PART I.
COGNITIVE PSYCHOLOGY:

Chapter 1

PRAGMATIC SYLLOGISTIC REASONING IS CONDITIONAL REASONING

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ABSTRACT

Ford (1995) has proposed that syllogisms can be solved by means of conditional rules. In opposition, mental models (Johnson-Laird and Byrne, 1991) argues that syllogisms are solved following the semantic procedure of building up mental models. In this paper we consider the hypothesis that syllogisms could be solved by means of conditional rules depending on whether syllogistic deduction is aimed at practical purposes, or not. Specifically, we examine the case of syllogisms with a causal-agency content (one premise containing a causal relation, and the other premise making reference to an agent affected either by the causal antecedent or the consequence). For example, this causal-agency syllogism:

"All people that drive cars dangerously are risking a violent death",
"John drive cars dangerously",

would lead reasoners to draw the conclusion "John is risking a violent death ". This is a practical conclusion because it contitutes a predictive agency consequence in which John himself or people related to him would be interested. This conclusion would be made by means of the application of a conditional rule as modus ponens: "If everyone that carries out the conduct of driving cars dangerously has the consequence of risking a violent death, and an agent (John) is found that carries out the conduct, then John has the consequence of risking a violent death".
One experiment was carried out that compared causal-agency and control content syllogisms which were presented in different conditional forms (the agency premise affirming the antecedent, or denying the consequence of the causal premise). We found that the conclusions to causal-agency syllogisms clearly followed the pattern to be hoped for if the subjects made use of conditional rules, which clearly contrasted with the conclusions given to the control syllogisms. Our results support the idea that human deduction is practical in several relevant cognitive domains (Cheng and Holyoak, 1985; Cosmides, 1989).

A categorical syllogism has two premises, the major and the minor, and three terms: the subject, predicate and middle terms. The task consists of finding a relation between the premises in order to draw a logically necessary consequence. The consequences or conclusions must relate the end terms (the subject and the predicate), based on their mutual reference to the middle term. The following is a classic example of a syllogism:

First premise: "All men (middle term) are mortal (predicate)" .
Second premise: "Socrates (subject) is a man (middle term)".

Conclusion or consequence: "Socrates (subject) is mortal (predicate)".

Both premises and conclusion are statements of one of four types or moods: "All A are B" (A), "Some A are B" (I). "No A are B" (E) and "Some A are not B" (O). The arrangement of the end and middle terms in each of the premises gives rise to a four -way classification known as the figure of the syllogisms. The combination between the figure of the syllogisms and its mood gives rise to a substantial number of different syllogisms of which only a few have a propositionally (logically correct) valid conclusion; that is to say, a conclusion necessarily derived from the premises.

An important question in the debate concerning syllogistic reasoning refers to whether reasoners solve syllogisms by means of rules (i.e. Rips, 1994; Stenning and Yule, 1997, Ford, 1995), or they solve them by means of building up mental models (Johnson-Laird and Byrne, 1991). In this context, Ford (1995) has proposed that reasoners solve syllogisms by means of conditional rules when they follow a verbal strategy. According to Ford (1995) reasoners manipulate the verbal form of syllogisms as an algebraic problem, and "take one premise as having a term that needs to be substituted with another term and the other premise as providing a value for that substitution. The premise that provides the value for substitution acts as a rule relating membership of class C to a property P, while the premise containing the term that needs to be substituted acts as a case of specific objects, O, whose status with regard to either C or P is known" (pg.21). Subsequently, appropriate rules are applied in order to draw a conclusion. For example, the application of the modus ponens rule-type is as follows: "if every member of the class, C, has the property, P, and a specific object, O, is a member of C, then O has the property P. The application of modus tollens rule-type is as follows: "if every member of class, C, has the property, P, and a specific object, O, does not have the property P, then O is not a member of class C". The following syllogism for example is represented in this way:

"All pilots (C) are beekeepers (P)"
"All physicists (O) are pilots (C)
_____
O= Specific objects; C=Class; P=Property.

Such a representation would lead reasoners, by means of a modus ponens application, to the conclusion:

"All physicists (O) are beekeepers (P)".

In a clearly different position, Johnson-Laird and Byrne´s (1991) proposal bases syllogistic resolution on a semantic process: the building up of mental models. Firstly, a mental model of each premise is constructed according to the quantifier. Then the premise models are integrated in a composite mental model which enable the drawing of an informative conclusion. A following deductive stage deals with searching for conclusions compatible with the premises, but contradictory with the informative conclusion. This search is made in order to find the conclusion necessarily derived from the premises. From the mental models approach, reasoners build-up a composite mental model of the previously shown syllogism as follows:

$$[[P] B] Ph$$
$$...$$
_____
P= Pilots; B=Beekeepers; Ph=Physicists.

In this composite mental model the class relationship described in the premises is represented by means of specific tokens, and the square brackets around P mean that the set of people that are pilots have been exhaustively represented in the model. The three dots allow other sorts of individual yet to be made explicit. For simplicity, the number of individuals is likely to be small. This composite mental model directly enables reasoners to draw the conclusion "All pilots are physicists".

PRAGMATIC SYLLOGISTIC REASONING

In this paper we consider the hypothesis that conditional syllogistic resolution could depend on whether syllogistic reasoning is aimed at drawing a practical conclusion, or not. Specifically, we examine the case of syllogisms formed of a causal premise and an agency premise such as follows:

"All persons that drive cars dangerously are risking a violent death", and
"John drives cars dangerously ",

The first premise is the causal premise and relates a certain conduct to the consequence of risking a violent death. The second is the agency premise and introduces the supposition of a certain agent (i.e. John) carrying out the conduct. This syllogism would lead to the conclusion "John is risking a violent death", but this conclusion is practical because its goal would be to predictively inform (to John himself, or other people interested in him) about a potential danger to him if he carries out the conduct. We hypothesised that this conclusion is reached by means of the application of a modus ponens conditional rule such as "If every person that carries out the conduct of driving cars dangerously has the consequence of risking a violent death, and an agent (John) is found that carries out the conduct, then John has the consequence of risking a violent death.

We suggest that the causal-agency syllogistic reasoning would constitute a type of deductive reasoning that people frequently carry out in social contexts. This would be a type of reasoning whose goals are to anticipate and explain the effects on the agents of certain causal conditions in which they could be involved. This type of reasoning would act in behavioural planning and could refer to both negative (as in the previous example) and positive consequences. For example, if someone is interested in being socially-responsible[1] then he/she could construct an argument composed of a causal premise (whose source is his/her world knowledge) and an agency premise as follows:

> " People who cooperate with humanitarian associations are people that make themselves socially-responsible",
> " I cooperate with humanitarian associations".

This causal-agency argument leads him/her to the conclusion " I make myself socially-responsible" and confirms to the planner the utility of the conduct of cooperating with humanitarian associations in order to attain the goal of making himself/herself socially-responsible. As can be seen, predictive causal-agency syllogistic reasoning could be related to the prevention of negative consequences or the search for positive consequences. Likewise the argument could apply to oneself as an agent, or to the others as the agent. The agent could be individuals or refer to a collective agency.

Its activation is quite mechanical. In general the presentation of a causal premise joined to a premise with an agency supposition, is enough to trigger a reasoning process aimed at the goal of drawing a practical conclusion. The agency premise is a supposition so that its recognition is not dependent on it being realistic or whether or not the consequence is desired by the agent. For example, causal-agency reasoning would perform in this syllogism containing a warning of religious punishment as the causal premise:

> "All people that behave badly are people that go to hell"
> "All chemists are people that behave badly",
> leading to the predictive (but unrealistic) conclusion: "all chemists are people that go to hell".

In the above examples causal-agency reasoning is used with the goal of anticipating consequences in a behavioural planning context. This type of reasoning could also have the goal of explaining the agent's achievements and characteristics. For example, suppose that someone met a man, John, and became intrigued by his unaggressive personality. He/she could ask himself/herself about this appealing personality trait and then elaborate the following argument:

> "People who have been brought up in a violent family are people who have an aggressive personality",
> "John is a person who does not have an aggressive personality", so that:
> "John is a person who has not been brought up in a violent family",

which constitutes an explicative conclusion about John's personality. We hypothesised that this conclusion is reached by means of the application of a modus tollens conditional rule such as "If every person affected by the condition of being brought up in a violent family had the consequence of having an aggressive personality, and an agent (John) is found that does not have the consequence, then John has

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[1] Socially-responsible was the nearest translation of the spanish word "solidario". Solidario has a common meaning related to being sensitive to the problems of socially disadvantaged people and acting altruistically in order to help them. There is no direct synonym in english.

not been affected by the condition of being brought up in a violent family". The prediction process proceeds forwards towards the consequence while the explicative process proceeds backwards towards the cause.

Several researchers have demonstrated that conditional inferences could be practically aimed (Cheng and Holyoak, 1985, Cosmides, 1989; Cheng and Nisbett, 1993; Gingerenzer & Hug, 1992; Manktelow, Fairley, Kilpatrick and Over, 2000; Fiddick, Cosmides and Tooby, 2000). For example, Cheng and Holyoak (1985) noted "Although a syntactically based system tells us which inferences are valid, it does not tell us which inferences are useful among the potentially many that are valid" and illustrated the point with an example. Given the statement "If I have a headache then I should take some aspirin", a logic-based reasoning system permits its contra-positive transformation to "If it is not the case that I should take some aspirin, then I do not have a headache" (p.395). However, this is hardly a useful inference to make. The fact of having a problem creates the goal of finding a remedy to it, but the absence of the need for a remedy does not imply the absence of the problem. Cheng and Holyoak (1985) stated that reasoning about permission, obligation and causation is based on pragmatic schemes.

Cheng and Nisbett (1993) have proposed that causal conditional deductive reasoning is pragmatically aimed at the goals of informative prediction and explanation. These authors noted that "causal deduction cannot be subsumed under rules of natural logic associated either with the connective if or with the condition relations of necessity and sufficiency" (pg.208). According to Cheng and Nisbett (1993), and focusing on prediction, deductions based on a causal conditional will elicit assumptions about contingency which cannot be represented in propositional logic. Contingency is related to the difference between the probabilities of the effect given the presence versus the absence of the cause...Contingency predicts that "A is a sufficient cause of B" implies not only "if A occurs then B always occurs" but also "if A does not occur then B is less likely to occur (p. 215). These authors also pointed out that temporal directionality (the cause happening before the effect) is also taken into account in causal reasoning. In this paper we propose that causal-agency syllogistic reasoning constitutes another form of causal deductive reasoning. Moreover, and as can be seen in the previous examples, the causal premise of causal-agency syllogisms fulfilled the requirements necessary to be interpreted as such: that is, contingency and temporality between the causal condition and the consequence.

EXPERIMENT

In this experiment we tested the hypothesis that conditional syllogistic resolution depends on the content. Specifically, we predicted that the subjects would solve syllogisms with a causal-agency content by means of the application of conditional rules. The causal-agency syllogisms were presented in two different forms: either the agency premise affirming the antecedent or denying the consequence of the causal premise:

> "All persons that participate in experiments are persons that contribute to scientific progress"
> "All students are persons that participate in experiments"(affirming the antecedent).
> "All persons that participate in experiments are persons that contribute to scientific progress"
> "No student is a person that contributes to scientific progress"(denial of the consequence).

The predicted conclusions are different from the mental models and conditional syllogistic resolution. From conditional syllogistic resolution, the subjects would give the conclusion: "All students are person that contribute to scientific progress" in the affirming of the antecedent version because they made use of a modus ponens conditional rule such as: "If every person that carries out the conduct of participating in experiments has the consequence of contributing to scientific progress, and an agent (the students) is found that carries out the conduct, then the students has the consequence of contributing to scientific progress"; in the case of the denial of the consequence version they would give the conclusion: "No student is a person that participates in experiments" because they made use of modus tollens conditional rule such as: "If every person that carries out the conduct of participating in experiments has the consequence of contributing to scientific progress, and an agent (the students) is found that does not have the consequence, then no student carries out the conduct of participating in experiments". On the other hand, from mental models resolution, the same conclusion to the affirming of the antecedent version is predicted because the subjects build-up a composite mental model that directly enables them to draw it:

$$[S]\ P]\ C$$
$$...$$

_____

S=Students; P=Persons that participate in experiments; C=Persons that contribute to scientific progress.

But mental models predicts a different conclusion: "No person that participates in experiments is a student" in the case of the denying the consequence version. The subjects in this case also build-up a composite mental model that directly enables them to draw the above conclusion(see Johnson-Laird and Byrne, 1991):

                                        [[P] C]
                                        [[P] C]
                                               [S]
                                               [S]

_____

    P=Persons that participate in experiments; C=Persons that contribute to scientific progress; S=Students.

We introduced a control content by presenting the syllogism as follows:

    "All persons that participate in experiments are persons that normally drink beer"
    "All taxpayers are persons that participate in experiments" (*control content of affirming the antecedent version*).
    "All persons that participate in experiments are persons that normally drink beer"
    "No taxpayer is a person that normally drinks beer" (*control content of denial of the consequence version*).

As can be seen, the terms in the first premise were not causally related while the agent "students" in the second premise was replaced by a lesser agency role (the role of taxpayer is basically related to a social obligation). As a consequence, we expected that the conclusions for both syllogism versions would follow the pattern to be hoped for if the subjects solve the syllogisms by means of building up mental models. We also introduced an additional experimental manipulation. We reversed the order of the terms in both syllogism premises as follows:

    "All persons that contribute to scientific progress are persons that participate in experiments"
    "All persons that participate in experiments are students" (*reversed affirming the antecedent version*).
    "All persons that contribute to scientific progress are persons that participate in experiments"
    "No person that contributes to scientific progress is a student" (*reversed denial of the consequence version).*
    "All persons that normally drink beer are persons that participate in experiments"
    "All persons that participate in experiments are taxpayers" (*reversed control affirming the antecedent version*).
    "All persons that normally drink beer are persons that participate in experiments"
    "No person that normally drinks beer is a taxpayer" (*reversed control denial of the consequence version*).

    This manipulation enables us to make a greater contrast between the predictions from mental models and conditional syllogistic reasoning. From conditional syllogistic reasoning the more frequent conclusions to causal-agency syllogisms are the same as in the non-reversed version. The subjects tend to recognise the causal-agency content and then they reversed the order of the terms in order to draw a conditional conclusion (see Gámez and Marrero, 2000). In a different way, mental models predicts the conclusion :"All persons that contribute to scientific progress are students" and "All persons that normally drink beer are taxpayers" to the experimental and control reversed versions of the affirming the antecedent syllogisms. This is because the subjects directly build up the corresponding composite mental models as follows:

Causal-agency content   Control content
[[C] P] S   [[D] P] T
...   ...
_____

    C=Persons that cooperate in experiments, P=Persons that participate in experiments, S=Students, D=Persons that normally drink beer, T=Taxpayers.

In the case of reversed denial of the consequence syllogisms both in the experimental and control versions, mental models predicts two possibilities. If subjects attained a valid conclusion they gave these conclusions: "Some persons that contribute to scientific progress are not students" and "Some persons that normally drink beer are not taxpayers" to causal-agency and control content syllogisms. But this does not happen so frequently (23.8%, see Johnson-Laird and Byrne, 1991). Another possibility is that the subjects

gave the informative conclusion as valid without checking it against other syllogism models. This informative conclusion is universal and negative, and given that these syllogisms are not affected by the figural effect (see Jonhson-Laird and Byrne, 1991), mental models predicts that the subjects gave one of these conclusions: "No person that contributes to scientific progress is a student" and "No student is a person that contributes to scientific progress" half of the time; and in the case of the content control syllogisms: "No person that normally drinks beer is a taxpayer" and "No taxpayer is a person that normally drink beer".

In this experiment we controlled the effect of conclusion believability. This effect is related to subjects´ tendency to accept or to draw believable but invalid conclusions or, conversely, to reject or not to draw valid but unbelievable conclusions (Oakhill, Jonhson-Laird & Garnham, 1989; Newstead , Pollard, Evans & Allen, 1992; Santamaría, García-Madruga and Carretero, 1996; Cherubini, Garnham, Oakhill and Morley, 1998). As the believability effect is a potential source of biasing syllogistic conclusions we need to discard it as an alternative explanation of our experimental hypothesis.

Method.

Subjects. Ninety six pedagogy students at the University of La Laguna.
Design. The design had a within-subjects factor "Form of syllogisms": standard and reversed, and two between-subjects factors "Type of agency premise: affirming the antecedent and denial of the consequence and "Type of content": causal-agency and control content. The dependent variables were the frequencies of conditional-type conclusions.
Material. Four booklets were elaborated: causal-agency content-affirming the antecedent, causal-agency content-denial of the consequence, control content-affirming the antecedent and control content-denial of the consequence. The experimental within-subjects condition "Form of syllogisms" was counterbalanced so that if a certain syllogism appeared in one of the booklets in the standard form then it appeared in the other booklet in the reversed form (and vice versa) within the same between-subjects condition. As a result eight booklets were provided for the subjects. On the first page of each booklet, standard instructions were given about how to solve the task, with two completed examples. The following four pages contained 16 syllogisms, the 8 experimental syllogisms alternating with the 8 filler syllogisms (four syllogisms for each). Below each syllogism there were three lines for the participants to write the conclusion(s). The filler syllogisms had different forms.
Below are the 8 versions of the previously shown experimental syllogism:

Causal-agency syllogisms:

"All persons that participate in experiments are persons that contribute to scientific progress"
"All students are persons that participate in experiments" (*standard and affirming the antecedent version*).
"All persons that participate in experiments are persons that contribute to scientific progress"
"No student is a person that contributes to scientific progress" (*standard and denial of the consequence version*).
"All persons that contribute to scientific progress are persons that participate in experiments"
"All persons that partipate in experiments are students" (*reversed and affirming the antecedent version*).
"All persons that contribute to scientific progress are persons that participate in experiments"
"No person that contributed to scientific progress is a student" (*reversed and denial of the consequence version*).

Control content syllogisms:

"All persons that participate in experiments are persons that normally drink beer"
"All taxpayers are persons that participate in experiments" (*standard and affirming the antecedent version*).
"All persons that participate in experiments are persons that normally drink beer"
"No taxpayer is a person that normally drinks beer" (*standard and denial of the consequence version).*
"All persons that normally drink beer are persons that participate in experiments"
"All persons that partipate in experiments are taxpayers". (*reversed and affirming the antecedent version*).

> "All persons that normally drink beer are persons that participate in experiments"
> "No person that normally drinks beer is a taxpayer" (*reversed and denial of the consequence version*).

The causal-agency and control syllogisms differed in the first and the second premises. In the case of causal-agency syllogisms the first premise performed as the causal premise and contained a generic agent (" All persons") carrying out a conduct, and a term referring to an agency behavioural consequence. The interpretation of these terms as consequences was reinforced by means of using the following verbal expressions: to promote, to encourage, to show (two items), to get, to make, to contribute and to help to improve. In the case of control syllogisms, the terms referring to consequences were replaced by terms that were not related to the conducts, and the verbal causal indicators were suppressed. And, in the second premise the agent students was substituted by a less active term (taxpayers).

Twenty raters evaluated the suitability of a causal interpretation of the causal premise of experimental and control syllogisms. The sixteen questions were presented in a booklet with 10 filler questions and a short instruction about the nature of the task. After the presentation of a premise, its causal interpretation appeared, and the raters were asked to evaluate its suitability. For example:

> "All persons that participate in experiments are persons that contribute to scientific progress".

Causal interpretation: that, frequently, "those persons that participate in experiments contribute as a consequence to scientific progress".

> (   )SUITABLE   (   )UNSUITABLE.

We found that the raters considered the causal interpretation of the causal premises as suitable 74% of the time, the range being from 55% to 95%. However, in the case of the control syllogisms we found that the raters considered the causal interpretation as unsuitable 90% of the time, ranging from 80% to 100%.

Forty raters evaluated the believability of both the conditional and (alternative) formal syllogism conclusions (twenty raters evaluated the causal-agency syllogisms-ten the affirming of the antecedent and ten the denial of the consequence versions-) and twenty the control content syllogisms). We consider as alternative formal conclusions those conclusions that had the same mood (either universal affirmative or universal negative) as the conditional conclusion but that presented the end terms in the alternative order. Syllogisms with universal quantifiers in both premises favour the drawing of universal conclusions, being the affirmative conclusion if both syllogism premises are affirmative, and negative if at least one of the premises is negative (Woodworth and Sells, 1935, Begg and Denny, 1969, Wheterick and Gilhooly, 1990). Moreover the fact that the syllogisms had a universal affirmative premise (the first premise) would facilitate that a subject had a choice between the two conclusions representing the two possible end terms order. This possibility would be the result of first premise misinterpretation inasmuch as All quantified premises are frequently misinterpreted to implicate the identity set (All A are B= All B are A) (Chapman and Chapman, 1959; Newstead and Griggs, 1999). If the subjects had the possibility of choosing between two conclusions then they could select that of these conclusions that seem to them more believable.

Both conclusion versions (conditional and formal) were presented to the raters in pairs. We considered that comparative assessment of related conclusions would more closely approximate what happens when subjects are solving a syllogism and evaluating putative conclusions. However, the raters were not given any premises. They were simply asked to rate the plausibility of the conclusions as statements. Their task was to rate each statement on a scale of 1 (completely unbelievable) to 7 (completely believable). The data will be considered in the results below.

Procedure. The different booklets were randomly given out to the students during regular class time without a time limit being imposed. Forty eight subjects were given the causal-agency content condition: Twenty four (affirming the antecedent version) and twenty four (denial of the consequnce version), and forty eight subjects received the control content condition: Twenty four (affirming the antecedent version) and twenty four (denial of the consequence version). Within each between-subject condition half of the subjects received one of the booklets and the other half the other booklet corresponding to the counterbalancing of the within-subjects factor "Form of the syllogisms".

Results

In Table 1 the percentages of subjects who drew conditional conclusions (the complementary percentages

corresponded to formal conclusions) for causal-agency and control content syllogisms in the affirming the antecedent and denial of the consequence versions, with both standard and reversed forms are shown. Ten subjects (six from the agency-content condition and four from the control content condition) were excluded because a substantial number of their conclusions were not acceptable. This was because they included the middle term, or that the conclusion was only a mere repetition of one of the premises, with their terms usually inverted.

Table 1. Percentages of conditional conclusions for causal-agency and control content syllogisms in figure1and figure 2 (Exp. 1).

		Causal-agency content		Control content	
		Affirming the antecedent	Denial of Consecuent	Affirming the antecedent	Denial of Consecuent
Form of syllogism	Standard	93%	88%	59%	56%
	Reversed	65%	85%	13%	26%

We carried out an analysis of variance, with a within-subjects factor, "Form of the syllogisms", and two between-subject factors "Type of agency premise" and "type of content".
The interaction form of syllogism*type of content was significant, $F_{(1,82)}=10.23$ $p=0.002$. As can be seen in table 1, the reversion of syllogism terms had a visible effect in reducing the percentage of conditional conclusions only in the case of control content syllogisms (75% for reversed causal-agency syllogisms in contrast to 19% for control content syllogisms). The interaction form of syllogisms*type of agency premise was also significant, $F_{(1,82)}=8,21$, $p=0.005$. As can be seen in table 1, the reversion of syllogism terms had a greater effect in reducing the percentage of conditional conclusions in the case of affirming the antecedent syllogism version in comparison to the denial of the consequence version (37% in contrast to 56%). The within-subjects condition "form of syllogisms" was highly significant, $F_{(1,82)}=57.07$, $p<0.000$. The percentage of conditional conclusions was greater in the standard form condition (74%) than in the reversed form condition (46%). The between-subjects condition "type of content" was also highly significant, $F_{(1,82)}=68.33$ $p<0.000$. The percentage of conditional conclusions was clearly higher in the causal-agency content (83%) than in the control content (38%). The between-subject condition type of agency premise and the interactions type of content*type of agency premise and form of syllogisms*type of content*type of agency premise were not significant, $p>.20$.
As a whole these results show several relevant effects. Firstly, a strong effect of the content is demonstrated. Causal-agency content lead subjects to draw a high proportion of conditional conclusions in a clear contrast with the control content. Therefore, this result supports our hypothesis: the causal-agency content syllogisms would have been solved by means of the application of the appropriate conditional rules. Conversely, the more frequent conclusions to the control content syllogisms were those predicted from a mental models procedure of syllogistic resolution.The form of syllogism was also shown as a strong effect. The reversion of the syllogism terms had a clear effect in reducing the percentage of conditional conclusions. But, as we expected, the reversion had this effect mainly in the case of control content syllogisms as the interaction form of the syllogism*type of content demonstrated.
The results also show that the reversion of syllogism terms had a greater effect in reducing the percentage of conditional conclusions in the case of affirming the antecedent version than in the case of the denial of the consequence version (interaction form of syllogism*type of agency premise). This result would be due to the fact that the reversion of syllogism terms favours the formal conclusion in the case of affirming the antecedent condition. These syllogisms had the form of figure 1 and this figure favours the drawing of conclusions that start with the end term in the first premise, that is, the formal conclusion (see Johnson-Laird and Byrne, 1991).
In the case of causal-agency syllogisms we found that the believability degree of conditional and formal conclusions in the case of affirming the antecedent versions was similar and between the "a little believable" and "moderately believable" degree (3.70 and 3.10, respectively). In the case of causal-agency denial of the consequence version the believability degree of conditional and formal conclusions was also similar and low (2.64 and 2.35). In the case of control content syllogisms we found that the believability degree of conditional and formal conclusions to the affirming of the antecedent version was similar and around the "a little believable" degree (2.71 and 2.92, respectively). If we consider the denial of the consequence version, we found that the believability degree of conditional and formal conclusions was also similar (2.84 and 2.84, respectively). These results clearly show that the causal-agency bias towards conditional conclusions that we have found cannot be attributed to a believability effect because both conditional and formal conclusions had a low and similar degree of believability.
Although the causal-agency bias did not seem to be affected by the conclusion believability this does not

imply that the subjects were not trying to draw plausible conclusions. The plausibility of a conditional conclusion would not depend on its true status in the real world but would rather depend on the appropriate evaluation of a causal agency supposition; in this context, if we accept the possibility that all students carry out a certain action, then it plausibly follows that the students are affected by the consequence.

CONCLUSIONS

The debate about the cognitive process involved in syllogistic reasoning is extensive. At the core of this debate there is a dichotomy between the authors that claim that syllogistic reasoning is based on rules (Rips, 1994; Ford, 1995; Stenning and Yule, 1997) and those that posit mental models (Johnson-Laird and Bara, 1984; Johnson-Laird and Byrne, 1991). Although the former share the idea that syllogistic reasoning is based on rules, they differ widely in modelling the nature of these rules and the way they act, for example, the natural deduction approach (Rips, 1994) and the conditional rules verbal strategy approach (Ford, 1995). Other recent approaches are also relevant in the debate. This is the case of the Heuristic approach (Chater and Oaksford, 1999) that explores the possibilities of a probabilistic theoretical framework in understanding syllogistic reasoning. Our contribution to the research is the idea that syllogistic reasoning is not based on a general cognitive procedure (either rules or mental models). The syllogism content is very relevant in inducing reasoners to the procedure for syllogistic resolution. As we have demonstrated, a causal-agency content induces the subjects to draw a practical conclusion based on applying the appropriate conditional rules. However, the conclusions given by the subjects to syllogisms with a more arbitrary content (control content syllogisms) fulfilled the predictions if the subjects use a mental model procedure.

The effect of content in syllogistic reasoning research has been focused on the believability effect. This effect is related to subjects´ tendency to accept or to draw believable but invalid conclusions or, conversely, to reject or not to draw valid but unbelievable conclusions.

According to the mental models approach, believability can influence syllogism resolution in three different ways (Oakhill et al., 1989): firstly it can affect the comprehension and representation of the premises. Secondly, it can influence the search for alternative conclusions in the case of multiple-model syllogisms by curtailing the search process, depending on the informative conclusion being believable or not. And thirdly the believability of the content could also act as a filter in the case of one-model syllogisms, by rejecting those conclusions that are unbelievable although valid.

More recently Cherubini et al. (1998) have suggested that prior knowledge could facilitate the conclusion process.. " if the relations between the end terms could be recovered from general knowledge before the modelling of the premises, this recovered information would provide a single believable conclusion which could be accepted without considering other possible conclusions (pg. 181)". According to the above authors the belief bias is due to the retrieval of prior knowledge relating the end terms, then checking that the premises are compatible with that knowledge, and then accepting the previous knowledge as a true conclusion from the premises.

As can be seen the believability effect is related to the process of comparing what conclusion follows from the syllogism premises and what is true in the real world (the direction of the process is under discussion). However, as we have shown the content could affect syllogistic deductive reasoning in a different way, that is, as inducing a conclusion of a practical nature. Both the believability and pragmatic effects are related to the requirement of giving plausible conclusions to syllogistic problems. However the plausibility of a pragmatic conclusion is not related to adapting the conclusion to the truth in the real world, insofar as it depends on the appropriate evaluation of an agency supposition. The conclusion "all chemist go to hell" is unbelievable but plausible if it is given to the causal-agency syllogism previously mentioned. In short, the causal-agency and conclusion believability biases differ in the type and nature of the influence that they have on syllogistic reasoning.

Deductive reasoning research has implications about the nature of the human mind: Is the human mind a general purpose processor, or is it a domain-specific modular cognitive system?. The idea of the mind as a general processor is well represented by the mental models approach. The same cognitive processes act in the resolution of deductive problems with different contents. On the other hand, the idea that the human mind is a domain-specific modular cognitive system is upheld by authors such as Cosmides (1989) and Cheng and Holyoak (1985). From this perspective, the cognitive procedures involved in solving deductive problems can vary according to the content. The mind would furnish cognitive rules specialised in solving different classes of adaptatively relevant problems. This specialisation could be the result of evolution (Cosmides, 1989) or learning (Cheng and Holyoak, 1985). There also are conciliatory positions. Within the framework of mental models, Bara and Bucciarelli (1997) have suggested that reasoning over

experienced content could be based on rules, while in the case of novel contents it would be based on mental models. These authors argue that " It is possible that previously acquired, well-organized knowledge is expressed in the abstract form of formal rules that might guide reasoning through a process which is straightforward and less costly than the construction and manipulation of models (p. 67).

Both the mental models and domain-specific rules approach are open to criticism. For example, the mental models proposal lacks a theory of the effect of the content in human deduction. Mental model researchers usually give post-hoc explanations about the effect of the content found by domain-specific rules authors. But the domain-specific rules approach is criticised because the basis of evidence for the effect of the content in human deductive reasoning is limited to some social activities (such as social contracts, or social permissions). In this context, our findings are relevant because they extend the basis of evidence of the effects of the content in human deduction.

We have claimed that causal-agency syllogistic reasoning acts in daily life in the service of the goals of agency prediction and explanation. Obviously, its form in real contexts would be more simple than that of the experimental syllogisms used here. Moreover its actuation and activation in real contexts deserve special attention. For example, if a condition of triggering causal-agency reasoning is when a person activates an agency premise (either related to prediction or explanation) then it is relevant to ask ourselves how the pertinent causal premise is searched for from his/her world knowledge. Further research is necessary to examine questions of this nature.

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