premise interpretation in conditional reasoning

Guy Politzer

In D. Hardman & L. Macchi (Eds.), Thinking: Psychological perspectives on reasoning, judgment, and decision making (pp.79-93). Chichester: Wiley

Premise Interpretation in Conditional Reasoning

Guy Politzer

Centre National de la Recherche Scientifique

Saint-Denis, France

Premise Interpretation in Conditional Reasoning

Conditional sentences are pervasive in human communication. Many arguments contain conditional premises or a conditional conclusion. The expression *conditional reasoning* could appropriately be applied to such arguments. However, there is a tradition in psychological research, which will be followed here, to restrict the use of this expression to refer to two-premise arguments that have one conditional premise (called the major), and a second premise (called the minor) made of either the antecedent of the conditional or its negation, or the consequent of the conditional or its negation. This leads to the following four arguments:

Two deductively valid arguments:

Modus Ponendo Ponens (henceforth MP):

if P then Q; P; therefore Q.

Modus Tollendo Tollens (MT):

if P then Q; not-Q; therefore not-P.

Two deductively invalid arguments:

The fallacy of affirming the consequent (AC):

if P then Q; Q; therefore P.

The fallacy of denying the antecedent (DA).

if P then Q; not-P; therefore not-Q.

Conditional reasoning is, on par with Wason's selection task, the most investigated paradigm in the psychology of reasoning . The general trend of performance with formal material (in which arguments are presented in their

symbolic form) seems robust, even though there is some variability due to factors such as instructions and response format. The conclusion of MP is endorsed by nearly eveybody, that of MT by around two thirds of the participants only, while both fallacies are committed by around one half of them (for a review, see Evans, 1982; Evans, Newstead & Byrne, 1993). It is hard to have as clear a picture of performance with thematic material, that is, material in which symbols P and Q are instantiated by short meaningful sentences. In some early studies (e. g. Matalon, 1962; T. C. O'Brien, 1972; Staudenmayer, 1975) it was already observed that the rate of endorsement was a function of the semantic content of the sentences; but this observation was rather incidental. More recent studies of conditional reasoning, with planned observations, have shown that the effects may be of considerable magnitude; they will be reviewed below. These results are not surprising given that investigations of conditionals have regularly shown differences in interpretation as a function of content (Fillenbaum, 1975, 1978; Legrenzi, 1970; Politzer, 1981; Wason & Johnson-Laird, 1972). Such effects have been given greater emphasis in the context of research on the thematic version of Wason's selection task where they soon became the main center of interest.

"Content effect" is the name traditionally given to the variation of responses and consequently of reasoning performance as a function of the semantic content of the premises. The present chapter aims to propose a theoretical framework to explain these effects in conditional reasoning. It will not concern itself with issues that oppose theories of deductive reasoning (such as the mental model - mental logic debate). The reason is that in focusing on the interpretative step (in particular, the pragmatic processes

involved in utterance interpretation) that precedes the inferential step proper, it is orthogonal to such a debate: This interpretative step yields the final semantic representation (be it a mental model or a syntactic expression) which serves as the input to the deductive step.

A formalisation of conditionals in context

When looking for a formal description of conditionals that could at the same time account for content effects, one area suggests itself, namely causality. The search for causal factors and the formation of a good hypothesis rely crucially on knowledge of the domain under investigation. Mackie's (1974) theory of causality provides two important concepts within a formalism that seems susceptible to generalisation to other conditionals. The first concept is that of a causal field. A cause acts in a context that contains other factors which formally are possible candidates for the role of a cause. However, they are not usually considered as a cause. They are not even mentioned in causal statements because it is tacitly accepted that they are present in the normal state of the world. This set of factors constitutes the causal field against which the factor identified as a cause is extracted by virtue of its difference in the field. A classical example of a factor that belongs to the causal field is the presence of oxygen in the air in case of an accidental explosion. Although physically a cause (in the sense that it is necessary for the explosion to occur) it is usually not considered as a cause and usually need not be mentioned.

Second, Mackie pointed out that a cause often has a fine-grained structure that can be described formally as a disjunctive form, so that the causal relation can be written as:

$[(A_m \&. . . \& A_1 \ \& A) \ v \ (B_n \&. . . \& B_1 \ \& B) \ v \ . . .] \text{ ----> } Q$

While the whole disjunctive form is both necessary and sufficient for the effect Q to occur, each disjunct as a whole such as $(A_m \&. . . \& A_1 \ \& A)$ is sufficient and each conjunct $(A, A1, . . , A_m)$ separately is necessary with respect to the disjunct in which it appears. $A_1, . . , A_m$, and $B_1, . . , B_n$ play the role of background conditions in the causal field with respect to A and B (the focal factors), respectively. Mackie did not explicitly combine both analyses, that is, the disjunctive form structure of a cause and the causal field (note 1). But given that any factor in the causal field has the same logical status as the cause, it is clear that these factors can be formally integrated conjunctively within the disjuncts of a normal form.

Generalising to other conditionals than causals (with possible exceptions such as analytically true conditionals) *if A then Q* could also be formalised as above. The factors with a subscript constitute what could be called by analogy a conditional field. The following abridged form, restricted to only two disjuncts of two conjuncts each, will be more manageable for purpose of exposition:

$[(A_1 \ \& A) \ v \ (B_1 \& B)] \text{ ----> } Q.$

1. Conjunctive components. *A* is the only factor in the antecedent that appears in the verbalisation of the conditional sentence, *If P then Q*. A_1 is a background condition which is assumed to be satisfied in the normal state of the world. Since its satisfaction is necessary to complement the antecedent

and turn the conjunct into a sufficient compound factor, it will be called a complementary necessary condition (CNC for short). In conversation, A_1 is assumed to be part of common knowledge. The necessity status of many such conditions is assumed by the speaker to be indisputable; their satisfaction is tacitly assumed in the same manner as factors in the causal field remains unmentioned. The existence of such conditions was recognised long ago, as suggested by the following quotes, first from Ramsey (1931): "In general we can say with Mill that 'if P then Q' means that Q is inferrable from P, that is, of course, from P together with certains facts and laws not stated but in some way indicated by the context", and second from Goodman (1947): "the assertion that a connection holds is made on the presumption that certain circumstances not stated in the antecedent obtain". The status of these facts or circumstances can nowadays be clarified on the basis of pragmatic theory. It is not the aim of the present paper to develop it. Suffice it to say that the assumption of satisfaction of CNC's comes as an epistemic implicature. Conditionals are typically uttered with an implicit *ceteris paribus* assumption to the effect that the speaker believes that the normal conditions of the world (the satisfaction of the CNC's that belong to common knowledge) hold. Should further information deny or just raise doubt on this assumption, the implicature is cancelled and the conditional premise no longer conveys a sufficient condition (note 2).

The properties of CNC's need to be analysed in some more detail. First, CNC's vary in their degrees of necessity. Consider for example *If Mary needs bread, she drops in the supermarket.* Among the various CNC's some are *sine qua non* conditions (call them strong conditions, e. g. *Mary is not bedridden)*

and others are less indispensable (weak conditions, e. g. *she has the time, she has got small change).* As this example shows, necessity is a matter of degree, and the degree is immediately suggested by knowledge of the domain.

Second, there are two kinds of CNC's. Some of them are such that it cannot be the case (or it is less likely) that *Q* in their absence (they are called enablers in the domain of causality) and some others are intrinsically negative in the sense that it cannot be the case (or it is less likely) that *Q* in their presence (they are called disablers in the domain of causality). By "satisfaction" of a CNC, it is meant their presence (or truth) in the first case, or their absence (or falsity) in the second case (note 3).

Third, although it is easier for exposition purposes to consider CNC's as discrete, this need not be the case. Referring again to the domain of causality, recall that Mill's methods concern first the discrete case and subsequently the continuous case (in the method of concomitant variation). Similarly, in a conditional field, the CNC's (as well as the focal factors) can vary by degree, so that there can be a functional relation between a CNC and the consequent Q. This often gives rise to rules of the type *the more A¡, the more Q* called *topoi* in studies of argumentation (Anscombre, 1995).

Finally, the CNC's vary in their availability. Some have low or very low availability; these may be virtually unlimited in number. They can be described as preconditions for the sentence to be asserted. Some others have high availability but are usually limited in number. For a causal sentence such as *If one turns the ignition key then the engine starts, the engine has not been removed from the car* is an example of the first kind (a prerequisite before one even thinks of starting the engine) while *the battery has not run down* is an

example of the second kind. Besides the objective knowledge of the domain, there is a psychological criterion to distinguish between the two. If one is asked what is necessary for the engine to start after the ignition key has been turned, most people should propose the same few conditions (e. g. state of battery, petrol, or plugs) after a rapid search in memory, whereas different people should generate different preconditions (e. g. the engine is in the car, the car is not on the moon, etc.) after a rather long process of abduction. In brief, the assumption of satisfaction of the preconditions is not questionable; without it the sentence would not be assertable, or at the very least it would be deceptive. The assumption of satisfaction of the conditions is questionable on the part of the hearer and it is the one which concerns us. It is at the basis of the possibility that a conditional sentence is susceptible to controversy. Except for cases where there is a lack of relation between antecedent and consequent (to be considered below) most disputes over the credibility of a conditional statement revolve around the question of the satisfaction of a CNC, more precisely of the extent to which the speaker is right in assuming the satisfaction of a CNC. The relevance of an indicative conditional statement stems principally from the fact that one is licensed to infer the consequent, the antecedent being granted, or reasonably likely (Sperber, Cara & Girotto, 1995). Given that, like any other statement, a conditional is uttered with a guarantee of relevance, the speaker must be credited with belief in the satisfaction of the CNC's; failing this, the truth of the compound antecedent and that of the whole sentence could not be assumed and the inference from the antecedent to the consequent would fail. However, the

hearer may have independent reasons to question this satisfaction, due to diverging or new sources of information, consideration of plausibility, etc.

2. Disjunctive components. There are usually supplementary factors like those in the second disjunct *(B1 & B)* whose conjunction, if satisfied, would be sufficient for *Q* to hold. With respect to *B*, *B1* is also a CNC. The status of disjuncts such as *(B1 & B)* with respect to *(A1 & A)* is that of an alternative sufficient condition. *A* and *B*, which are the factors of interest in the conditional field, are antecedents. Given that *B1*, like *A1*, is tacitly assumed, *B* acts as an alternative antecedent.

If the hearer has some reason to believe that *A* is the only antecedent, or that the alternative antecedents are not satisfied, he is licensed to infer *if it is not the case that A then it is not the case that Q.* This is the well-known "invited inference". Technically, it is also an implicature, but notice that it need not be a default assumption. It is essentially dependent on the context, part of which is determined by the knowledge base, and another part by preceding utterances that constitute the dialogue. Nevertheless, if the implicature has been generated, it can be cancelled by an additional piece of information. All this can be illustrated by the classic example from Geis & Zwicky (1971), *If you mow the lawn, I'll give you five dollars.* In this underspecified context, there is a lack of cues that could suggest alternative antecedents and reasons to assume their satisfaction: It is the intuition of most people that the inference *If you don't mow the lawn, I will not give you five dollars* is implied, an implicature that could be cancelled if the speaker added, for example, *There are also a number of things to repair in the house.* As Lilje (1972) argued, the invited inference is less likely to occur if the sentence is

uttered in response to *How can I earn five dollars?* , which triggers a search for, and retrieval of alternatives in the knowledge base. In brief, the possible interpretation of *if* as a biconditional stems from an implicature which the hearer generates or not on the basis of the knowledge base, given the aim of the talk exchange (note 4).

3. Relation within the conditional link. The antecedent should be related to the consequent, in the sense that knowing the antecedent should be a good reason to believe the consequent. The various antecedents (including the main antecedent A) may be more or less strongly linked to the consequent in that sense and here again the connection is indicated by knowledge of the domain. In the case of *If Mary needs bread, she drops in the supermarket,* there are many alternative antecedents, some of which are strongly linked to the consequent *(Mary needs matches)* some moderately *(Mary feels bored)* and yet others weakly or not at all *(Mary is looking for a new house).* In the latter case, that Mary needs a new house is not a good reason to believe that she goes to the supermarket; but such judgments are defeasible upon hearing a new piece of information, for example that there is an advertisement board in the supermarket where she can find offers for houses to rent. In brief, background knowledge is a determinant of belief in the conditional as a whole through the appraisal of the link between antecedent and consequent. This differs from the process considered in section 1 where background knowledge provides conditions whose satisfaction determine belief in the compound antecedent.

In summary, the judgment of sufficiency of the antecedent may be revised if the satisfaction of the CNC is doubted or denied or partial; the

judgment of necessity of the antecedent results from the assumption of non-satisfaction or of absence of alternative antecedents; this judgment may be cancelled if new information arouses doubt or brings denial of this assumption; both judgments of sufficiency and necessity of the antecedent may be questioned right away if the antecedent is not strongly related to the consequent.

The foregoing framework enables one to derive the following general consequences for conditional reasoning arguments.

(D_1) The rate of endorsement of MP and MT will decrease

(i) in case the satisfaction of a CNC is denied;

(ii) in case a doubt on the satisfaction of a CNC is suggested (in particular when a new piece of information enters the context) or stated;

(iii) in case it is stated or known that the CNC is not fully satisfied.

In these cases belief in the consequent of the conditional is not warranted, by virtue of the definition of a CNC. Consequently, Modus Ponens fails to deliver a sure conclusion; so does Modus Tollens too because its conclusion is *not* $(A_1 \,\&\, A)$: since A_1 is now uncertain, one cannot conclude about A with certainty.

(iv) with weak CNC's, the effect of these manipulations will be weaker because the consequent is less dependent on weak than on strong CNC's.

(D_2) The rate of endorsement of AC and DA

(i) will increase as a function of the ease with which the context invites the implicature;

(ii) will decrease as a function of the salience of alternative antecedents in the context;

(iii) will decrease with knowledge of additional information that emphasizes the existence or the satisfaction of alternative antecedents (so leading to the cancellation of the implicature).

This is because the rate of acceptance of the two arguments under consideration is known to be an increasing function of the rate of biconditional interpretation (which is assumed to depend on the implicature).

(D_3) The rate of endorsement of the conclusion of the four arguments should be an increasing function of the relatedness of the antecedent to the consequent. This derivation will not be considered in the rest of this paper because, to the best of the author's knowledge, it has not been addressed experimentally.

A review of the literature

The interest for the phenomena which, from the present point of view, are linked to the manipulation of alternative antecedents or of CNC's is relatively recent: it dates back to the early eighties in the first case and to the late eighties in the second case.

Studies of valid arguments.

Byrne (1989) is the first author to have applied to valid arguments a manipulation similar to the one which Rumain et al. (1983, reviewed below) used only for invalid arguments. One group of participants solved standard arguments such as, for Modus Ponens: *If she has an essay to write then she will study late in the library; she has an essay to write;* therefore: (a) *she will study late in the library;* (b) *she will not study late in the library;* (c) *she may or may not*

study late in the library. Another group solved the same arguments as the first group, modified by the addition of a third premise; this premise was a conditional that had the same consequent as the major and an antecedent that was a CNC with regard to the major, like *if the library stays open then she will study late in the library.* While for the first group a high level of correct responses on MP and MT was observed, for the second group (with mention of a CNC) this rate collapsed to around 35 percent for both MP and MT, that is, the majority did not endorse the conclusion. As claimed by D_1 (ii), the addition of the conditional premise (e.g. *if the library stays open. . .)* arouses doubt on the CNC which constitutes its antecedent through an epistemic implicature, hence the observed effect.

Chan & Chua (1994) used various non causal conditional rules with MP and MT arguments. For each conditional premise, they defined three necessary conditions for the consequent of the conditional to hold; these conditions varied in strength (that is, in degree of necessity or importance as estimated by judges). For example, with a MP whose major was *If Steven is invited then he will attend the party* the three levels of necessity were introduced each time by an additional premise following Byrne's (1989) paradigm: *If Steven knows the host well then he will attend the party* (or *If Steven knows at least some people well then he will attend the party,* or *If Steven completes the report to night then he will attend the party).* The response options were *he will attend the party; he will not attend the party; he may or may not attend the party.* It was observed that the endorsement rate of the conclusion of these three-premise arguments was a decreasing function of the degree of necessity. In brief, the statement of an additional conditional premise which

contained a CNC in its antecedent diminished the rate of endorsement of the conclusion all the more sharply as the condition was strong, in accordance with D_1 (iv).

Stevenson and Over's (1995) first experiment had two controls and five experimental conditions. The first control was a standard argument, e. g. (for MP), *If John goes fishing, he will have a fish supper; John goes fishing* whose conclusion was evaluated on a five-option scale: *John will have a fish supper; . . will probably have. . ; . . may or may not have. . ; probably won't have. . ; won't have. . .* The second control had a third premise with a CNC as antecedent (like in Byrne's experimental condition): *if John catches a fish, he will have a fish supper.* The five experimental conditions had a fourth premise that informed the subject about the likelihood of the satisfaction of the CNC: *John is always lucky; . . almost always. . ; . . sometimes. . ; . . rarely. . ; . . very rarely. .* While in the second control condition Byrne's results were replicated, the effect of the fourth premise on both MP and MT was to decrease the rate of endorsement of the conclusion and correlatively to increase the uncertainty ratings in a near-monotonic fashion across conditions. This shows that the manipulation of degrees of necessity results in functionally related degrees of belief in the conclusion of the arguments, again supporting D_1 (ii).

In their second experiment the same authors used three-premise arguments in which the second premise was a categorical sentence that introduced various levels of frequency directly into the necessary condition. For example, given the major premise *If John goes fishing, he will have a fish supper,* there were five levels in the second premise: *John always catches a fish when he goes fishing; . .almost always. . ; . . sometimes. . ; . . almost never. . ; . .*

never. . . For both MP and MT the rate of endorsement of the conclusion decreased monotonically as the frequency mentioned in the second (categorical) premise decreased (with a floor effect on the two smallest frequencies). In brief, in agreement with D_1 (i) and (ii), the denial, and explicit introduction of various degrees of doubt on a CNC diminished the endorsement of the conclusion; moreover, the greater the doubt, the greater the decrease.

Cummins' studies (1995; Cummins, Lubart, Alksnis, and Rist, 1991) were focused on arguments with causal conditionals. She demonstrated that the acceptance rate of the conclusion depended on the number of disabling conditions for MP and MT. For example, of the following two MP arguments, *If the match was struck, then it lit; the match was struck / it lit* and *If Joe cut his finger, then it bled; Joe cut his finger / it bled*, people are less prone to accept the conclusion of the first, which can be shown to have many disabling conditions, than the conclusion of the second, which has few. Thompson (1994, 1995) obtained similar results not only with causals, but also with non causal rules such as obligations, permissions and definitions by using conditionals that varied in perceived sufficiency (independently rated by judges). She defined a sufficient relationship as one in which the consequent always happens when the antecedent does. The following sentences exemplify a high and a low level of sufficiency, respectively, for permissions: *If the licensing board grants them a license then a restaurant is allowed to sell liquor. If an athlete passes the drug test at the Olympics then the IOC can give them a medal.* The author observed that the rate of endorsement of the conclusion was an increasing function of the level of sufficiency. As these

examples show, the Thompson manipulation can also be described in terms of sentences with a high or a low number of CNC's, whether positive or negative (whereas Cummins' disablers were necessarily negative). Consequently, CNC's are less likely to be all satisfied when this number is high than when it is low, hence the difference in the acceptance rate of the valid conclusion, in line with D_1 (ii).

A more direct evidence of the effect of the assumption of satisfaction of CNC's on the willingness to endorse the conclusion was provided by George's (1995) third experiment. Two groups of participants received contrasted instructions. One group was asked to assume the truth of debatable conditionals such as *If a painter is talented, then his/her works are expensive* while the other group was invited to take into consideration the uncertain status of the statements. As a result, 60 percent in the first group endorsed the conclusion of at least three of the four MP arguments, while in the second group only 25 percent did so. By asking to asssume the truth of such conditionals, participants were invited to dismiss possible objections like *the painter must be famous,* whereas stressing the uncertainty of the statement is a way to invite them to take such objections into account.

Manktelow and Fairley (2000) manipulated the extent to which a CNC is satisfied: With a low degree of satisfaction the consequent was less likely to occur and with a high degree it was more likely to occur (a disabling condition and an additional requirement, respectively, in their terminology). A standard MP argument with the major premise *If you pass your exams, you will get a good job* served as a control while the other arguments were made of this MP to which one of the following premises was added: (i) got very

low grade; (ii) got low grade; (iii) got respectable grade; (iv) got excellent grade. The conclusion had to be assessed on a 7-point scale (from very low to very high certainty to be offered a good job). For the first two conditions the certainty ratings were below the control (and lower for the *very low grade* condition than for the *low grade* condition). For the last two conditions the certainty ratings were above the control (and higher for the *excellent grade* condition than for the *respectable grade* condition). In brief, the degree of certainty of the conclusion is an increasing function of the degree to which a necessary condition is satisfied, in keeping with D_1 (iii).

Recent papers on conditional reasoning (Newstead, Ellis, Evans, and Dennis, 1997) have reported differences in the rate of endorsement of the conclusion as a function of the content of the conditional; in particular, promises and threats on the one hand, and tips and warnings on the other hand seem to constitute two contrasted groups, the former giving rise to more frequent endorsements of the conclusion than the latter on all arguments (a result confirmed by Evans and Twyman-Musgrove, 1998). As noted by the authors, the key factor seems to be the extent to which the speaker has control over the occurrence of the consequent, which is higher for promises and threats than for tips and warnings. This result is in agreement with the present framework. On the one hand, weaker control implies greater difficulty to ensure the satisfaction of the CNC's, hence, as per D_1 (ii) , less certainty that the consequent will follow. On the other hand, weaker control implies the possibility that uncontrolled alternative antecedents exist, hence, as per D_2 (ii) fewer endorsements of the conclusion on invalid arguments, to which we now turn.

Studies of invalid arguments.

In a pioneering study, Rumain, Connell, & Braine (1983) demonstrated the effect of alternative antecedents on the endorsement of AC and DA. This was done by using additional premises that stated explicitly the existence of alternative antecedents. When adult participants were presented with a standard argument made of a major premise such as *if there is a dog in the box, then there is an orange in the box* (and the appropriate minor premise) they commited the fallacies 70% of the time; but when these two premises were presented together with two additional conditional premises such as *if there is a tiger in the box, then there is an orange in the box* and *if there is a pig in the box, then there is an apple in the box* they commited the fallacies only 30% of the time. The manipulation was specially designed to alert the participants in the second condition to the plurality of antecedents *(dog, tiger)* for a single consequent *(orange)* so that the invited inferences of the type *if there is not a dog, then there is not an orange* or *if there is an orange, then there is a dog* were countermanded in agreement with D_2 (iii).

This claim is also supported by the results of a similar experiment by Markovits (1985): The conditional premise (e. g. *If there is a snow storm in the night then school will be closed the next day)* was preceded by a scenario referring to a few alternative causes (teacher's strike, a fault in the plumbing), a procedure that resulted in improved performance.

The results of another experiment by Markovits (1984) support derivation D_2 (ii). He used an apparatus that had five cups at the top and five cups at the bottom and rubber tubes connecting the top and the bottom cups.

The connections between the top and the bottom cups were not visible, except for one of them (3-top to 3-bottom). In order to know participants' assumptions about the connexions, they were asked where a marble put in cup 1-top could go, following which they were asked analogues of the conditional reasoning questions, that is, which bottom cup they expected a marble to reach if it had been introduced in cup 3-top and similarly if it had been introduced in cup 5-top; which top cup they thought the marble came from, if it had reached cup 5-bottom or if it had reached cup 3-bottom. The answer to each of these questions is equivalent to the conclusion of one of the four arguments (MP, DA, MT, and AC, respectively) while the information provided is equivalent to the minor premise and knowledge of the visible connection provides the major premise. The results were more or less correct depending on whether or not participants assumed that any top cup could lead to any bottom cup. In brief, participants committed fewer fallacies when they assumed that there were alternative trajectories leading to the same outlet. The author argued that performance on conditional reasoning is mediated by an awareness of the existence of alternative antecedents to the consequent, as claimed by D_2 (ii).

In Cummins' studies of causal conditionals described above, the role of alternative causes on invalid arguments was also investigated. For example, comparing two AC arguments such as *If the match was struck, then it lit; the match lit / it was struck* and *If Mary jumped into the swimming pool, then she got wet; Mary got wet / she jumped into the swimming pool* people were more prone to accept the conclusion of the first, which has few alternative causes than that of the second, which has many. Thompson (1994, 1995) defined a

necessary relationship as one for which the consequent occurs only when the antecedent occurs. A sentence such as *If an athlete passes the drug test at the Olympics then the IOC can give them a medal* is also an example of a high level of necessity, whereas *If a person has a PhD in astrophysics, then they are allowed to teach at a university* is an example of a low level of necessity (note 5). The author observed that the rate of endorsement of invalid arguments was an increasing function of the level of necessity. These studies show, in line with D_2 (ii), that the more available the alternative antecedents, (high level of necessity, low number of alternative causes) the less likely the invited inference that leads to the endorsement of the conclusion.

Quinn & Markovits' experiment (1998) was restricted to causals. They compared conditionals that differed in the strength of the association between antecedent and consequent defined as follows. Given an effect, judges were requested to produce as many causes as they could in a limited time. Considering two causes produced for an effect, the more frequent was considered as the more strongly associated to the effect, so that the authors could define two groups of conditionals, a stong group (e. g. *If a dog has flees, then it will scratch constantly)* and a weak group (e. g. *If a dog has a skin disease, then it will scratch constantly).* No significant effect was observed for the valid arguments but for invalid arguments there were fewer endorsements of the conclusion. Within the present framework, this result is in agreement with D_2 (ii): With the weak association, the antecedent is not the most available; therefore it is relatively easy for a more available antecedent to be retrieved and play the role of an alternative cause. In contrast, with the strong association, the antecedent is the most available; it is therefore relatively

difficult for a less available antecedent to be retrieved and play the role of an alternative cause.

In Byrne's (1989) experiment described above, one group of participants solved standard arguments modified by the addition of a conditional premise that had the same consequent as the major and an antecedent that was an alternative antecedent to the major, e. g. *if she has an essay to write then she will study late in the library* (major); *if she has some textbooks to read then she will study late in the library* (additional). The rate of endorsement of the AC and DA collapsed from about 60 percent for the control group to 8 percent for the group with an alternative antecedent, confirming the Rumain & al. manipulation. Notice that, when the additional premise is added to the invalid arguments, its conditional expression suggests the existence of an alternative antecedent (e.g. *if she has some textbooks to read. . .)* hence the observed effect as expected on the basis of D_2 (ii).

Using the same major premise as above, *If you pass your exams, you will get a good job,* Manktelow and Fairley (2000) manipulated the extent to which the factor "performance on interview" was satisfied. There was a control (a standard DA argument) while the other arguments were made of this DA argument to which one of the following premises was added: (a) did not perform well on interview, (b) performed well, (c) performed brilliantly. The expressed certainty of the conclusion decreased across conditions from (c) to (a), the level for the latter group being close to the minimum of the scale. In keeping with D_2 (iii), the additional premises that mention alternative antecedents (conditions b and c) diminish the rate of acceptance of the conclusion of DA (and the greater the degree of satisfaction, the greater the

decrease in acceptance rate). For condition (a), it is interesting to note that, since "good interview" is an alternative antecedent,"bad interview" (which is potentially a disabling condition) qualifies as well as the denial of an alternative antecedent. In agreement with D_2 (i), the explicit statement of the non-satisfaction of an alternative antecedent (bad interview) reinforces the presumption that the antecedent (pass the exams) is the only factor at work, and it does so better than if no alternative antecedent was mentioned.

Manktelow and Fairley took the observation that a disabling condition seems to affect DA, and other observations reported in their paper as evidence in favour of the existence of superordinate principles. In the job scenario, participants would be guided by a principle like "produce favourable evidence of suitability" which is more general than the stated antecedent of the conditional. Similarly, with a permission rule such as *If you tidy up your room, then you may go to play for one hour,* participants declared to allow the boy out for half an hour knowing that he had washed the dishes, and for more than an hour knowing that he had both tidied the bedroom and washed the dishes; the superprinciple would be "be a good boy". Within the present framework, it is fully agreed that the endorsement of the conclusion requires more information than the antecedent; it has been hypothesised explicitly that a conditional is uttered in a context, part of which exploits the knowledge base. What has been called the conditional field precisely provides a formalisation of the notion that a consequent follows from a structured set of factors (organised as a disjunctive form), the stated antecedent being just one member of the set. Take for example a causal conditional such as *If a match is struck then the gas will explode.* The causal field

contains alternative causes such as *sparkler*, *incandescent objects*, etc. These are easily accessed and can be extensionally listed; at a metacognitive level they can be intensionally labelled as, and subsumed under, the notion "combustion catalytic starter" which could also be called a superprinciple, but is nothing else than the set of alternative causes.

The notions of superprinciple and of conditional field share a common idea but the latter has several advantages: While it is rooted in a long philosophical tradition, it has a formal description and it has the potential to give an explanation of virtually all the content effects known to affect conditional reasoning, as shown by this review.

Truth-table evaluation tasks.

Finally, a few studies which used the paradigm of truth table evaluation are highly relevant to the present review. Hilton, Jaspers and Clarke (1990) presented their subjects with three sets of arguments. The first set consisted of a number of instances of the four standard arguments. An example for Modus Ponens was: *If he works hard then he will pass; he works hard / he will pass.* To constitute the second set, these arguments were modified by the introduction of an additional categorical premise that affirmed an alternative antecedent: *If he works hard then he will pass; the exam is easy; he works hard / he will pass.* Similarly in the third set of arguments there was an additional categorical premise that denied a CNC: *If he works hard then he will pass; the exam is difficult; he works hard / he will pass* (note 6). For each set of arguments, on the basis of the responses (the conclusion was evaluated as: true; sometimes true and sometimes false; false) it was possible to infer

participants' interpretation of the conditional premise. The authors classified these interpretations as expressing (i) sufficient (but not necessary) conditions; (ii) sufficient and necessary conditions; (iii) necessary (but not sufficient) conditions. Taking the standard two-premise arguments as a basis of comparison, arguments in which an alternative antecedent was asserted gave rise to fewer "necessary" interpretations of the conditional (and to more "sufficient" interpretations); and arguments in which a CNC was denied gave rise to fewer "sufficient" interpretations of the conditional (and to more "necessary" interpretations). These results are in line with D_1 (i) and D_2 (iii). Notice that since it is claimed that performance on conditional argments is determined by the interpretation of the conditional premise, this experiment is particularly interesting; in effect, in showing that the interpretation of the conditional premise can be inferred from performance on conditional arguments and coincides with the one predicted, it supports the general claim.

Direct support of the rationale that underlies the derivation D_1(ii) can be found in the results obtained by O'Brien, Costa, and Overton (1986) with another truth-table evaluation task. Participants were presented with conditional sentences that expressed an hypothesis in the frame of medical or mechanical scenarios (e. g. *if the thermostat is replaced, then the car will not overheat).* They were then given the result of an observation: it stated that an operation was performed [P] (or not performed [not-P]) and the patient recovered [Q] (or did not recover [not-Q]) or that a part was replaced (or not replaced) and the engine still overheated (or did no longer overheat); all four combinations were proposed. Participants were then asked about the

doctor's (or mechanic's) certainty that the hypothesis was correct (the options were: certain that correct; certain that incorrect; cannot be certain) in each of the four cases. Two results of interest are that (i) the hypothesis was more often estimated as uncertain in the medical scenario than in the mechanical one (although to a lesser extent than in the [not-P, Q] case), after the observation of the [P, Q] case (operation and recovery or part replaced and engine working); and (ii) the hypothesis was less often estimated as falsified by the [P, not-Q] observation in the medical scenario (operation and no recovery) than in the mechanical one (part replaced and engine not working). As argued by the authors, the medical domain is generally viewed as less deterministic than the mechanical one, so that medically there may be hidden internal causes that prevent an action to be efficacious. It seems that the causal link between the antecedent and the consequent of the conditional may be less predictable in some domains than in others: The satisfaction of the salient CNC's is more open to doubt (because they are less controlable, or even assumed to be hidden).

D_2 (i) and (ii) also get direct support from the same experiment. The hypothesis was more often estimated as uncertain in the medical scenario than in the mechanical one for the [not-P, Q] case (no operation and recovery or no part replaced and engine working). A likely explanation put forward by the authors lies in the notion of spontaneous recovery, applicable to the medical domain but not to the mechanical one. This is an instantiation of the concept of alternative causal antecedent which is more available in the medical domain than in the mechanical one. In brief, this experiment shows

that information with the same logical status can affect belief in a conditional sentence differently depending on the conceptual domain involved.

Conclusion

It is basic to the distinction between induction and deduction that while the conclusion of the former contains factual assertions not included in the premises, the conclusion of the latter is free from any fact not already included in the premises. Although it is also widely agreed that inductive activity depends more on knowledge of the domain than on formal properties of the premises, but deduction depends entirely on the formal properties of the premises, the second part of this assertion seems questionable as far as human reasoning is concerned. In deduction, content plays a role that is complementary to form: The knowledge base is the source of implicated premises that are cancellable or of explicit uncertain premises. In conditional reasoning, the former may lead to the affirmation of an invalid conclusion; the former and the latter may also give rise to a doubt or a denial of a valid conclusion, depending on their degree of uncertainty. Premises constitute a skeleton that is fleshed out by other premises imported from knowledge base. Talking - and wondering about - "content effects" in deductive reasoning is as tautological as talking of "form effects" would be. Human deduction is a process by which the reasoner exploits the context jointly with the explicit premises in order to yield new information. One implication is that one of the commonest arguments directed at proponents of formal treatment of human deduction fails. This

argument says that if deduction was based on a formal analysis of the premises, no effect of content should occur. But this is to forget the premises provided by the knowledge base. In fact, "content effects" do occur because deduction is not only based on a formal analysis of the premises explicitly provided, but also on premises dictated by world knowledge (and on the interpretation of the explicit premises based on pragmatic principles). The phenomena reviewed in the present paper also exhibit "content effects". Conditional arguments are uttered in a context for some purpose. Their conditional premise is embedded in a conditional field whose factors are determined by world knowledge. When this is accepted, the "content effects" become understandable and explanable.

References

Anscombre, J.-C. (1995). *Théorie des topoï.* [Theory of topoi]. Paris: Kimé.

Byrne, R. M. J. (1989). Supressing valid inferences with conditionals. *Cognition, 31,* 61-83.

Chan, D. , & Chua, F. (1994). Suppression of valid inferences: Syntactic views, mental models, and relative salience. *Cognition, 53,* 217-238.

Cummins, D. D. (1995). Naive theories and causal deduction. *Memory and Cognition, 23,* 646-658.

Cummins, D. D. , Lubart, T. , Alkinis, 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 & Kegan Paul.

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

Evans, J. St. B. T. , & Twyman-Musgrove, J. (1998). Conditional reasoning with inducements and advice. *Cognition, 69,* B11-B16.

Fillenbaum, S. (1975). IF: Some uses. *Psychological Research, 37,* 245-260.

Fillenbaum, S. (1978). How to do some things with *if.* In J. W. Cotton & R. L. Klatzky (Eds.), *Semantic factors in cognition.* Hillsdale, N. J. : Lawrence Erlbaum.

Geis, M. L. , & Zwicky, A. M. (1971). On invited inferences. *Linguistic Inquiry, 2,* 561-566.

George, C. (1995). The endorsement of the premises: Assumption-based or belief-based reasoning. *British Journal of Psychology, 86,* 93-111.

Goodman, N. (1947). The problem of counterfactual conditionals. *Journal of Philosophy, 44,* 113-128.

Hilton, D. J. , Jaspars, J. M. F. , & Clarke, D. D. (1990). Pragmatic conditional reasoning: Context and content effects on the interpretation of causal assertions. *Journal of Pragmatics, 14,* 791-812.

Horn, L.R. (2000). From *if* to *iff* : Conditional perfection as pragmatic strengthening. *Journal of Pragmatics, 32,* 289-386.

Legrenzi, P. (1970). Relations between language and reasoning about deductive rules. In G. B. Flores d'Arçais & W. J. M. Levelt (Eds.), *Advances in Psycholinguistics.* (pp. 322-333). Amsterdam: North-Holland.

Lilje, G. W. (1972). Uninvited inferences. *Linguistic Inquiry, 3,* 540-542.

Mackie, J. L. (1974). *The cement of the universe.* Oxford University Press.

Manktelow, K. I. , & Fairley, N. (2000). Superordinate principles in reasoning with causal and deontic conditionals. *Thinking and Reasoning, 6,* 41-65.

Markovits, H. (1984). Awareness of the 'possible' as a mediator of formal thinking in conditional reasoning problems. *British Journal of Psychology, 75,* 367-376.

Markovits, H. (1985). Incorrect conditional reasoning among adults: Competence or performance? *British Journal of Psychology, 76,* 241-247.

Matalon, B. (1962). Etude génétique de l'implication. In E. W. Beth, J. B. Grize, R. Martin, B. Matalon, A. Naess, & J. Piaget (Eds.), *Implication, formalisation et logique naturelle. Etudes d'Epistémologie Génétique.* (pp. 69-93). Vol. XVI. Paris: P.U.F.

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.

O'Brien, D. P. , Costa, G. , & Overton, W. F. (1986). Evaluations of causal and conditional hypotheses. *Quarterly Journal of Experimental Psychology, 38A* , 493-512.

O'Brien, T. C. (1972). Logical thinking in adolescents. *Educational Studies in Mathematics, 4,* 401-428.

Politzer, G. (1981). Differences in interpretation of implication. *American Journal of Psychology, 94,* 461-477.

Quinn, S. & Markovits, H. (1998). Conditional reasoning, causality, and the structure of semantic memory: strength of association as a predictive factor for content effects. *Cognition, 68,* B93-B101.

Ramsey, F. P. (1931). *The foundations of mathematics and other logical essays.* Ed. R. B. Braithwaite. London: Routledge and Kegan Paul.

Rumain, B. , Connell, J. , & Braine, M. D. S. (1983). Conversational comprehension processes are responsible for reasoning fallacies in children as well as adults: If is not the biconditional. *Developmental Psychology, 19,* 471-481.

Sperber, D. , Cara, F. , & Girotto, V. (1995). Relevance theory explains the selection task. *Cognition, 57,* 31-95.

Sperber, D. , & Wilson, D. (1986). *Relevance: Communication and cognition.* London: Blackwell.

Staudenmayer, H. (1975). Understanding conditional reasoning with meaningful propositions. In R.J. Falmagne (Ed.), *Reasoning: Representation and process in children and adults.* (pp. 55-79). Hillsdale, N. J. : Erlbaum.

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

Thompson, V. A. (1994). Interpretational factors in conditional reasoning. *Memory and Cognition, 22,* 742-758.

Thompson, V. A. (1995). Conditional reasoning: The necessary and sufficient conditions. *Canadian Journal of Experimental Psychology, 49,* 1-60.

van der Auwera, J. (1997). Conditional perfection. In A. Athanasiadou & R. Dirven (Eds.), *On conditionals again.* (pp. 169-190). Amsterdam: John Benjamins.

Wason, P. C. , & Johnson-Laird, P. N. (1972). *Psychology of reasoning. Structure and content*. London: Batsford.

Footnotes

1. Mackie may have had reasons for this, linked with a concern to distinguish particular causal events from general ones. This need not concern us here.

2. Artificial systems such as default logics require the search for exceptions in the whole data-base, which soon becomes intractable. This formidable problem is solved in human communication by the speaker's guarantee of normality: any exception ought to be mentioned and an absence of qualification means that the normal state of the world obtains. In a sense, the "burden of the proof" is reversed.

3. Mackie described the antecedent as

$$(A\&B\&\neg C) \vee (D\&F\&\neg G) \vee \cdots,$$

where A (and D) are INUS conditions (each is an Insufficient but Non redundant part of an Unnecessary but Sufficient condition), B (and F) are enablers and C (and G) are disablers (or counteracting causes in Mill's terms) marked by an explicit negation.

4. Pragmaticists do not all agree on the mechanism of generation of this implicature. For two recent (and diverging) accounts, see Horn (2000) and van der Auwera (1997, of which the present account is a variation).

5. High level of necessity as defined by Thompson should not be confused with strong CNC's as defined here. The former characterise A antecedents (with regard to the consequent), the latter are A1 or A' conditions complementary to A.

6. Under normal conditions, an exam is neither too easy nor too difficult, so that easiness acts as an alternative antecedent, and difficulty as a disabler.