthermore, the interaction registered between the probability of empirical occurrence and the type of rule reveals that, in the AC and DA rules, the lower the possibility of activating empirical knowledge, the better performance will be. These results may be explained by the existence of a bias towards nonpropositional conclusions that guides subjects towards a correct conclusion. In this respect, the subjects may choose the correct alternative simply because the absence of an empirical relation between the elements of the rule leads them to reject the task more often, and, consequently, to answer that it is not possible to arrive at 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. These authors observed that, as confidence decreased in the conditional relation, reasoning with the AC became more difficult, whereas it had no effect upon the DA rule. Our results in the without-specific-relation condition, with AC and DA rules, support those of Stevenson and Over. Effectively, the lack of an empirical relation between the antecedent and the consequent make performance more difficult with AC rules than with DA rules. In general, these authors explained 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, p. 640).

Similarly, other authors (Cummins, Lubart, Alksnis, & Rist, 1991) underlined the importance of the *content* of conditional statements on the production of inference rules. These authors designed an investigation that analyzed the influence of the statements' *form* and *content* on the subjects' reasoning with decontextualized conditional arguments. As in our experiment, the authors presented the subjects with problems using 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 interaction between form and content, which led them to characterize human reasoning as fundamentally pragmatic: "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 et al., p. 275).

If we note the similarity of the probability of empirical occurrence variable that we used, the deterministic level may be considered similar to the condition of a narrow relation between antecedent and consequent, so that there are no possible "alternative causes" in the conclusion that is presented. On the contrary, we can consider the probabilistic level to be similar to the condition where the content is flexible about 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, the lower the probability of interpreting the statements as biconditionals. In conditionals whose consequence is probable, the subjects produce MP and MT rules less frequently than in deterministic statements. The subjects make the AC and DA inferences with deterministic statements, because they are interpreted more often as biconditionals. According to the authors, the less "alternative causes" the subject is able to elaborate, the better the performance of MP, MT, AC, and DA rules.

As they had predicted, Cummins et al. (1991) found a similar interaction to the one we obtained between form and empirical frequency. These results confirm that the type of inference was 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 is reflected in the possibility of activating empirical knowledge from the empirical frequency of the statements that were presented. These variables determine the search for plausible conclusions elaborated from empirical knowledge, and not from logical or necessary conclusions elaborated by the activation of formal rules.

Moreover, we confirm our empirical expectations with regard to availability. As Evans (1984) stated, availability

was not sufficient 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 decontextualized arguments does not improve the subjects' performance when compared to the inclusion of unavailable professions. However, the subjects' degree of confidence about their answers increases.

Nonetheless, we could not confirm one of our predictions made regarding availability of the scenario. Like Pollard and Evans (1987), who proposed the influence of context-content variables on reasoning, we expected to register a significant interaction 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 confidence about their answers when the subjects reasoned about deterministic relations, presented in available contexts. Similarly, the poorest performance and lowest degree of confidence about their answers would be registered when the subjects reasoned about statements without specific relation, in unavailable contexts. However, we could not confirm these predictions because no interaction was observed.

In spite of this, in the context of this experiment, when referring to "available scenarios," we are simply referring to conditional arguments that include available professions. Perhaps the way we manipulated this variable and the type of task presented may explain the absence of significant effects of this factor on correct performance. It is important to undertake new investigations in the future to see whether the effect of this variable on reasoning is greater when conditional arguments included in texts are used, which would 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 & De Vega, 1988, p. 58).

References

Byrne, R.M.J., & Johnson-Laird, P.N. (1992). The spontaneous use of propositional connectives. *The Quarterly Journal of Experimental Psychology, 45A*, 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 reasoning and causation. *Memory and Cognition, 19*, 274-282.

Evans, J.St.B.T. (1982). *The Psychology of deductive reasoning.* London: Routledge.

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

Evans, J.St. B.T. (1989). *Bias in human reasoning: Causes and consequences.* Hillsdale, NJ: Erlbaum.

Evans, J.St.B.T. (1993). The mental model theory of conditional reasoning: Critical appraisal and revision. *Cognition, 48*, 1-20.

Evans, J.St.B.T. (1995). Relevance and reasoning. In S.E. Newstead & J.St.B.T. Evans (Eds.), *Perspectives on thinking and reasoning. Essays in honour of Peter Wason* (pp. 147-171). Hove: UK: Erlbaum.

Evans, J.St.B.T., Newstead, S.E., & Byrne, R.M.J. (1993). *Human reasoning: The psychology of deduction.* Hove, UK: Erlbaum.

Holyoak, K.J., & Cheng, P.W. (1995a). 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, NJ: Erlbaum.

Holyoak, K.J., & Cheng, P.W. (1995b). Pragmatic reasoning with a point of view. *Thinking and Reasoning, 1*, 289-313.

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

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

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

Johnson-Laird, P.N., & Byrne, R.M.J. (1994). Models, necessity, and the search for counterexamples. *Behavioral and Brain Sciences, 17*, 775-777.

Manktelow, K.I., & Over, D.E. (1991). Social roles and utilities in reasonig with deontic conditionals. *Cognition, 39*, 85-105.

Martín, M. (1996). *Una exploración del razonamiento cotidiano: importancia del conocimiento en inferencia condicional.* Unpublished doctoral dissertation. University of Santiago de Compostela, Spain.

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

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.

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

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

Seoane, G., & Valiña, M.D. (1988). Efecto del contenido y microgénesis de la tarea en inferencia condicional. *Cognitiva, 1*, 217-298.

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

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

Valiña, M.D. (1988). Efecto del contenido y microgénesis de la tarea en razonamiento silogístico con cuantificadores

probabilísticos: un estudio cronométrico. *Cognitiva, 1,* 199-212.

Valiña, M.D. (in press). Razonamiento pragmático. In M. Carretero (Ed.), *Psicología del Pensamiento.* Madrid: Aique.

Valiña, M.D., Seoane, G., Ferraces, M.J., & Martín, M. (1995). Tarea de selección de Wason: un estudio de las diferencias individuales. *Psicothema, 7,* 641-653.

Valiña, M.D., Seoane, G., Ferraces, M.J., & Martín, M. (1996a, August). *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, London.

Valiña, M.D., Seoane, G., Ferraces, M.J., & Martín, M. (1996b, September). *Pragmatic factors in conditional reasoning.* Paper presented at The Ninth Conference of European Society for Cognitive Psychology, Würzburg, Germany.

Valiña, M.D., Seoane, G., Ferraces, M.J., & Martín, M. (1998). La tarea de selección de Wason: ¿efecto del contenido, efecto de las instrucciones o ambos? *Estudios de Psicología, 60,* 15-34.

Valiña, M.D., Seoane, G., Gehring, S., Ferraces, M.J., & Fernández-Rey, J. (1992, September). *Conditional reasoning: Scenario or context effects.* Paper presented at The Fifth Conference of the European Society for Cognitive Psychology, Paris.

Valiña, M.D., Seoane, G., Martín, M., Fernández-Rey, J., & Ferraces, M.J. (1992, September). *The role of content and context in pragmatic reasoning.* Paper presented at The Fifth Conference of the European Society for Cognitive Psychology, Paris.

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

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

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