Linguistische
Arbeiten 83

Herausgegeben von Herbert E. Brekle, Hans Jürgen Heringer,
Christian Rohrer, Heinz Vater und Otmar Werner

Time, Tense, and Quantifiers

Proceeding of the Stuttgart Conference on the
Logic of Tense and Quantification
Edited by Christian Rohrer

Max Niemeyer Verlag
Tübingen 1980

CIP-Kurztitelaufnahme der Deutschen Bibliothek

Time, tense, and quantifiers : proceedings of the Stuttgart Conference on the Logic of Tense and Quantification / ed. by Christian Rohrer. – Tübingen : Niemeyer, 1980.
(Linguistische Arbeiten ; 83)
ISBN 3-484-10374-4

NE: Rohrer, Christian [Hrsg.]; Conference on the Logic of Tense and Quantification ⟨1979, Stuttgart⟩

ISBN 3-484-10374-4 / ISSN 0344-6727

INHALTSVERZEICHNIS

Introduction

The present volume contains the proceedings of the March 21st–24th, 1979, colloquium on Formal Semantics: the two main topics were the analysis of temporal constructions and quantifiers in natural languages.

This colloquium was organized during the final phase of a research project on tense, aspect and verbclassification[1] at the Institute of Linguistics of the University of Stuttgart. Its purpose was to provide an overview of the research in progress and to prepare the ground for similar meetings.[2]

Although it is too early to draw any definite conclusions one can nevertheless discern certain general trends. Classical tense logic was developed in order to solve certain philosophical problems. It was not intended as a tool for describing tense forms of natural languages. Nevertheless tense logic is still the most precise and adequate means for the description of temporal phenomena expressed in natural languages. Nearly all contributions are based on classical tense logic. There are of course differences, e.g. evaluation at points or at intervals, multiple indexing, two-valued versus many-valued logics, sentence semantics versus discourse semantics, etc., but the framework is basically tense logic and its model-theoretic semantics. However, if one wants to account for the intricate interaction between verb meanings, temporal adverbs, and tense forms, one obtains extremely complicated reconstructions. This degree of complication seems to suggest that in the long run one might need a completely new approach. An indication of how such a new approach might look like can be found in several contributions.

During the last few years pragmatics has become more and more important in linguistics. At the colloquium it was argued quite convincingly that an adequate description of tense forms requires a pragmatic component. Unfortunately, at the conference, nobody presented a formal framework within which the pragmatics of tense forms could be accounted for. Since all the contributions to the colloquium appear in this volume, the reader can draw his own conclusions. I would like to thank the DFG and the University of Stuttgart for supporting the colloquium financially; I also extend my gratitude to the members of my research project for their help in organizing the meeting, to the participants for their papers and the stimulating discussion and above all to Mrs. Zettl for her invaluable administrative help and her excellent typing.

C.Rohrer, University of Stuttgart / Institut Linguistik, September 1979.

---

1 This project (Ro 245/8 and 10) is financed by the DFG.
2 The next meeting will be held in Bar-Ilan (Israel).

ADVERBS OF FREQUENCY

Lennart Åqvist, Jaap Hoepelman and Christian Rohrer* (Universität Stuttgart)

1. *Introductory remarks*

In this paper we propose to give a logical treatment of the following nine adverbs, at the very least:

Always	Very often	Very seldom
Never	Often	Seldom
Sometimes	Fairly often	Fairly seldom

More precisely, we wish to arrive at a plausible analysis of certain sentences involving these adverbs. By "analysis" we then have in mind both a *syntactic* analysis purporting to clarify the logical form of those sentences and a *semantical* analysis intended to account for their meaning. In sec. 3 below we summarize the technique of analysis which emerges from the treatment, given in sec. 2, of our first example sentence. Further examples are dealt with in sec. 4. Our choice of examples to be handled is much inspired by David Lewis's significant article "Adverbs of Quantification" /Lewis (1975) in the reference list below/. The formal theory resulting from our discussion is presented in full detail in the Appendix, secs. 6 - 9.

2. *A pattern of analysis*

Consider the sentence

(1) very often the fog lifts before noon here.

As for the meaning of (1) one might suggest à la Lewis that it asserts that the fog lifts before noon here *on very many days* or, perhaps rather, *on very many days when the fog lifts here* (at all).

The present contribution reports research done under the auspices of the Deutsche Forschungsgemeinschaft (DFG) project "Die Beschreibung mit Hilfe der Zeitlogik von Zeitformen und Verbalperiphrasen im Französischen, Portugiesischen und Spanischen", led by Chr. Rohrer. We are grateful to our colleagues D.M.Gabbay, F.Guenthner and H.Kamp for stimulating discussions.

Assuming this idea to be reasonably viable, how are we then to cast it into an appropriate logical form? Well, trying first-order predicate calculus as our framework, we suggest to begin with that the formalization of (1) should somehow involve the following two *conditions* (sentential functions, *open* sentences containing one *free* variable):

(1a) x is a day & the fog lifts before noon here on x

(1b) x is a day & the fog lifts here on x

Call (1a) the *target* condition and (1b) the *reference* condition with respect to the example sentence (1). Again, from a semantical viewpoint, we claim that these conditions (1a) and (1b) determine or specify certain *sets*, viz. the set of days on which the fog lifts before noon here *and* the set of days on which the fog lifts here (at all), respectively. We then bring out the force of "very often" in (1) by taking (1) to assert that the *conditional probability* of the first set (determined by the target condition (1a)) *given* the second set (determined by the reference condition (1b)) is very high, say, $\gtrsim 0.9$. And by this conditional probability we mean, following Laplace, nothing but the *cardinality* of the intersection of the two sets *divided by* the *cardinality* of the second set (which we assume to exceed 0 in order to avoid division by 0). Or, if you prefer, the *ratio* of the number of "favorable" cases in the first set *to* that of all the "admissible" or "possible" cases in the second set.

So far, so good. Several technical aspects of the analysis just indicated remain to be straightened out, though. For one thing, what is the status of the open, free-variable-containing, sentences (1a) and (1b) and exactly how do they "determine" or "specify" the respective sets mentioned? We suggest the following mechanism: first, we associate with the conditions (1a) and (1b) the matching one-place *predicates* using the variable-binding operator λ for *property* (and, in general, *relation*)*abstraction*, viz.

(1c) λx: x is a day & the fog lifts before noon here on x

(1d) λx: x is a day & the fog lifts here on x

Call (1c) the *target* λ-predicate and (1d) the *reference* λ-predicate with respect to the *analysandum* sentence (1).

Furthermore, in the semantics of first-order predicate logic supplemented with λ,there will be *models* assigning to each predicate in the formal language a suitable set as its *extension;* e.g. the extension in a given model of the predicates (1c) and (1d), respectively, may be the two sets of days that were characterized above in an intuitive way. This settles the question how the open sentences (1a) and (1b), involving free variables, "determine" those sets of days; they do so *via* the associated λ-predicates (1c) and (1d), which are in turn interpreted relatively to set-theoretical models in a familiar way.

The next technical problem concerns the exact syntactic status of the frequency adverb "very often". It is an operator, all right. But what are the arguments for this operator? and how many are there? just one, or maybe more than one? In answer to these questions we suggest that the operator, formally represented by VeryOften-When, is a *binary* or *two-place* one which forms sentences out of *pairs* of predicates, like the pair (1c), (1d). The logical structure of (1) would then be captured by the following formalization:

(1*) VeryOften-When($\lambda x Fx$, $\lambda x Gx$)

where "Fx" and "Gx" are short for the conditions (1a) and (1b), respectively, and the reading of (1*) as a whole is as follows: "it is *very often* the case that the property $\lambda x Fx$ is realized *when* the property $\lambda x Gx$ is realized". The property $\lambda x Fx$ / $\lambda x Gx$/ is then the property of being a day on which the fog lifts before noon here /...the fog lifts here at all/.

Finally, we claimed above that the meaning of (1) could be characterized in terms of a certain conditional probability, interpreted in a Laplacean sense. In order to bring out this idea semantically we must enrich our aforementioned *models* with appropriate cardinality functions and use these to define conditional probabilities. We then lay down a *truth condition* for the formalization (1*) of (1) as follows: (1*) is true in a model M iff

$$P(ext^{M}(\lambda x Fx) \ / \ ext^{M}(\lambda x Gx)) \geq 0.9,$$

provided that the cardinality of $ext^{M}(\lambda x Gx) > 0$; where P(/) is our conditional probability function, and where $ext^{M}($ $)$ means the *extension in* the model M *of*.

For a more rigorous and neat presentation of the formal machinery here suggested the reader should consult the Appendix below, where the theory of our nine frequency adverbs is set forth in full detail.

3. *Summary of analysis technique*

We now make an attempt to describe systematically the procedure applied in the analysis of the sentence (1). Given an *analysandum* sentence involving an adverb of frequency, go through the following steps:

Syntactic level

Step 1. Determine *target* and *reference conditions* to be associated with the *analysandum*, possibly introducing abbreviatory shorthands!
Step 2. Form the corresponding *target* and *reference* λ*-predicates!*
Step 3. Apply to these λ-predicates the formal counterpart of frequency adverb in order to obtain a *formalization* of the *analysandum!* This formal counterpart will usually be a two-place operator forming sentences out of pairs of predicates. Check the *reading* of the formalization thus obtained!

Semantic level

Step 4. Specify a model built on a finite Laplacean frame (see sec. 8 - 9 in the Appendix below) and determine the extensions of the λ-predicates in the model!
Step 5. Determine the cardinality of these extensions and of their intersection as well as the conditional probability of the extension of the target λ-predicate given that of the reference λ-predicate in accordance with the definition given in sec. 8 below!
Step 6. Use the appropriate truth condition (sec. 9 in the Appendix) to determine the meaning of the *analysandum* sentence and to check its truth-value!

Let us quickly repeat the results of going through Steps 1 - 3 on the syntactic level in the case of our sentence (1), leaving the semantical steps aside for the time being. As applied to (1) Step 1 gave us the target condition (1a) and the reference condition (1b), for which we introduced "Fx" and "Gx" as shorthands. Step 2 then gave us "$\lambda x Fx$" and "$\lambda x Gx$" as target and reference λ-predicates, respectively. Finally, we obtained the formalization (1^*) of (1) as a result of taking Step 3; we also indicated how (1^*) was to be read.

4. *Further examples*

Consider

(2) Caesar seldom awoke before dawn.

discussed by Lewis (1975) in support of the claim "that the range of quantification is often restricted". We suggest the following analysis of (2):

Step 1.
Target condition:

(2a) x is a day & Caesar awoke before dawn on x; formally: Hx

Reference condition:

(2b) x is a day & Caesar awoke on x (at all); formally: Jx

Step 2.
Target λ-predicate:

(2c) $\lambda x Hx$

Reference λ-predicate:

(2d) $\lambda x Jx$

Step 3.
As a formalization of (2) we propose

(2*) Seldom-When($\lambda x Hx$, $\lambda x Jx$)

the reading of which is: "it is *seldom* the case that the property $\lambda x Hx$ of being a day on which Caesar awoke before dawn is realized *when* the property $\lambda x Jx$ of being a day on which Caesar awoke (at all) is realized".

Lumping the semantical steps 4 - 6 together we take (2) and (2*) to assert that the ratio of the number of "favorable" days on which Caesar awoke before dawn to that of the "admissible" days on which Caesar awoke (at all) is low, say, ≤ 0.3. Expressed more technically: (2*) is true in a model M iff

$$P(\text{ext}^M(\lambda x Hx) \,/\, \text{ext}^M(\lambda x Jx)) \leq 0.3,$$

with the usual proviso.

Our next example is adduced by Lewis (1975) to show "that the entities we are quantifying over, unlike times, may be distinct although simultaneous":

(3) Riders on the Thirteenth Avenue line seldom find seats.

The interest of this example, we claim, is due to the fact that the open sentences will have to contain *two* distinct free variables and, consequently, the corresponding λ-predicates will be *binary*. We propose the following analysis of (3):

Step 1.

Target condition:

(3a) x is a person & y is a time & x finds a seat on the Thirteenth Avenue line at y; in symbols: Sxy

Reference condition:

(3b) x is a person & y is a time & x is a rider on the Thirteenth Avenue line at y; in symbols: Rxy

Step 2.

Target λ-predicate:

(3c) $\lambda xySxy$

Reference λ-predicate:

(3d) $\lambda xyRxy$

Step 3.

We suggest formalizing (3) as

(3*) Seldom-When($\lambda xySxy$, $\lambda xyRxy$)

the reading of which is as follows: "it is *seldom* the case that the binary 'seat-finding' relation $\lambda xySxy$ between persons and times is realized *when* the binary 'riding' relation $\lambda xyRxy$ among persons and times is realized".

Going through the semantical steps 4 - 6 we arrive at a model M such that (3*) is true in M iff

$P(ext^M(\lambda xySxy)/\ ext^M(\lambda xyRxy)) \leq 0.3$ (say), provided that the cardinality of $ext^M(\lambda xyRxy) > 0$.

Note here that these extensions will be *binary relations* on the domain of the model, i.e. sets of *ordered pairs* of persons and times, or, in Lewis's terminology, sets of *cases*, whereby he means "tuples" or "sequences of coordinates" - in perfect agreement with the standard interpretation of predicates of degree > 1 in the semantics of predicate logic. We may add that Lewis's own discussion of (3) - his (9) - convincingly shows that any attempt to handle (3) on the basis of merely *one*-place predicates of *times* is doomed to failure.

We now deal with an example involving open sentences in *three* distinct free variables and, consequently, *three*-place λ-predicates:

(4) A man who owns a donkey always beats it now and then.

Step 1.
Target condition:

(4a) x beats y now and then during z; in symbols: Bxyz

Reference condition:

(4b) x is a man & y is a donkey & z is a period of time & x owns y throughout z; in symbols: Oxyz

Step 2.
Target λ-predicate:

(4c) $\lambda xyzBxyz$

Reference λ-predicate:

(4d) $\lambda xyzOxyz$

Step 4.
As a formal translation of (4) we then propose

(4^*) Always-When($\lambda xyzBxyz$, $\lambda xyzOxyz$)

the reading of which should by now be straightforward.

From a semantical point of view (4) and (4^*) assert that *the ratio of* the number of "favorable admissible" cases, i.e. triples of men, donkeys and periods such that the man *both* owns the donkey throughout the period *and* beats it now and then during the period, *to* that of all the "admissible" cases, i.e. those triples where the man just owns the donkey throughout the period, *is equal to* 1. Technically speaking, (4) is true in a model M iff

$$P(ext^M(\lambda xyzBxyz)/ext^M(\lambda xyzOxyz)) = 1,$$

with the usual proviso.

5. *A comparison-of-frequency operator*

Consider

(5) John often goes to church for a Catholic.

We suggest that the analysis of (5) might involve *two pairs of* target and reference conditions in the following way:

1st target condition:

(5a) x is an occasion & John goes to church on x; formally, Jx

1st reference condition:

(5b) x is an occasion & on x John has an opportunity to go to church & John is a Catholic on x; formally, OJx

2nd target condition:

(5c) x is an occasion & Innocentius goes to church on x; formally, Ix

2nd reference condition:

(5d) x is an occasion & on x Innocentius has an opportunity to go to church & Innocentius is a "normal" or "typical" Catholic on x; formally, OIx

Then we form the corresponding λ-predicates λxJx, λxOJx, λxIx and λxOIx and propose the following formalization of (5):

(5*) MoreOftenThan(λxJx / λxOJx , λxIx / λxOIx)

the reading of which is roughly as follows:
"The property λxJx of being an occasion on which John (a Catholic) goes to church *is realized in relation to* the property λxOJx of being an occasion on which John has an opportunity to go to church *more often than* the property λxIx of being an occasion on which Innocentius (i.e. a "normal" or "typical" Catholic) goes to church *is realized in relation to* the property λxOIx of being an occasion on which Innocentius has an opportunity to go to church".

Semantically, we take (5) and (5*) to assert that, relatively to a given model, the conditional probability of the extension of the predicate λxJx *given* that of λxOJx *is greater than* the conditional probability of the extension of the predicate λxIx *given* that of λxOIx. Expressed in more technical jargon, (5*) is true in a model M iff

$$P(ext^M(\lambda xJx) \;/\; ext^M(\lambda xOJx)) >$$
$$> P(ext^M(\lambda xIx) \;/\; ext^M(\lambda xOIx));$$

provided that the cardinality of $ext^M(\lambda xOJx)$ as well as that of $ext^M(\lambda xOIx)$ are both distinct from 0.

Note also that, relatively to a suitable model M, we might well have that $ext^M(\lambda xOJx) = ext^M(\lambda xOIx)$, i.e. the set of occasions on which John has an opportunity to go to church might well be identical to the set of occasions on which the typical Catholic Innocentius has such an opportunity. This *need* not be so, though.*

MoreOftenThan is then a four-place or "tetradic" operator on predicates of the same degree. In our Appendix below we have chosen to define it in terms of another, primitive, tetradic operator of this kind, AtLeastAsOftenAs; see sec. 7 below.

---

* Hans Kamp has raised the following objection to our analysis of example (5). According to the analysis, (5) is true iff John (a Catholic) utilizes his opportunities to go to church *to a higher degree than* Innocentius (the typical Catholic) utilizes *his* ones. Now, this condition is fulfilled in a situation where John has, say, just one opportunity to go to church which he indeed utilizes, whereas in the same situation Innocentius has several such opportunities and does not utilize them all. According to the proposed analysis of (5), (5) will be true in the situation described (the first conditional probability being = 1, the second not); but, as Kamp argues, (5) is definitely *not true* in that situation, hence, our analysis is inadequate. -

A way of countering this objection is to point out that it is rather doubtful whether we are really able to judge of the question whether (5) is true, or is false, in the situation at hand. In order to be able to make a meaningful comparison between John and Innocentius here, we have to presuppose that the number of their respective opportunities to go to church is *sufficiently high* - this applies to both of them. But this requirement is obviously not met in the situation envisaged by Kamp; hence, we suggest, his objection ceases to apply to our analysis. This is one way of getting around the difficulty; another is, of course, not to use the notion of opportunity at all in the analysis of (5), but to base it on some different conception. At this juncture we have to leave the matter open for further debate.

6. *Languages of FA*

A *language* L of the *logic* FA of *frequency adverbs* or, in short, a FA-*language*, is a structure made up of the following disjoint *basic syntactic categories:*

I. A denumerable set Var_L of *individual variables*. Syntactic or meta-linguistic notation: $x, y, z, x_1, \ldots, x_n, \ldots$.

II. A denumerable set $Cons_L$ of *individual constants*. Syntactic notation: $a, b, c, a_1, \ldots, a_n, \ldots$.

III. For each nonnegative integer n, a denumerable set Pr^n of n-place *predicate letters*. Syntactic notation: P^n $(n = 0,1,2\ldots)$.

IV. *Logical constants.*

(a) For each nonnegative integer n, a fixed *tautologous* n-place *predicate* $T^n (n = 0, 1, 2, \ldots)$.

(b) *Sentential connectives:* $-$, &, v and $\rightarrow$ for, respectively, negation, conjunction, disjunction and material implication (in terms of which the symbol $\leftrightarrow$ for material equivalence is defined in the usual way).

(c) *Quantifiers* (over individuals): $\forall$ ("for each") and $\exists$ ("for some").

(d) A symbol for *identity* (among individuals): =.

(e) A predicate-forming variable-binding operator λ for *relational abstraction*.

(f) Nine dyadic sentence-forming *adverbs of frequency*, viz.

Always-When	VeryOften-When	VerySeldom-When
Never-When	Often-When	Seldom-When
Sometimes-When	FairlyOften-When	FairlySeldom-When

(g) A four-place *comparison-of-frequency operator:* AtLeastAsOftenAs.

By simultaneous recursion (or induction) we now single out two categories of symbol strings, viz. the set $Sent_L$ of (well formed) *sentences of* L, and for each positive integer n = 1, 2,..., the set $Pred_L^n$ of n-place *predicates of* L:

(0) T^0 as well as all members of Pr_L^0 are in $Sent_L$.

(1) For all a, b in $Cons_L$, $(a = b)$ is in $Sent_L$.

(2) If Q^n is in $Pred_L^n$ and $a_1, \ldots, a_n$ are (not necessarily distinct) members of $Cons_L$, then $Q^n a_1, \ldots, a_n$ is in $Sent_L$ $(n > 0)$.

(3) If A, B are in $Sent_L$, then so are $-A$, $(A \& B)$, $(A \vee B)$ and $(A \rightarrow B)$.

(4) If x is in Var_L, a is in $Cons_L$, and if A is in $Sent_L$ and contains a but not x, then $\forall x A^x/a$ and $\exists x A^x/a$ are in $Sent_L$. (Here A^x/a is the result of replacing every occurrence of a in A by one of x).

(5) If Q^n and R^n are in $Pred_L^n$ $(n > 0)$, then

$$\left.\begin{array}{l} \text{Always-When}(Q^n, R^n) \\ \text{VeryOften-When}(Q^n, R^n) \\ \text{Often-When}(Q^n, R^n) \\ \text{FairlyOften-When}(Q^n, R^n) \\ \text{FairlySeldom-When}(Q^n, R^n) \\ \text{Seldom-When}(Q^n, R^n) \\ \text{VerySeldom-When}(Q^n, R^n) \\ \text{Never-When}(Q^n, R^n) \\ \text{Sometimes-When}(Q^n, R^n) \end{array}\right\} \quad \text{are in } Sent_L.$$

(6) If Q^n, R^n, S^n and U^n are in $Pred_L^n$ $(n > 0)$, then AtLeastAsOftenAs$(Q^n/R^n, S^n/U^n)$ is in $Sent_L$.

(7) T^n as well as all members of Pr_L^n are in $Pred_L^n$ $(n > 0)$

(8) If $x_1, \ldots, x_n$ are *distinct* members of Var_L, if $a_1, \ldots, a_n$ are *distinct* members of $Cons_L$, and if A is in $Sent_L$ and contains $a_1, \ldots, a_n$ but none of $x_1, \ldots, x_n$, then $\lambda x_1, \ldots, x_n A^{x_1}/a_1, \ldots, {}^{x_n}/a_n$ is in $Pred_L^n$ $(n > 0)$. (Here $A^{x_1}/a_1, \ldots, {}^{x_n}/a_n$ is the result of replacing every occurrence of a_i in A by one of x_i, for each i such that $1 \leq i \leq n$.).

(9) Nothing is in $Sent_L$ or in $Pred_L^n$ $(n > 0)$ except by virtue of the rules (0) - (8) above.

7. *Some definitions, readings and notational conventions*

It appears from clause (5) of the recursive definition just given that our adverbs of frequency Always-When, VeryOften-When,..., Sometimes-When are *binary* or *dyadic* operators which form sentences in L out of *pairs of* n-place predicates of L. These L-sentences can be understood in accordance with the following paradigm: read Always-When(Q^n, R^n) as "it is *always* the case that (the relation) Q^n is realized *when* (the relation) R^n is realized", and analogously for the remaining eight frequency adverbs. We now introduce a series of matching unary, i.e. one-place, operators as follows.

Let Q^n be in Pred^n_L $(n > 0)$. We then lay down the definitions:

D1. ALWAYS Q^n =df Always-When(Q^n, T^n)

D2. VERY OFTEN Q^n =df VeryOften-When(Q^n, T^n)

.
.
.

D9. SOMETIMES Q^n =df Sometimes-When(Q^n, T^n).

These definitions then make use of our fixed tautologous n-place predicates T^n in an obvious way.

We can also use our nine dyadic frequency adverbs to obtain definitions of the following series of *frequentative quantifiers*, where $x_1,\ldots,x_n$ are assumed to be *distinct* members of Var_L not occurring in Q^n or in R^n $(n > 0)$:

D10. ForAll $x_1,\ldots,x_n$-When($Q^n x_1,\ldots,x_n$, $R^n x_1,\ldots,x_n$) =df
Always-When(Q^n, R^n)

D11. ForVeryMany $x_1,\ldots,x_n$-When($Q^n x_1,\ldots,x_n$, $R^n x_1,\ldots,x_n$) =df
VeryOften-When(Q^n, R^n)

.
.
.

D14. ForFairlyFew $x_1,\ldots,x_n$-When($Q^n x_1,\ldots,x_n$, $R^n x_1,\ldots,x_n$) =df
FairlySeldom-When(Q^n, R^n)

.
.
.

D18. ForSome $x_1,\ldots,x_n$-When($Q^n x_1,\ldots,x_n$, $R^n x_1,\ldots,x_n$) =df
Sometimes-When(Q^n, R^n)

The quantifiers just defined could also be made more "absolute" by having T^n do duty for R^n in the manner illustrated by our definitional series D1 - D9.

Again, L-sentences of the form AtLeastAsOftenAs(Q^n/R^n,S^n/U^n) may be read somewhat as follows: "Q^n is realized in relation to R^n *at least as often as* S^n is realized in relation to U^n". In terms of this primitive tetradic operator we can now define the following operators, where Q^n,R^n,S^n and U^n are in Pred^n_L and $n > 0$:

D19. AtMostAsOftenAs(Q^n/R^n, S^n/U^n) =df
AtLeastAsOftenAs(S^n/U^n, Q^n/R^n).

D20. EquallyOftenAs(Q^n/R^n, S^n/U^n) =df
AtLeastAsOftenAs(Q^n/R^n, S^n/U^n) & AtMostAsOftenAs(Q^n/R^n, S^n/U^n).

D21. $\text{MoreOftenThan}(Q^n/R^n,\ S^n/U^n) =\text{df}$
$-\text{AtLeastAsOftenAs}(S^n/U^n,\ Q^n/R^n)$.

D22. $\text{LessOftenThan}(Q^n/R^n,\ S^n/U^n) =\text{df}$
$-\text{AtLeastAsOftenAs}(Q^n/R^n,\ S^n/U^n)$.

In view of the paradigm given above the readings of these new locutions are obvious.

Finally, in connection with L-sentences of the kind introduced by clause (2), we shall sometimes write $\{Q^n\}a_1,\ldots,a_n$, thus enclosing the predicate in braces. This convention facilitates reading when Q^n is formed by the use of λ (see clause (8) and cf. Prawitz (1965) p.63 f.).

8. *Finite Laplacean frames*

First, a preliminary explanation of some familiar terminology. If D is a non-empty set, then D^k (where k is a positive integer, i.e. k = 1,2,3,...) is to be the set of all ordered k-tuples of elements of D or, as we might as well put it, the k-th Cartesian cross-product of D with itself. Also, $D^1=D$ so that ordered 1-tuples are identified with their sole terms.

By a *finite Laplacean frame* we shall now understand an ordered pair $\langle D, \{c_k\}_{k \text{ is a positive integer}}\rangle$ where

(i) D is a non-empty and finite set ("domain of individuals"), and

(ii) $\{c_k\}$ is a family of cardinality functions indexed by the set of positive integers; which means that, for each k = 1,2,3,..., $c_k: \wp D^k \to \text{Nat}$ is a function from the power set of D^k into the set Nat of all natural numbers (= $\{0,1,2,\ldots\}$) satisfying the following conditions, for all $X,Y \subseteq D^k$:

(a) $c_k(X) = 0$ iff $X = \emptyset$

(b) if $X \subseteq Y$, then $c_k(X) \leq c_k(Y)$, and

(c) if $X \cap Y = \emptyset$, then $c_k(X \cup Y) = c_k(X) + c_k(Y)$.

Also, we require any c_k to be such that

(d) for all x in D^k: $c_k(\{x\}) = 1$ (or, in other words, that for all $d_1,\ldots,d_k$ in D: $c_k(\{\langle d_1,\ldots,d_k\rangle\}) = 1$).

The intuitive import of $c_k(X)$, for any $X \subseteq D^k$, is then obviously the *cardinality of* X (or the *number of elements in* X).

Definition. Let $\langle D, \{c_k\}_{k \text{ is a positive integer}}\rangle$ be any finite Laplacean frame, let X and Y be any subsets of D^k such that $Y \neq \emptyset$ so that, by (ii)(a), $c_k(Y) \neq 0$. We define the k-*th conditional probability of* X *given* Y, in symbols: $P_k(X/Y)$, by stipulating that

$$P_k(X/Y) = \frac{c_k(X \cap Y)}{c_k(Y)} .$$

Again, we define the k-*th "absolute" probability of* X, $P_k(X)$, by requiring that

$$P_k(X) = P_k(X/D^k) = \frac{c_k(X \cap D^k)}{c_k(D^k)} \left(= \frac{c_k(X)}{c_k(D^k)}, \text{ since } X \subseteq D^k\right).$$

Note that $P_k(X)$ is well defined because, by (i) above, $D \neq \emptyset$ so that for each $k = 1,2,3,\ldots$, $D^k \neq \emptyset$ and, by (ii)(a), $c_k(D^k) \neq 0$.

Exercise. Prove that, as defined, the probability measures $P_k(\ /\ )$ and P_k are real-valued functions on $\wp D^k \times (\wp D^k - \{\emptyset\})$ and on $\wp D^k$, respectively with the following familiar properties, where $X,Y,Z \subseteq D^k$ and $Y \neq \emptyset$:

P1. $0 \leq P_k(X/Y) \leq 1$.

P1.1 $0 \leq P_k(X) \leq 1$.

P2. $P_k(D^k) = P_k(D^k/D^k) = 1$.

P3. $P_k(-X/Y) = 1 - P_k(X/Y)$.

P3.1 $P_k(-X) = 1 - P_k(X)$.

P4. If $X \cap Z = \emptyset$, then $P_k(X \cup Z/Y) = P_k(X/Y) + P_k(Z/Y)$.

P4.1. If $X \cap Z = \emptyset$, then $P_k(X \cup Z) = P_k(X) + P_k(Z)$.

P5. $P_k(X/Y) = \dfrac{P_k(X \cap Y)}{P_k(Y)}$.

9. *FA-models and truth conditions*

Let L be any FA-language. By a FA-*model for* L we mean a triple $M = \langle D, \{c_k\}_{k = 1,2,3,\ldots}, V\rangle$ such that

(i) $\langle D, \{c_k\}_{k = 1,2,3,\ldots}\rangle$ is a finite Laplacean frame,

(ii) V is a *valuation of* L *on* the domain D in the sense of a one-place assignment-function satisfying the following conditions:

(a) $V(a) \in D$, for each a in $Cons_L$.

(b) $V(P^0) \in$ the set of truth-values $\{1,0\}$, for each P^0 in Pr^0_L.

(c) $V(P^n) \in$ the cartesian product D^n, for each P^n in Pr^n_L where $n > 0$.

Let $M = \langle D, c_k\ {}_{k = 1,2,3,\ldots}, V\rangle$ be any FA-model for L. By simultaneous induction we now define two notions, viz. $\models^M$, i.e. *truth in* the model M, and ext^M, i.e. *extension* (or denotation) *in* the model M, where the former concept applies to the members of $Sent_L$ and where the latter applies to the members of $Pred^n_L$ $(n > 0)$. Thus, we read the locution $\models^M A$ as "the sentence A is true in the FA-model M" and we read the locution $ext^M(Q^n)$ as "the extension in M of the n-place predicate Q^n". The recursive definition runs as follows (cf. the various clauses in the definition of $Sent_L$ and of $Pred^n_L$ $(n > 0)$ above):

(0) $\models^M T^0$

(0.1) $\models^M P^0$ iff $V(P^0) = 1$, where $P^0 \in Pr^0_L$

(1) $\models^M (a = b)$ iff $V(a)$ is identical to $V(b)$

(2) $\models^M Q^n a_1,\ldots,a_n$ iff $\langle V(a_1),\ldots,V(a_n)\rangle \in ext^M(Q^n)$, where $n > 0$

(3) $\models^M -A$ iff it is not the case that $\models^M A$

(3.1) $\models^M (A \;\&\; B)$ iff both $\models^M A$ and $\models^M B$

The truth conditions (3.2) and(3.3) for L-sentences having v and $\rightarrow$ as their main connective are then familiar.

(4) $\models^{M = \langle D, \{c_k\}, V\rangle} \forall x A^x/a$ iff $\models^{\langle D, \{c_k\}, V'\rangle} A$,

for each valuation V' on D such that $V' =_a V$ (see explanation below). Here A is assumed to be any L-sentence containing the individual constant a but not the individual variable x; in other words, A, a, x are to satisfy the hypothesis of the formation rule (4) in section 6 above.

(4.1) $\models^{M = \langle D, \{c_k\}, V\rangle} \exists x A^x/a$ iff $\models^{\langle D, \{c_k\}, V'\rangle} A$,

for some valuation V' on D such that $V' =_a V$ (see explanation below). Here A, a, x are to satisfy the hypothesis of the formation rule (4) in section 6 above.

Clauses (5) - (5.8) below are throughout to be understood with the following proviso: "provided that $ext^M(R^n) \neq \emptyset$ $(n > 0)$".

(5) $\overset{M}{\models}$ Always-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) = 1$

(5.1) $\overset{M}{\models}$ VeryOften-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) \in$
$\in [0.9, 1]$

(5.2) $\overset{M}{\models}$ Often-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) \in$
$\in [0.7, 1]$

(5.3) $\overset{M}{\models}$ FairlyOften-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) \in$
$\in]0.5, 1]$

(5.4) $\overset{M}{\models}$ FairlySeldom-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) \in$
$\in [0, 0.5[$

(5.5) $\overset{M}{\models}$ Seldom-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) \in$
$\in [0, 0.3]$

(5.6) $\overset{M}{\models}$ VerySeldom-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) \in$
$\in [0, 0.1]$

(5.7) $\overset{M}{\models}$ Never-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) = 0$

(5.8) $\overset{M}{\models}$ Sometimes-When(Q^n, R^n) iff $P_n(ext^M(Q^n)/ext^M(R^n)) \neq 0$

Note that there is nothing sacrosanct about the particular choice of values for P_n in the series of clauses (5.1) - (5.6) but that, on the other hand, a certain kind of symmetry is to be preserved if one makes changes in these values in the series.

(6) $\overset{M}{\models}$ AtLeastAsOftenAs$(Q^n/R^n, S^n/U^n)$ iff
$P_n(ext^M(Q^n)/ext^M(R^n)) \geq P_n(ext^M(S^n)/ext^M(U^n))$; provided that $ext^M(R^n) \neq \emptyset$ and $ext^M(U^n) \neq \emptyset$ $(n > 0)$.

(7) $ext^M(T^n) = D^n$ $(n > 0)$

(7.1) $ext^M(P^n) = V(P^n)$, for all P^n in Pr^n_L $(n > 0)$

(8) $ext^M(\lambda x_1, \ldots, x_n A^{x_1/a_1, \ldots, x_n/a_n}) = |A|^M =$
$\{<d_1, \ldots, d_n> : d_1, \ldots, d_n$ are in D, $V'(a_1) = d_1$ and ...
...and $V'(a_n) = d_n$, and $\overset{<D, \{c_k\}, V'>}{\models}$ A, for some V' on D
such that $V' \underset{a_1 \ldots a_n}{\underline{\qquad}} V\}$;

see explanation below. Here A, $a_1, \ldots, a_n$, $x_1, \ldots x_n$ are to satisfy the hypothesis of the formation rule (8) for λ-expressions in section 6 above.

Explanation. Let V, V' be valuations of L on a non-empty domain D, and let a be any member of $Cons_L$ /let $a_1, \ldots, a_n$ be distinct members of $Cons_L$/. We say that V' *differs from* V *at most with respect to* a /*with respect to*

$a_1,\ldots,a_n$/, in symbols: $V =_a V$ / $V \underset{a_1,\ldots,a_n}{\rule{2cm}{0.4pt}} V$/,

iff

(i) $V^\cdot(P^n) = V(P^n)$ for each P^n in Pr^n_L where $n \geq 0$, and

(ii) $V^\cdot(b) = V(b)$ for each b in $Cons_L$ that is distinct from a /from each of $a_1,\ldots a_n$/.

This completes our simultaneous inductive definition of $\models^M$ and ext^M.

Let A be any L-sentence, and let $M = \langle D, \{c_k\}_{k=1,2,3,\ldots}, V\rangle$ be any FA-model for L. We say that M is *appropriate for* A just in case the concept of truth in M ($\models^M$) is defined for A. We ought to be able to verify that M is appropriate for A iff (i) there is no subformula of A having any of the forms Always-When(Q^n,R^n),...(down to)... Sometimes-When(Q^n,R^n) which is such that $ext^M(R^n) = \emptyset$, *and* (ii) there is no subformula of A of the form AtLeastAsOftenAs$(Q^n/R^n,\ S^n/U^n)$ such that $ext^M(R^n) = \emptyset$ or $ext^M(U^n) = \emptyset$.

Given this notion of appropriateness, we say that an L-sentence A is FA-*valid* iff $\models^M$ A for each FA-model M such that M is appropriate for A. Note that this conception of validity is slightly unorthodox in the following two respects: (a) FA-models are built on *finite* sets, viz. Laplacean frames, and (b) we have to restrict ourselves to such FA-models as are appropriate for L-sentences.

Bibliographic References

Lewis, D., 1975, Adverbs of Quantification, in E. Keenan (ed.) *Formal Semantics of Natural Language*. Cambridge University Press, pp.

Prawitz, D., 1965, *Natural Deduction*. Stockholm: Almqvist & Wiksell.

TENSES AND ASPECTS AS FUNCTIONS ON VERB-PHRASES*

Emmon Bach, University of Massachusetts/Amherst

0. *Introduction*

Practically all tense logicians that I've read have assumed that tenses and aspects are to be interpreted as sentence operators (one exception: Bäuerle, 1977). And there is a good deal of motivation for this idea. To take just one example, consider one test offered by Thomason and Stalnaker (1973), for helping to determine whether adverbials are sentential or not:

> Criterion 2: Only if an adverb is a sentence modifier can it give rise to quantifier scope ambiguities in simple existential or universal sentences.

Their example for this test is the following:

(1) Frequently, someone got drunk -- Someone got drunk frequently.

By this criterion, *frequently* must be a sentence adverb. By the same reasoning we could show that the present perfect is a sentence level operator if (2) is scopally ambiguous:

(2) Every president has resigned.

In Montague's PTQ (Paper 8 in Montague, 1974) sentences like (2) are claimed to be ambiguous. By direct generation (S17) we get a version like (3), by "quantifying in" (S14), we get one like (4):

(3) $H\ \hat{P} \bigwedge x\ [\mathit{president}'(x) \rightarrow P\{x\}]\ ({}^{\wedge}\mathit{resign}')$

(4) $\hat{P} \bigwedge x\ [\mathit{president}'(x) \rightarrow P\{x\}(\hat{x}_3\ H\ \mathit{resign}\ (x_3))$

It's easy to see that to retain this account in the theory of English presented in PTQ, the tenses/aspects *must* be sentential operators.

A consequence of this general way of looking at tenses/aspects can be seen in the very rules of PTQ: there are six totally independent ways of putting together subjects and verb phrases, one for each of the six combi-

---

* Dedicated to the memory of Michael Bennett.

nations of negation, present perfect, *will* and nothing (i.e. present tense) which are allowed by PTQ. We can make a typical linguist's argument against Montague's treatment. It is a complete accident, on that account, that English sentences in the six combinations end up showing the same basic structure: *NP(Aux)VP*; the distribution could just as well be this:

(5) John leaves.
Doesn't leave John.
Won't leave John.
John has left.
Hasn't left John.
John will leave.

The grammar of English would be just as simple if (5) were the correct distribution. Note also that things just get worse as we add other tenses and modals.

What is it about PTQ that requires this sort of treatment? I will argue that the reason for this state of affairs is the view that subject NP's are functions taking IVP's as arguments. If we drop this idea and revert to an analysis given by Montague in "Universal Grammar" (Paper 7 in Montague, 1974) we can accomodate the facts about tenses and aspects in English in a much more natural way. The theory of UG, which has recently been argued for strongly by Keenan and Faltz (1978) within a different framework, takes intransitive verb phrases as denoting functions from (intensions of) NP-type things (sets of properties) to truth values. Once we take this step, we can reconsider the status of tenses and aspects.

My paper goes in three stages. In Section 1, I'll sketch some of the evidence for the UG, Keenan/Faltz analysis (henceforth 'UG/KF'). In Section 2, I'll show how this permits us to treat tenses/aspects as functions defined on IVP's and give rules that result in a system exactly equivalent to that of PTQ. In Section 3, I'll speculate in a more informal way about a more thoroughgoing revision that doesn't end us up exactly where PTQ does, and in Section 4 I'll consider extensions of PTQ under the new framework.

1. Why IVP's are of category t/T.

In this section, I'll consider evidence for the notion that intransitive verb-phrases should be assigned a higher-type category than *t/e*. It should be pointed out at the outset that PTQ has no category of tensed IVP's, since the tenses and aspects are introduced syncategorematically. So the view that tensed IVP's at least are of category t/T is quite consistent with PTQ and amounts only to adding a higher category (t/T) and spelling out the surface forms of English via an intermediate stage. For a number of arguments for the more general idea that IV's themselves are of this category I refer to the monograph by Keenan and Faltz (1978). I'll confine myself here to a few ways in which this view solves a number of problems in an elegant way. To them should be added the considerations about tense and aspect that make up the bulk of this paper.

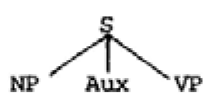
1.1 *English constituent structure.*

On the assumption that conjunction should be defined for all or almost all and only genuine syntactic categories of English (or "major" categories), the UG/KF view predicts that tensed IVP's should be conjoinable. They are:

(6) Harry left at three and is here now.

(7) John lives in New York and has always lived there.

Note that these assumptions and facts are incompatible with a popular view of English sentences as having this structure:



1.2 *Raising verbs*

Verbs like *seem* or phrases like *seem to me* seem semantically to work like propositional operators. That is, a sentence like (8) feels like it ought to have the indicated structure in its interpretations (cf. Wotschke, 1972):

(8) A unicorn seems to be approaching.

$seem'\ (\phi)$

where ϕ corresponds to the proposition expressed by (9):

(9) A unicorn is approaching.

It's hard to get this in the PTQ system. But if we take the view that IVP's are functions, it's easy. We can let *seem* take IV's with *to* and assign it this interpretation:

(10) $\lambda P \lambda \mathcal{P}\ seem'\ (\mathcal{P}\{P\})$

(This assumes that we retain PTQ's analysis of IVP's *without tenses* as of category *t/e*.)

1.3 *Syntactic category theory.*

One of the problems of Montague's syntax in PTQ is that there seems to be no natural connection between various subcategories of verbs: IV's are of category t/e, TV's of category $(t/e)/T$. If we regard IV's as of category t/T there is a unified way of classifying at least these two types together, and explaining why for example adverbial modifiers can often go with either type (c.f. Keenan and Faltz, 1978).

Moreover, it begins to look as if we will be able to establish connections between verbs and other categories. For example, verbs and prepositions share some properties. In the UG/KF system they share the property of being functions of category X/T.

Finally, we may begin to get a handle on why verbs are different from other kinds of things classified as t/ne in PTQ. (Keenan and Faltz provide a number of arguments of this general sort).

1.4 *Montague phonology.*

Finally, let me mention an argument that comes from a rather surprising source: the study of phonology.

Recent work in phonology (Selkirk, ms., Liberman & Prince, 1973) has shown that it makes a lot of sense to think of the phonology of a language as including a system that specifies various domains along a hierarchy: the syllable, the foot, the word, the phonological phrase, etc. (This work is in part a revival and vindication of a lot of older ideas, e.g. those of Kenneth Pike). It turns out that Montague grammar -- or more precisely categorial grammar — offers an interestingly different way to think about such problems.

Among the rules of English phonology are principles that tell us how to organize sequences of words into phonological phrases. In a categorial framework it appears that we can state a very general principle of phrasal organization (for English and some other languages):

> Phonological phrases are the maximal chunks that you get by putting functions together with arguments on their "right".

This principle tells us for example that prepositions will go with their NP's, that a determiner will go together with its common noun phrase, that a transitive verb will go together with its object NP and so on. The principle seems to work just right for such disparate processes as the assignment of stress to English phrases, the organization of phrases for the purposes of assigning intonations (at the next level up), for defining the domain of French liaison, and Italian syntactic gemination.

Given this principle, the two views of subject NP's set forth in PTQ and UG/KF make opposite predictions. In fact, the UG/KF view seems correct: liaison never happens from a subject noun phrase to the tensed VP, nor does gemination in Italian take place here, and English phrasing respects the independence of the subject NP. (Work in progress by myself and Deirdre Wheeler is devoted to these questions, much oversimplified here.)

2. *Redoing PTQ*

In this section, I will sketch the simplest possible modification of PTQ. I retain the category assignments of PTQ, but add a new category of tensed verb phrases. In order to make everything work out right it's necessary to make a distinction between verbal and non-verbal predicate types. The system is very "surfacy" in that it generates auxiliary elements directly in place without recourse to obligatory rules like Affix Hopping (cf. Lapointe, ms.).

Let us first add a new category for tensed IVP's: $P_{t/T}$. There are no basic members of this category. Expressions in the category are formed in the first place by a rule that takes PTQ's IV's ($P_{t/e}$) and changes the tenseless main verbs of the phrase to their present tense singular forms. The new phrases are to be interpreted as functions from intensions of NP's (sets of properties) to truth values. We have two choices: one is to give the truth conditions for these functions directly (as do Keenan/Faltz, Gazdar), equivalently we can interpret each such tensed IVP as $\lambda\mathcal{P}\mathcal{P}\{{}^\wedge\gamma\}$ where γ translates the old IV.

This rule will give us tensed IVP's like *walks, is a fish, sees a unicorn.* We can now treat the various tensed auxiliaries of English as functions from the old IV's to members of the new category $P_{t/T}$. To do this right, however, it's necessary to remove *be* from the category of transitive verbs. It has long been known (Chomsky, 1957; more recently Akmajian and Wasow, 1975) that the tensed forms of *be* act like auxiliaries. That is, we have paradigms like these:

(11) John doesn't walk.
John isn't a fish.
*John doesn't be a fish.
John walks, doesn't he?
Mary is Bill, isn't she?
*Mary is Bill, doesn't she?

So let's introduce a syntactic distinction between verbal IV's and copular IV's (letting the latter be $P_{t////e}$, P_{COP} for short).

We need to distinguish four classes for Auxiliaries. First, we have *will* and *won't* which can go directly with verbal and copular IV's; call them Aux-1. Second, we have *doesn't*, which can go only with verbal IV's; call them Aux-2. Third, we have the tensed forms of *be*, *is* and *isn't*, which take term phrases (or other things in a fuller fragment); call them Aux-3. Finally, we have the tensed forms of *have*, *has* and *hasn't*, which take both verbal and copular IV's in their participial forms.

The rules for forming tensed IVP's with auxiliaries are straightforward. For the first three we just concatenate the Aux element with the appropriate kinds of predicates. For the present perfect we have to form the participial version of the predicate. Translations for the Aux elements except for *is* and *isn't* all have the form $\lambda P \lambda \mathcal{P}\, X\, \mathcal{P}\{P\}$, where X = W, ¬ W, H, ¬ H, ¬ , For *be* we simply reconstruct Montague's interpretation. We let *be* itself form copular predicates by combining it with a term phrase. (This is all spelled out formally in Appendix A.).

The new system allows us to correct a minor mistake implicit (I think) in PTQ. PTQ allows us to conjoin arbitrary IVP's (by rule S12): *walk* or *be a fish*, for example. But what is the present tense third person negative of this phrase? The answer is that there is none: **John doesn't walk and be a fish*. The best we can do is *John doesn't walk and isn't a fish*. As suggested above, we do want to conjoin tensed IVP's, so we can add a rule to do this. And we can formulate rules that will allow *John will walk and be a fish* but exclude the bad sentence above. (This problem was pointed out to me by Barbara H. Partee.). I'll defer further discussion of the conjoining rule to the next section.

This might all appear unduly complex, but please note that the rules of Appendix A spell out much of what is buried in Montague's phrases "third singular present" (S4) and the corresponding phrases of S17. Moreover, an explicit definition of *main verb* allows us to correct a mistake in PTQ (which gives **John walks and talk*; cf. Bennett, 1974, and also the more careful formulation of UG with explicit definitions of the relation *main verb of*).

Finally, it's pretty straightforward to extend the fragment by adding new members to the Aux categories, for example, the other modals of English.

3. *Revising PTQ.*

In this section I want to explore a more radical revision of PTQ's type assignments along the lines suggested by Keenan and Faltz.[1] That is, we let the old IV's themselves be mapped into expressions (or interpretations) of type $<<s,f(T)>, t>$. I take *walk* to denote a function from intensions of sets of properties to truth values. For an extensional verb like *walk* we can say that the value of *walk'(^NP')* at a world and time is 1 just in case $walk'_*$ is in *NP'* at that world and time. In the formalism of PTQ we replace the category IV by a new category $P_{t//T}$ — distinct from tensed IV's which stay in $P_{t/T}$.

On this view, then, the translation of *John walks* will be just $walk'(\hat{\ }j^*)$. The interpretations of the Auxiliaries will be more simply represented as just $\lambda \mathbb{P}\ X\ \mathbb{P}$, where $\mathbb{P}$ ranges over things of type $<s, f(t/T)>$, X as above = $W, \neg W, H, \neg H, \neg$ but these operators are redefined. One immediate advantage is this: we can add *have* to the fragment (in it's infinitive form) to get things like *will have walked*. On this view the Auxiliaries are more truly VP-operators. What are we to say about their interpretations?

In the logic we eliminate all clauses introducing W, H, $\neg$ as sentence operators and replace them by these definitions:

> If $\gamma \in ME_{<<s,f(T)>, t>}$ then so are $H\gamma$, $W\gamma$, $\neg\gamma$.

And similarly we want to replace the clauses giving the denotations of expressions involving the old sentence operators by ones like these:

> $H\gamma$ is that function *h* defined for NP intensions such that $h(\alpha)$ at i, j is 1 iff there is j', j' < j, and $\gamma(\alpha)$ is 1 at i, j', and similarly for W and $\neg$.

Let's now think about the rule for conjoining tensed IVP's as in these sentences.

(12) John has walked and is a fish.

(13) A woman has walked and will run.

---

1 And apparently independently by Gazdar, 1979. Again, let's note that this was the system of *UG*. Hoepelman, 1978, follows the same system.

The syntactic rule is simple:

If $\gamma, \delta \varepsilon P_{t/T}$, then so are γ *and* γ *or* δ

A first stab at a translation rule fails:

If γ, δ translate as γ', δ' respectively, then γ *and* δ and γ *or* δ translates as $\lambda \mathcal{P} [\gamma'(\mathcal{P}) \wedge \delta'(\mathcal{P})]$ and $\lambda \mathcal{P} [\gamma'(\mathcal{P}) \vee \delta'(\mathcal{P})]$ respectively.

This rule would work fine for (12) but would make (13) come out as equivalent to (14).

(14) A woman has walked and a woman will run.

(This was one of the stumbling blocks of the old meaning-preserving conjunction reduction transformation.). My judgment is that (13) has no reading like (14). So we need something fancier, say, this:

If γ, δ translate as γ', δ' respectively, then γ *and* δ and γ *or* δ translates as
$\lambda \mathcal{P} \mathcal{P}\{\hat{x}\ \gamma'(\hat{P}\ P\{x\}) \wedge \delta'(\hat{P}\ P\{x\})\}$ and $\lambda \mathcal{P} \mathcal{P}\{(\hat{x}\ \gamma'(\hat{P}\ P\{x\}) \vee \delta'(\hat{P}\ P\{x\})\}$
respectively.

This rule has the effect of reconstructing the "quantifying in" interpretation. This rule will have the same effect as the more direct interpretations made available in systems like those of Keenan/Faltz (1978) and Gazdar (1979) where Boolean operations on a whole bunch of categories besides sentences are allowed. The interpretation of (13) on this account will now come out equivalent to this formula:

(15) $\bigvee x\ [\text{woman}'\ (x)\ \wedge H\ \text{walk}'\ (x)\ \wedge W\ \text{run}'\ (x)]$

I take this to be correct.[2]

In favor of this view of tenses and negation as basically VP operators in English is the following fact. There are no simple ways in English of giving negations or tense operations on conjoined sentences, in striking contrast to the simple syntax of negation and tenses in logics. Thus, in treatises on tense logic, it is necessary when discussing examples to resort to higher verbs: *it is not the case that p and q, it will be the case that p or q*, etc. (We'll see that this fact doesn't hold for time adverbials: *Yesterday John left and Mary arrived.*).

---

2 In the discussion at the conference, Lauri Karttunen and Ed Keenan disagreed with my judgments about such sentences, offering examples that seemed to show that you do need to provide for interpretations like (14). Note that if this is correct we can provide a very strong argument for the analysis adopted here, in the case of intensional expressions such as the following sentence: A secretary is being sought and will be required to know three languages. One reading for this sentence (like the second interpretation above) is available via the usual route of quantifying in. But the other reading cannot be captured by an interpretation of the first sort given. Apparently, all we can say is that the interpretation is some function from NP intensions to truth values (Keenan pointed out to me that this is generally true for conjunctions of intensional expressions). So the inability to state a generalization about such conjunctions turns out to be an argument for the general point!

4. *Extending PTQ.*

What we've done so far isn't really a very good test of our theory. To really check it out we have to consider the harder problems, to wit, the progressive, the past tense, and time adverbials. This section will be devoted to an attempt. Clearly, in a paper of this length, I can only scratch the surface.

4.1 *The progressive.*

The best treatment of the English progressive that I know of is due to Frank Vlach (ms. a.). Vlach argues persuasively (as have others) that an adequate analysis of the progressive must take into account something like the classification of certain English expressions developed by Vendler, Kenny, and others. According to this view English expressions must be divided into those having to do with *states*, *processes*, *accomplishments*, and *achievements*. I say "expressions" advisedly, since one problem we must address is this: what kinds of things are to be divided into these classes?

Recall that Vendler and Kenny talked in the first place in terms of *verbs*, interpreted liberally to be sure, since they included things like *push a cart*, already some sort of verb phrase. Dowty (1972)[3] pointed out that the nature of the object and other things in the verb phrase made a crucial difference and that the subject had to be taken into account as well. For example, (16) is an achievement predicate, (17) a process predicate, (18) an achievement sentence, (19) a process sentence:

(16) ...find a unicorn

(17) ...find unicorns

(18) I discovered the village (? all summer).

(19) Tourists discovered the village (all summer).

For such reasons, Dowty, Vlach and others have concluded that the domain of the progressive must be the sentence.

Let me note once more that this flies in the face of English syntax. Writers like Akmajian and Wasow (1975) have given evidence that the progressive ought to be the element of the English tense/aspect system that is farthest "down" in the verb phrase system. The progressive is then a major test of our theory, since if the progressive has to be a sentence operator, then everything in the system, since "higher", must also be.

3 Following Verkuyl (1971).

I don't want to try to provide a full theory of the progressive here. I agree with Vlach that an adequate theory must take at least this fourfold classification into account. I am solely concerned here with showing that we can work out a way of looking at the classification, within the framework proposed here, which does not require that the progressive be a sentence operator. For simplicity, I'll confine myself to three cases: (i) sentences in which the nature of the object affects the nature of the predicate; (ii) cases where one kind of adverbial (hopefully this case will generalize to many) affects the nature of the predication, (iii) cases where the nature of the subject affects the nature of the predication. The first and the last cases were illustrated already. The second case can be illustrated by these sentences:

(20) Max pushed a cart (process)

(21) Max pushed a cart for an hour (accomplishment on one reading)

(Hoepelman, 1976, has discussed some of these examples).
The facts to be explained can be summarized thus:

(i) If an object (subject) in the singular makes a nonprocess predicate (sentence) then replacing the object (subject) by a mass noun or bare plural allows the interpretation of the predicate (sentence) as a process expression.

(ii) If certain adverbials (e.g. *for an hour*) are added to process predicates (sentences) then the result is interpreted as an accomplishment or achievement.

Intuitively, the difference between processes and events (as I prefer to call both of the other types of accomplishments and achievements) is this: an event is a one-time kind of thing, it has a beginning and middle and an end (if it is an accomplishment, if it is an achievement its beginning is its end and it has no middle, cf. Mourelatos, 1978, and Gabbay and Moravcsik, this conference/volume), processes just go on and may never have begun or never end. Events are countable, processes aren't. Processes are like mass nouns, events like count nouns. Suppose we had an ontology in which there were entities like events and processes. Then we could say various things this: if x and y are processes of the same kind and x abuts y then there is a process z of the same kind of which x and y are parts (call this *additivity*). Clearly, events aren't like this. Similarly, if x is a process, we can often subdivide x into parts that are also processes of the same sort. But with events this is never true: if x is an event of a certain sort (*building a cabin*, *finding a unicorn*), then no proper part of x is also an event of that sort. Call this *indivisibility*. Considerations like these, by the way, convince me that it is futile to attempt to reconstruct such notions in terms of properties of moments or intervals of time (as Montague tried to do for events in his paper "On the nature of certain philosophical entities", Paper 6 in Montague, 1974). We certainly can't say that if *John build a cabin* is a property of an interval of time, then there is no proper subinterval of that interval of which *John build a cabin* holds; similarly, there can be several strikings of Shem by Shaun that are simultaneous but different (I owe this last example to Terry Parsons). In fact, I believe that our notions of time itself are built up from more primitive notions about events and the like and their relationships.

Now, still intuitively, it seems obvious that if you put together a verb like *find* with a bare plural or mass noun the result is going to be a process predicate: it is additive and not indivisible. Similarly if you put together a plural subject with a verb like arrive the result will be a process. And if you put together an expression like *for an hour* (or e.g. a goal expression like *to the store*) with a process predicate like *run* or *push a cart* you will now have an event predicate or sentence: pushing a cart for an hour, running to the store, do have beginnings, middles, and ends, are indivisible and not additive.

How are we to understand this classification? There are two aspects to the problem. One is what we might call the *ethnometaphysical* problem. I believe that this problem is best attacked by providing an ontology in which there are things like events (instantaneous and protracted), processes, and states. We may not be able to say what they are exactly, but we can say something about their properties, as I have tried to do above. (Work in progress is devoted to this problem, where I try to reconstruct our notions about time on the basis of more primitive notions about events and the like and their relationships, following a line initiated by Whitehead (1920), Russell (1956) and currently being pursued by Hans Kamp. The second problem we might call the *descriptive* problem: how are we to represent all of this in an explicit account of English syntax and semantics. For example, one might try to build into a fragment of English purely syntactic distinctions corresponding to the metaphysical ones. I believe that such an attempt would be misguided, since it would be treating the classification as purely artibrary, like German gender. In effect, we would be saying that there could be a language just like English, say Shmenglish, in which *find a unicorn* and *push a cart* would mean exactly what they mean in English but had just the opposite properties with respect to the progressive, time adverbials, and the like. So the facts are at least semantic. How should they be reflected in a semantics for English? One way would be to state meaning postulates individually for each verb, since the hub of the interpretation does seem to be the verb (or one might do some kind of decomposition of the meanings of the verbs, à la Jackendoff, 1976; or Dowty, 1976; Hoepelman, 1978). I think that even this is too much, so I'll take a Cresswellian stance and say that it's just part of our understanding of the function denoted by *find* that tells us that *find a unicorn* corresponds to a set of events (cf. Cresswell's remarks on *walk*, 1978).[4]

With this as background, let's introduce the progressive as an operator on verbal phrases. I'm only going to try to give an account of the semantics, and that only in part, and not try to spell out the syntax. Let's use a shorthand for the differing truth conditions that must be given for the different types of expressions: condition P for the case of processes, conditions E-1 and E-2 respectively for the cases of achievement (instantaneous events) and accomplishments (protracted events) (protracted events) (say, along the lines of Vlach, ms. a.).

> We add Prog(γ) to our list of well-formed expressions in the logic, where γ is a meaningful expression of type $\langle s,f(t/T)\rangle$ *and* Prog(γ) is also. Prog(γ) is that function h such that h(^NP') = 1 under conditions P, E-1, E-2, according as γ(^NP') is a process, an instantaneous event, or a protracted event.

4.2 The Past tense.

I endorse the view that there is a semantic difference between the past tense in English and the present perfect. (As a matter of ordinary usage, it must be admitted that the two are often interchangeable.). The difference is that in the present perfect the truth conditions explicitly quantify over a time in the past, while a past tense sentence without a time adverbial must be understood under some contextual assignment of an interval or point in the past. Without such an assignment a past tense sentence has something of the status of a sentence with an unbound pronoun in it (cf. Partee, 1973). Suppose you ask

---

4 Barbara Partee has pointed out to me that the view followed here, taken together with Vlach's treatment of the progressive is quite problematical for a compositional semantics, since it makes it impossible to give an explicit statement of truth conditions for sentences in the progressive. This observation forces us to one of three conclusions: (1) we must include meaning postulates or some other device of the sort rejected here; (2) the semantics of the progressive can't be given compositionally, i.e. it requires reference to matters of knowledge and belief; or (3) there is a uniform truth condition for the progressive, but we just haven't found it yet.

me *Did Mary leave?* Unless it's clear from the context what period you are talking about I can't answer the sentence Yes or No. Some contexts might yield something equivalent to a present perfect sentence. Thus we do get a kind of pragmatic entailment:

If Mary left, then Mary has left.

By now it should be fairly obvious what the *form* of my treatment of the past tense is going to be. It is going to be some kind of modifier or operator on IV phrases (or our new type). One way to capture the context dependence of the past tense just mentioned is to think of the past tense as adding a variable over intervals or points to the interpretation of a sentence. In the next section I'll treat time adverbials as elements that can bind such a variable. So the first question we might ask is this: should this variable be a variable over points or intervals? It seems as if both kinds of adverbials can specify the context of a past tense sentence:

What happened at 3 o'clock? Mary left.
What happened yesterday? Mary left.

At 3 o'clock is a typical point-time adverbail, *yesterday* a typical interval adverbial.

Vlach (ms. b.) has argued that the semantics of tense and time in English (and undoubtedly other languages) needs three somewhat independent notions: truth *in* an interval, *at* an interval, and *for* (throughout) an interval. I believe this is correct. For example, sentences like *Mary builds a cabin* or *Mary finds a unicorn* are true at intervals (the latter an instant), sentences like them can be true in intervals (iff they are true at some subinterval of the interval): *Mary built a cabin in 1972*. Neither kind of sentence can be true *for* an interval. Sentences about processes and states can be true *at* as well as *for* intervals. Note, however, that we can reduce *in* to *at* in the special case of an instant. I believe that the proper view of the past tense variable is as one ranging over intervals and that truth for past tense sentences should be thought of in terms of the *in* relation. In this way we can explain why the past tense variable can be bound either by a point-time adverbial like *at 3* or a proper interval variable like *yesterday*. Thus, I think that the correct semantics of the past tense is rendered almost exactly by the English phrase *in the past*.

The way I propose to do this is by introducing a distinguished variable over intervals in the translation of past tense sentences, in some manner yet to be spelled out. A pragmatic theory in the sense of Stalnaker (1978) will assign values to this variables from context if the variable remains unbound. In the next section I'll suggest that certain time adverbials can act to bind this distinguished variable.

I was hung up for a long time by the fallacious assumption that the use of a single distinguished variable would require giving it the same value throughout a sentence. On that view a conjunction of sentences in the past tense would require the same contextually specified value for the variable in each conjunct. To avoid this consequence, I worked out a very elaborate system using an infinite set of indexed past tense variables in the syntax, somewhat like Montague's indexed variables for pronouns. But clearly, parts of a sentence can themselves help to establish the context, and hence the context can change throughout a sentence, as von Stechow (1977) has argued. Consider the following sentences:

(22) Mary got married and got pregnant.

If we interpret this sentence as containing two occurrences of a free variable over intervals and if we allow the first part of the sentence to change the context then the value of the free variable can also change. On the other hand, addition of a point time adverbial can bind (indeed must bind on the normal interpretation) both occurrences of the variable:

(23) At 3 o'clock (on such and such a day) Mary got married and got pregnant.

This requires a somewhat unusual wedding ceremony to be sure.).

Dowty (1977) suggested that the past tense be considered to get into sentences when time adverbials are added to them. I am going to consider the past tense as *being* in some sense an adverbial, but in line with the general approach of this paper as a modifier at the IVP level, and as just suggested, as an interval adverbial. So the semantics of a past tense sentence is going to be just like that of a sentence with an interval adverbial in it. Suppose I is an interval, then we can say this:

In $I(\gamma)$ is that function h defined for NP intensions such that $h(\alpha) = 1$ at i, j iff $\gamma(\alpha) = 1$ in I at i, j.

Now let's translate verb phrases in the past tense as containing a distinguished variable I_p. A pragmatic rule would take a sentence with this variable in it and interpret it from context. What we need from the context for such an interpretation is the set of ordered pairs $\langle I, j\rangle$ such that I is an interval and j a moment and $I < j$.

4.3 Time adverbials.

Are time adverbials like *yesterday*, *at 3*, *when I arrived*, sentence operators or verb-phrase operators? My answer is yes. In a sentence like (24) *yesterday* is acting like a sentence modifier, in (25) as an IVP modifier (or possibly also as a sentence modifier):

(24) Yesterday, Mary left and John arrived.

(25) Mary left yesterday.

Let's let such expressions be interpreted primarily as IVP modifiers. We can handle interval adverbials like *yesterday* and point adverbials like *at 3* with the machinery set up so far. They can receive these interpretations:

yesterday: $\lambda \mathbb{P} \lambda I_p \mathbb{P}$ (*yesterday'*)

at 3 : $\lambda \mathbb{P} \lambda I_p \mathbb{P}$ (*at-3'*)

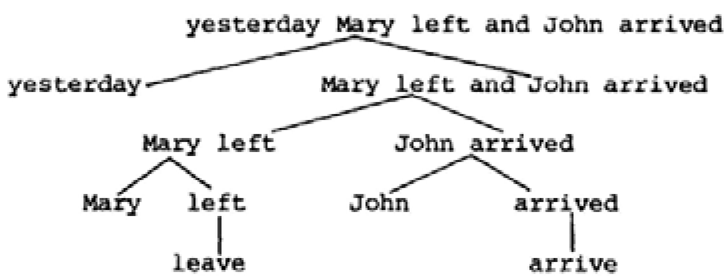
And we can provide a rule that lets each such adverbial act also as a sentence operator, binding the distinguished past tense variable:

yesterday: $\lambda p \lambda I_p p$ (*yesterday'*)

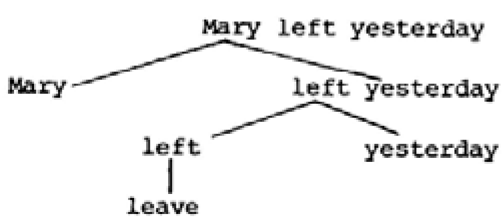
at 3 : $\lambda p \lambda I_p p$ (*at 3*)

All we need do is say that if I is a moment, than *in I* reduces to *at I*.

Examples (24) and (25) work like this:



Translation: $\lambda p \lambda I_p p(\textit{yesterday}')\lambda_p\ \lambda I_p P(\textit{yesterday}')(\hat{}[\mathrm{In}\ I_p(\textit{leave}')(\hat{}m^{*})] \wedge [\mathrm{In}\ I_p\ (\textit{arrive}')(\hat{}j^{*})])$.



Translation: $[\lambda \mathbb{P} \lambda I_p\ (\textit{yesterday}')\mathbb{P}\ (\mathrm{In}\ I_p\ (\mathrm{leave}'))](\hat{}m^{*})$

It remains for us to say something about durational adverbials like *for three hours*, *between 3 and 4*. (I'm excluding the modal temporals with explicit *for* as in the natural interpretation of *Mary got up for three hours*, which are a whole other story.). Given that we have interpreted the past tense as an *in*-type adverbial, how can we connect it up to durational adverbials?

I believe that the answer to this question is that durational adverbials do not function to bind the past tense variable at all and that we must think of a sentence like (3) not as somehow resulting from the application of a durational adverbial to a past verb phrase (or sentence) but rather as the past of a sentence with a durational in it already:

(26) Mary ran for an hour.

In Priorian language (3) asserts that it was the case that Mary 'runs' for an hour rather than it is the case for an hour that Mary ran. But that story and the right interpretation of frequency adverbials takes us into mysteries of the present tense that I am not prepared to discuss in this paper.[5]

---

5 I would like to thank Irene Heim and Barbara H. Partee for discussion and critical comments on this paper. Many of the details of the paper were worked out or initiated in discussions with Rick Saenz. Naturally,none of these friends should be held responsible for any blunders on my part. Much of my preliminary research on tenses and aspects was carried out at the Center for Advanced Studies in the Behavioral Sciences, in part under a grant from the National Endowment for the Humanities.

Appendix A: A minimal revision of PTQ

1. Remove *be* from B_{TV}.
2. Delete S4 and S17.
3. Add these categories:

   t/T: the category of tensed verb phrases

   t////e: the category of non-verbal (copular IV's (in *be*) (abbreviation: COP) and the categories whose basic members are as follows:

   $B_{COP/T}$: {*be*}

   B_{Aux-1} : ((t/T)/COP): {*will, won't, ...*} (true modals)

   B_{Aux-2} : ((t/T)/(t/e)): {doesn't, ...} (tensed forms of *do*)

   B_{Aux-3} : ((t/T)/T): {*is, isn't, ...*} (tensed forms of *be*)

   B_{Aux-4} : ((t/T)/(t/e)): {*has, hasn't, ...*} (tensed forms of *have*)

4. Assume basic forms of pronouns are him_i.
5. Assume the definitions of these relations:

   main verb(s) of, main term phrase(s) of

6. Define the following subfunctions:

   NOM(α) where α is a term-phrase = the result of replacing all main term phrases of α that have the form him_i, by he_i, otherwise leave them the same.

   PRES(γ) where γ is in P_{IV} = the result of replacing the main verb(s) of γ by their present tense singular forms.

   EN(γ) where γ is in P_{IV} or P_{COP} = the result of replacing the main verb(s) of γ by their past participle forms.

7. Add these rules:

   S99 : (lexical): If γ is in P_{Aux-1}, then γ is in P_{Aux-2}.
   Tr : γ'.

   S100 : If γ is in P_{IV}, then PRES(γ) is in $P_{t/T}$.
   Tr : $\lambda \mathcal{P} \mathcal{P} \{{}^\wedge\gamma'\}$

   S101 : If γ is in $P_{COP/T}$ and α is in P_T, then $F_6(\gamma,\alpha)$ is in P_{COP}.
   Tr : $\gamma'({}^\wedge\alpha')$

S102 : If γ is in $P_{Aux\text{-}1}$, δ is in P_{COP}, then $F_6(\gamma,\delta)$ is in $P_{t/T}$.

Tr : $\gamma'(\hat{}\delta')$

S103 : If γ is in $P_{Aux\text{-}2}$, δ is in P_{IV}, then $F_6(\gamma,\delta)$ $P_{t/T}$.

Tr : $\gamma'(\hat{}\delta')$

S104 : If γ is in $P_{Aux\text{-}3}$, α is in P_T, then $F_6(\gamma,\alpha)$ is in $P_{t/T}$.

Tr : $\gamma'(\hat{}\alpha')$

S105 : If γ is in $P_{Aux\text{-}4}$, δ is in $P_{IV} \cup P_{COP}$, then $F_{100}(\gamma,\delta)$ is in $P_{t/T}$

where $F_{100}(\gamma,\delta) = \gamma\mathrm{EN}(\delta)$

Tr : $\gamma'(\hat{}\delta')$

S106 : If γ is in $P_{t/T}$ and α is in P_T, then $F_{101}(\gamma,\alpha)$ is in P_t

where $F_{100}(\gamma,\alpha) = \mathrm{NOM}(\alpha)$

Tr : $\gamma'(\hat{}\alpha')$

New translations:

will : $\lambda P \lambda \mathcal{P}\ W\mathcal{P}\{P\}$

won't : $\lambda P \lambda \mathcal{P} \neg W\mathcal{P}\{P\}$

doesn't : $\lambda P \lambda \mathcal{P} \neg \mathcal{P}\{P\}$

has : $\lambda P \lambda \mathcal{P}\ H\mathcal{P}\{P\}$

hasn't : $\lambda P \lambda \mathcal{P} \neg H\mathcal{P}\{P\}$

is : $\lambda \mathcal{P}_1\ \lambda \mathcal{P}_2\ \ \mathcal{P}_2 \left\{\hat{x}\mathcal{P}_1\ \ \{\hat{y}[{}^{\vee}x = {}^{\vee}y]\}\right\}$

isn't : $\lambda \mathcal{P}_1\ \lambda \mathcal{P}_2 \neg \mathcal{P}_2 \left\{\hat{x}\mathcal{P}_1\ \ \{\hat{y}[{}^{\vee}x = {}^{\vee}y]\}\right\}$

References

Akmajian, A. and Wasow, T., 1975, The constituent structure of VP and AUX and the position of the verb BE. *Linguistic Analysis* 1: 205-45.

Bäuerle, R., 1977, Tempus, Temporaladverb und die temporale Frage. Universität Konstanz: *Sonderforschungsbereich 99 "Linguistik"* 13, 16.

Bennett, M., 1974, Some extensions of a Montague fragment of English. Unpublished doctoral dissertation, UCLA.

Cresswell, M.J., 1978, Prepositions and points of view. *Linguistics and Philosophy* 2: 1-41.

Dowty, D., 1972, Studies in the logic of verb aspect and time reference in English. Unpublished doctoral dissertation, The University of Texas, Austin.