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THE SYNTAX AND SEMANTICS OF *WHEN*-QUESTIONS

0. Introduction

In a recent article, Karttunen (1977) has proposed a rigorous and elegant treatment of the syntax and semantics of certain wh-questions within the framework of Montague (1974). This paper is an attempt to extend Karttunen's analysis to include constructions involving *when.* Although rarely treated in its own right in the ever-expanding literature on *wh*-phenomena, *when* possesses properties arising from its interaction with the English tense system which single it out from its fellow wh-words. These properties pose a problem for Karttunen and for the task of assigning a uniform semantic interpretation to *wh*-words. We begin with a brief review of Karttunen's (1977) analysis of *who, what* and *which* questions (Section 1), and proceed to show how one might mimic this treatment for *when* (Section 2). With this enriched framework the problem posed by *when* will become apparent. Two possible solutions are outlined, (Section 3), a syntactic one deriving from Pullum and Wilson (1977), and a semantic one along the lines of Cooper (1978).

1. Karttunen's analysis

The fundamental problem to be faced in developing an adequate semantics for *wh*-questions – indeed for questions in general – is to decide what sort of denotation should be assigned. The central insight underlying the Karttunen (1977) analysis is that questions should denote the set of propositions expressed by their true and complete answers.[1] So, for example, the questions *Does John sleep?* is taken to denote the set of propositions p such that p is true and p is the proposition that *John sleeps.* Accordingly, in Montague's intensional logic *Does John sleep?* (or more precisely the corresponding embedded question *Whether John sleeps*) receives the translation $\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}\mathrm{sleep}'_{*}(j) \vee p = {}^{\wedge}\sim \mathrm{sleep}'_{*}(j)]$. If John sleeps, then this set of propositions is the unit set whose only member is the proposition that John sleeps. If John does not sleep, then this set of propositions is the proposition that John does not sleep (Karttunen, 1977, p. 14). The idea here is that to know the answer to the question *Does John sleep?* is just to know the membership of this set. Convincing argumentation is presented by Karttunen that this type of

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denotation – a set of propositions – should be assigned to *wh*-questions as well. Thus, contrary to the intuitively plausible suggestion that a question such as *who loves Mary*? should denote the set of individuals who love Mary, it is instead proposed that this question should denote the set of true propositions such that for some x, p is the proposition that x loves Mary. That is, *Who loves Mary* should have the *IL* translation $\hat{p}\,\exists x[{}^{\vee}p \wedge p = {}^{\wedge}\text{love}'_{*}({}^{\vee}x, m)]$. We will not reproduce Karttunen's arguments here, but will turn directly to the technical issue of getting the semantics to assign the appropriate denotation to *wh*-questions.

Wh-question formation is handled in Karttunen (1977) by means of three rules[2]:

PROTO QUESTION RULE (*PQ*): If $\alpha \in P_t$, then $\ulcorner ?\alpha \urcorner \in P_Q$. If α translates as α', then $\ulcorner ?\alpha \urcorner$ translates as $\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}\alpha']$

E.g. *John sleeps* $\in P_t$ with translation $sleep'_{*}(j)$

?John sleeps $\in P_Q$ with translation $\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}sleep'_{*}(j)]$

WH-PHRASE RULE (*WHP*): If $\alpha \in P_{CN}$, then $\ulcorner$*which* $\alpha\urcorner$ and $\ulcorner$*what* $\alpha\urcorner \in P_{WH}$. If α translates as α', then $\ulcorner$*which* $\alpha\urcorner$ and $\ulcorner$*what* $\alpha\urcorner$ translate as $\hat{P}\exists x[\alpha'(x) \wedge P\{x\}]$.

E.g. *man* $\in P_{CN}$ with translation *man'*

which man $\in P_{WH}$ with translation $\hat{P}\exists x[man'(x) \wedge P\{x\}]$

(*Note*: *who* and *what* are basic *WH*-phrases and have the same translation as *someone* and *something*. Ignoring animate vs. inanimate they are both translated as $\hat{P}\exists x[P\{x\}]$.)

WH-QUANTIFICATION RULE (*WHQ*, *n*): If $\alpha \in P_{WH}$ and $\theta \in P_Q$ containing an occurrence of PRO_n and θ does not begin with *whether*, then $F_{WHQ,n}(\alpha, \theta) \in P_Q$, where $F_{WHQ,n}(\alpha, \theta)$ is defined as follows:

(A) If θ begins with '?', then $F_{WHQ,n}(\alpha, \theta)$ is derived from θ by performing the operations:

(i) substitute α for the initial '?' in θ

(ii) delete the first occurrence of PRO_n in θ.

If α translates as α' and θ as θ', then $F_{WHQ,n}(\alpha, \theta)$ translates as $\hat{p}[\alpha'(\hat{x}_n[\theta'(p)])]$.

Example: *which girl sleeps*; *who sleeps*

which girl sleeps: $\hat{p}[\hat{P}\exists x[girl'(x) \wedge P\{x\}](\hat{x}_0[\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}\, sleep'_*({}^{\wedge}x_0)](p)])]$
$\hat{p}[\exists x[girl'(x) \wedge {}^{\vee}p \wedge p = {}^{\wedge}\, sleep'_*({}^{\vee}x)]]$

which girl: $\hat{P}\exists x[girl'(x) \wedge P\{x\}]$?*he*$_0$ *sleeps*: $\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}\, sleep'_*({}^{\vee}x_0)]]$

girl: *girl'* *he*$_0$ *sleeps*: $sleep'_*({}^{\vee}x_0)$

he$_0$: $\hat{P}P\{x_0\}$ *sleep*: *sleep'*

who sleeps: $\hat{p}[\hat{P}\exists x[P\{x\}](\hat{x}_0[\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}\, sleep'_*({}^{\wedge}x_0)](p)])]$
$\hat{p}[\exists x[{}^{\vee}p \wedge p = {}^{\wedge}\, sleep'_*({}^{\vee}x_0)]]$

who: $\hat{P}\exists x[P\{x\}]$?*he*$_0$ *sleeps*: $\hat{p}[{}^{\vee}p \wedge p = {}^{\vee}\, sleep'_*({}^{\vee}x_0)]$

2. ADAPTING KARTTUNEN'S ANALYSIS TO *WHEN*

An important aspect of Karttunen's analysis is that *wh*-words and phrases are treated uniformly as quantifiers. That is, in a *wh*-question the translation of the *wh*-phrase will contain an existential quantifier which binds a variable in the proposition expressing the true and complete answers to the question. The effect of *WHQ, n* is thus to quantify into Proto-questions formed on an open sentence (e.g., *he*$_0$ *sleeps*) with the binding quantifier originating in the *wh*-phrase. This suggests that in adapting Karttunen's analysis to *when*-questions we should proceed along the following lines:

(1) *when* should denote a set of properties of points of time, just as *what* and *who* denote sets of properties of individual concepts (i.e., *when* should get the same denotation and translation as *sometime*), and

(2) time variables ('temporal pronouns') should be used to provide a site for quantifying in by some modified version of *WHQ, n*.

Now these suggestions cannot be implemented within the framework of Montague (1974) since Montague's *IL* has no expressions whose denotations are points of time. Sentences are evaluated with respect to times, but time points are not denoted directly. To overcome these initial difficulties we introduce the following set of modifications into *IL* (call this modified logic IL^{τ}):

(i) Introduce time variables $t, t_0, t_1, t_2, \ldots$ and let τ be the type of time variables which we introduce as a basic type. $D_{\tau,A,I,J} = J$, i.e. the set of possible denotations of type τ is the set of moments of time.

(ii) Introduce a temporal intension operator $\uparrow$:
Syntax: if $\alpha \in ME^{\tau}_{K}$, then $[{}^{\uparrow}\alpha] \in ME^{\tau}_{\langle\tau,K\rangle}$
Semantics: if $\alpha \in ME^{\tau}_{K}$, then $[{}^{\uparrow}\alpha]^{\mathfrak{A},i,j,g}$ is that function h with domain J such that if $j' \in J$, $h(j')$ is $[\alpha]^{\mathfrak{A},i,j',g}$.

(iii) Introduce formulae which express 'earlier than'.
Syntax: if $\alpha, \gamma \in ME^{\tau}_{\tau}$, then $\alpha < \gamma \in ME^{\tau}_{t}$
Semantics: if $\alpha, \gamma \in ME^{\tau}_{\tau}$, then $[\alpha < \gamma]^{\mathfrak{A},i,j,g} = 1$ iff $[\alpha]^{\mathfrak{A},i,j,g} < [\gamma]^{\mathfrak{A},i,j,g}$.

(iv) Introduce a distinguished constant, t^*, of type τ such that $[t^*]^{\mathfrak{A},i,j,g}$ is j.[3]

Note that the sematics guarantees that the following will be valid in IL^{τ}:

$$\varphi \leftrightarrow [{}^{\uparrow}\varphi](t^*)$$
$$H\varphi \leftrightarrow \exists t[t < t^* \wedge [{}^{\uparrow}\varphi](t)]$$
$$W\varphi \leftrightarrow \exists t[t^* < t \wedge [{}^{\uparrow}\varphi](t)]$$
$$[{}^{\uparrow} \sim \varphi](t) \leftrightarrow \sim [{}^{\uparrow}\varphi](t)$$
$$[{}^{\uparrow}\alpha({}^{\wedge}\beta)](t_i) = [{}^{\uparrow}\alpha(t_i)]({}^{\wedge}\beta)^4$$

Next we add the following to the syntactic rules of tense and sign in *PTQ*.

If $\alpha \in P_T$ and $\delta \in P_{IV}$, then $F_{16,n}(\alpha, \delta)$, $F_{17,n}(\alpha, \delta)$, $F_{18,n}(\alpha, \delta)$, $F_{19,n}(\alpha, \delta)$, $F_{20,n}(\alpha, \delta)$, $F_{21,n}(\alpha, \delta) \in P_t$ where:

$F_{16,n}(\alpha, \delta) = \alpha\delta'$ at t_n where δ' is the result of replacing the first verb in δ by its third person singular present,

$F_{17,n}(\alpha, \delta) = \alpha\delta''$ at t_n where δ'' is the result of replacing the first verb in δ by its negative third person singular present,

$F_{18,n}(\alpha, \delta) = \alpha\delta'''$ at t_n where δ''' is the result of replacing the first verb in δ by its third person singular future,

$F_{19,n}(\alpha, \delta) = \alpha\delta''''$ at t_n where δ'''' is the result of replacing the first verb in δ by its negative third person singular future,

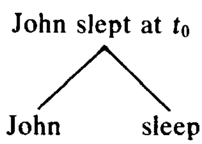
$F_{20,n}(\alpha, \delta) = \alpha\delta'''''$ **at** $\mathbf{t}_n$ where δ''''' is the result of replacing the first verb in δ by its third person singular past,

$F_{21,n}(\alpha, \delta) = \alpha\delta''''''$ **at** $\mathbf{t}_n$ where δ'''''' is the result of replacing the first verb in δ by its negative third person singular past.

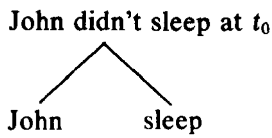
The corresponding translation rules will be as follows:

$F_{16,n}(\alpha, \delta)$ translates into $t_n = t^* \wedge \quad [{}^{\uparrow}\alpha'({}^{\wedge}\delta')](t_n)$
$F_{17,n}(\alpha, \delta)$ translates into $t_n = t^* \wedge \sim [{}^{\uparrow}\alpha'({}^{\wedge}\delta')](t_n)$
$F_{18,n}(\alpha, \delta)$ translates into $t^* < t_n \wedge \quad [{}^{\uparrow}\alpha'({}^{\wedge}\delta')](t_n)$
$F_{19,n}(\alpha, \delta)$ translates into $t^* < t_n \wedge \sim [{}^{\uparrow}\alpha'({}^{\wedge}\delta')](t_n)$
$F_{20,n}(\alpha, \delta)$ translates into $t_n < t^* \wedge \quad [{}^{\uparrow}\alpha'({}^{\wedge}\delta')](t_n)$
$F_{21,n}(\alpha, \delta)$ translates into $t_n < t^* \wedge \sim [{}^{\uparrow}\alpha'({}^{\wedge}\delta')](t_n)$

Examples



Reduced translation: $t_0 < t^* \wedge [{}^{\uparrow}\ \text{sleep}'_*(j)](t_0)$.



Reduced translation: $t_0 < t^* \wedge \sim [{}^{\uparrow}\ \text{sleep}'_*(j)](t_0)$.

Note that both of these examples entail that t_0 is prior to the moment of evaluation and that the scope of the negation is essentially different from the scope of negation in the corresponding sentence without the free time variable (represented in PTQ by the sentence *John hasn't slept*). The translation of the sentence without the time variable would be equivalent to:

$$\sim \exists t[t < t^* \wedge [{}^{\uparrow}\ \text{sleep}'_*(j)](t)]$$

We are now ready to build in a treatment of *when*-questions. We let τ also represent a category of English and let *when* $\in B_{t/(t/\tau)}$, which translates into IL^{τ} as $\hat{T}\exists t[T\{t\}]$. (T is a variable of type $\langle s, \langle \tau, t\rangle\rangle$ i.e., a variable over properties of time points). Let *WHQ* abbreviate $t/(t/\tau)$. We adopt Karttunen's rule of Proto-question formation and introduce the following *WHEN* QUANTIFICATION RULE.

> If $\alpha \in P_{WHQ}$ and $\theta \in P_Q$ containing an occurrence of *at* t_n (and θ does not begin with *whether*), then $F_{WHQ,n}(\alpha, \theta) \in P_Q$ where $F_{WHQ,n}(\alpha, \theta)$ is formed by
> (i) substituting α for the initial '?' in θ,
> (ii) deleting every occurrence of *at* t_n in θ.
> If α translates as α' and θ as θ', then $F_{WHQ,n}(\alpha, \theta)$ translates as $\hat{p}[\alpha'(\hat{t}_n[\theta'(p)])]$.
>
> *Example*:
> *when John will sleep*:
> $\hat{p}[\hat{T}\exists t[T\{t\}](\hat{t}_0[{}^{\vee}p \wedge p = {}^{\wedge}t^* < t_0 \wedge [{}^{\uparrow}\ sleep'_*(j)](t_0)])]$.
> $\hat{p}[\exists t[{}^{\vee}p \wedge p = {}^{\vee}t^* < t \wedge [{}^{\uparrow\prime}sleep'_*(j)](t)]]$.
>
> *when*: $\hat{T}\exists t[T\{t\}]$ *?John will sleep at* t_0:
> $\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}t^* < t_0 \wedge [{}^{\uparrow}\ sleep'_*(j)](t_0)]$,
> *John will sleep at* t_0:
> $t^* < t_0 \wedge [{}^{\uparrow}\ sleep'_*(j)](t_0)$
> *John*: $\hat{P}P\{{}^{\vee}j\}$ *sleep*: *sleep'*

We can now make clear the problem that is posed by *when*-questions which is not encountered in the treatment of other *wh*-questions. Consider the following examples with embedded *when*-questions:

$$\text{Harry} \begin{Bmatrix} \text{knows} \\ \text{wonders} \\ \text{asks} \end{Bmatrix} \text{when John will sleep}$$

All of these sentences can be true without the information represented by $t^* < t_0$ being part of what is known, wondered or asked about. Suppose, for example, that John has been given a sleeping potion and Harry knows that it will take its effect at exactly 6 o'clock. Meanwhile, Harry has lost his watch and is not sure whether it is 5:30 or 6:30. We may truly report at 5:30 that Harry knows when John will sleep even though he does not know whether that time is after the moment of evaluation or not. Similarly if Harry wonders or asks when John will sleep he is not looking for information about the ordering of moments of time. The situation is similar to that with *which girl sleeps*. Harry may know which girl sleeps if he knows that Leslie is asleep, even if he does not know whether Leslie is a girl or a boy. Similarly if he wonders or asks which girl sleeps, there need not be any question in his mind about whether certain individuals are girls or not. Now, of course, in this latter example, the rules of *wh*-question formation do assign the correct denotation. (See example, p. 157). This is because we have formed a composite *wh*-phrase *which girl* with translation $\hat{P}\exists x[girl'(x) \wedge P\{x\}]$. The expression $girl'(x)$ does not become part of the representation of the propositions which are true and complete answers. This suggests that the correct derivation for *when John will sleep* should be along the lines of *which girl sleeps*, i.e.:

when John will sleep:

$$\hat{p}[\hat{T}\exists t[t^* < t \wedge T\{t\}](\hat{t}_0[\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}[{}^{\uparrow}\ sleep'_*(j)](t_0)](p)])]$$

$$\hat{p}[\exists t[t^* < t \wedge {}^{\vee}p \wedge p = {}^{\wedge}[{}^{\uparrow}\ sleep'_*(j)](t)]]$$

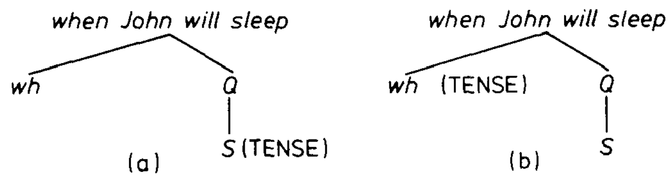
when: $\hat{T}\exists t[t^* < t \wedge T\{t\}]$?*John sleeps at* t_0: $\hat{p}[{}^{\vee}p \wedge p = {}^{\wedge}[{}^{\uparrow}\ sleep'_*(j)(t_0)]]$

FUTURE: $t^* < t$ *John sleeps at* t_0: $[{}^{\uparrow}\ sleep'_*(j)](t_0)$

John: $\hat{P}P\{{}^{\wedge}j\}$ *sleep*: *sleep'*

This derivation does indeed assign the right translation to *when John will sleep*. It also makes clear why the previous derivation failed, viz., because of a crucial interaction between *when* and TENSE. This interaction (which is represented above by a constituency relation) produces, in effect, a restricted quantifier – a quantifier over times whose domain is delimited by TENSE. This interaction is exactly analogous to the effect of the *CN girl* in the derivation of *which girl sleeps*; there we got a quantifier whose domain was restricted to the set of girls. Now this interaction was not represented in the previous derivation for *when John will sleep*. So although the existential quantifier in *when* got wide scope, TENSE did not; TENSE ended up incorrectly as part of the proposition representing possible answers.

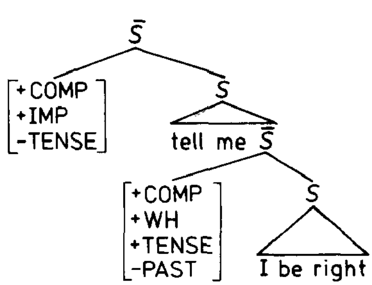
If we analogize the derivation of *when John will sleep* to that of *which girl sleeps* we seem to arive at the right semantic results. But of course there is a significant problem with this move: while there is solid syntactic evidence for the constituent status of *which girl*, there is no such direct evidence for *wh*-TENSE. On the standard analysis TENSE is a constituent of AUX which is introduced at the sentence level. It therefore seems that TENSE should enter the derivation of *when John will sleep* in the right hand branch (with *S*) and not in the left hand branch with *wh*-[5]:



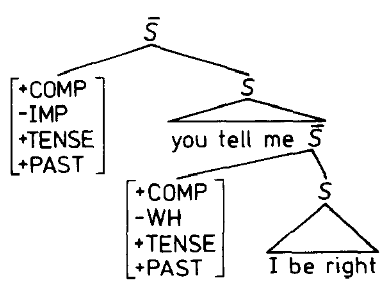
Since we do not wish to sacrifice the syntax of English for the sake of an easy route to its semantics, we should hesitate to accept the (b)-type derivation without syntactic justification. On the other hand, it is not at all clear how to write a rule of *WH*-Quantification in which the translation of TENSE is somehow extracted from the translation of the Proto-question. So, in summary, we seem to be caught between the competing claims of syntax and semantics in trying to give an account of *when*.

3. Possible solutions

The first solution is suggested by Pullum and Wilson's (1977) recent analysis of English auxiliaries. On the basis of some interesting syntactic argumentation it is proposed that the traditional AUX node be discarded and that TENSE be treated syntactically as a feature of the COMP node. That is, COMP nodes are to be labeled as [±TENSE], and if [+TENSE] then [±PAST]. Accordingly, we get trees like the following:

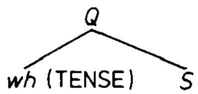


Tell me whether I am right



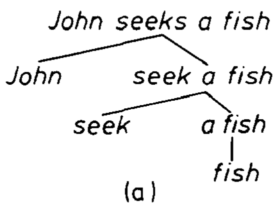
You told me that I was right

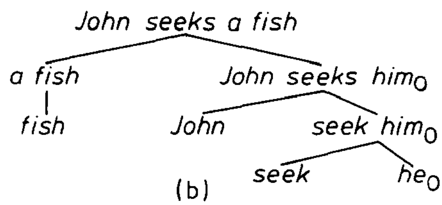
If such an analysis is adopted it is clear that we will be a long way toward solving the problem of *when*-TENSE interaction without requiring any modification in Karttunen's framework. We will have effectively justified the analysis tree which was earlier regarded with some suspicion, viz.,



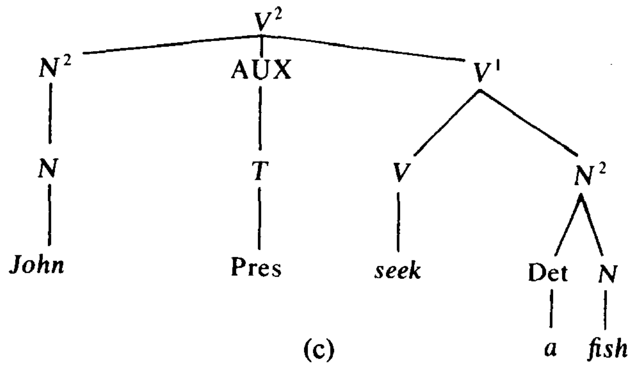
We will not repeat Pullum and Wilson's arguments here for TENSE as a feature of COMP, but it is clear that this solution might be an optimally simple one.

The second solution derives from Cooper (1975, 1978). This analysis of *wh*-phenomena begins by modifying the treatment of quantifier scope ambiguities given in Montague (1974). In the latter, the ambiguity of ***John seeks a fish*** is captured by assigning this sentence distinct analysis trees – essentially (a) and (b) below:



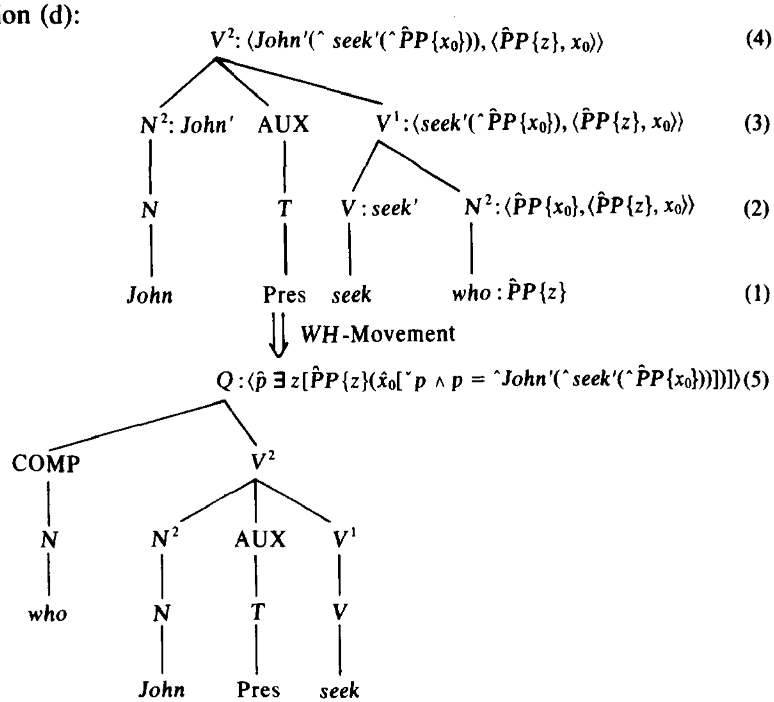


Here (a) represents the narrow-scope, or non-specific, reading, whereas (b) represents the wide-scope interpretation. These trees will receive different *IL* translations and hence different semantic interpretations. In the Cooper (1975, 1978) treatment, a single tree is assigned to ***John seeks a fish*** and the ambiguity is handled by a new formal device viz., *NP* storage. The idea is that ***John seeks a fish*** is assigned a single phrase marker:



However, when this tree is interpreted (from the bottom up) we have the option of 'storing' *NP* $(= N^2)$ interpretations. Suppose we begin to interpret (c), starting at the bottom. First we encounter the *NP a fish* to which we assign the interpretation *a fish'*. If we choose *not* to store this interpretation, we proceed by combining it with the interpretation of *seek* and ultimately arrive at the narrow-scope interpretation for V^2: $\langle John'\,(^\wedge\, seek'(^\wedge\, a\, fish'))\rangle$. On the other hand, if we *do* choose to store *a fish'* then the lowest *NP* receives the interpretation $\langle \hat{P}P\{x_0\}, \langle a\, fish', x_0\rangle\rangle$ where $\langle a\, fish', x_0\rangle$ is in the store and x_0 is the *variable address* for *a fish'*. The interpretation of *seek* then combines with $\hat{P}P\{x_0\}$ (not *a fish'*) and the stored *NP* interpretation is carried up the tree until it is ultimately quantified-in at the V^2 node. The result is the wide-scope interpretation for V^2: $\langle a\, fish'\,(\hat{x}_0[John'\,(^\wedge\, seek'(^\wedge \hat{P}P\{x_0\}))])\rangle$. These two interpretations are precisely the ones assigned to trees (a) and (b) above under the standard Montague analysis. Thus with this new device we can capture the ambiguity of *John seeks a fish* without positing distinct syntactic representations for the sentence.

This analysis is extended to *wh*-questions through the notion of *controlled quantification*. In the example sentence, *John seeks a fish*, we were free to store or not store the interpretation *a fish'* as we moved up the tree. With *wh*-words, however, storage is taken to be obligatory. That is, we are obliged to store the interpretation of any *wh-NP*. In the case of *wh*-questions, this interpretation is carried up the tree to the V^2 node where it is quantified-in in a special way. To illustrate, consider the derivation (d):



In the upper tree we begin (line (1)) with the *wh*-word *who*, which is assigned the interpretation $\hat{P}P\{z\}$ (where z is a distinguished variable). In processing the N^2 dominating *who* (line (2)), we obligatorily store the interpretation of *who* and replace it by a dummy *NP* interpretation with variable address x_0. This dummy *NP* interpretation combines with the interpretation of *seek* (line (3)), and then with *John'* (line (4)) to give the full interpretation for V^2. An acceptable interpretation must have an empty store; hence the interpretation assigned to V^2 in line (4) is not yet acceptable. Some rule must be utilized which empties the store. *WH*-Movement is such a rule and its effect is shown in the lower part of (d). Syntactically, the upper tree in (d) is mapped into the lower one. Semantically, the interpretation of *who* is retrieved from the store and is combined with the non-stored portion of the V^2 interpretation. This combining includes forming a set of propositions '$\hat{p}\ldots$', adding an existential quantifier over the distinguished variable '$\exists z\ldots$', lambda-abstracting over the variable address x_0, and adding in '${}^{\vee}p \wedge p = {}^{\wedge}\ldots$'. The result of this is the formidable expression:

$$\hat{p}\,\exists z[\hat{P}P\{z\}(\hat{x}_0[{}^{\vee}p \wedge p = {}^{\wedge}John'(seek'({}^{\wedge}\hat{P}P\{x_0\}))])],$$

$$\text{which yields } \hat{p}\,\exists z[[{}^{\vee}p \wedge p = {}^{\wedge}John'({}^{\wedge}seek'({}^{\wedge}\hat{P}P\{z\}))]$$

after lambda-conversion. This latter result is exactly the same as in the Karttunen treatment, i.e., this analysis assigns the same interpretation to *Who does John seek*? as does Karttunen's.

This analysis also permits a uniform interpretation of *wh*-words for both *wh*-questions and relative clauses. That is, line (4) in tree (d) above can be operated on to give both the *wh*-question interpretation *and* the interpretation of the relative clause *who John seeks*, as in *the man who John seeks*. In order to give such a uniform interpretation it is crucial that the existential quantifier appearing in line (5) above be introduced by the *WH*-Question rule, and that it not be present in the translation of *who*. This is different from the Karttunen treatment where *who* is assigned the translation $\hat{P}\,\exists x[P\{x\}]$, with the existential quantifier already present.

We would like to propose that the storage plus quantifying-in approach also provides a reasonable alternative to our Karttunen-style analysis of *when*-questions. In particular, with some minor extensions of the apparatus just discussed we can give an account of *when*-questions which is free of the annoying difficulties arising from the *when*-TENSE interaction. The extension we are proposing includes the following moves:

(i) we alter the interpretation of *when* from $\hat{T}\,\exists t[T\{t\}]$ (= the interpretation of *sometime*) to $\hat{T}[T\{\bar{t}\}]$, where $\bar{t}$ is a distinguished time variable. This amendment precisely parallel's Cooper's (1978) reinterpretation of *who*;

(ii) we stipulate that *when* and TENSE interpretations may be stored as well as *NP* interpretations;

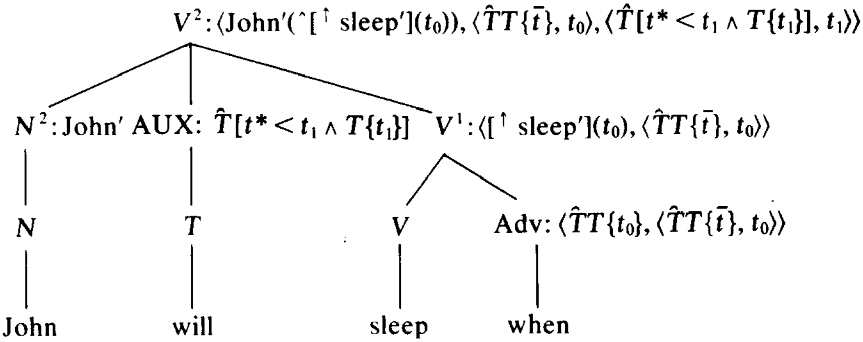
(iii) we stipulate that *when'* is obligatorily stored when *V'* and *when'* are put together. Furthermore, whenever *when'* is stored TENSE' must be stored as well;

(iv) we provide a revised rule of *when*-Question formation which moves *when* to the front of the sentence in the syntax and changes a translation as indicated below.

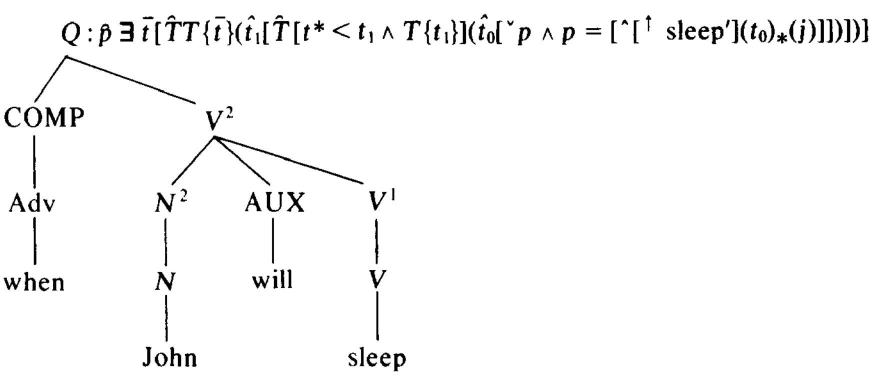
$$\langle \varphi, \ldots, \langle \mathit{when}', t_i \rangle, \ldots, \langle \mathrm{AUX}', t_j \rangle, \ldots, \rangle$$

$$\Rightarrow \langle\, \hat{p}\, \exists \bar{t} [{}^{\wedge} \mathit{when}'(\hat{t}_j[\mathrm{AUX}'(\hat{t}_i[{}^{\vee} p \wedge p = [{}^{\wedge} \varphi]])])], \ldots \rangle$$

With these changes we can give the following sample derivation for *when John will sleep*:



⇓ *WH*-Movement



The translation of the question is equivalent to:

$$\hat{p}\, \exists \bar{t}[t^* < \bar{t} \wedge {}^{\vee}p \wedge p = {}^{\wedge}[{}^{\uparrow}\ \mathrm{sleep}'_*(j)](\bar{t})]$$

There are three observations which support this solution. First, independent investigation by Sag and Weisler (1979) has suggested that an adequate treatment of *when* adverbials should involve TENSE storage. This holds out the promise of a unified treatment of all *when*-constructions. Second, the objects stored in the present analysis – *when* and TENSE – both correspond to denotations which are sets of properties (of moments of time). Within the framework of generalized quantification theory, this means that they are both quantifiers, (see Barwise and Cooper, 1981). Thus we may maintain the hypothesis that only quantifiers (i.e. sets of properties) may be entered in the store. These quantifiers may correspond to either *NP*'s, temporal adverbs like *when* or TENSE.

Finally the notion of TENSE storage seems to be supported by sentences which do not involve *wh*-movement. Consider the sentence:

Harry believes that the bomb will explode at six o'clock.

It seems to us that this sentence may be interpreted *de dicto* or *de re* with respect to the contribution of the tense morpheme. The two readings may be symbolized informally as:

de dicto: believe (h, $\hat{}t^* <$ six o'clock $\wedge$ [$^\uparrow$ the bomb explode] (six o'clock))

de re: $t^* <$ six o'clock $\wedge$ believe (h, $\hat{}$[$^\uparrow$ the bomb explode] (six o'clock))

Uttered at 5: 30, the sentence is true on the *de re* reading of a situation where Harry has set a time bomb to go off at six o'clock but has since fallen asleep. Thus the sentence is still true even though Harry is not aware of the time and hence it is not part of his belief that six o'clock is later than the moment of evaluation as would be required by the *de dicto* reading. If such readings are to be treated as scope ambiguities then quantifiers over moments of time must allow optional storage not controlled by any syntactic rule in addition to obligatory storage controlled by *wh*-movement. This is exactly the same situation we find with quantifiers represented by *NP*'s as discussed in Cooper (1978). In addition such a treatment would motivate a storage solution over a non-storage solution following Pullum and Wilson's work. On such an analysis, the interpretation of TENSE located in COMP would only be given scope over the sentence in which the tense morpheme actually occurs and not over a higher sentence as in this example.

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NOTES

[1] The idea that questions should denote a set of propositions was put forward by Hamblin (1976). The Hamblin analysis differs from Karttunen's in that in the former questions denote the set of possible answers rather than the set of true and complete answers.

[2] In a recent unpublished work Karttunen abandons the *PQ* rule on the grounds that it violates Partee's well-formedness constraint, i.e., it produces non-well formed objects ($?\alpha$). The work which the *PQ* rule does is simply imported into *WHQ*, *n*, hence in this modified version *WHQ*, *n* puts a *wh*-phrase together with a P_t directly. For our purposes this modification is irrelevant, and since depicting a P_Q stage is useful for seeing what is going on in the derivation we will hold to the (1977) treatment.

[3] We believe that this semantics for t^* will allow us to imitate the scope relationships of tense operators in *PTQ*. At least for certain cases, it might be more adequate for the treatment of English to let t^* denote the moment of speech rather than the moment of evaluation. This would involve evaluating logical expressions with respect to two moments of time in the manner of Kamp (1971) and would allow us to account for examples similar to Kamp's sentence (i).

(i) A child was born that will become ruler of the world.

See Ladusaw (1977) for some reasons why the treatment of the scope relationships of tense operators in *PTQ* should be adjusted.

[4] We check the validity of expressions of this form. Let $\mathfrak{A}, i, j, g$ be any interpretation, world, time and assignment to variables, respectively.

Then:

$$[[{}^{\uparrow}\alpha({}^{\wedge}\beta)](t_i)]^{\mathfrak{A},i,j,g} = [\alpha({}^{\wedge}\beta)]^{\mathfrak{A},i,g(t_i),g} = \alpha^{\mathfrak{A},i,g(t_i),t}({}^{\wedge}\beta^{\mathfrak{A},i,g(t_i),g})$$
$$= \alpha^{\mathfrak{A},i,g(t_i),g}(\beta^{\mathfrak{A},g}) = \alpha^{\mathfrak{A},i,g(t_i),g}({}^{\wedge}\beta^{\mathfrak{A},i,j,g}) = [[{}^{\uparrow}\alpha](t_i)]^{\mathfrak{A},i,j,g}({}^{\wedge}\beta^{\mathfrak{A},i,j,g})$$
$$= [[{}^{\uparrow}\alpha](t_i)({}^{\wedge}\beta)^{\mathfrak{A},i,j,g}$$

[5] Larry Horn has suggested to us that analysis tree (b) may well *not* be the semantically desirable one – that *when* and *which girl* may not actually represent parallel cases. He contrasts the exchanges:

(1) (A) When will John vote?
    (B) (?) Never, he already has.
(2) (A) Which girls voted?
    (B) None, only the boys did.

If *when* really did range over future time points only, then (the argument goes) one would expect (1B) to be a possible answer to (1A), which it is not. *Which girls*, on the other hand, does range over girls only, and hence the acceptability of (2B). The suggestion here is that perhaps (1A) does not ask 'At which future time t_0 . . . ?', but rather 'At which time t_0 . . . ?' + the conventional implicature $t^* < t_0$. (1B) would thus be a violation of the implicature borne by *when*.

We feel that the treatment of tense as conventional implicature is an interesting possibility to explore (see also Cooper, 1979), but that it would take us too far from the standard analysis of natural language tense for us to be able to justify such an analysis in this paper.

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