

Necessary Conditions in a Natural Language

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1. Introduction^{*}

Necessary condition relations can be expressed in a variety of ways in a language like English.¹ This paper addresses the semantics of a particular class of locutions, conditionals with an expression of necessity, like *must* or *have (to)*, in the matrix and an expression of intention, like *want (to)* or *be (to)*, in the conditional clause:

- (1) You must take the A train if you want to go to Harlem.
- (2) If the unicorn is to recover, we have to feed it Himalayan moss.

It is problematic to treat sentences like these (on their natural interpretations; cf. 2.2) as normal conditionals. For one thing, they can be paraphrased as purpose constructions (cf. 2.3). Moreover, they are intuitively equivalent to conditionals like the following, which look like contrapositives but where the verbs *want* and *be* are absent:

- (3) If you do not take the A train, you cannot go to Harlem.
- (4) The unicorn will not recover unless we feed it Himalayan moss.

One needs an integrated and sophisticated theory of modals and conditionals for a satisfactory analysis of sentences like (1) and (2). The theory of Angelika Kratzer (1981) is such a theory. However, as it stands it does not offer a straightforward account of these sentences. Yet I shall argue that it can be generalized so as to derive the correct truth conditions.

In Kratzer's theory, a modal depends for its interpretation on two contextual parameters (*conversational backgrounds*), functions from worlds to sets of propositions; a modal base, consisting of facts, and an ordering source, typically consisting of norms

^{*} Based on my 1986 dissertation, partly written in Constance under the supervision of Arnim von Stechow, this paper reflects on more recent developments in directions suggested by him.

¹ While all the examples in the paper are English, we find analogous phenomena in German, Scandinavian, and numerous other languages.

and intentions. The general function of a conditional clause is to supply a proposition to the modal base. Now on the intuitive interpretation of (1) and (2), the proposition that is most relevant for the modal in the matrix is not the proposition expressed in the conditional clause as such. Rather, it is the proposition expressed in the sentence embedded under the verb *want* or *be*. Moreover, there is reason to assume that this proposition is added to the ordering source.

In the next section, I set out the problematic properties of these constructions. Section 3 is a brief summary of the relevant aspects of Kratzer's theory of relative modality. In section 4, I motivate and formulate an extension to the theory that permits a compositional treatment in accordance with our intuitions. In section 5, I discuss problems and remaining questions.

2. The Problem

Although the sentences under consideration play a central role in natural-language reasoning, they have attracted little attention in linguistics or philosophy. One exception is G. H. von Wright. In *Norm and Action*, he comments on the sentence "If the house is to be made habitable, it ought to be heated" (1963:10f.):

[This sentence] ... says that heating the house is a *necessary condition* of making the house habitable. [...] An equivalent formulation ... would be 'Unless the house is heated, it will not be habitable'.

A type of sentence the normal use of which is for stating that something is (or is not) a necessary condition for something else von Wright calls an *anankastic sentence*. But neither he nor anyone else has stated a compositional semantics for such anankastic sentences as the one he considers in the passage quoted. It proves problematic, and in this section I try to specify the problem and to make it as precise as possible in relatively pretheoretic terms.

2.1 Problematic Paraphrases

Let us take a closer look at the sentence (1). (Mutatis mutandis, what I say about this type of sentence in the following will also apply to the type represented by (2).) On the surface, this is an indicative conditional with the proposition expressed by (1.i) as the antecedent and the proposition expressed by (1.ii) as the consequent.²

² I follow Kratzer (1981) in assuming that a modal like *must* in the matrix of a conditional is to be identified with the conditional operator and thus does not form part of the consequent.

- (1) i. You want to go to Harlem.
 ii. You take the A train.

However, intuitively, (1) entails (3) and vice versa.³ This felt equivalence cannot easily be accounted for on the assumption that (1) is a normal indicative conditional. (3) certainly is, with the proposition that you do not take the A train as the antecedent and the proposition that you do not go to Harlem as the consequent.

According to common usage of the term *necessary condition*, an indicative conditional expresses that the negation of the antecedent is a necessary condition for the negation of the consequent. (3) thus says that the proposition expressed by (1.ii) is a necessary condition for the proposition expressed by (1.iii).

- (1) iii. You go to Harlem.

If (1) and (3) entail each other, (1) also expresses this, so it looks as if a sentence on the form *if ... want to ϕ , must ψ* expresses that ϕ is a necessary condition for ψ . However, apparently, (1) does not express a relation between ϕ (the *internal* proposition) and ψ but a relation between the proposition ... *want to ϕ* (the *external* proposition) and ψ . What happens to the expression of intention in the paraphrase?

Problem 1 How can a sentence on the form *if ... want to ϕ , must ψ* mean the same as a sentence on the form *if not ψ , not ϕ* ?

On the other hand, this expression of intention is not superfluous, since the corresponding sentence without *want (to)* does not mean quite the same:

- (5) If you go to Harlem, you must / (will) take the A train.
 (6) If you go to Harlem, you must / (will) have taken the A train.

The relationship between (3) and (5) is a – not very convincing – case of *contraposition*. Because contraposition reverses the temporal relation between antecedent and consequent (Cooper 1978:165f.), a contrapositive can often be improved by using a perfect tense. However, (1) is an even better paraphrase of (3) than (6) is. The expression of intention, here *want*, makes a positive difference. What this difference consists in is an open question.

Problem 2 Why is the expression of intention in the antecedent clause essential for the construction to convey the necessary condition relation?

³ Assuming, of course, that the relevant contextual parameters are constant. (1) has an original generic interpretation; for simplicity I here intend a nongeneric interpretation.

The expression of necessity in the consequent clause is also necessary to preserve the meaning of sentences like (1). If *must* is replaced by *will* or deleted, the sentences do not convey the necessary condition relation anymore:

- (7) If you want to go to Harlem, you (will) take the A train.

In principle, in Kratzer's theory, the presence of a necessity modal like *must* in the matrix of a conditional does not make a semantical difference; it just explicates an operator that would otherwise be covert. Indeed, in sentences like (6), the choice between *must* and *will* is not important. In (1), however, the overt necessity modal serves some purpose.

Problem 3 Why is the expression of necessity in the consequent clause essential for the construction to convey the necessary condition relation?

2.2 Ambiguities

Note that it would not be correct to assume that sentences like (1) can only mean what they mean, in the sense that a compositional semantics in terms of the words *if*, *want*, and *must* forces the necessary condition interpretation. A sentence made up of these parts does not invariably express that the consequent is a necessary condition for the internal antecedent. There is, in principle, a possibility of interpreting it as a conditional expressing that the external antecedent is a sufficient condition for the consequent. This was observed by Richard Hare in *Wanting: Some Pitfalls* (1971:45f.):

- (1) If you want sugar in your soup, you should ask the waiter.
 (2) If you want sugar in your soup, you should get tested for diabetes.

The difference...can be brought out, first, by noticing the entirely different grounds that would be given to justify them. The first would be justified by pointing out that the waiter has the only access to sugar. The second would be justified by arguing that an inordinate desire for sugar is a symptom of diabetes, and that those with diabetes should have it treated. Alternatively, we might bring out the difference in the following way: the first suggests that asking the waiter would be a means to having sugar in one's soup; the second does not suggest that getting tested for diabetes is a means to having sugar in one's soup. [...] Let us consider the meaning of 'If you want' in the two cases. In the 'diabetes' case, a first approximation would be to say that it means the same as 'If you, as a matter of psychological fact, have a desire'. I am very much inclined to deny that it means anything like this in the 'waiter' case.

It is not easy, but it is possible, to find relatively minimal pairs on the form of (1) and (2) which show this meaning variance. Compare (8a) with (8b) and (9a) with (9b):

- (8) a. If you want to be owner of North America, you must find the Golden Helmet.
 b. If you want to be owner of North America, you must see a psychiatrist.
- (9) a. If the plane is to leave on time, the ground personnel have to hurry up.
 b. If the plane is to leave in an hour, the passengers have to hurry up.

The ‘diabetes’ reading is a plausible interpretation of (8b) and (9b). In fact, this is the more predictable interpretation on the basis of the semantics of the words involved. A relation is expressed between the external antecedent, including the intentional component, and the consequent. This is what one would expect, while the necessary condition reading, where a relation is expressed between the internal antecedent, excluding the intentional component, and the consequent, seems noncompositional in the sense that the internal structure of the *if* clause has to be considered to determine the relevant proposition. The two interpretations would appear to correspond to two structurally different representations; for (8a,b), (8c,d):

- (8) c. **If** you_i **want** (φ [PRO_i to be owner of North America]),
 you_j **must** (ψ [t_j find the Golden Helmet])
- d. **If** (φ , you_i want [φ PRO_i to be owner of North America]),
 you_j **must** (ψ [t_j see a psychiatrist])

(8d), expressing a relation between the external antecedent φ' and the consequent ψ , is straightforward. There seems to be no way that these structures can express a relation between the internal antecedent φ and ψ . (8c), on the other hand, might express such a relation, but this structure is problematic in that *want* is treated syncategorematically, forming a unit with *if*.

However, I am going to argue that it is possible to interpret structures like (8d) in such a way as to predict the necessary condition interpretation, without assuming structures like (8c). The difference between the two readings can be reduced to a case distinction concerning the contribution of an *if* clause to the interpretation of a modal. The explanation will require a revision of Kratzer’s definition of the function of an *if* clause. On the original definition, an *if* clause contributes the proposition it expresses to the conversational background facts. On the revised definition, the proposition expressed in the *if* clause can determine the value of whatever conversational background, facts or intentions, is expressed in the clause, by supplying the indices to which that conversational background is applied. This move will account for the interdependence between the expression of intention in the *if* clause and the expression of necessity in the matrix of our anankastic sentences.

2.3 Purpose and Necessity

A more complete survey of the relevant phenomena would comprise sentences that do not have the appearance of conditionals at all but the same semantic properties. The semantics of *purpose* constructions has not been widely studied; studies tend to focus on control (e.g., Jones 1991). But in the standard case, the purpose clause can be paraphrased by a *causal* clause with an intentional expression (Sæbø 1991). Here, however, it must be paraphrased by a *conditional* clause with an intentional expression.

(10) a. If I want to be owner of North America, I must find the Golden Helmet.

b. To be owner of North America, I must find the Golden Helmet.

(11) a. If the bird is to faint, you must sprinkle salt on its tail.

b. For the bird to faint, you must sprinkle salt on its tail.

The Danish linguist Gunnar Bech developed a theory of German sentences corresponding to (10b) in *Studien über das deutsche verbum infinitum* (1957).⁴ He introduced a distinction between a *determinative* and an *indeterminative* type of purposive clause (320ff.). The indeterminative is the normal purposive type. A determinative *to* phrase does not express an intention but serves to restrict the meaning of some expression in the superordinate clause, the determinatum. Necessity words are typical determinata. In a case like (10b), Bech would say that the *to* phrase determines *must* and that the necessary proposition is a necessary condition for the content of the *to* phrase. Bech's theory points directly to a modern theory of modality like Kratzer's when he says that the *to* phrase serves to identify the contextual meaning of the modal and indicates in view of what the modal is to be interpreted.

A general characterization of the problematic sentence type could look like this:

- A complex sentence with a subordinate clause and a superordinate clause.
 The subordinate clause is either a conditional or a purposive clause.
 The superordinate clause contains an expression of necessity.
 The conditional clause contains an expression of intention.

The word of intention is in English mostly *want* or *be* (in German *wollen* or *sollen*).⁵ The distribution of *want (to)* and *be (to)* does not follow the usual pattern where the former denotes an intention in the subject, while the latter denotes an intention not in the subject. If paraphrases like (3) or (4) are possible, where there is no trace of either,

⁴ Reintroduced to the contemporary linguistic community by Stechow (1984).

⁵ There are alternatives to *want*: Within certain limits, any intentional attitude can occur in the same function, e.g., *intend*, *hope*, *plan*, *aim*, even *fear*, with an implicit negation. I will let the verb *want* represent these other possibilities. One may question the term "expression of intention" for the raising verb *be (to)*. In any case, this verb expresses something over and above futurity: plan, aim, norm, or the like. I subsume this under the term intention.

this distinction is obsolete. What governs the distribution instead is something like the following.

- Whenever the grammatical subject of the subordinate clause coincides with the logical subject of the superordinate clause, *want (to)* is used. Otherwise, in particular when the subject of the subordinate clause is inanimate, *be (to)* is used.

This implies that a sentence like (12b), where the subject of *want* does not corefer with that of the main clause, is not an instance of the problematic sentence type: It does not mean that the proposition that we find David a maid is a necessary condition for the proposition that he recovers. (12a), on the other hand, does mean this, as does (12c), where the subject of *want* does coincide with that of the consequent clause.

- (12) a. If David is to recover, we must find him a maid.
 b. If David wants to recover, we must find him a maid.
 c. If we want David to recover, we must find him a maid.

It is remarkable that it does not seem to make any essential difference which is chosen, (12a) or (c). This indicates that the “external antecedent”, the proposition expressed in the *if* clause in its entirety, does not play any significant role. To the extent that we do sense a difference between (12a) and (c), it seems to be a difference in the internal antecedent; in the *want* case, (12c), we tend to read it not as *David recovers* but as *we make David recover*.

The expression of necessity may be one of a variety: beside *must* and *have (to)*, *need*, *necessary*, *ought*, *should*, etc. Some, like *ought* and *should*, express a necessity that may seem weaker than *must*. In Kratzer’s theory of modality, such nuances can be attributed to varying constraints on conversational backgrounds (section 3).

Note that the consequent proposition does not have to represent an action:

- (13) If the polar ice is to melt, CO₂ levels must double.

3. A Theory of Modals and Conditionals

A satisfactory analysis of necessary condition sentences presupposes a theory of modals and a theory of conditionals. The theory of relative modality developed by Angelika Kratzer is at the same time a theory of conditionals, so this is the most promising framework for a solution to the presented problems. This section is a survey of Kratzer’s theory (1978, 1981, 1991).

3.1 Conversational Backgrounds

Any modal depends on context. To determine the truth conditions of a modalized sentence, one needs to consult the context for the relevant parameter, the *conversational background*. Modals are uttered *in view of* this parameter. For example, the following sentence may be false in view of the circumstances, but true in view of some norm.⁶

(14) You can't be sick in here, Sir.

A conversational background is the entity denoted by a phrase like *the circumstances* or *the norms*, a set of propositions. Actually, it is the *meaning* of such a phrase; a function from possible worlds w to sets of propositions. If H is a conversational background, $H(w)$ is the set of propositions in terms of which truth conditions are formulated.

Two modals may differ in two respects. They may express two different modal relations (or modal forces). For example, *must*, *ought*, and *should* all express (a weak or a strong) necessity. Second, they may carry different restrictions on the conversational background. Thus *ought* and *should* require a background of a certain sort, while *must* has no restrictions.

Since (1981), Kratzer has assumed two conversational backgrounds: the modal base and the ordering source, conventionally f and g . The difference is primarily that the modal base is *realistic* whereas the ordering source may not be. A realistic conversational background is one that always returns a set of true propositions. Thus a modal base cannot be inconsistent, but an ordering source can; more generally, it is possible that $\cap(f(w) \cup g(w)) = \emptyset$.

- A conversational background H is **realistic** iff for any index w , $w \in \cap H(w)$.

The substance of the distinction between modal base and ordering source is that the former contains facts – circumstances, knowledge – while the latter contains ideals – norms, intentions, universal statements encoding normal courses of events.

Both backgrounds may be *empty*, that is, they may assign every index the empty set; however, most modals require a nonempty modal base. The two necessity modals *ought* and *should* in addition require a nonempty ordering source.

- A conversational background H is **empty** iff for every index w , $H(w) = \emptyset$.

Originally, necessity was defined as logical consequence from $H(w)$. Since (1981), however, Kratzer has assumed a set of refined relations, using the distinction between f and g to treat inconsistencies in a nontrivial way. The definition of (human) necessity says, roughly:

⁶ Toulmin uses this example to show this point in *The Uses of Argument* (1958:11).

- A proposition is a necessity at w wrt. f and g iff it contains all those indices in $\cap f(w)$ that are contained in as many propositions in $g(w)$ as possible.⁷

Note that when $\cap(f(w) \cup g(w)) \neq \emptyset$, human necessity collapses into *simple* necessity:

- A proposition is a **simple necessity** at an index w wrt. a modal base f and an ordering source g iff it contains all indices in $\cap(f(w) \cup g(w))$.

For our purposes, the relevant parameters are

- a modal base consisting of relevant circumstances (a **circumstantial** modal base);
- an ordering source consisting of, unless empty, intentions in a wide sense, including norms, aims, wishes, plans, preferences (a **normative** ordering source).

As simple sentences, the superordinate clauses in the section 2 problem sentences suggest a circumstantial modal base and a normative ordering source; for (15), the ordering source could be described as *what is good for North America*. Note that the intentional expressions between the “external” and “internal” proposition in the subordinate clauses in the section 2 problem sentences, *be (to)* or *α want (to)*, express possible normative ordering sources.

(15) I must find the Golden Helmet.

Consider a simplistic case: (15) with respect to the modal base *the relevant circumstances* and the ordering source *what I want*. Let $\phi = \parallel$ I become owner of North America \parallel , and let $\psi = \parallel$ I find the Golden Helmet \parallel . Assume a world w where what I want consists in just ϕ , and the relevant circumstances consist in just the proposition $\psi \cup \neg \phi$ (the union of ψ and the complement of ϕ – I either find the helmet or do not become owner of North America). This is a case of truth. As there is no inconsistency involved, ψ is a (human) necessity iff it is a simple necessity, that is, ψ is a necessity in w wrt. f and g iff $\cap(f(w) \cup g(w)) \subseteq \psi$; via the substitution $\cap(\{\psi \cup \neg \phi\} \cup \{\phi\}) \subseteq \psi$ this definiens reduces to $(\psi \cup \neg \phi) \cap \phi \subseteq \psi$, which is indeed true.

This minimal case of, essentially, modus ponens may be trivial; but although more realistic cases will be more complex, insofar as, in particular, the modal base will contain a greater number of relevant facts, any truth scenario for a sentence like (15) will basically depend on a similar mechanism.

In the following, attention will be restricted to necessity modals with no constraints on the ordering source, like *must*, *have (to)*, or *necessary*. I shall be assuming that the modal base and the ordering source are consistent. As soon as this assumption becomes

⁷ The precise definition says (Kratzer 1981:47f.): “For all worlds w and $z \in W$: $w \leq_A z$ iff $\{p \mid p \in A \text{ and } z \in p\} \subseteq \{p \mid p \in A \text{ and } w \in p\}$ [...] A proposition p is a human necessity in ... w with respect to ... f and ... g if and only if ... : For all $u \in \cap f(w)$ there is a $v \in \cap f(w)$ such that (i) $v \leq_{g(w)} u$ and (ii) for all $z \in \cap f(w)$: If $z \leq_{g(w)} v$ then $z \in p$.”

essential, I shall return from simple necessity to the more complex notion of (human) necessity.

3.2 Conditionals

There are conversational backgrounds whose values share a common element, i.e., there are H and ϕ such that for any w , $\phi \in H(w)$. This constant ϕ is the antecedent of a conditional. When a modalized sentence is the superordinate clause of a conditional, the subordinate clause serves to restrict the domain of the modal operator in the sense that the proposition it expresses enriches the value of the conversational background. And when the superordinate clause of a conditional is not an explicitly modalized sentence, the subordinate clause restricts the domain of an implicit necessity operator in the same way.

Kratzer bases her theory of conditionals on Lewis' *Adverbs of Quantification* (1975). Lewis regards an *if* clause in the context of a quantifier over cases like *often* as a device for restricting the domain of quantification, and Kratzer generalizes this to say that any *if* clause functions as a restrictive device for some operator, for example, a modal. A modal may be viewed as a quantifier over indices (possible worlds), and the obvious way for an *if* clause to restrict the domain of such a quantifier is to contribute a proposition to the background that is required to restrict the indices anyhow.

It is the modal base, not the ordering source, that ultimately constantly contains the antecedent. Kratzer's (1981) definition of the contribution of an *if* clause to a modal is (p. 68):

Consider an utterance of a sentence of the following form:

(*if* α), (*then modal*....)

This utterance has two parts: The first ... the utterance of the *if* clause, the second ... the utterance of the *then* clause. Suppose that ... p is expressed by the utterance of α . [...]

- (ii) If f is the modal base and g the ordering source for the first part of the utterance, then f^+ is the modal base and g the ordering source for the second part of the utterance. f^+ is that function from possible worlds to sets of propositions such that for any world w , $f^+(w) = f(w) \cup \{p\}$.

It is semantically (though not syntactically) natural to regard an *if* clause as something that modifies a modal, and to describe its semantics solely in terms of the alteration in the conversational backgrounds that it causes. I adopt the following simplistic rule.

Rule 0 (Conditionals)

$$\| (if \alpha) ((must)) \|^{f,g} = \| must \|^{f^+,g}$$

where if α expresses the proposition ϕ then for any w , $f^+(w) = f(w) \cup \{\phi\}$.

I shall refer to f as the **preliminary** and to f^+ as the **ultimate** modal base.

The modal *must* represents any necessity modal. The parentheses around it in the definiendum indicate that it may not be manifest. Wherever there is no overt operator for the *if* clause to restrict, Kratzer's theory posits an implicit necessity operator.

But does it really make no difference whether the necessity modal is overt or covert? The following pair of sentences indicate the opposite. It seems that the intentional, or normative (deontic) interpretation we can get with (16a) we cannot get with (16b).

- (16) a. If China enters the Vietnam war the US must use nuclear weapons.
 b. If China enters the Vietnam war the US will use nuclear weapons.

There is a natural interpretation of this: As far as truth conditions go, (16a) and (b) are synonymous, but there are different utterance situations in which they can be interpreted: They license different conversational backgrounds. The explicit and the implicit necessity modal carry different restrictions on the ordering source. The impression that (16b) excludes a normative interpretation can be explained if we assume that a covert modal requires an empty (normative) ordering source.

- A nonempty normative ordering source requires an overt modal.

In other words, a covert modal requires an empty normative ordering source. This constraint, based on suggestions made by Kratzer (1978:259ff.) and supported by empirical investigations (Sæbø 1986:154ff.), will prove important in the next section.⁸

Consider, again, a simplistic case: (17) in view of the modal base *the relevant circumstances* and the ordering source *what is good for North America*.

- (17) If the curator doesn't find the Golden Helmet before Azure Blue does, then Donald must.

Let ξ be the proposition that Azure Blue does not become owner of North America, let ϕ be the proposition that the curator does not find the Golden Helmet before Azure Blue does, and let ψ be the proposition that Donald finds the Golden Helmet before Azure Blue does. Assume a world w where what is good for North America consists in just ξ and where the relevant circumstances consist in just the proposition $\psi \cup \neg \phi \cup \neg \xi$ (the union of ψ , the complement of ϕ , and the complement of ξ – either Donald finds the Golden Helmet before Azure Blue does, or the curator does, or Azure Blue does become owner of North America). By Rule 0, the meaning reduces to ψ being a necessity wrt. $f(w) \cup \{\phi\}$ and $g(w)$, and as there is no inconsistency involved, ψ is a necessity iff it is a simple necessity, which it is: ψ is a necessity in w wrt. f and g iff $\bigcap (f(w))$

⁸ Conversely, an overt modal does not in general require that the ordering source be nonempty, although mostly it will be. In particular, the negative possibility modals typically found in sentences like (3) are not motivated by a nonempty ordering source, but by considerations relating to agentivity (Sæbø 1986:85ff.).

$\cup \{\varphi\} \cup g(w)) \subseteq \psi$; this definiens reduces, via the substitution $\cap (\{\psi \cup \setminus \varphi \cup \setminus \xi\} \cup \{\varphi\} \cup \{\xi\}) \subseteq \psi$, to $(\psi \cup \setminus \varphi \cup \setminus \xi) \cap \varphi \cap \xi \subseteq \psi$, which is indeed true.

4. The Analysis

In this section, I show, first, that Kratzer's theory of modals and conditionals as it stands cannot account for the intuitive interpretation of sentences like (1), repeated below. Then, modifying the theory, I develop an analysis of the sentences which does predict, or at least go a long way toward predicting, that interpretation.

- (1) You must take the A train if you want to go to Harlem.
 (5) If you go to Harlem, you must / (will) take the A train.

Recall from 2.1 that the sentences have three problematic properties, Problems 1, 2, and 3. To solve Problem 1, it is necessary to answer the question of how the sentences can convey a relation between, not the **external**, but the **internal** proposition (cf. 2.1), or antecedent, on the one hand, and the consequent on the other. This weaker version of Problem 1 can be stated as a separate problem, Problem 4:

Problem 4 How can a sentence *if ... want to φ , must ψ* express a relation between the proposition expressed in φ and the proposition expressed in ψ ?

This means that the analysis of, say, (1) must be similar to the analysis of (5) – similar, but not equal: Still, both *want* and *must* should have a significant function.

Intuitively, the modal in the superordinate clause is interpreted in view of the intention in the subordinate clause, so it appears to be a reasonable approach to regard *you want* as a clue to the ordering source for *must*. (1) can in fact be rephrased as *if you want to go to Harlem, then in view of what you want, you must take the A train*.

Note how Problems 4, 2, and 3 would all be accounted for if the internal antecedent could be treated as an ordering source proposition: The internal proposition would be relevant; the expression of intention would not be redundant, for it would ensure that this proposition is added to the ordering source for the modal; finally, this modal would have to be explicit, for there would ultimately be a nonempty normative ordering source, and an implicit necessity modal requires an empty normative ordering source (cf. 3.2). In sum, it seems that on a satisfactory analysis of sentences like (1), *you want to* ought to define an ordering source 'what you want' in such a way that the proposition that you go to Harlem is included.

4.1 A First Step

The first question is whether in order to treat the internal antecedent as an ordering source proposition it is necessary to alter the theory at all, and it is: The original rule for conditionals, Rule 0 from 3.2, must be revised for the simple reason that it excludes the possibility that (something in) the *if* clause can cause the ordering source to grow. What is required is some specification of Rule +, where the ultimate ordering source g^+ is not necessarily the same as the preliminary ordering source g , so that it may be possible for some expression in the *if* clause to influence the ordering source:

Rule + (Conditionals)

$\| (if \alpha) ((must)) \|^{f,g} = \| must \|^{f^+,g^+}$ where if α expresses the proposition ϕ then for any w , $f^+(w) = f(w) \cup \{\phi\}$ and $g^+ = g$ **or**

Recall from 2.2 the distinction made by Hare (1971) between the ‘waiter’ and the ‘diabetes’ conditional. Assuming that the difference between the two readings is that in the ‘waiter’ case the verb *want* gives a clue to the ordering source for the necessity modal, whereas in the ‘diabetes’ case it does not, Rule 0 only captures the ‘diabetes’ reading, while Rule +, where g^+ can be different from g , leaves room for the ‘waiter’ reading.

The question is how to describe the difference between the preliminary and the ultimate ordering source, g and g^+ , to ensure that the internal proposition is added. On one possible specification of Rule +, the *if* clause in (1) contributes, as usual, the external proposition, that you want to go to Harlem, to the modal base, and at the same time, it sees to it that the ordering source for the necessity modal in the superordinate clause includes what you want. In this way, the necessity sentence would be uttered in view of the relevant facts – in union with the hypothesis that you want to go to Harlem – and your wants:

Rule 1 (Conditionals)

$\| (if \alpha) ((must)) \|^{f,g} = \| must \|^{f^+,g^+}$ where if α expresses the proposition ϕ then for any w , $f^+(w) = f(w) \cup \{\phi\}$ and $g^+(w) = g(w)$ **or** $g^+(w) = g(w) \cup G_\alpha(w)$, where G_α is the ordering source expressed in α (e.g., ‘what you want’).

One may expect the intended interpretation to be a consequence of this analysis, supposing that the internal antecedent will be included in the ordering source. However, this is not so. The ordering source will not contain the internal proposition, that you go to Harlem, invariably, but only in case the external proposition, that you want to go to Harlem, is true, so that the membership of the internal antecedent in the ordering source will depend on the actual truth value of the external antecedent. There are two cases to be distinguished:

- **Either** the external antecedent ϕ is such that $w \in \phi$, in which case the internal antecedent $\xi \in G_\alpha(w)$ where G_α is what you want,

- **or**, $w \notin \wp$, in which case the internal antecedent $\xi \notin G_\alpha(w)$.

In other words, $G_\alpha(w)$ *may* contain the intention specified in the *if* clause, that is to say, the internal proposition, but it may just as well not contain it. And this is not what we want: We want the internal proposition to be relevant independently of the accidental truth value of the external proposition, i.e., we want it to be a *constant* member of the ordering source.

To see the inadequacy of Rule 1 in detail, consider this simplistic case where \wp happens to be false: The sentence (1) is uttered in view of the modal base *the relevant circumstances* and an empty ordering source. Let \wp be the proposition that you want to go to Harlem, the external antecedent, let ξ be the proposition that you go to Harlem, the internal antecedent, and let ψ be the proposition that you take the A train. According to Rule 1, \wp enters into the modal base and G_α , *what you want*, may be added to the hitherto empty ordering source. Let us say that it is indeed added, so that the ultimate ordering source is G_α , *what you want*. Assume, now, a world w where the relevant circumstances consist in just the proposition $\psi \cup \neg \xi$ (either you take the A train or you do not go to Harlem), and where what you want consists in, as it happens, just the proposition that you go to Brooklyn. Then, intuitively, the sentence should be true, independently of what you want; in fact, however, the sentence is false: There being no inconsistency involved, ψ must follow from the set consisting of $\psi \cup \neg \xi$, \wp , and the proposition that you go to Brooklyn, which of course it does not.

4.2 A Second Step

The key to a more adequate analysis seems to lie in the following general paraphrase:

- *if you want to ..., then in view of what you want, you must ...*

Rule 1, now, is not really an implementation of this, but rather of the following, much less plausible paraphrase: *if you want to ... and in view of what you want, you must ...*

Let us focus on the following paraphrase of the *if* clause: *if you want to ..., then in view of what you want*. This is in a sense ambiguous: The phrase *what you want*, in the scope of the *if* clause, can be interpreted extensionally or intensionally. Rule 1 reflects the *de re*, extensional reading, while on the *de dicto*, intensional reading, the ordering source *what you want* is evaluated not at the actual index, but at the indices in the external antecedent. This is the only possible interpretation of the following, equally plausible paraphrase:

- *in view of what you want if you want to ...*

This means that we need a rule according to which an *if* clause *if you want to...* can supply the ordering source ‘what you want in all those worlds where you want to...’:

Rule 2 (Conditionals) (preliminary)

$\| (if \alpha) ((must)) \|^{f,g} = \| must \|^{f^+,g^+}$ where if α expresses φ then for any w ,
 $f^+(w) = f(w) \cup \{\varphi\}$ and $g^+(w) = g(w)$ **or** $f^+(w) = f(w)$ and $g^+(w) = g(w) \cup \bigcap_{v \in \varphi} G_\alpha(v)$, where G_α is the ordering source expressed in α (e.g., ‘what you want’).

Rule 2 distinguishes two cases: Either the modal base or the ordering source grows as a consequence of processing the *if* clause. In the latter case, this clause is taken to supply the set ‘ G_α in all those worlds where φ ’, where G_α is what ordering source is indicated in α , typically what somebody wants to be the case. As to (1), the rule says that this sentence has an interpretation where the *if* clause contributes the set ‘what you want in all those worlds where you want to go to Harlem’. This is the set of propositions that you want to be the case in every world v for v ranging through the proposition that you want to go to Harlem. If we assume that the worlds where you want to go to Harlem are the worlds $w_1 \dots w_n$, the added set of propositions is the intersection of the values of $G_\alpha =$ ‘what you want’ at w_1 through $w_n - G_\alpha(w_1) \cap \dots \cap G_\alpha(w_n)$.

Now, what all values of ‘what you want’ at the worlds in the proposition that you want to go to Harlem will have in common is the proposition that you go to Harlem. For any other independent proposition that you may want to be true in some of those worlds, there will be some other worlds where you do not want it to be true. The internal antecedent will be the only (interesting) proposition that all $G_\alpha(v)$ for v in the external antecedent will contain. This analysis thus ensures not only that the internal antecedent is an addition to the ordering source, but also that it is the only (interesting) addition. To see this as clearly as possible, consider this formulation of $\bigcap_{v \in \varphi} G_\alpha(v)$ for $\varphi =$ that you want p and $G_\alpha =$ what you want: The set of q such that for all v , if in v you want p to be the case, in v you want q to be the case. It is evident that p is such a q , and that not much else is; at most what follows from p .⁹

As it stands, Rule 2 seems very ad hoc. If the modal base grows, then by the singleton set consisting of the external antecedent; while if the ordering source grows, then by the G indicated in the *if* clause as evaluated at all the indices in the external antecedent (and thus effectively by the singleton set consisting of the internal antecedent). However, there is a way to reformulate the case where the modal base grows so as to generalize the definition. The *if* clause can alternatively be thought of as supplying the modal base ‘what is the case in all those worlds where φ ’. This provides an equivalent formulation of Rule 2:

⁹ One may want to say that if you want p you necessarily want the logical consequences of p , and thus that the set of q that you necessarily want if you want p includes the supersets of p . For the moment, we may leave this open (but cf. 5.1, fn. 12).

Rule 2 (Conditionals) (final)

$\| (if \alpha) ((must)) \|^{f,g} = \| must \|^{f^+,g^+}$ where if α expresses ϕ then for any w ,

- (i) $f^+(w) = f(w) \cup \bigcap_{v \in \phi} F(v)$ and $g^+(w) = g(w)$
where F is the general modal base ('the facts', 'what is the case'), **or**
- (ii) $f^+(w) = f(w)$ and $g^+(w) = g(w) \cup \bigcap_{v \in \phi} G_\alpha(v)$
where G_α is the ordering source expressed in α (e.g., 'what you want').

Here, the case where the modal base grows, effectively by the external antecedent,¹⁰ and the case where the ordering source grows, effectively by the internal antecedent, are parallel. The difference is that in the latter case, the background G_α must be explicit in the *if* clause, while in the former case, the background F may be implicit. This reflects the general fact that normative ordering source propositions, if cotextually expressed, are embedded under some attitude, while modal base propositions are normally expressed in simple sentences.

The common core of Rule 2 is that any *if* clause defines a conversational background to be evaluated with respect to the proposition expressed. This may be the general modal base, *the facts*, *what is the case*, but it may also be an ordering source like *what you want*, *what is to be the case*, etc., if such an ordering source is indicated.

Rule 2 is a disjunctive interpretive rule, reflecting a case distinction and an ambiguity in the contribution of an *if* clause as a distinguished piece of context. 2(ii) presupposes that G is defined for α . If it is, there is still a choice between 2(i) and 2(ii), to account for Hare's two readings ('waiter' vs. 'diabetes', cf. 2.2); the context decides, via g^+ , whether G_α is also relevant for the interpretation of the modal so that we get the necessary condition reading. The analysis does not depend on a distinct semantic representation for this interpretation.

Still, one may question its compositionality. In a certain sense, we have to look into the *if* clause to see if an ordering source is indicated there by some expression of intention. Importantly, however, the analysis does not refer to the content of the clause directly, but through the contextual parameter G_α . The expression of intention thus functions as a piece of context, influencing the ultimate ordering source parameter g^+ in the usual way, only, occurring in a conditional clause, it is evaluated against the background of the antecedent.

For a conditional to be interpreted according to Rule 2(ii), a normative ordering source must be indicated in the *if* clause. And, there must be an overt modal in the matrix clause, since the ultimate ordering source will not be empty and a covert modal requires an empty normative ordering source (cf. 3.2). If, now, a conditional is indeed interpreted according to Rule 2(ii), it will express a relation between the 'internal antecedent' and the consequent. Thus the analysis solves Problem 2, concerning the func-

¹⁰ To be exact, the addition to the modal base is under this revised formulation not $\{\phi\}$ but – what is the case in all those worlds where $\phi - \{\psi \mid \phi \subseteq \psi\}$. However, since on the definition of necessity (or another modal relation), as far as modal bases $f(w)$ for some w are concerned, only the intersection $\cap f(w)$ is relevant, this difference is negligible, $\cap \{\psi \mid \phi \subseteq \psi\}$ being ϕ .

tion of the expression of intention, Problem 3, concerning the function of the expression of necessity, and Problem 4, of how such a conditional can express a relation between the internal antecedent and the consequent.

However, the Problem 2 question of why the expression of intention is necessary is only answered in a superficial way. Without it, the antecedent would end up in the modal base instead of in the ordering source. The deeper question is what substance this distinction has. It ought to have some substance, as intuitively, (18) and (19) mean two different things. This question is closely related to Problem 1 concerning the intuitively felt equivalence between conditionals like (19) and (20). It seems that these form a case of contraposition but that contraposition functions better if in one conditional the antecedent is an ordering source, not a modal base proposition. Section 5 is intended to resolve these questions.

(18) If the hunt is a success, the hunter must offer a sacrifice.

(19) If the hunt is to be a success, the hunter must offer a sacrifice.

(20) If the hunter does not offer a sacrifice, the hunt cannot be a success.

5. Contraposition and Time

This section is concerned with the semantics of conditionals whose antecedent enters into the ordering source as compared to conditionals whose antecedent is added to the modal base. I show, first, that the distinction made between the ordering source and the modal base in Kratzer's theory as it stands is not sufficient to account for the intuitive semantic difference. I then discuss the temporal properties of the two species of conditionals and propose to augment the truth conditions for modalized sentences by differentiating (normative) ordering source propositions and (circumstantial) modal base propositions in terms of time.

5.1 The Modal Dimension

Quite generally, modal bases are different from ordering sources in that they are realistic, assigning to any world a set of propositions all true in the world. A modal base will consist of facts, whereas an ordering source will contain ideals. However, a modal base to which a conditional antecedent has been added is not realistic, as this would require the antecedent to be true in any world. A conditional antecedent is of course not a fact but a hypothetical fact, no more necessarily true than a hypothetical ideal. So this characteristic of modal bases vs. ordering sources does not help to separate conditionals like (18) from conditionals like (19).

However, ordering source and modal base propositions are treated differently in the truth conditions for the modals; they play different roles in the definitions of the modal

relations. The difference comes to surface in the event of an inconsistency in the union $f(w) \cup g(w)$; then the former has a sort of priority. As long as there are worlds where all the modal base propositions and all the ordering source propositions are true, a proposition is a necessity just in case it is true in all those worlds. As soon as there is some inconsistency, however, for a proposition to be a necessity it must be true in all the worlds where all the modal base and as many as possible of the ordering source propositions are true (cf. 3.1, fn. 7).

It can be shown that a necessity conditional where the antecedent ends up in the ordering source is stronger than a conditional where the same proposition is added to the modal base. A sentence like (19) will entail one like (18), but not vice versa. It is the possibility of an inconsistency in the two conversational backgrounds which is responsible for the difference. The question is whether this is an appropriate description of the real semantical difference.¹¹

Considering the question of **contraposition**, comparing (18) and (19) with (20), we may note that if the (preliminary) ordering source is nonempty, contraposition is not valid, no matter where the antecedent goes. But if we concentrate on cases where the preliminary ordering source is empty, contraposition between two modal base antecedent conditionals is predicted to be valid. And on such a background, (19), or generally, the conditional where the antecedent goes to the ordering source, is predicted to entail (20), the conditional where the negation of the former consequent goes to the modal base; but not vice versa. Again, it is the possibility of an inconsistency which is responsible for the difference in strength.¹²

However, these predictions hardly do justice to our intuitions. The different role of the antecedent in the event of an inconsistency appears to be too marginal a difference to account for the true difference in meaning between (18) and (19). As far as the modal dimension is concerned, the latter is a margin stronger, a property that comes to surface in the case of an inconsistency. Yet intuitively, the two sentences simply mean two slightly different things. In particular, (19) and (20) form a convincing case of contraposition, while (18) and (20) definitely do not. In the next subsection, I will suggest an explanation for this and sketch how the theory could be extended to accommodate this explanation.

5.2 The Temporal Dimension

It seems that the semantical difference between (18) and (19), as between (18) and (20), has to do with the temporal relation between the antecedent and the consequent. We tend to read (18) in the sense that the consequent event must succeed the antece-

¹¹ It has been suggested to me that the given analysis makes conditionals like (19) too strong. I think this point is debatable, but actually debating it would carry us too far afield. In any case, it is difficult to have clear intuitions about truth values in cases of inconsistency.

¹² Here the question arises of whether the added ordering source $G(v)$ for v ranging through φ contains just the internal antecedent or also the propositions including it (cf. 4.2, fn. 9). The conditional is somewhat weakened if the added ordering source does contain the supersets.

dent event, and we tend to read (19) in the sense that the consequent event must precede the antecedent event.

- (21) If the hunt is a success, the hunter must *#first / subsequently* offer a sacrifice.
 (22) If the hunt is to be a success, the hunter must *first / #subsequently* offer a sacrifice.

It has been noted (e.g., by Settekorn 1974:150, Cooper 1978:165) that one reason that contraposition often fails is that antecedent and consequent are not necessarily simultaneous. The conditional can be true if the consequent event succeeds the antecedent event at the relevant index. If there are two distinct reference times (location times), that of the consequent can succeed that of the antecedent, but the converse is impossible. If such a conditional is contraposed, the temporal order is reversed. It has also been noted that the contrapositive can be improved by replacing the tense of the “new” consequent by the perfect, transposing the ultimate event time back into the past. This method may produce fairly good results in the case of two separate reference times. In cases like (23a), however, where the consequent event may succeed the antecedent event within one reference interval, it is difficult to judge whether in a sentence like (23c) the temporal relation is preserved.

- (23) a. If you shout “Sesame,” the cave opens.
 b. ?If the cave does not open, you do not shout “Sesame.”
 c. If the cave does not open, you have not shouted “Sesame.”

In fact, if we formulate a general constraint on time relations in conditionals, it turns out that contraposition will fail to maintain truth conditions, even with a perfect substitution. Such a constraint has been formulated by Max Cresswell (1977). It says, roughly, that the consequent must *weakly outlast* the antecedent; the end point of its event time must be at least as late as the end point of the event time of the antecedent.¹³

What about a semantics for the word IF. One suggestion might be that $\langle \text{IF}, \alpha, \beta \rangle$ is true at an interval iff whenever α is true at some subinterval within that interval β is true at a subinterval which ends no earlier than the subinterval at which α is true. Put formally we have: $V(\text{IF})$ is the function ω such that for any $\alpha, \beta \in D_0$, and $\langle w, t \rangle \in W$, $\langle w, t \rangle \in \omega(\alpha, \beta)$ iff for any subinterval t_1 of t if $\langle w, t_1 \rangle \in \alpha$ then there is a subinterval t_2 of t such that there is no $m \in t_1$ which occurs after every $m' \in t_2$ and $\langle w, t_2 \rangle \in \beta$. (Cresswell 1977:19)

Though based on material implication, the condition can be adapted to another conditional semantics by relating the time index to the relevant world indices satisfying the antecedent. Let e be a function assigning to a time interval its end moment. Then for

¹³ The proposal is based on one common reference time for the consequent and the antecedent, but it is easy to extend it to the more general case of two reference times which may coincide.

every w where the antecedent α is true and the consequent β must be true for the conditional to be true:

- **Time in Conditionals (preliminary)**

$$(\forall t_1 \subseteq t) [t_1 \in \alpha \supset (\exists t_2 \in t) [e(t_2) \geq e(t_1) \wedge t_2 \in \beta]]$$

If we “contrapose” this structure by simply replacing α by the negation of the consequent β and β by the negation of the antecedent α we do not get an equivalent structure. The reason is obvious: The temporal relation is asymmetrical and should be “contraposed” as well.

- **Contraposition 1**

$$(\forall t_1 \subseteq t) [t_1 \in \neg \beta \supset (\exists t_2 \in t) [e(t_2) \geq e(t_1) \wedge t_2 \in \neg \alpha]]$$

Even if in this structure we substitute for α its perfect-tense version, we do not get a valid contrapositive, no matter how we interpret the perfect. What is needed for the contrapositive to be valid is the following, where s is a function assigning to an interval its start moment.

- **Contraposition 2**

$$(\forall t_1 \subseteq t) [t_1 \in \neg \beta \supset (\exists t_2 \in t) [s(t_2) \leq s(t_1) \wedge t_2 \in \neg \alpha]]$$

However, since normal conditionals express the relation $e(t_2) \geq e(t_1)$, to express the relation $s(t_2) \leq s(t_1)$ there is a need for a separate form of sentence. Suppose that conditionals where the antecedent is an ordering source proposition represent this form of sentence.

- **Time in Conditionals (final)**

$$\begin{aligned} (\forall t_1 \subseteq t) [t_1 \in \alpha \supset (\exists t_2 \in t) [e(t_2) \geq e(t_1) \wedge t_2 \in \beta]] & \quad \text{(modal base } \alpha) \\ (\forall t_1 \subseteq t) [t_1 \in \alpha \supset (\exists t_2 \in t) [s(t_2) \leq s(t_1) \wedge t_2 \in \beta]] & \quad \text{(ordering source } \alpha) \end{aligned}$$

If we thus ascribe to conditionals like (24b) a temporal structure that reverses the structure ascribed to conditionals like (24a) or (24c), this can account for the felicity of contraposition between two conditionals like (24b) and (24c) as compared to the infelicity of contraposition between two conditionals like (24a) and (24c).

- (24) a. If the cave opens, *(then at least as late as that)* you shout “Sesame.”
 b. If the cave is to open, *(at least as early as that)* you must shout “Sesame.”
 c. If you do not shout “Sesame,” *(at least as long as that)* the cave stays shut.

The requirement that an ordering source antecedent must be (weakly) preceded, not succeeded, by the consequent would be rather ad hoc if it were postulated as a property of conditionals. However, it can be anchored to a general temporal feature of ordering source propositions. Ordering source antecedents are special instances of normative ordering source propositions, and, in a rough sense, intentions are “in the future”. The general idea is that propositions that are to be necessities must be “late” in relation to facts but “early” in relation to ideals. Ultimately, these constraints must be incorporated into the definition of the modal relations. Actually doing so would go beyond the scope of this paper. Even so, a case has been made that the main semantical difference between conditionals with hypothetical ideals, like (19), and with hypothetical facts, like (18), is to be sought and found in the temporal dimension.

6. Conclusions

The problem discussed in this paper derives from the intuitively felt equivalence between a sentence like (1) and one like (3). While we have a good notion of how a sentence like (3) is interpreted, if we apply the same semantics to (1), we are not in a position to describe the role played by the expression of intention. To answer the question of why this expression has to be present here but absent in (3), we need a theory of conditionals that has something to say about intentions. Kratzer’s theory is such a theory, a combined theory of modals and conditionals in which intentions play a definite role in relation to modals.

As I have shown in section 4, Kratzer’s theory is almost, but not quite, equipped to give a satisfactory description of sentences like (1). What seems to be going on is that the modal is interpreted in view of the intention, in the terms of the theory, that the conditional clause contributes the “internal” proposition to the ordering source for the modal. It will not do to assume that the *if* clause gives a clue to the ultimate ordering source through the verb *want*. We need to say that an *if* clause can contribute whatever ordering source is indicated in it, *with respect to the external proposition*. Thus (1) can mean that in view of what you want if you want to go to Harlem, you must take the A train. The original definition of standard conditionals like (3) can be reinterpreted to fit into a uniform definition, a disjunctive rule reflecting a contextual choice between a standard and the necessary condition interpretation. Relying on contextual parameters, the analysis of this interpretation is compositional.

Still, as noted in 2.3, there is an element of conventionalization, or grammaticalization, in the semantics of the sentences. For one thing, the conditional clause can be replaced by a purposive clause; for this no analysis has been offered. Another apparent idiosyncrasy is the constraint that a verb like *want* can only be used as an ordering source indicator in the relevant sense if its subject corefers with that of the verb of the consequent clause.

Problem 1, of how (1) can mean the same as (3), reduces to the question of the validity of contraposition when one sentence has an ordering source antecedent. We re-

call from 5.1 that in the modal dimension, contraposition is not valid in the general case; the fact that we nevertheless accept the inference must be attributed to a tendency to factor out nonempty preliminary ordering sources or to abstract away from possible inconsistencies.

Finally, to explain why the inference relation between two conditionals like (1) and (3) is less problematic than contraposition usually is, I propose to discriminate between modal base and ordering source propositions temporally; necessities have to be “late” in relation to facts, but “early” with respect to ideals. In particular, conditionals like (1) and ones like (3) are subject to two distinct temporal constraints that render contraposition temporally symmetrical, and this completes the semantic description of the former type of sentence.

Note that this analysis would be impossible outside a framework like Kratzer’s, where a word like *must* in the consequent clause of a conditional is identified with the conditional operator and this operator may be sensitive to a word like *want*. Only thus can sentences like (1) be described as conditionals with the argument proposition of *want* as an antecedent and the argument of *must* as the consequent. In the version of the theory developed here, the picture emerges that there are two kinds of conditionals, one where the antecedent is a hypothetical fact and another where it is a hypothetical ideal. The difference is moderate, but sufficient to say that the second kind states that the consequent is a necessary condition.

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