

AN ANALYSIS OF 'IF' SENTENCES
FROM THE STANDPOINT OF COMMUNICATION¹

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The challenge of 'if' sentences

This article examines 'if' sentences and asks how one can explain the acceptability of one sentence over another in specific written contexts. It takes into account the temporal relations expressed in 'if' sentences and the communicative intents that lie behind their use. The analysis presented has its roots in our work on robots that understand English. We hold the strong conviction that the many subtle but clear distinctions that exist in English, such as those expressed in 'if' sentences, are there for good purpose. They have developed historically and are used for effective and accurate communication. Although it may well be that our ultimate objective in communication with robots is to have the same completely free and sloppy use of language characteristic of spoken speech, a necessary first step toward this goal is to have robots understand the standard uses of English typically found in well-written text. It is in this framework that the analysis presented in this paper is conducted.

Why are 'if' sentences such a challenge in general to semantics? One reason is the wide range of complex notions they can be used to communicate. A recent issue of *The New York Times Book Review* (July 26, 1992) contains these examples. Notice not only what complex idea is being communicated in each case, but what specific temporal, logical, or causal relation is being described.

- (1) If I gave up the thing I loved most in the world, then maybe God would respect my desperation.
- (2) If local residents talk about Italy's south, the word 'Mafia' is likely to be heard.
- (3) If you keep a camera running too long inside a car, you're dead
- (4) If the author did know him fairly well, you couldn't tell from the sketches presented in his book

- (5) If time is irrelevant to atoms, how do complicated assemblages like ourselves arise?
- (6) If ... we can do anything to make you happier, please let us know.
If you want the [book] Selection, do nothing.
If you want another book ..., send us the Reply Form
- (7) If sequels beg comparison to their predecessors, then these further adventures of Chris and Ellen ... feel too imaginary, grotesque and adventitious to fully measure up.
- (8) If most editors ... do not read the blind manuscript, they also rarely write the long rejection letter
- (9) If Troy was a city of secret horrors, the Selzer family fit in well there.

In (1) we have an imagined unfolding of a sequence of events. First a condition is fulfilled – there is an act of giving up. Then there is a consequence – the Deity responds. Relative to what is generally called the speech time, that is, the time of utterance or the time at which the thought is expressed, the act of giving up may in fact have already taken place, but in the imagined unfolding, both it and its consequence are in the future relative to some reference point.

The sentence in (2) expresses a generalization about occasions on which a condition is fulfilled. Whenever the condition – local residents talking about the south – is fulfilled, some other event occurs, namely, hearing the word 'Mafia' spoken during the condition's fulfillment. The generalization is true of the past, the present, and is projected to be true of the future.

The sentence in (3) expresses a temporal and causal relation between a camera's being kept running too long inside a car and what happens to the director's career as a result – it "dies." Contrast (3) with the following three sentences.

- (3') If you kept a camera running too long inside a car, you would be dead
If you had kept a camera running too long inside a car, you would be dead
If you had kept a camera running too long inside a car, you would have been dead

The sentence in (3) is in the indicative mood whereas those in (3') are in the subjunctive mood. All four, however, present imagined unfoldings of sequences of events. The difference between (3) and the first sentence in (3') is subtle, the latter carrying with it some doubt about the likelihood of the condition's fulfillment. The last

two sentences in (3'), known as counterfactuals, are used when the speaker wishes to express doubt about the condition's fulfillment in the past, or in fact believes the condition to be contrary to fact, but nevertheless wishes to project the condition's fulfillment into the future relative to some reference point. Contrast the four sentences in (3) and (3') with

(3'') If you kept a camera running too long inside a car, you will be dead.

This sentence has quite different import. In it, although the speaker does not know whether the condition has been fulfilled or not, its fulfillment or non-fulfillment is understood to be a settled matter and for purposes of argument the assumption is made that it is fulfilled. The 'if' sentence is used to say: Let us suppose that at some time in the past you kept a camera running too long; given that, at some time in the future you will be "dead."

In (4) and (5) we have counterfactuals in which the speaker believes the conditions in the subordinate clauses to be contrary to fact. What is being asserted, or at least suggested, in (4) is that the author did *not* know the subject well and that this is evident from the book's content. The question in (5) can be recast as a statement saying, 'If time is [were] irrelevant to atoms, it is hard to see how [it is unlikely that] complicated assemblages like ourselves could [would] arise'. What is being stated is that time *is* relevant to atoms and that that relevance is needed to explain or make plausible our coming into existence.

Next, from an advertisement, we have the three conditional commands in (6). The condition in the first example is a complex one and there is additionally an implied promise in the main clause. This imperative can be paraphrased as 'For anything, if we can do it and it makes you happier, then tell us what it is and we will do it'.

The last three examples are interesting in that they are "logical counterparts" to the counterfactuals. In them, the speaker is asserting that the condition in the subordinate clause *does* indeed or did hold and that there is some connection *between* that condition's holding and the truth of the proposition expressed in the principal clause. What is being expressed in (7) is that sequels do invite comparison to their predecessors and that after making the comparison,

it can be concluded that the sequel does not measure up to its predecessor. Sentence (8) also presents a conjunction of propositions disguised as a conditional statement for specific effect. What is being stated is that most editors do not read unsolicited manuscripts and that having established that fact, it is just as clear, or similar arguments establish, that editors write only short rejection letters. Sentence (9) states that Troy was a city of secret horrors and that for that very reason the Selzer family fit in there.

A similar wide range of 'if' sentences can be found in verbal interactions with robots. Conditional commands are ubiquitous and their importance for precisely specifying the conditions under which a robot should take specified action cannot be overstated. Conditional statements are used in a variety of ways. They can summarize the purpose and projected effect of preceding commands, as in

(10) If you complete these steps, the meal will be cooked

A conditional statement can also be used to reinforce a preceding command by giving a means of checking whether an action has been successfully carried out. Consider, for example,

(11) If you closed the door securely, there will be no draft.

A conditional statement can also express generalizations about a condition's satisfaction and so help stipulate the robot's action under specified conditions. For instance,

(12) If the door is closed, the meeting is over

will inform a robot that it can take whatever action is appropriate to the conclusion of the meeting.

Traditionally, 'if' sentences have been categorized as either subjunctive or indicative as determined by the mood of the verbs in the subordinate and principal clauses. Under this view, sentence (1), the sentences in (3') and the sentence in (4) are subjunctive (with counterfactuals such as (5) also included because the subjunctive 'were' can replace for 'is' without change of meaning). The remaining sentences are categorized as indicatives. The general assumption has been that the two kinds of conditionals have distinct logical and semantical properties.

Our belief is that an entirely different kind of taxonomy is needed, that 'if' sentences must be differentiated, in part, in terms of the communicative intent of the speaker and the kinds of temporal relations expressed in the sentence. We also find ourselves concerned less with the truth or falsity of 'if' sentences than with evaluations of how suitable a given form of 'if' sentence is for communicating a given idea in particular circumstances. Central to such evaluations is the interpretation of tense in the conditional. Before presenting our proposal, to put it in perspective, we briefly review the standard approaches that have been taken to both conditionals and tense.

Approaches to conditionals and tense

The indicative conditionals are typically thought to be truth functional; that is, it is assumed that the truth value of the conditional can be assessed by evaluating the truth values of the antecedent, expressed in the subordinate clause, and consequent, expressed in the principal clause. It has also been assumed, surprisingly often, that these conditionals have the same truth conditions as the material conditional; that is, it has been assumed that an indicative sentence of the form *If p then q* is true just in case proposition *p* is false or proposition *q* is true. Other proposals reject any such simple assessment of truth, arguing that we should take into account not only the truth values of the antecedent and consequent in the actual world but also their truth values in any number of so-called "possible worlds." Along completely different lines, proposals have been made that reject truth conditions altogether and analyze indicative conditionals instead in terms of assertibility and conditional probabilities. So, for instance, *If p then q* is assertible if and only if the probability of *q* given *p* is high. See Appiah (1984), for instance.

Possible-world proposals have dominated in analyses of subjunctive conditionals. These proposals differ from one another largely in terms of the restrictions placed on the possible worlds that should be considered. For instance, the idea originally advanced by Stalnaker (1968) was that the conditional *If p then q* is true just in case *q* is

true in the world “most like” the actual world in which p is true. Since the publication of Stalnaker’s proposal, which included both a formal semantics for conditionals and an axiomatic system of conditional logic, a vast amount of material on conditionals has been generated. In its simplest form, the language of conditional logic (restricting ourselves to the sentential case) is a set L of sentences that can be constructed from the symbols of classical sentential logic, namely the sentential variables p_0, p_1, \dots and the connectives \neg (negation) and \wedge (conjunction), together with the symbol $>$ for the subjunctive conditional connective. The conditional $p > q$ is true at a world w if and only if q is true at a world $w' = s(p, w)$ where s is a selection function that for each antecedent p and world w picks out a world w' . The various axiomatizations of the logic and the various selection functions that have been proposed for both the indicative and the subjunctive conditionals are too numerous and detailed to present here. A useful review is provided by Nute (1984).

The nagging concern in many recent analyses of ‘if’ sentences, however, is that there is some connection between what is expressed in the subordinate clause and what is expressed in the principal clause, and that this connection cannot be captured by conditional logics and possible-world semantics. See, for example, Barwise (1985). This connection may be causal, temporal, explanatory or some combination of such factors. In the examples that opened this article, the richness of these connections was evident. Barwise in fact explicitly rejects truth conditions for conditionals, proposing rather that they be analyzed in terms of information conditions that capture the connection between subordinate and principal clauses.

Further complicating the issue of ‘if’ sentence semantics is that these sentences exhibit various tense and mood combinations that appear to strongly influence their meaning. Consider how different the circumstances are under which it is appropriate to use each of the following sentences.

- (13) If she travels by Easy Airlines, she buys insurance
 If she travels by Easy Airlines, she will buy insurance
 If she travelled by Easy Airlines, she bought insurance.
 If she travelled by Easy Airlines, she will buy insurance.
 If she travelled by Easy Airlines, she will have bought insurance.
 If she travelled by Easy Airlines, she would buy insurance
 If she had travelled by Easy Airlines, she would buy insurance

If she had travelled by Easy Airlines, she would have bought insurance.

Consideration of tense, we believe, should figure as large as mood in evaluations of ‘if’ sentences.

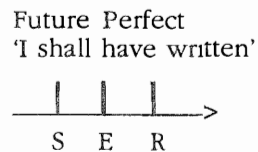
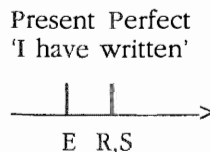
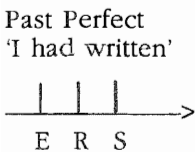
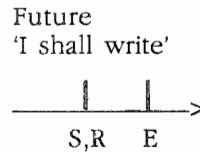
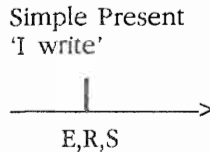
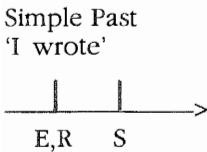
It is generally assumed that the truth value of a sentence in the present tense may very well differ from the truth value of the corresponding sentence in the past tense or the future tense. So at any particular moment in time, for instance, ‘Sue walks to town’, ‘Sue walked to town’, and ‘Sue will walk to town’ may have different truth values. To capture these distinctions, temporal logic adds to classical sentential logic several 1-place tense operators. At its simplest, it adds F (it will be the case at some time), and P (it was the case at some time). If p symbolizes ‘Sue walks to town’, then Fp symbolizes ‘Sue will walk to town’, and Pp symbolizes ‘Sue walked to town’.

The language of traditional temporal logic (restricting ourselves to the sentential case) is a set L of sentences that can be constructed from the sentential variables p_0, p_1, \dots (typically writing p and q for the first two variables, the connectives \neg (negation) and \wedge (conjunction), and the temporal operators F and P . The semantics for this language includes a set S of moments of time with a relation $R \subset S^2$ on it representing the “flow” of time (the earlier-later or before-after relation). So for $t, s \in S$, tRs reads t is in the past of s or s is in the future of t . With each moment of time t is associated the function $D_t: L \rightarrow \{0, 1\}$ which gives the truth values of the atomic propositions at time t . That is, $D_t(p) = 1$ if and only if p is true at the moment t . The truth value of a non-atomic proposition is defined by induction. Specifically, for the P and F operators, $D_t(Pq) = 1$ if and only if $D_s(q) = 1$ for some s such that sRt , and $D_t(Fq) = 1$ if and only if $D_s(q) = 1$ for some s such that tRs .

Studies in tense logic have been concerned primarily with asking what conditions should be imposed on R and what axioms should be proposed for the tense operators. That is, the concern has generally been to find axioms that “fit” various assumptions about the nature of time. Relatively little work has been done on the question of representational adequacy, that is, the question of how adequate tense logic is for representing the temporal relations expressible in a natural language such as English.

There are notable exceptions. Some studies have investigated the difficulties posed by words such as 'since', 'until', 'uninterruptedly', 'recently', 'soon', 'now', and 'then', showing that the system of tense logic sketched above is inadequate to express these temporal notions. An additional tense operator J (it is the case at the time of utterance) has been proposed to meet the need. A good overview of this work can be found in Burgess (1984). It has been further suggested that we need to evaluate the truth of some statements not at a single point but at a sequence of points, where each point is identified with one of the events referred to in the sentence (Gabbay 1974). A sentence that makes this point intuitively is the following: 'She will realize that by the time she finishes her book the contract will have been cancelled'. In this statement, the interpretation of the future perfect 'will have been cancelled' is relative not to the time of utterance but to the woman's realization and the book's completion.

This proposal – that more than one time point is required for the analysis of a tensed expression – has an interesting precursor in the work of Hans Reichenbach (1947). Reichenbach identifies three time points in his analysis of tensed verbs: the time of the event described by the verb phrase (E), the time of utterance (S , for "speech time"), and a reference point (R). For all past-tense sentences, the event time E is prior to the speech time S . For all present-tense sentences, the event time E is co-temporaneous with the speech time S . For all future-tense sentences, the speech time S is prior to the event time E . The reference point R allows the perfect tenses to be differentiated from the simple present, the simple past, and the future as follows.



It should be noted that the future tense can also be analyzed with the reference time occurring simultaneously with the event time rather than the speech time. In addition, adverbial phrases of time have the effect of shifting the reference time. For example, 'I shall write after dinner' apparently has the temporal structure *S* followed by *R* (the time of dinner) followed by *E* (the time of writing). And 'I shall write before dinner' appears to have the structure *S* followed by *E* followed by *R*. It should not be surprising that this structure is the same as that for the future perfect. A natural paraphrase of the sentence is 'By dinner time I shall have written'.

For English sentences involving both tense and conditional constructions, it is typically assumed that they can be adequately represented within a formal language containing a conditional operator (such as the $>$ connective of Stalnaker's proposal) together with tense operators such as *P* and *F*. One detailed study along these lines is that of Thomason and Gupta (1980), who acknowledge, however, that the simple indicative-subjunctive distinction is not sufficient to account for the temporal differences expressed in the following pair of sentences, now familiar in studies of conditionals:

(14) If Oswald did not shoot Kennedy then Kennedy is alive today,

and

(15) If Oswald had not shot Kennedy then Kennedy would be alive today.

They suggest that the first has the logical form $Pp > q$ and the second $P(p > q)$, where *p* symbolizes 'Oswald does not shoot Kennedy' and *q* symbolizes 'Kennedy is alive'. The difference, they say, is one of scope. In the first, the temporal operator has scope only over *p*, in the second it has scope over the conditional $p > q$.

Our contention is that the temporal differences are more profound and that these differences become clear when we evaluate the sentences not in terms of their truth or falsity but in terms of their use in communicating certain kinds of ideas. In what follows in the next section, we have adopted the approach taken in much of our work on verbal communication with robots in that we assign a primary role to the speaker's intent (Crangle 1989, Crangle & Suppes forthcoming, Suppes and Crangle 1988). That is, we believe that sentences, whether imperative or indicative, are used with specific com-

municative intent and that they can be correctly interpreted only if the speaker's intent is taken into account. For the interpretation of tense in 'if' sentences, we adopt a version of the tripartite schemata of Reichenbach and argue that the conditional construction shifts around in various ways the reference, speech and event times of the subordinate and principal clauses.

One study of 'if' sentences that should be mentioned before we present our ideas in more detail is that of Dudman. See Dudman (1984), for instance. This work is notable in that it embraces a large number and a wide variety of 'if' sentences actually found in written contexts. It also advocates a new taxonomy for 'if' sentences and incorporates temporal considerations directly into its proposed taxonomy, a feature we consider important to an adequate understanding of 'if' sentences. We recognize four categories of 'if' sentences, the first three of which owe much to Dudman. We want to make the point that we think the ideas we are presenting are by no means the final word. In fact, the more we study the temporal and conditional subtleties of English the more we are convinced that there is no end in sight for additional systematic analyses and additional theoretical insights. The likelihood of a fixed and final theory of these matters at any time in the near future seems very small.

Communicative intent and a taxonomy of 'if' sentences

Our proposal is that we use a declarative 'if' sentence to do one of four things:³ I) to present an argument from hypothesis (expressed in the subordinate clause) to conclusion (expressed in the principal clause); II) to present an imagined unfolding of a sequence of events; III) to form generalizations about occasions on which a condition is satisfied; and IV) to make two connected assertions.

I. To present an argument from hypothesis to conclusion.

The distinguishing mark of 'if' sentences used in this way is that the subordinate and principal clauses are understood exactly as they

would be if they were used as sentences on their own, particularly with regard to their temporal significance. Consider, for example, the following statement addressed to the house painter as you walk up the driveway to inspect her work.

(16) If you painted the wall as directed, you will get paid.

Here a specific event of painting that either did or did not take place in the past is being referred to, as is a specific future event of being paid. For purposes of argument the hypothesis is made that you did paint the wall as directed, that is, that the event referred to in the subordinate clause did take place. The conclusion then is that you will be paid. Other examples are given by

(17) If it is raining, I will take my umbrella,

and

(18) If Graeme did not take the cake, Gwendoline did.

So 'you painted the wall', 'Graeme did not take the cake' and 'Gwendoline did' (past tense) designate events in the past, 'it is raining' (present tense) designates an event in the present, and 'you will get paid' and 'I will take my umbrella' (future tense) designate events in the future. These clauses can all stand on their own, as they appear, as sentences. In each case, even within the conditional, they have their ordinary temporal interpretations. Sentence (3'') is also an example of this kind of 'if' sentence.

II. *To present an imagined unfolding of a sequence of events.*

Examples (1), (3), (3'), (4), and (5) fit into this category. But consider also these sentences.

(19) If you painted the wall you would get paid

(20) If you paint the wall you will get paid.

(21) If you had painted the wall you would get paid

(22) If you had painted the wall you would have got paid.

In each, the subordinate and principal clauses cannot be used as sentences on their own with the same temporal significance they

carry in the conditional. Take (19), for example. When used to present an imagined unfolding of a sequence of events, it operates as a prediction as to what will happen if you paint the wall some time in the future relative to some reference point. There is no past event of painting being referred to, as there is if the subordinate clause were used on its own. Note that this use of the sentence is distinct from that in which 'would' is the emphatic form of 'will'. There the speaker would be arguing from hypothesis – you painted the wall some time in the past – to conclusion – you will definitely get paid some time in the future. Note too that the sentence in (20), although it can be, is not as naturally used in the first way. The most natural expression of the hypothesis that you are painting the wall now with the conclusion that you will get paid some time in the future uses the present continuous tense, as we just did. The appropriate 'if' sentence is

(23) If you are painting the wall, you will get paid

'You are painting the wall' has its natural present-tense interpretation both in and separate from the conditional; 'you paint the wall' does not.

For sentences having the form of (21) or (22), the condition in the subsidiary clause is assumed not to have been satisfied in the actual past. The condition's satisfaction is nevertheless projected into the future relative to some reference point which is in the past relative to the speech time *S*. The principal difference between (21) and (22) is that for (22), with its use of the modal 'would have' as opposed to 'would', the event in the principal clause is constrained to have occurred in imagination before the speech time *S*. These sentences express the idea that if the condition had held – which it did not – the event described would have taken place – but it did not or will not take place.

This category of 'if' sentence use is complex and we suspect it could be usefully broken down into subcategories. It is presented here as one category, however, because the sentences all have in common that they present an unfolding sequence of events in imagination and the principal and subordinate clauses cannot be used as sentences on their own and carry the same temporal significance as they do in the 'if' sentence.

The third and fourth categories will not figure in the detailed example we turn to later. We therefore have only brief discussions of them here.

III. *To form generalizations about occasions on which a condition is satisfied.*

For the sentences used in this way, the subordinate and principal clauses, taken on their own, also do not have the same temporal force as they do in the 'if' sentence. These 'if' sentences typically cut a broad swath through time, some extending all the way from the past through the present and into the future. An example from our opening sentences is (2). Other examples abound in expository text in which universal laws or abiding truths are expounded.

IV. *To make two connected assertions.*

Sentences (7), (8), and (9) are examples of 'if' sentences used in this way. The distinguishing mark of these sentences is that there is no supposition or doubt being expressed. The subsidiary clause makes an assertion that is the basis for the assertion in the principal clause. The conditional construction is used to emphasize a connection of some sort between the two assertions, a connection that cannot be adequately expressed using the connectives 'and', 'but', 'although', and so on available in English. The exact nature of the connection is typically highly context dependent.

It is important to note, as already observed above, that some sentences can be used in more than one way. The sentence in (19) was discussed as one that can be used in the second way to present an imagined unfolding of a sequence of events and as an emphatic form of the first kind of sentence. This sentence can also be used to express a generalization about occasions on which you painted the wall. Clearly grammar alone does not determine how an 'if' sentence is being used. However, the speaker's intent does place specific

constraints on the choice of tense and mood in the principal and subordinate clauses. As already noted, an ‘if’ sentence that argues from hypothesis to conclusion about an event taking place in the present will typically use the present continuous tense in the subordinate clause, not the simple present. The use of the simple present is far more likely to signal a sentence used in the second way. And ‘if’ sentences that present the unfolding of a sequence of events in imagination while denying that the event in the subsidiary clause actually took place will use the past-perfect form of the verb.

Analyzing compatibility an extended example

We turn now to a specific example to illustrate the importance of the distinctions we advocate. Consider the following sentence which appears at the end of a set of written instructions on setting a table for a Thanksgiving dinner.⁴

- (24) If you followed my instructions then you will have a perfect setting for a Thanksgiving dinner

On its own, this sentence is without fault. However, coming as it does at the end of instructions written for someone who was not present during the writing, it presents a problem. On reaching this, the last sentence, the natural response is to object that there has not yet been time to follow the instructions. Two acceptable rewrites are

- (25) If you follow my instructions then you will have a perfect setting for a Thanksgiving dinner,

and

- (26) If you followed my instructions then you would have a perfect setting for a Thanksgiving dinner,

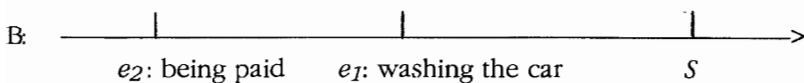
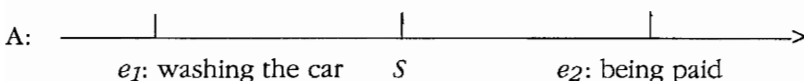
both of which express a contingent relation between the two events regardless of whether they have actually occurred yet or not. Both (25) and (26) present unfolding sequences of events. They are sentences used in the second way. The sentence in (24) argues from

hypothesis – you followed the instructions – to conclusion – you will have a perfect setting. It is used in the first way.

In order to account for the acceptability of one sentence over another we introduce the notion of compatibility and show how an interpretation can be judged to be compatible or incompatible with the circumstances of a sentence's use. The notion of compatibility can be illustrated intuitively as follows. Suppose the following sentence is interpreted the first way, that is, as an argument from hypothesis to conclusion with each of the clauses having its natural temporal interpretation.

(27) If you washed the car, you will be paid.

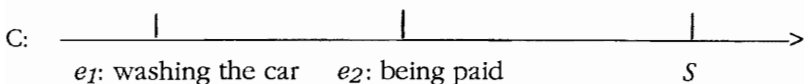
The subordinate clause has a past-tense interpretation. The principal clause has a future-tense interpretation. Adopting the tripartite schemata outlined earlier, the event e_1 of washing therefore precedes the speech time S , and the speech time S precedes the event e_2 of being paid. This interpretation is therefore compatible with the set of circumstances A but is incompatible with the set of circumstances B .



The following sentence is compatible with set of circumstances B , however.

(28) If you washed the car you were paid.

And it is also compatible with the following set of circumstances.



In general, when we talk about the circumstances of an ‘if’ sentence’s use, we are talking about two things. The first is the ordering of the two events described by the principal clause and subsidiary clause. The second is the occurrence of those events relative to some “anchoring” event, that is, an event that the speech time or other reference time is associated with. Different anchoring events have to be considered for one can allow a sentence to make sense when the other does not. For written communication, the anchoring event is either the time at which the sentence is written or the time at which it is read. For language that has been recorded on some audio medium, the anchoring event is either the time it was recorded or the time it is played back. For spoken communication, the anchoring event is either the time the utterance is made or the time it is responded to. In the case of communication with a robot, the difference between the time at which the human supervisor issues a command and the time at which the robot obeys the command can be crucial. Consider, for instance, the command

(28) If the door is closed return to the reception room

What is probably of interest is not whether the door is closed when the command is issued but when the robot gets there. If communication with a robot is to have any of the natural flow that English has, future-oriented communication in which the human supervisor says something now for later must be permitted.

The events described in the principal and subsidiary clauses may be ordered in several different ways. For two events e_1 and e_2 that extend through time, e_1 may totally precede e_2 , e_1 and e_2 may occur simultaneously, e_1 may begin before e_2 ends and end after e_2 ends, and so on. Of the thirteen possibilities, we use two to illustrate the notion of compatibility for our example. In the first e_1 and e_2 overlap, in the second there is a gap between them. The thirteen possibilities are as follows: e_1 and e_2 occur simultaneously, starting and ending at the same time; e_1 and e_2 start at the same time but e_1 ends before e_2 ; e_1 totally precedes e_2 (there is a gap between the end of e_1 and the start of e_2); e_1 precedes e_2 with e_2 starting precisely when e_1 ends (there is no gap); e_1 starts before e_2 but they end at the same time; e_1 starts before e_2 starts and ends before e_2 ends; e_1

starts before e_2 starts and ends after e_1 ends; all of the above, except the first, with e_1 and e_2 interchanged.

We use the following simple representation for sequences of events, recognizing both instantaneous events and extended events of determinate duration and assuming that an extended event has both an instantaneous beginning event and an instantaneous concluding event.⁵ We use the notation e_i for events of determinate duration, Be_i for the instantaneous beginning event of e_i and Ce_i for the instantaneous concluding event of e_i . We use $<$ for the familiar earlier-later relation defined on points in time, extended here to apply to instantaneous events. The equality relation between two instantaneous events denotes that the events are co-temporaneous. For each extended event e_i it is the case that $Be_i < Ce_i$. We call this the extended event axiom.

The two event sequences we use in our example are labelled I and II and they have the following relational representations.

$$\text{I:} \quad \begin{array}{l} Be_1 < Be_2 < Ce_1 < Ce_2 \\ e_1 \text{ —————} \\ e_2 \text{ —————} \end{array}$$

$$\text{II:} \quad \begin{array}{l} Ce_1 < Be_2 \\ e_1 \text{ —————} \quad e_2 \text{ —————} \end{array}$$

We use this same notation to represent tensed expressions, adding an instantaneous speech event S and two instantaneous reference events R and R' . Interpreted the first way, sentence (24) has a past-tense interpretation for its subsidiary clause and a future-tense interpretation for its principal clause. Using the tripartite schemata introduced earlier, extended in the obvious ways for events of determinate duration, the temporal interpretation of the sentence can thus be represented as follows:

$$Be_1 < R < Ce_1 < S < Be_2 \quad \& \quad R' = S,$$

where R is the reference event of the subsidiary clause, R' is the reference event of the principal clause, e_1 is the event, described in the subsidiary clause, of following instructions, and e_2 is the event,

described in the principal clause, of having a perfect setting. Sentences (25) and (26) interpreted the second way, that is, as sentences that present an imagined unfolding sequence of events in the future relative to some reference point, have the following very simple temporal representation:⁶

$$R < Ce_1 \ \& \ R < Ce_2.$$

No specific temporal ordering is imposed on the two events, for the event described by the principal clause could occur in imagination before or at the same time as the condition is satisfied. Consider as examples the following two sentences.

- (29) If Emma takes the bus she will get up early
 (30) If Emma took the bus she would pass the cathedral

Note too that aspectual considerations require that the projected events may have already begun, but they will not have reached their conclusion before the reference event. The following sentences illustrate.

- (31) If she wrote the letter she would get a reply.
 (32) If she got a reply she would write a letter

The letter may have been started but it is the completion of the action that is significant in the unfolding sequence of events.

Having representations for the event sequences and the sentence interpretations, we are ready to see how a particular interpretation can be judged to be compatible with a given set of circumstances. To make this judgment, we perform the following steps.

- (i) Combine the sentence representation with the representation of the ordered events. The result is a relation that represents the ‘if’ sentence interpreted within the context of that event sequence.
- (ii) Take the transitive closure of this relation under the operation of relative product.⁷ The result shows the “consequences” of interpreting the sentence in the context of that event sequence.

- (iii) Check that the resulting relation in (ii) is both irreflexive and asymmetric and that it is consistent with the extended event axiom.⁸ For obvious reasons we do not want inequalities such as $Be_1 < Be_1$. Nor do we want inequalities that contradict the axiom $Be_i < Ce_i$ for each extended event e_i . We also do not want inequalities that contradict each other; if $Be_1 < Ce_2$ holds, $Ce_2 < Be_1$ should not, for instance.

The results of these steps for our sentences are as follows. For sentence (24) interpreted in the context of event sequence I we have:

$$\text{Step (i)} \quad Be_1 < R < Ce_1 < S < Be_2 \quad \& \quad R' = S \quad \& \\ Be_1 < Be_2 < Ce_1 < Ce_2$$

$$\text{Step (ii)} \quad Be_1 < R < Ce_1 < S < Be_2 \quad \& \quad R' = S \quad \& \\ Be_1 < Be_2 < Ce_1 < Ce_2 \quad \& \quad Ce_1 < Ce_1 \quad \& \dots$$

- Step (iii) The relation in (ii) is neither irreflexive nor asymmetric, as shown by the last inequality and the contradiction between $Ce_1 < Be_2$ and $Be_2 < Ce_1$. The interpretation is therefore not compatible with event sequence I.

For sentence (24) interpreted in the context of event sequence II we have:

$$\text{Step (i)} \quad Be_1 < R < Ce_1 < S < Be_2 \quad \& \quad R' = S \quad \& \quad Ce_1 < Be_2$$

$$\text{Step (ii)} \quad Be_1 < R < Ce_1 < S < Be_2 \quad \& \quad R' = S$$

- Step (iii) The relation in (ii) is both irreflexive and asymmetric and does not contradict the extended event axiom. The interpretation is therefore compatible with event sequence II.

For event sequence II we now take the speech event and anchor it first to the time of writing, then to the time of reading. It emerges that there is a problem with the sentence if the speech event is anchored to the time at which the statement is written because at that time event e_1 (following the instructions) could not have taken

place. The instructions were being written for someone who was not present at the time. If the speech event is taken to be the time at which the statement is read, the only way event e_1 could have taken place is if the instructions had been obeyed on the fly, that is, as they were being read, much as one might follow a recipe in a cook book. A difficulty with this sentence, then, is that while it can be made sense of, it imposes inappropriately strong requirements on the circumstances that must hold.

If we look at the rewrites in (25) and (26), we find that they are compatible with both event sequences. The interpretation of (25) and (26) in the context of event sequence I is:

$$R < Ce_1 \quad \& \quad R < Ce_2 \quad \& \quad Be_1 < Be_2 < Ce_1 < Ce_2.$$

The interpretation of (25) and (26) in the context of event sequence II is:

$$R < Ce_1 < Be_2 \quad \& \quad R < Ce_2.$$

Furthermore, as specified by these interpretations in the context of the event sequences, the reference event R can occur anytime before the conclusion of e_1 . These statements therefore explicitly acknowledge that the instructions have not yet been followed although the event of their being followed may indeed have begun. The rewrites allow the reference event to be anchored both to the time of writing and the time of reading.

Concluding Remarks

Evaluations of truth and falsity will undoubtedly be of enduring interest in semantics. However, for 'if' sentences with their wonderful capacity to connect past events to present and future events, not only in fact but in imagination, additional kinds of analyses are called for if we are to fully understand their semantic significance. We have proposed that 'if' sentences be analyzed in terms of communi-

cative intent and in terms of the temporal relations they express. The utility of this approach was illustrated in an evaluation of the suitability of one 'if' sentence over another in a particular context. The ideas we have presented are intended to show how specific, detailed questions can be framed about the way 'if' sentences work, whether they occur in literary text or in verbal communication with a robot.

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FOOTNOTES

1 The authors acknowledge the partial support of the Spencer Foundation for work reported in this article.

2 Current address is 848 Cambridge Avenue, Menlo Park, CA 94025, USA.

3 Imperative 'if'-sentences are not included in the remaining discussions.

4 See Note Number 1 below for the full text of the written instructions.

5 From an intuitive point of view, many events have well-defined start or end points – the actions of putting an item down and picking it up, for instance. Putting object *a* down on *b* can be thought to end at the moment when *a* comes to rest on the surface of *b* and picking *a* up off *b* can thought to begin at the moment when *a* is no longer in contact with the surface of *b*. However, not all events have start and end events that we could readily identify, nor are those we would identify necessarily instantaneous. Clearly other event types need to be considered also.

6 See Note Number 2 below for representations of other sentences used in the second way.

7 The relative product of two relations *R* and *S* (in symbols *R/S*) is defined as follows: $R/S = \{ \langle x, y \rangle : (\exists z) (\langle x, z \rangle \in R \text{ and } \langle z, y \rangle \in S) \}$. The transitive closure of the relation *R* under relative product (in symbols *R**) is defined as follows: $R^* = \{ \langle x, y \rangle : (\exists n) (\langle x, y \rangle \in R^n) \}$ where R^n is defined as: $R^n = R$ if $n = 0$; $R^n = R^{n-1}/R$ otherwise.

8 A relation *R* is irreflexive in a set *A* if and only if $(\forall x \in A) \neg \langle x, x \rangle \in R$. A relation *R* is asymmetric in a set *A* if and only if $(\forall x, y, \in A) (\text{if } \langle x, y \rangle \in R \text{ then } \neg \langle y, x \rangle \in R)$. The set of interest for judgments of compatibility is $\{Be_1, Be_2, Ce_1, Ce_2, S, R, R'\}$.

NOTES

1 The full text for sentence (24) is the following letter. It is taken from a study of high-school students' writing. (See Crangle and Suppes, 1989)

Bob,

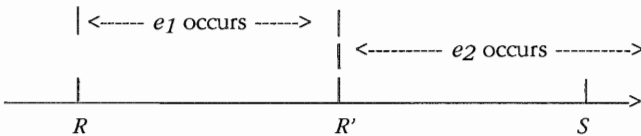
I had to walk our dog. I need you to set the table before Mom and Dad get home. Here is how you set the table.

Set the table for eight. At each place, put a plate, then on the right of the plate, put a knife and soup spoon. On the left of the plate, put a salad fork close to the plate, then a dinner fork on its left. Place a bread and butter plate on the left front of the plate and put a butter knife on it. On the front right, place a water glass with a napkin in it.

In the middle of the table put an arrangement of flowers. Then put two candles on each side of the flowers. On each end of the table put salt and pepper shakers.

Thanks a lot for doing this. If you followed my instructions then you will have a perfect setting for a Thanksgiving Dinner.

- 2 We show here the representations of two other forms of 'if' sentence used in the second way. For sentences having the form in which the past-perfect tense is used in the subsidiary clause, the condition in the subsidiary clause is assumed not to have been satisfied in the actual past. Its satisfaction is nonetheless projected into the future relative to some reference event R which is in the past relative to the speech event S . If the sentence is of the form *If e_1 then e_2* where e_1 represents the event described in the subsidiary clause using the past-perfect tense and e_2 represents the event described in the principal clause using the modal auxiliary 'would', the temporal relations expressed in the sentence may be represented as follows [For simplicity we limit ourselves only to certain modal auxiliaries, namely 'would' and 'would have' in the principal clause.



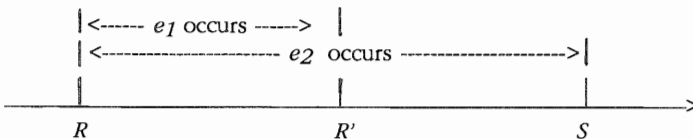
The condition in the subsidiary clause is imagined to have been satisfied by some instantaneous event R' that is in the future of R but in the past of the speech event S . The event in the principal clause is imagined to occur after the condition is satisfied, that is, after R' , and perhaps in the future relative to the speech event. The representation of

- (a) If you had followed my instructions you would have a perfect setting

is therefore as follows:

$$R < Be_1 \quad \& \quad Ce_1 < R' < Be_2 \quad \& \quad R < R' < S.$$

If the sentence is of the form *If e_1 then e_2* where e_1 represents the event described in the subsidiary clause using the past-perfect tense and e_2 represents the event described in the principal clause using the modal auxiliary 'would have', the temporal relations expressed in the sentence may be represented as follows:



The condition in the subsidiary clause is imagined to have been satisfied by some event R' that is in the future of R but in the past of the speech event S . The event in the principal clause is imagined to occur any time after R (that is, it

could occur before the condition is satisfied) but it is constrained by the tense and mood of the principal clause to have occurred in imagination before *S*. Sentences such as 'If she had taken the bus she would have been at the bus stop beforehand' show how the event in the principal clause can occur before the condition's satisfaction. The representation of

- (c) If you had followed my instructions you would have had a perfect setting.

is as follows:

$$\begin{array}{l} R < Be_1 \quad \& \quad R < Be_2 \quad \& \quad Ce_1 < R' \quad \& \quad Ce_1 < S \\ \& \quad R < R' < S. \end{array}$$

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