A Constructive Approach to Intensional Contexts

—Remarks on the Metaphysics of Model Theory*

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0. Introductory remarks

The basic distinction between extensional and intensional contexts is one of different denotation conditions (truth conditions).[1] This difference in denotation conditions has been related to a fundamental question of semantic theory, namely: what do expressions of natural language denote? Most authors assume that in extensional contexts expressions denote 'real objects.' Since the rules of substitutivity of identicals and existential generalization do not hold in intensional contexts (cf. section 1), they are thus forced to postulate that in intensional contexts expressions denote something else. Frege, for example, assumes a denotational ambiguity between 'Bedeutung' and 'Sinn', Russell between 'primary occurrences' and 'secondary occurrences', Quine between 'proper occurrences' and 'accidental occurrences', and Montague between 'extensions' and 'intensions.'[2]

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[1] I prefer the term "denotation conditions" over "truth conditions" because truth values are only one type of possible denotation.

[2] For a detailed discussion of Frege's and Quine's approach to intensional contexts see Kaplan (1969).

In this paper, I propose that expressions of natural language denote the same kind of 'object' in extensional as well as in intensional contexts. This denotation is a certain kind of function (called 'intension') from an index to a formal extension. The difference between intensional and extensional contexts is thus not treated in terms of different kinds of denotations, but rather in terms of different denotation *conditions*. The formal treatment of this idea is formulated in terms of a 'strictly intensionalized' logic, i.e. a logic where the recursion of the syntactic and semantic rules is defined uniformly on the intensional level, and no intension operator '^' is defined. This captures the intuition that there is 'no way back' from an extension to the respective intension. Extensions may be obtained in this logic over the extension operator '$^\vee$', which is still available. Such a system is formally much simpler than the intensional logic defined in Montague (1974, chapter 8-henceforward PTQ) because the switching between the intensional and extensional level inherent in PTQ is avoided. In our system, an extensional predicate like *find'* and an intensional predicate like *seek'* are treated alike in that they are both analyzed as from intensions to intensions. But their denotation conditions differ in that the extension of *find'*(x) at an index depends solely on the extension of the argument x at that index, while the extension of *seek'*(x) at an index will *not* depend solely on the extension of the argument x at that index.

While the indicated treatment of intensional versus extensional contexts in terms of uniform denotations but differentiated denotation conditions(defined in a strictly intensionalized system) is technically straightforward, it is ontologically objectionable insofar as the kind of denotation chosen, i.e. intensions defined as functions from indices to extensions, depend on the concept of possible worlds, regarded by many as highly dubious. Thus, one might object to the indicated treatment in terms of a strictly intensionalized treatment because it generalizes the problems formerly restricted to intensional contexts to all kinds of expressions. Clearly, as long as the ontological problems associated with possible worlds are not resolved, extensions will be regarded as the primary kind of denotation and the extensional approach to meaning will appear on general grounds to be preferable as the conceptually simpler and ontologically more conservative analysis. For this reason a major portion of this paper will be devoted to the question of how to interpret model theoretic semantics in such a way that intensions rather than extensions become plausible as the primary kind of denotation.

In standard model theory, the model structure is interpreted as a representation of reality and the denotation conditions as instructions to determine whether a sentence is true or false relative to the model structure and an index. Depending on how serious we take this identification of the model structure with reality, we have an intuitive problem with possible worlds. What does a possible world correspond to in reality? How could we go to one to check the truth value of sentence? How could we individuate possible individuals in possible worlds? These problems disappear, however, if we reinterpret the intuitive role of the formal model structure. Alternatively to the standard approach let us view the model structure as a *representation of the lexical intuition* of a speaker/hearer and the denotation conditions of a sentence as instructions to *synthesize* or construct a model (or set of models) relative to which the sentence would be true. Thus the purpose of interpreting an expression is not to determine its denotation relative to a model given in advance and regarded as a representation of reality, but rather to construct a denotation (or set of models) that would satisfy the expression and that it regarded as a formal representation of its literal meaning. We assume that *tokens* are synthesized in the 'lexical space' of a speaker, or rather an abstract speaker simulation device (SID). The lexical space is a partially defined model structure which specifies the denotation of all unanalyzed logical constants only insofar as to accommodate the presumed speaker's lexical intuition.

While the switch from the "verifying mode" to the "synthesizing mode" in model theory resolves the intuitive problems with possible worlds, as I will argue in section 3, and thus obviates one of the objection to treating intensions as the primary kind of possible denotation, it raises the question: How do synthesized models relate to reality? In order to relate the literal meaning of a token to reality, it is proposed in section 4 to complement the token models with a formal *context* which is defined as a model theoretic synthesis of what the speaker perceives and remembers at the moment of the token interpretation. *Reference* (in contradistinction to denotation) is defined as the process of matching the token model with the context model. The pragmatic notion of reference provides, among other things, for a characterization of pragmatic truth of a token relative to a context. On the other hand, the semantic notion of denotation provides, among other things, for a characterization of semantic truth of a declarative sentence or formula relative to a (synthesized) model.

That the traditional model theoretic approach may be too narrow to allow accommodation of such problems as context dependency, metaphor, and other natural language phenomena that go beyond a purely extensional approach to referential semantics has been acknowledged in some of the recent literature.[3] So far, however, proposals to overcome the limits of the traditional approach have consisted in piecemeal additions which provide more or less ad hoc — and usually very abstract — solutions for specific problems, but do not question the fundamental setup. Examples are the so-called 'coordinates approach' (Montague, 1974; chapter 4 & Lewis, 1972), which consists in adding new parameters to the point of reference in order to handle context dependency, and the proposal to use two-dimensional

[3] Bartsch (1979), for example, writes: "The question is how far one wants to go analyzing expressions in this manner, namely treating them as 'grammatical' or 'logical' formatives in the grammar of a language that is understood as a theory of truth for that language." In order to relativize semanics to speakers, Bartsch then introduces the concept of "semantical correctness", which is based on the notion "counting as evident or true for a population P with a language L", rather than on the notion "true in L" (relative to a model).

possible world matrices to distinguish between the literal meaning of a token and its evaluation relative to an index (Stalnaker, 1978).

Partee (1978) has argued on the basis of problems arising with the treatment of propositional attitudes that "Montague's theory (and relevantly similar ones) cannot be *the basis of a linguistic theory without some radical revisions in the foundations of* semantics." The constructive approach to model theory outlined in sections 3 & 4, it seems to me, represents such a radical revision. What is essentially changed is our notion of assigning denotations to ***unanalyzed logical constants***—a part of model theory that has been presumed without much question or interest. The formal side of logical semantics (i.e. the denotation conditions associated with logical operators), however, is not affected by the switch from the "verifying mode" to the "synthesizing mode."

As far as the analysis of intensional versus extensional contexts in the present paper is concerned, the constructive approach to model theory is motivated because:

a) It allows a natural denotation conditional treatment of propositional attitudes, due to the relativization of the lexical model structure to a speaker (cf. sections 6 & 7).

b) It avoids the standard ontological objections against the use of possible worlds, since models are treated as constructed representations of literal meaning, rather than representations of reality given in advance (cf. section 3).

c) It *allows treating intensions rather than extensions as the primary* kind of denotation of the logic. Thus sentences are defined to denote propositions rather than truth values and predicates are defined to denote properties rather than sets. In this way the counterintuitive consequence that all true sentences denote the same entity is avoided.[4]

In more general terms, the constructive approach is preferable because the separation of denotation and reference allows a surface compositional treatment of literal meaning and gives a precise definition of pragmatics. The ***use*** of an expression relative to a context is analyzed in terms of matching two model theoretic structures (i.e. the token-model and the context-model). As far as the definition of pragmatics and the role of context is concerned, the alternative approach to model theoretic presented in this paper constitutes the semantico-pragmatic basis for my treatment of non-declarative sentence moods (interrogatives, imperatives) in terms of characteristic types of possible denotation (Hausser, 1976b

[4] It was Frege (1892), who proposed that declaratives denote truth values (functions from possible worlds into extensions had not been proposed at the time). On the one hand, Frege's idea was a great achievement because it completed the assignment of precise possible denotations to the major parts of speech: proper names were thought to denote individuals, predicates sets of individuals, and sentences truth values. On the other hand, it had the indicated counterintuitive consequence that all true sentences denote the same object. Frege was aware of this problem. For a discussion see R.S. Wells (1951).

& 1978a) and my treatment of pronouns in terms of context variables (Hausser, 1979a & b).

1. What is the problem posed by intensional contexts?

In logic, extensional contexts are characterized by two rules, namely (i) substitutivity of identicals and (ii) existential generalization. Substitutivity of identicals is illustrated as follows:

(1) John finds *the morning star*.

Since the morning star happens to be the evening star and (1) happens to be an extensional context, we may replace 'the morning star' by 'the evening star' *salva veritate*. That is, the substitution in (2)

(2) John finds *the evening star*.

does not result in a change in truth value.

Existential generalization is illustrated as follows:

(3) John finds a unicorn.

(3) entails (4).

(4) There is at least one unicorn.

That is, whenever (3) is true, (4) is true.

The rules of substitutivity of identicals (SI) and existential generalization (EG) are important to the extensional approach to logical semantics, which characterizes meaning as a direct relation between expressions and referents, without the intermediate stage of a concept. It has long been noted, however, that in natural language there are systematic exceptions to the rules of SI and EG. Those syntactic environments in which SI and EG fail are called *opaque context* (Quine, 1960) or *intensional contexts* (Montague, 1974). Consider for example (5) and (6):

(5) Necessarily, the morning star is the morning star.
(6) Necessarily, the morning star is the evening star.

While (5) is intuitively true, (6) is not, even though (7)

(7) The morning star is the evening star.

happens to be true. Thus the modal operator *necessarily* creates an intensional context which causes substitutivity of identicals to fail.

Turning to EG, consider (8).

(8) John seeks a unicorn.

While (3) entails (4), (8) does not entail (4).

(3) John finds a unicorn.
(4) There is at least one unicorn.

Thus, *seek* in contrast to *find* creates an intensional context, causing existential generalization with respect to the object term to fail.

As long as expressions like *the morning star* or *a unicorn* are regarded as denoting their extensional referents, SI and EG clearly must hold. In intensional contexts, however, where SI and EG do not hold, the expressions in question cannot denote their 'natural' extensional referents. After all, (8) can be true whether or not any unicorns exist. Intensional contexts raise a serious problem for the extensional approach to meaning insofar as they represent a systematic exception to the extensionalist doctrine stated below:

(9) *extensionalist doctrine*
Meaning is a direct relation between expressions and their 'real' referents.

For the extensional approach, the problem with intensional contexts may be summarized in the following question: what is the denotation of expressions in intensional contexts? Any solution to this problem must accommodate the following intuitive facts observable in connection with intensional contexts:

i) An expression like *a unicorn* is as meaningful in an intensional context as in an extensional context.
ii) An expression like *a unicorn* does not denote its 'natural', extensional referent in intensional contexts (as witnessed by the failure of SI and EG).

However, no matter how the question of *denotation* in intensional contexts is resolved, the basic distinction between intensional and extensional contexts is one of different denotation *conditions*. The essential objective of a semantic analysis of intensional and extensional contexts is to account for the respective failure versus validity of SI and EG. Note that to define different denotation conditions does by no means require the use of different *kinds* of denotations.

2. Extensional versus intensional approaches to meaning

Besides the extensional notion of meaning summarized in (9), which Frege (1892) called "Bedeutung", there has traditionally been another notion according to which the meaning of an expression is a *concept* rather than an object. This conceptual notion of meaning, called "Sinn" by Frege (op. cit), may be traced back to Plato. The work in model theoretic semantics, as developed by Carnap (1947), Church (1951), Kripke (1963), Montague (1974), and others, provides a formalization of the conceptual notion of meaning in terms of so-called *intensions*. According to this approach, an intension is defined as a function from *indices* (world/time pairs) to extensions.[5] This formalization captures the intuition that to know the meaning of an expression A is to know the extension of A in any given situation.[6]

Let us call an approach to meaning *intensional* if the relation between an expression and its referent is mediated via the concept associated with the expression. An intensional approach to meaning may be schematically characterized as in (10a):

(10) a. expression
|
concept (intension, "Sinn")
|
referent (extension, "Bedeutung")

The definition of conceptual meaning in terms of certain functions (intensions) provides a denotation for expressions in intensional contexts which has the desired characteristics regarding SI and EG.

Regarding SI (substitutivity of identicals), consider for instance the Fregean examples given above:

(5) Necessarily, ***the morning star*** is ***the morning star***.

(6) Necessarily, ***the morning star*** is ***the evening star***.

That substitution of ***the evening star*** for ***the morning star*** in (6) does not preserve truth values follows from the assumption that the underlined terms in (5) and (6) denote their

[5] Putnam (1975, chapter 12) points out that the notion of an intension as a concept, on the one hand, and the notion of an intension as an extension-determining function, on the other, are two different notions which are moreover incompatible. The reason according to Putnam is that concepts are something mental and thus in the head of the speaker/hearer, whereas extensions are treated as the objects of the external world. Since Putnam chooses to define meaning as an extension-determining function (cf. Putnam, 1975:270), he is led to the counterintuitive conclusion that "meanings just ain't in the head" (Putnam, 1975:227).

However, if we interpret the notion 'extension' as a conceptual extension, then an intension may be regarded as a concept which is defined as a function from conceptual (i.e. speaker-subjective) world/time pairs to conceptual extensions. The purpose of a thus interpreted intension continues to be the formal treatment of modal operators, tense operators, and the distinction between intensional and extensional predicates.

When we talk in the following about intensions as functions from indices to "formal extensions" we mean conceptual extensions. Reference to objects of the real world (i.e. Putnam's extensions) is treated in our theory in terms of matching a speaker internal meaning-concept of a token with a speaker internal context, whereby the context reflects the external reality on the basis of the speakers perception.

[6] Let us keep in mind, however, that the notions "concept" and "intension" are not equivalent. For example, while the formal intensions of '2+2' and '4' are identical in the sense that they always have the same extension, '2+2' and '4' intuitively express different concepts. We may provide a more appropriate formalization of the notion "concept" on the basis of so-called ***intensional isomorphisms*** (Carnap, 1947). That is, two expressions express the same concept if and only if they have the same syntactic structure and all their respective constituents have the same intensions.

respective intensions, rather their extensions. Though these intensions take the same extension in our world, namely the planet Venus, the morning star and the evening star could have had different extensions, and thus must have different intensions.

While intensions provide the formal basis for a systematic model theoretic analysis of many traditional puzzles of natural language (as illustrated in Montague's PTQ), the use of intensions is not generally accepted. The main reason seems to be an ontological one: most philosophers of language prefer to let language expressions denote 'real' objects rather than abstract concepts.[7] Even though intensional logic has provided a formal definition of concepts in terms of certain functions, these functions are defined by means of the notion of 'possible worlds' -which cannot be real. We call an approach to meaning extensional if it avoids the postulation of an intermediate level of concepts or intensions, and defines meaning as a direct relation between expressions and referents (c.f. (9)). An extensional approach to meaning may be schematically characterized as in (10b)—in contrast to (10a):

(10) b. expression
|
referent (extension, "Bedeutung")

The extensional approach claims to represent a more realistic attitude towards the entities admitted as referents of expressions. In this sense it seems to suit better the philosophical quest for 'real' truth. After all, how can we arrive at reliable results with our logic if the objects referred to are not real?

The question of what is real, though, is notoriously controversial. One tradition is that of *nominalism*, which takes a 'real' thing to mean a spatio-temporal thing. That is, a thing we can potentially touch. As a consequence of this view, many noun and verb phrases of natural language (e.g. *hope*, *desire*, *pain*, etc.) do not have a denotation and thus cannot be assigned a meaning. In another tradition, that of *realism*, mathematical entities like numbers are also admitted to be real. The realists thus admit at least mathematical truth into their ontology, but the problem still remains that there are no suitable objects to serve as referents for many expressions of natural language.

It is a consequence of the extensionalist definition of meaning that only those expressions have a meaning for which there exists a referent. Since the referents are furthermore required to be 'real' in some intuitive sense, the question of which expressions are regarded to have meaning depends on what is considered to be real (or existent). Furthermore, only expressions of the main linguistic categories (i.e. noun phrase, verb, and sentence) are assumed to have meaning, since there are no 'objects' to which prepositions, conjunctions, or articles could refer to.

Since for most expressions of natural language there are no intuitively plausible

[7] For a discussion see Carnap (1950).

objects or sets of objects available, proponents of the extensional approach are faced with a choice between the following two positions:

a) In order to assign meaning to expressions where no natural referents are available, *the range of referents is expanded* by adopting an extremely wide notion of what is considered to be real.
b) In order to maintain a strict notion of what is considered real, *most expressions of natural language are simply assumed to have no meaning* by themselves.

The first position was advocated by Meinong (1904), who took the view that every grammatically well formed expression of natural language has a meaning. Note that Meinong's approach is extensional insofar as it does not assume an intermediate level of conceptual meaning.[8] The second position was defended by Russell (1905), in direct opposition to Meinong. According to Russell, "denoting expressions never have any meaning in themselves, but ... every proposition in whose verbal expression they occur has a meaning."

While Meinong's assumption of non-existent real objects leads to contradictions, Russell's postulate that only complete declarative sentences have a meaning violates a very basic linguistic intuition. An approach using intensions, on the other hand, is not subject to these objections. Frege, for example, avoids breach of the law of contradiction by distinguishing "in a denoting phrase two elements, which we may call the *meaning* and the *denotation*" (Russell, 1905:45) or *Sinn* and *Bedeutung*. According to Frege, expressions like *the present King of France*, *Pegasus*, or *the square circle* are meaningful in that they denote certain concepts, but lack a natural referent and are therefore assigned the null class as referent. Russell's only objection to Frege's theory is that Russell regards the null-class as an "artificial" referent.

Concluding this section on what we called extensional versus intensional approaches to meaning, let us summarize the possible answers to the question "What should natural language expressions be defined to denote?".

(12) a. We may strictly maintain the extensionalist doctrine (9), according to which expressions denote their real life referents directly and either
   (i) pay the price as far as the description of natural language is concerned by not assigning any meaning to most expressions (this approach is exemplified by Russell (1905), or
   (ii) pay the price as far as ontology is concerned by postulating "virtual" objects in order to provide referents for all grammatically well-formed

[8] At first sight, and without a precise definition of what an extensional vs. intensional approach to meaning is, one would perhaps be inclined to classify Meinong as an intensionalist rather that an extensionalist. The obiections to weaknesses in Meinong's theory, however, do not carry over to intensional systems, since Meinong's system is in fact a purely extensional one.

expressions (this approach is exemplified by Meinong (1904)).

(12) b. We may adopt a weakened version of the extensionalist doctrine according to which expressions denote their real life referents whenever possible (i.e. in extensional contexts) and denote concepts or intensions otherwise. This approach is exemplified by Frege (1892), who assumes that expressions are systematically ambiguous between a referential meaning ("Bedeutung") and a conceptual meaning ("Sinn").

(12) c. We may abandon the extensionalist doctrine completely by letting expressions always denote intensions, defined as functions from indices to formal extensions.

As indicated already we will adopt the approach (12c). In order to justify this choice, let us turn now to some of the basic ontological questions raised by the intensional approach to meaning.

3. Reinterpreting the intuitive role of the formal model

When we evaluate a model theoretic treatment of meaning in natural language, we must distinguish between two different questions. First, there is the formal question of defining a system which assigns the right entailments and general meaning structures to expressions. Then there is also the ontological question of what intuitive role the model is assumed to play. In the case of intensional logic, there is a troublesome dichotomy between a very successful treatment of denotation conditions (and associated paradoxes), on the one hand, and a continuing difficulty with old, fundamental and well-rehearsed ontological issues, on the other. Since the source of the specific success as well as the problems may be located in the use of possible worlds, let us discuss the formal role of possible worlds and then turn to the question of which ontological interpretations one might attach to them.

Formally, model theoretic denotations are built up from the *basic sets* of the model structure (A, I, J, $\leqslant$, F). The non-empty sets A, I, and J are regarded as sets of individuals, possible worlds, and moments of time, respectively, $\leqslant$ is a linear ordering on J, and F is a denotation which assigns logical constants their model-theoretic denotation in accordance with their semantic type. The domain of intensions is defined as the set of ordred pairs (i, j), $i \in I$, $j \in J$, in the Cartesian product $I \times J$. The three basic sets A, I and J function alike in that they (i) provide the building blocks for the denotations of logical constants (i.e. they provide the domain and range of the functions denoted) and (ii) they serve in the definitions of the logical operators. Thus, just as individuals serve in the definition of quantifiers like $\vee x(\phi)$ or $\wedge x(\phi)$, and moments function in the definition of tense operators like $W(\phi)$ or $H(\phi)$, possible worlds function in the definition of modal operators like $\Box(\phi)$ or $\Diamond(\phi)$. Formally speaking, possible worlds are no different from individuals or moments of time, i.e. they are elements of one of the basic sets which serve as the domain and range of the denotation functions and which are referred to in the denotation conditions of the logic.

While the model structure is formally a set- or function-theoretic construction which assigns values (denotations) to the logical constants relative to indices, this same model structure is intuitively usually interpreted as a representation of reality. This conceptualization of the formal model structure (or interpretation) is in some respects a convenient abstraction which seems to allow reasoning about real things without adressing the question of how reference is actually established by the speaker/hearer. Yet, as long as the model structure is treated as a substitute for reality relative to which truth or falsity of formulas is determined, possible worlds constitute an enigma: what does a possible world correspond to in reality? How could we individuate possible individuals in possible worlds? We cannot go to a possible world to check the denotation of expressions because there is only one world, namely our present day real world. This intuitive problem with possible worlds, which depends on how serious we take the identification of the model structure with 'reality', constitutes the basis for the standard ontological objection against intensional logic, namely that possible worlds cannot be real.

The basis for this objection is removed, however, if we reinterpret the intuitive role of the formal model structure. Rather than treating the model structure as a representation of reality and the denotation conditions as instructions to determine the truth value of formulas relative to an index, let us view the model structurure as a *representation of the lexical intuition* of the speaker/hearer and the denotation conditions of a sentence token as instructions to synthesize or construct a model (or set of models) relative to which the sentence would be true. Thus the purpose of semantically interpreting an expression is not to determine its denotation relative to a model (in a model structure at an index) given in advance and regarded as a representation of reality (at that index), but rather to construct a denotation (or model) that would satisfy the expression and that is regarded as a *formal representation of its literal meaning.*

We assume that the synthesis of a token meaning is executed in a partially defined model structure, called *lexical space*, which is assumed to be part of a speaker simulation device (SID). What is required for the synthesis of a token meaning? While the *logical operators* like $\sim$, $\wedge$, λ, etc. in the translation of a token receive their meaning in terms of the denotation conditions associated with these operators (where the denotation conditions are specified in a metalanguage or in terms of certain operations), *unanalyzed logical constants* like *man'* or *walk'* are assigned their denotation by the model structure. The structuring principles of the lexical space are:

i) the category/type/denotation correspondence inherent in Montague Grammar, and
ii) the speaker's intuition concerning the semantic interrelations between constants of equal type such as inclusion, overlap, etc.

Take for example the expressions *cat*, *dog*, and *mammal*, which are of categegory t//e. They translate into the unanalyzed constants *cat′*, *dog′*, and *mammal′*, which are of type ⟨s,⟨⟨s,e⟩,t⟩⟩. This type uniquely determines the denotation of these expressions as functions with the following domain range structure:[9]

$$(I\times J\rightarrow((I\times J\rightarrow A)\rightarrow\{0,1\}))$$

In order to implement the lexical intuition of an English speaker we define the denotation of *cat′* and *dog′* in the lexical model as disjunct sets (extensionally speaking). Furthermore, we define the denotation of *cat′* and *dog′* as subsets of the denotation of *mammal′*. In this way, we arrive at a definition of lexical meaning which avoids the use of paraphrase (which would be circular) and which employs the model theoretic technique without identifying the model structure with reality.

To synthesize a token in the lexical space of an SID means to set the denotations of the constants in the translation formula into certain interrelationships specified by the logical operators in the formula. For example, to synthesize the meaning of *John walks* we have to set the denotation of j as an element of the denotation of *walk′*.[10] Note that the partially defined model structure of our lexical space differs form the partial models proposed in Friedman *et al.*(1978). In Friedman *et al.* the model is conceived as a partially defined substitute for reality, which means that as new expressions come up in a text, new denotations are defined in the model. Thus, in order to interpret *John walks* at an index a denotation is assigned to, e.g. *walk′*, if it has not been specified already. The evaluation of expressions relative to indices in the Friedman model structure is still intended to determine truth values. Our lexical space, on the other hand, is a partially defined model structure not because certain aspects of reality have not been filled in yet, but because the model structure specifies only the semantic interrelation of constants according to the speakers intuition. A completely specified model (or denotation) comes about only once the synthesis instructions associated with the logical operators present in the translation of a token have been executed.

The synthesizing approach, it seems to me, effectively removes the standard

[9] We anticipate here the strictly intensional category/type correspondence outlined in section 3, according to which a surface expression of category *a* translates into an expession of type ⟨s, f(a)⟩ rather than of type ⟨f(a)⟩ as in PTQ.

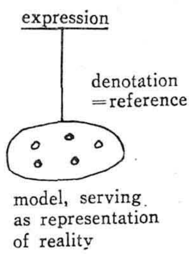
[10] This description of the partial model-structure underlying our synthesis approach is still preliminary. For a more detailed discussion see Hausser (1981), where it is pointed out that a characterization of, e.g. RED and BLUE as denoting distinct sets in the partial model structure which are both sub-sets of COLOR does not suffice for a complete analysis of these elementary meanings. What is needed is a characterization of the specific difference between, e.g. RED and BLUE. It is proposed to specify this difference by means of concepts which are defined in terms of matching different kinds of elementary sense data. Thus the difference between, e.g. RED and BLUE would ultimately be explained in terms of the SID's perception (e.g. of light of different wave length). Another important notion used in the paper mentioned is that of an 'operationalized meta-language definition'.

ontological objections to the use of possible worlds and intensions.[11] Since we do not treat the model structure as a representation of reality, we are not faced with intuitive problem of what would correspond in reality to going to a possible world and checking a truth value there. Questions of transworld identity are likewise unproblematic. Since we interpret possible worlds merely as ***indices*** of alternative states which are constructed, identity is simply asserted rather than verified.

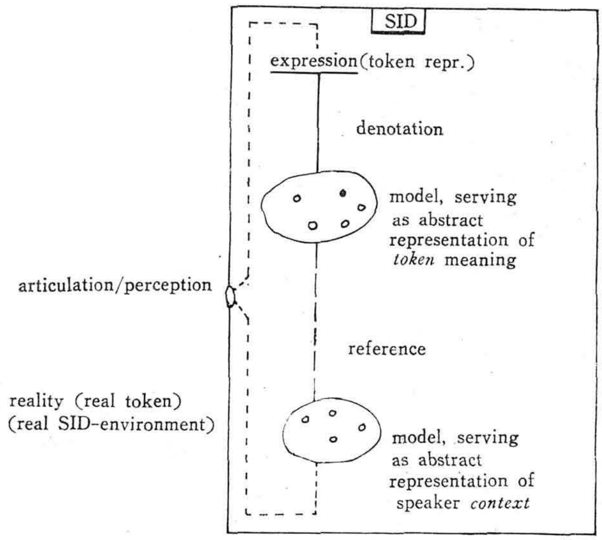
4. Denotational semantics versus referential pragmatics

While the switch from the "verifying mode" to the "synthesizing mode" in model theory resolves the intuitive problems with possible worlds, and thus obviates one of the main objections against treating intensions as the primary kind of possible denotation, it also creates new problem. The question is: how do synthesized models relate to reality? In order to relate the literal meaning of a token to reality, let us complement the synthesized token meaning with a formal *context* which is defined as the model theoretic synthesis of what the speaker (SID) perceives and remembers at the moment of the token interpretation. *Reference* (in contradistinction to denotation) is treated as the process of matching the synthesized token with the synthesized context. We may schematically indicate the difference between the traditional model theoretic approach and the constructive approah advocated here as follows:

i) traditional approach:



ii) constructive approach:



[11] V.d. Emde Boas and Janssen (1978) propose to treat possible worlds as computer states and point out "Since these states can actually be constructed no ontological problems arise." They do not adress the question, however, of how these states may be related to reality, a question we have treated in terms of matching the synthesized token-meaning with the synthesized context.

The SID functions as a speaker if the direction of the indicated mapping is from reference over the token model and token expression to ***articulation***. If the direction is from ***perception*** over the token expression and the token model to *refernce*, on the other hand, the SID functions as a hearer.

While our synthetic approach to literal meaning remains formally completely within the standard model-theoretic approach in that nothing in the denotation conditions has to be changed, it differs ontologically from various formulations of the traditional logical view in that the basic sets A, I, J (regarded as sets of individuals, sets of possible worlds, and sets of moments of time, respectively) in our formal model ⓐ=(A, I, J, ⩽,F) cannot be assumed to contain any real objects. Instead, in line with our synthetic approach, we assume that our model operates exclusively with abstract entities (e.g. memory cells in the SID). By dealing only with abstract denotations we arrive at the most uniform and parsimonious ontology for model theoretic semantics possible. Physical existence is simply treated as another property which may be asserted.

The legitimate questions of ontology reappear, however, in the separate construction of the context. Regarding the model-theoretic construction of what the speaker or the SID perceives optically, acoustically, touch-wise, smell-wise, and taste-wise we must indeed consider the question what is real, what the categories of things are, etc. By having two model theoretic structures between which the pragmatic process of reference is sandwiched, we separate the linguistic categories (determined on the basis of the combinatorial and denotational properties of surface expressions) from ontological categories.

The indicated reinterpretation of model theoretic semantics and the associated formal treatment of context permits a strict distincation between the *literal meaning* of an expression ($meaning_1$) and the *speaker meaning* ($meaning_2$), i.e. the meaning intended by the speaker or arrived at by the hearer. The literal meaning of an expression ($meaning_1$) is analysed semantically in terms of the *denotation*, i.e. the synthesized model which satisfies the literal meaning of the expression. The speaker meaning ($meaning_2$) is analysed pragmatically in terms of *reference*, i.e. the use of the literal meaning relative to a context:[12]

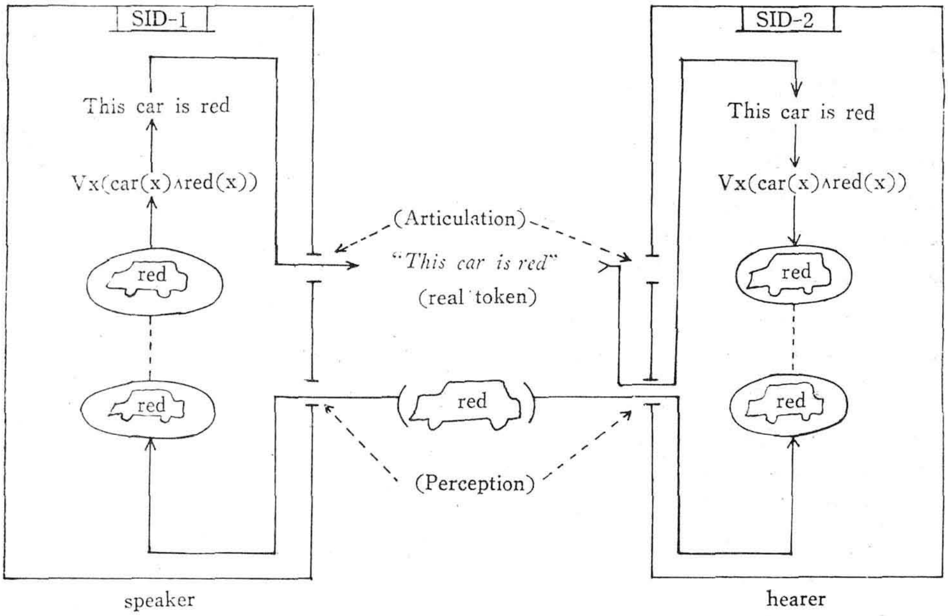
use of $meaning_1 = meaning_2$

The use of $meaning_1$ relative to a context is treated in our system in terms of interpreting the matching relation between the two model structures. Since we assume that both model-structures (representing (a) the token and (b) the context) are synthesized in the same lexical space, we have two distinct patterns in one medium such that the two can

[12] Our notion of literal meaning is more restricted that that of Wunderlich (1976), who defines the literal meaning of a sentence as a *speech act concept* which determines the result of using the sentence relative to a *neutral context*. For us, literal meaning is defined completely within the domain of syntax and semantics. Closest to Wunderlich's notion is our concept of *literal reference* discussed below.

be directly compared or matched.

While the semantic analysis of literal meaning (denotation) is strictly compositional, the pragmatic analysis of use (reference) is flexible in the sense that we may distinguish between different types of matching a synthesized token with a synthesized context. One type of reference is *literal reference*, which we analyse as the case where the model structure representing the token meaning matches the context completely. Let us consider an example ot literal reference where a speaker and a hearer see a red car and the speaker says "This car is red".



SID-1 represents an SID in a 'speaker-state'. We assume that the SID perceives a certain pattern which relates to the constant 'car' in its lexical space. SID-1 also perceives a certain color (wave-length in the electromagnetic spectrum) which relates to the constant 'red' in its lexical space. Based on these perceptions, the context model is built up. Assuming SID-1 has an impulse to report its perception, the context model structure (or relevant parts of it) are mapped into a token surface representation and articulated. SID-2 represents an SID in a 'hearer-state'. Like SID-1, SID-2 perceives the red car, and assuming SID-2 has the same perception as SID-1, SID-2 will construct the same context model as SID-1. Furthermore, SID-2 perceives the token uttered by SID-1. Assuming that SID-2 speaks the same language as SID-1, this token will be represented in the lexical space of SID-2 in the same way as in the lexical space of SID-1, and SID-2 will judge SID-1's utterance as true because the statment agrees with its observation.

While the analysis of this example is still somewhat crude, it suffices to demonstrate that the classical view of truth as correspondence between what is said and what is

(Aristotle, Metaphysics) reappears in our system as a special case, namely the case of *literal reference* in which the sensory input is faithful to reality. As an example where perception is mistaken on part of the speaker consider Donnellan's case (Donnellan, 1966), in which someone refers to a man with a glass of ginger ale as 'the man with the champagne in his glass', asserting of him correctly that he is happy. On the extensional approach (according to which meaning is defined as a direct relation between expressions and real situations or objects), the following problem arises: how can we say something true of an intended referent if the description used is incorrect—i.e. if no reference should have been possible in the first place? On our alternative approach, the problem disappears. We analyse the speaker as follows: the context-representation disagrees with reality, but the token-representation (complete with champagne) agrees with the context-representation. The hearer, on the other hand, is analyzed such that the context-representation agrees with reality (complete with ginger ale), while the token-representation disagrees with the context-representation. Donnellan's example describes an instance of 'charitable' reference on part of the hearer in the sense that there is a partial matching between the token meaning (model representing a man with champagne) and the context model (representing a man with ginger ale).

Another type of charitable reference is *vague* reference. While in Donnellan's case charitable reference on part of the hearer is due to an incorrect perception on part of the speaker, vague reference may come about simply by failure to find the 'right words.' Charitable reference must be distinguished from *metaphoric* reference. In the case of charitable reference, the discrepancy between the token model and the context model is 'repaired' to a state of literal reference. In the case of metaphoric reference, however, the discrepancy is associated with a 'higher meaning'. Consider for example the token 'The old fox quietly left the room' interpreted relative to a context in which our favorite detective is seen in action. Again, we systematically synthesize the literal meaning (complete with fox) and base the pragmatic interpretation (what amounts to the speaker meaning) in part on a matching of higher order properties (in our case *cunningness*). This approach to metaphor is in concord with the scholastic analysis, which held that each thing meant (denoted) by a word has itself a set of meanings, consisting of the properties of a denotation of an expression determines the potential for its metaphoric use.

On the standard approach, where denotation and reference are not distinguished, the indicated differences between literal, charitable, and metaphoric reference cannot be handled without ad hoc changes in the formal semantics, usually formulated in terms of so-called 'ambiguities'. These ambiguities, however, have no *structural* basis, they are ambiguities of use rather than genuine syntactico-semantic ambiguities. On our constructive approach, on the other hand, no ambiguities need to be postulated for the cases in question. Rather, the literal meaning is treated strictly compositionally as a function of the meaning of the basic constituents and their mode of composition (Frege's principle), while different speaker meanings are treated in terms of different types of reference (i.e. different interpretations of the matching relation between the synthesized token and the synthesized context). In that our approach allows to restrict the syntactico-semantic analysis to the most literal meaning, it provides the semantico-pragmatic basis for maintaining the principle of surface compositionality (Hausser, 1978a & b).

While the reinterpretation of model theoretic semantics in terms of synthesis does not affect the formal side of meaning analysis (as formulated terms of denotation conditions), it represents a rather radical departure from the traditional view of semantics. Semantics is usually said to investigate the relation between expressions and the 'world'. This characterization, however, no longer holds in the constructive approach to model theory outlined above. Instead semantics is limited to a model-theoretic characterization of the literal meaning of language expressions, while the relation between expressions and the world is treated in terms of pragmatics and perception. The central notion of *truth in a model* is common to both the traditional approach and the constructive approach, but this notion has quite a different flavor depending on whether the model is treated as a substitute for reality or as an abstract entity synthesized in such a way that it would make the sentence under interpretation true.

Let us retrace the line of our argument so far. In order to treat intensions as primary denotations, we wanted to eliminate the ontological objections to possible worlds. We did that by reinterpreting the model structure from a representation of reality to a representation of lexical intuition. This raised the question of how synthesized token models relate to reality. Our answer was to define context as a model theoretic representation of what the speaker/hearer perceives and remembers, and reference as the matching of the two model structures. By far the best developed part of the described theory is the compositional (in contrast to lexical) aspect of the mapping from surface expressions of natural language to model-theoretic denotations (our synthesized token models)—known as Montague Grammar. Note, however, that as far as the intuitive interpretation of the formal model is concerned, Montague remained firmly within the traditional approach. The re-analysis of intensional contexts in a PTQ-type system developed in the following two sections will show in what way our reinterpretation of model theory leads to an overall simplification of Montague's syntactico-semantic system.

5. The role of meaning postulates in Montague's analysis

As long as the model is viewed as a substitute for reality and no distinction is made between denotation and reference, extensions may be plausibly viewed as the primary kind of possible denotation. On the synthesis approach, however, extensions are merely certain values in an abstract lexical space. Thus we may view intensions, i.e. the functions which take formal extensions as their values, as the primary kind of possible denotation—especially since

a) the intuitive problems with possible worlds do not arise on the synthesis approach, and
b) it allows definition of expressions in intensional contexts to denote the same 'things' (functions) as in extensional contexts.

Let us call a grammatical system in which expressions are uniformly represented by intensional types a ***strictly intensionalized*** system.

Due to the general acceptance of extensions as primary denotations, strictly intensional systems have not yet been widely explored. The first formal grammar of English where surface expressions translate uniformly into intensions (such that sentences denote propositions, predicates denote properties, etc.) was defined in Hausser (1978b). In this strictly intensionalized system, called IL_1-E_1, which generates basically the same fragment as PTQ, the logical rules are defined in such a way that the recursion operates uniformly on the intensional level.[13]

As an illustration of the difference between the PTQ and the IL_1 logic consider the respective rules for '$\wedge$' (i.e. the connective "and"):

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[13] An earlier attempt to define such a logic is Lewis (1972, 1974). But Lewis did not succeed since he defined functions from intensions to intensions which are themselves extensions:

extension
|
$\langle\underline{\langle s,a\rangle}, \underline{\langle s,b\rangle}\rangle$
intensions

Therefore, the recursion does not work in Lewis system in those cases where a functor (e.g. verb *walks*) serves as the argument of a higher functor (e.g. the adverb *slowly*). Let us consider the type structure of these two words. ***Walks*** takes the intension of a term (type ⟨s,T⟩) as argument and renders the intension of a sentence as value(type ⟨s,t⟩). Thus, ***walks*** is of type ⟨⟨s,T⟩, ⟨s,t⟩⟩. *Slowly*, on the other hand, takes the intension of intransitive verb like ***walk*** as argument and renders the intension of an intransitive verb as value. Thus, *slowly* is of type ⟨⟨s,⟨⟨s,T⟩, ⟨s,t⟩⟩⟩, ⟨s,⟨⟨s,T⟩, ⟨s,t⟩⟩⟩. Since *slowly* takes intensions as arguments while ***walk*** is an extension, *slowly* cannot be applied to ***walk*** in Lewis system.

Lewis may, of course, raise the type of, e.g. ***walk*** syntactically to an intension when it is used as an argument. But such a grammar would be even more complicated than Montague's PTQ. In PTQ, arguments of functional application are always extensions which are syntactically raised to intensions, whereas Lewis would have to distinguish between extensional and intensional arguments. Our system, on the other hand, is a strictly intensional system in that the recursion operates uniformly on the intensional level without any special syntactic remedies such as syncategorematic operations in the process of the translation from categorially analyzed English to intensional logic. Instead we define functors of intensional logic as intensions which take functions from intentions to extensions as their value. Thus, e.g. ***walk*** is of type ⟨s,⟨⟨s,T⟩,t⟩⟩ in our system. Functional application, furthermore, is defined as follows:

functor	argument	result
$\alpha_{\langle s,\langle\langle s,a\rangle,b\rangle\rangle}$	$\beta_{\langle s,a\rangle}$	$\alpha(\beta)_{\langle s,b\rangle}$

Our system is strictly intensional in that the functor, the argument, and the result of functional application of the functor to the argument are all of intensional types. ***Slowly*** is in our system of type ⟨s,⟨⟨s,⟨⟨s,T⟩,t⟩⟩,⟨⟨s,T⟩,t⟩⟩⟩. Functional application to ***walk*** renders *slowly* (***walk***), which is of type ⟨s,⟨⟨s,T⟩,t⟩⟩, as desired.

PTQ:

(13) a. If $\phi, \psi \in ME_t$, then $[\phi \wedge \psi] \in ME_t$.

b. If $\phi, \psi \in ME_t$, then $[\phi \wedge \phi]^{@,i,j,g}$ is 1 if and only if $\phi^{@,i,j,g}$ is 1 and $\psi^{@,i,j,g}$ is 1.

IL_1:

(14) a. If $\phi, \psi \in ME_{<s,t>}$, then $[\phi \wedge \psi] \in ME_{<s,t>}$.

b. If $\phi, \psi \in ME_{<s,t>}$, then $[\phi \wedge \psi]^{@,g}$ is a function from $I \times J$ to $D_{t,A,I,J}$ such that $[^{\vee}(\phi \wedge \psi)]^{@,i,j,g}$ is 1 iff $[^{\vee}\phi]^{@,i,j,g}$ is 1 and $[^{\vee}\psi]^{@,i,j,g}$ is 1.

The 'intensionalization' of '$\wedge$' from a sentential to a propositional operator indicated above applies mutatis mutandis to all logical operators of IL_1 (cf. appendix, section 4).

The crucial difference between (13) and (14) resides in the semantic *types*. In (13), the input expressions ϕ and ψ as well as the output expression '$\phi \wedge \psi$' are of type t, which means that these expressions denote truth values. In (14), on the other hand, the input and output expressions are of type $\langle s, t\rangle$, which means that these expressions denote functions from $I \times J$ to truth values (propositions). In this sense, '$\wedge$' is defined as a sentential operator in (13) but as a propositional operator in (14). As far as the actual assignment of truth values is concerned, however, (13) and (14) render precisely the same results.

The commonly known 'intensional logics' are so-called because of the presence of an intensional operator, and the concomitant presence of some intensional denotations (in addition to the 'normal' extensions). But PTQ, for example, like all these 'intensional' logics is really an essentially extensional system (compared to IL_1-E_1) in that in PTQ expressions always translate into extensional types and the recursion of the logical rules is defined on the extensional level whenever possible. Intensions are introduced in PTQ syntactically by prefixing the intension operator '$^\wedge$' to all functional arguments (e.g. $\alpha(^\wedge\beta)$). In this way, Montague maintains an extensional ontology for basic as well as derived expressions. That is, sentences denote truth values rather than propositions, predicates denote sets rather than properties, etc. The syntactic intensionalization of arguments (based on the use of the counterintuitive intensional operator '$^\wedge$') is motivated by the desire to provide a general basis for a uniform syntactic treatment of intensional and extensional contexts. While this syntactic uniformity is laudable from a linguistic point of view, it leads in the extensional environment of the overall PTQ-system not only to the cumbersome switching between intensional and extensional levels mentioned before, but also to an enormous overgeneration of intensions.

Consider for example Montague's analysis of sentence (8).

(8) John seeks a unicorn.

Following the traditional analysis kind of example, Montague treats (8) as being ambiguous between a *specific* (or *de re*) reading and a *non-specific* (or *de dicto*) reading regarding *a* *unicorn*. On the specific reading (8) entails the existence of a unicorn, while on the non-specific reading there need not be any unicorns in order for the reading to be true. Thus EG is not valid on the non-specific reading. The two readings are characterized in PTQ in terms of the following two formulas:

(8) a. specific reading:
$\vee x\ [unicorn'(x) \wedge seek'(^\wedge j, ^\wedge\lambda PP\{x\})]$
b. non-specific reading:
$seek'(^\wedge j, ^\wedge\lambda P \vee x\ [unicorn'(x) \wedge P\{x\}])$

Note that the only place in (8a) and (8b) where an intension is required for truth-conditional reasons is the second argument position of (8a). For all other intensions in (8a) and (8b) the existence of corresponding extensions is required in order for the sentences to have the right meaning properties.

In order to eliminate the inappropriate intensionalization of arguments in PTO, Montague defines a number of *meaning postulates*, which function as restrictions on models. Consider for example formula (15) (from PTO, p. 265) which guarantees the extensional first order reducibility of extensional common nouns and extensional intransitive verbs in all *logically possible models* (i.e. in all models obeying the meaning postulates of PTQ).

(15) $\Box[\delta(x) \leftrightarrow \delta_*(^\vee x)]$, if δ translates any member of B_{CN} or B_{IV} other than *price*, *temperature*, *rise*, or *change*.

On the basis of meaning postulates, (8a) and (8b) can be proven equivalent to (8a′) and (8b′), respectively, in all logically possible models.

(8) a′. $\vee u\ [unicorn'_{*} \wedge seek'_{*}(j, u)]$
b′. $seek'(^\wedge j, ^\wedge\lambda P \vee u\ [unicorn'_{*}(u) \wedge P\{^\wedge u\}])$

Though (8a) and (8b) are equivalent to (8a′) and (8b′), respectively, Montague takes great care in PTQ to apply all possible reductions, because only the reduced formulas exhibit the crucial denotation-conditional contribution of the meaning-postulates explicitely.

Let us now compare the semantic analysis of (8) with the corresponding extensional example (3):

(3) John finds a unicorn.

Since (3) has a similar surface structure to (8), it is given the same analysis as (8) and translates into the formulas (3a) and (3b):

(3) a. $\vee x\ [unicorn'(x) \wedge find'(^\wedge j, ^\wedge\lambda PP\{x\})]$
b. $find'(^\wedge j, ^\wedge\lambda P \vee x\ [unicorn'(x) \wedge P\{x\}])$

But (3), in contrast to (8), is not ambiguous. Therefore, Montague defines meaning postulates which guarantee that in all logically possible models (3b) is equivalent to the extensional version of (3a). The formula in question (from PTQ, p. 265) is:

(16) $\Box[\delta(x, P) \leftrightarrow P\{{}^\wedge\lambda y \delta_*({}^\vee x, {}^\vee y)\}]$, if δ translates any member of B_{TV} other than *seek* or *conceive*.

(P is defined as a variable ranging over term-denotations.)

On the basis of (15) and (16), the translations (3a) and (3b) may be shown equivalent to (3c) in all logically possible models:

(3) c. $\vee u\ [\text{unicorn}'_* \wedge \text{find}'_*(j, u)]$

Note that this reduction is not possible in the case of (8) since the predicate *seek* is explicitly excluded from (16).

Considering Montague's traditional approach to model theory (traditional in that the model functions as a substitute for reality) and the associated extensional ontology, his use of meaning postulates as a means to distinguish between intensional and extensional contexts may be regarded as reasonably well motivated. Montague follows the line of Frege as well as Quine in that for him the crucial difference between an extensional and an intensional context is a *difference in denotation*, i.e. a difference in the an intensional kind of object denoted by an expression, depending on whether the expression appears in or extensional context. Meaning postulates may be seen as a convenient tool to achieve this differentiation with regads to denotation without any differentiation in the respective denotation *conditions* of extensional versus intensional predicates. Note that Montague translates extensional and intensional predicates alike into unanalyzed constants (e.g. *find* and *seek* translate into *find′* and *seek′*, respectively). My objection to meaning postulates, however, is that they constitute an extremely cumbersome and obscure way of encoding essentially lexical information by restricting the set of possible models.

6. A lexical analysis of intensional versus extensional predicates

Let us turn now to an alternative analysis of intensional and extensional contexts in a strictly intensionalized system such that

a) expressions uniformly denote intensions in intensional as well as extensional contexts,
b) no intension operator is defined,
c) no meaning postulates are defined, and
d) the semantic difference between extensional and intensional contexts is formulated in terms of different denotation conditions for intensional versus extensional predicates.

The first question we have to answer is where in the grammar the distinction between extensional and intensional predicates should originate.

The behavior of extensional and intensional predicates of the same category (like *find* and *seek*) is syntactically alike but semantically different. The converse situation is constituted by such predicates as *man* ε $B_{t//e}$ and *walk* ε $B_{t/e}$, whose behavior is syntactically different but semantically alike. In PTQ, the latter case is treated in the lexicon in terms of different subcategories (defined in terms of different numbers of slashes '/') which correspond to the same semantic type. The former case, on the other hand, is treated in PTQ in terms of meaning postulates, which list the predicates to which they do or do not apply. For our treatment, however, let us also mark the difference between extensional and intensional predicates in the lexicon, by introducing different sub-types which correspond to the same category.

(17) If ϕ is an IL_1-constant of type $\langle s\langle\langle s, b\rangle, a\rangle\rangle$ (a, b$\in$TYPE), then ϕ is of the sub-type $\langle s, \langle\langle \overset{\downarrow}{s}, b\rangle, a\rangle\rangle$ if ϕ is an extensional predicate and of the sub-type $\langle s, \langle\langle \overset{\uparrow}{s}, b\rangle, a\rangle\rangle$ if ϕ is an intensional predicate.

We may now define the rule of functional application in IL_1 in such a way that the general difference between intensional and extensional predicates is reflected in terms of different denotation conditions (where the sub-type diacritics $^{\downarrow}$ and $^{\uparrow}$ control to which clause a given predicate should be the input).

(18) the rules of functional application in IL_1:

a. If $\alpha\in ME_{<s,<<s,b>,a>>}$ and $\beta\in ME_{<s,b>}$ (where a and b$\in$TYPE) then $\alpha(\beta)$ $\in ME_{<s,a>}$.

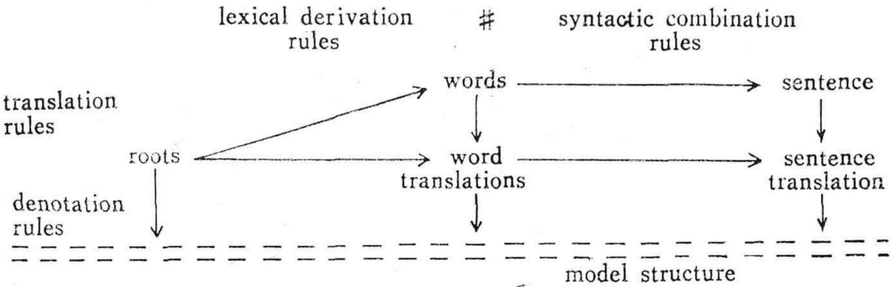
b-int. If $\alpha\in ME_{<s,<<^{\uparrow},b>,a>>}$ and $\beta\in ME_{<s,b>}$, then $\alpha(\beta)^{@,g}$ is a function from $I\times J$ to $D_{a,A,I,J}$ such that $[{}^{\vee}\alpha(\beta)]^{@,i,j,g}$ is $[{}^{\vee}\alpha]^{@,i,j,g}(\beta)^{@,i,j,g}$.

b-ext. If $\alpha\in ME_{<s,<<\overset{\downarrow}{s},b>,a>>}$ and $\beta\in ME_{<s,b>}$, then $\alpha(\beta)^{@,g}$ is a function from $I\times J$ to $D_{a,A,I,J}$ such that $[{}^{\vee}\alpha(\beta)]^{@,i,j,g}$ is $[{}^{\vee}\alpha_{*}]^{@i,j,g}$ $[{}^{\vee}\beta]^{@,i,j,g}$, where α_{*} is of type $\langle s, \langle\langle b\rangle, a\rangle\rangle$.

The rules in (18) account for the validity of SI (i.e. substitutivity of identical extensions) in extensional contexts and the failure of SI in intensional contexts. Thus, if α is a predicate of type $\langle s, \langle\langle s, b\rangle, a\rangle\rangle$, and β, γ are of type $\langle s, b\rangle$ such that ${}^{\vee}(\beta=\gamma)^{@,i,j,g}$ is 1 while ${}^{\vee}\Box(\beta=\gamma)^{@,i,j,g}$ is 0, then ${}^{\vee}(\alpha(\beta)=\alpha(\gamma))^{@,i,j,g}$ is 1 if α is an extensional predicate, but 0 if α is an intensional predicate. The pertinent definitions of '=' and '$\Box$', as well as all other operators of IL_1 are stated in the appendix (section 4).

Before we summarize our alternative analysis by presenting the derivations of the examples (3) and (8) in the IL_1-E_1 system, it remains to take care of the validity versus failure of EG in extensional versus intensional contexts. While Montague treats this feature in PTQ in terms of the derived meaning postulate stated under (16) above, I propose to encode the transparency versus opacity of an argument term directly in the translation of the predicates in question. This is done in terms of *lexical derivation rules*, which for numerous other reasons must be part of the grammar anyway. Generally speaking, we assume that *words* are derived via lexical derivation rules from a limited number of basic roots. In this way, complex expressions are bulit up only from complete words, syncategorematic operations are avoided in the non-lexical syntax, and the priniciple of surface compositionality is maintained. Schematically, the syntactic and semantic derivations of a sentence in our grammar may be characterized as follows:

(19)



For reasons of perspicuity, I will present lexical derivations schematically rather than in terms of surface derivation rules and translation rules. (20) specifies the lexical derivation of the word *finds*$\in B_{(t/T)/T}$ from the root *find'*$\in ME_{<s,f((t/e)/e)>}$, whereby the transparency of the object position is encoded in terms of variables and lambda operators:

(20)

$$\text{finds} \in B_{t/T/T}$$

$$\text{find}' \in ME_{<s,<<s,e>,<<s,e>,t>>>} \rightarrow \lambda P_1 \lambda P_0 (P_0 \lambda x_0 (P_1 \lambda x_1 (\text{find}'(x_0, x_1))))$$

Now consider the opaque object position of the intensional verb *seek*. It is characterized in our system in terms of the lexical derivation (21):

(21)

$$\text{seeks} \in B_{t/T/T}$$

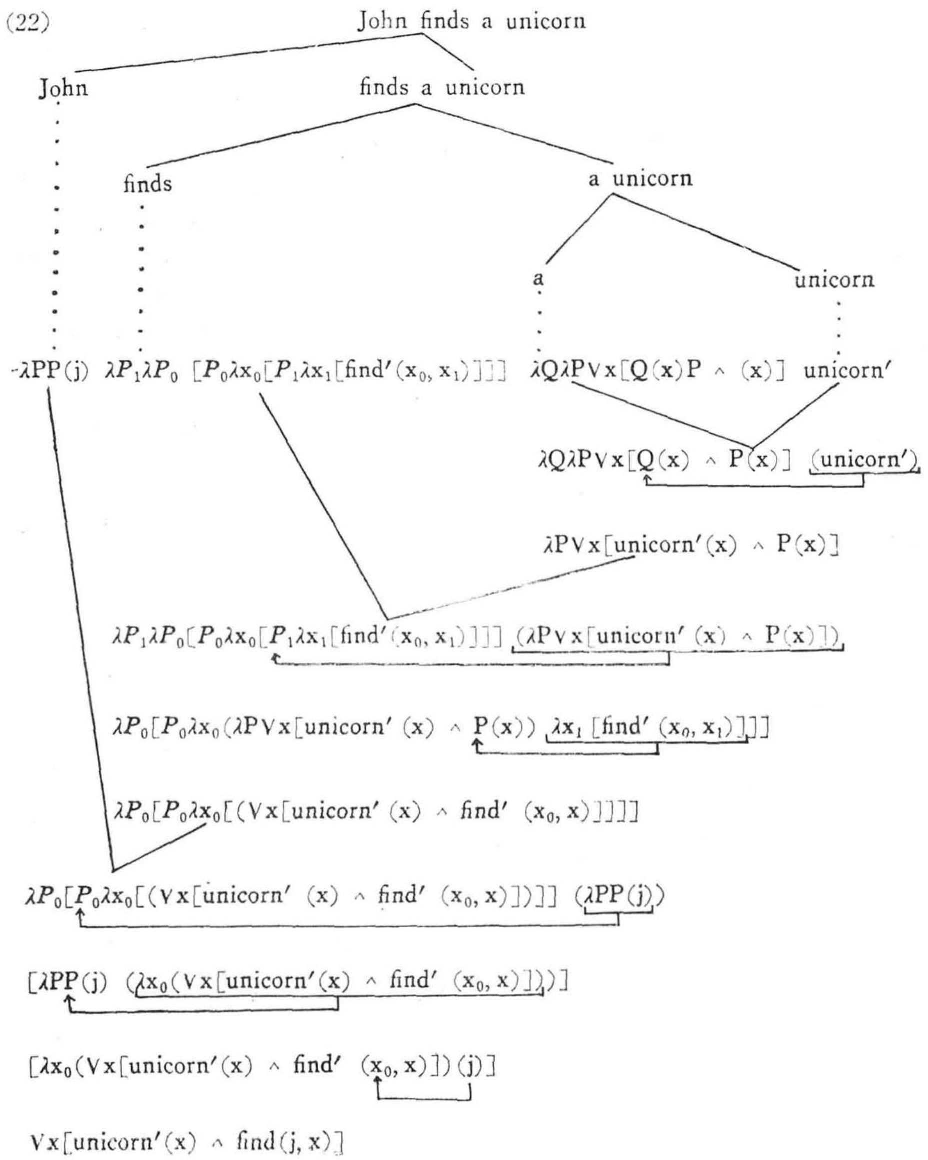
$$\text{seek}' \in ME_{<s,<<s,e>,<<s,f(T)>,t>>>} \rightarrow \lambda P_1 \lambda P_0 (P_0 \lambda x_0 (\text{seek}'(x_0, P_1)))$$

Though lexical derivations are not defined in PTQ, their introduction is straightorward. The input to the rules, i.e. the roots, are defined as the elementary constants of intensional logic and thus as elements of the set $ME_{<s,f(a)>}$ of meaningful expressions of IL_1. And B_a is the set of basic surface expressions or words of cateory a. The output of the lexical derivation rules, i.e. analyzed-words consisting of a surface form, a category and an IL_1-translation, are called *molecules* in Hausser (1982). As in PTQ, the type of the molecule translation must correspond to the molecule surface. Due to the strict intension inherent in IL_1-E_1, however, the type correspnding to category a will be $\langle s,f(a)\rangle$, and not $\langle f(a)\rangle$ as in PTQ.

Let us now consider the derivation of the exmples (3) and (8) in IL_1-E_1. IL_1-E_1 is like PTQ a *complete system* in that it simultaneously generates and interprets a fragment of English. Besides in having strict intensionalization, IL_1-E_1 differs from PTQ in that IL_1-E_1 is is ***surface compositional***, i.e. every surface word has a translation, and the syncategorematic introduction or elimination of surface or translation material is not permitted in the syntax (that part of the derivation where words are combined into complex expresssions). The lexical derivation rules, however, use syncategorematic operations quite commonly, as illustrated in (20) and (21) above.

Consider now (22) and (23), which constitute the surface compositional, strictly intensionalized derivation of (3) and (8).

(22)



(23') John seeks a unicorn

John — seeks a unicorn

seeks — a unicorn

a — unicorn

$\lambda P P(j)$ $\quad \lambda P_1 \lambda P_0\ (P_0 \lambda x_0 (seek'(x_0, P_1))$ $\quad \lambda Q \lambda P \vee x[Q(x) \wedge P(x)]\ (unicorn')$

$\lambda Q \lambda P \vee x[Q(x) \wedge P(x)]\ (unicorn')$

$\lambda P \vee x\ [unicorn'(x) \wedge P(x)]$

$\lambda P_1 \lambda P_0 (P_0 \lambda x_0\ (seek'\ (x_0, P_1))\ (\lambda P \vee x[unicorn'(x) \wedge P(x)])$

$\lambda P_0 (P_0 \lambda x_0 (seek'\ (x_0, \lambda P \vee x[unicorn'(x) \wedge P(x)])))$

$\lambda P_0 (P_0 \lambda x_0 (seek'\ (x_0, \lambda P \vee x[unicorn'(x) \wedge P(x)])))\ (\lambda P P(j))$

$\lambda P P(j)\ (\lambda x_0 (seek'(x_0, \lambda P \vee x[unicorn'(x) \wedge P(x)])))$

$\lambda x_0\ (seek'(x_0, \lambda P \vee x[unicorn'(x) \wedge P(x)]))\ (j)$

$seek'\ (j, \lambda P \vee x[unicorn'(x) \wedge P(x)])$

(The ↰⌞⌟-markings are intended to facilitate the reading of the lambda-reduction in the derivations (22) and (23). All constants in (22) and (23) are assumed to denote intensional types.)

Note that the PTQ derivation corresponding to (22) renders the ***narrow*** scope formula (3b).

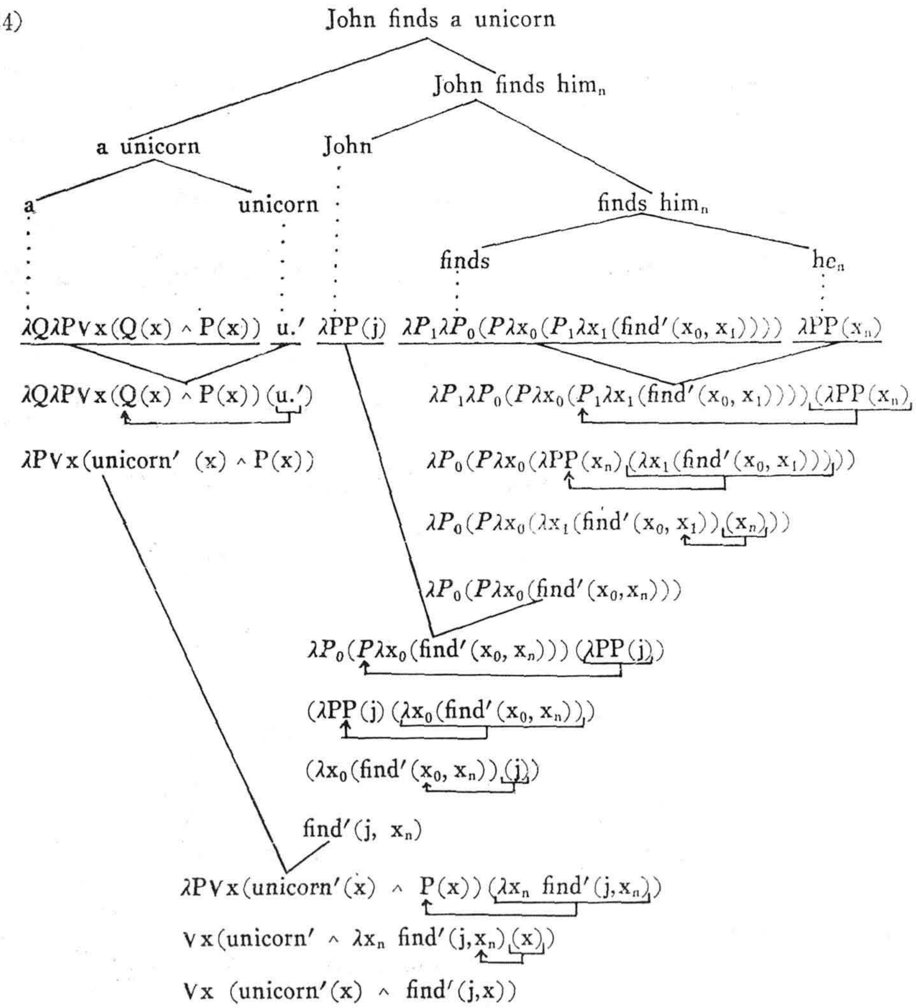
(3) b. $find'\ ({}^\wedge j, {}^\wedge \lambda P \vee x\ (unicorn'(x) \wedge {}^\vee P(x)))$

The wide scope formula (3a)

(3) a. $\vee x\ (unicorn'(x) \wedge find'\ ({}^\wedge j, {}^\wedge \lambda P {}^\vee P(x)))$

is generated in PTQ over an alternative derivation based on the surface syntactic technique of ***pronoun substitution*** (first introduced in Montague (1974, chapter 6), and incorporated in PTQ as well as in IL_1-E_1). Given an extensional predicate like ***find***, the two translations are made equivalent in PTQ by means of meaning postulate (16). In our system, on the other hand, the alternative derivation to (22) based on pronoun substitution automatically renders a translation which is equivalent to the output of (22), as shown in (24):

(24)



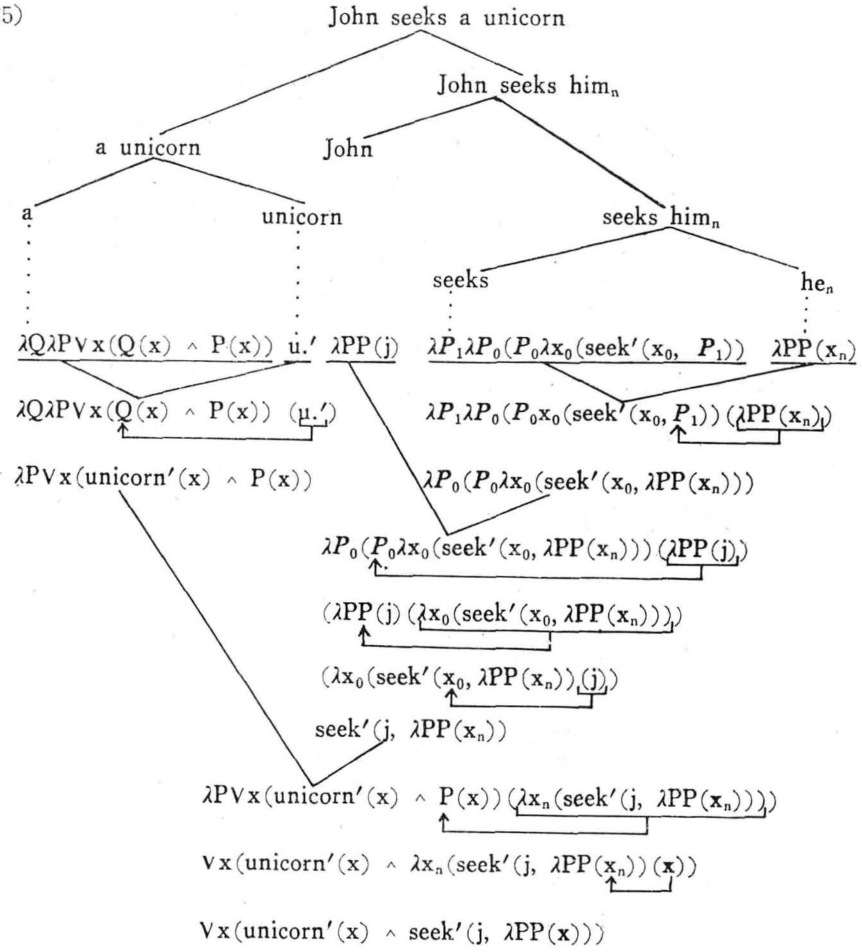
Thus our analysis requires no meaning postlates to guarantee the validity of EG for objects of extensional transitive verbs.

Let us turn now to the analysis of example (8) in our system. Besides the derivation (23), which renders the translation (23′)

(23′) $seek'(j, \lambda P \vee x(unicorn'(x) \wedge P(x)))$

there is again an alternative derivation based on pronoun subsitution. Due to the particular translation of *seek* (in contrast to *find*, c.f. (20) and (21)), this alternative derivation of (8) will not render the same translation as (23), but rather the translation of the *specific reading*, as shown in (25):

(25)



23) and (25) correspond to the PTQ-translations (8a) and (8b), respectively:

(8) a. $seek'({}^{\vee}j, {}^{\wedge}\lambda P \vee x[unicorn'(x) \wedge {}^{\vee}P(x)])$
b. $\vee x[unicorn'(x) \wedge seek'({}^{\wedge}j, {}^{\wedge}\lambda P {}^{\vee}P(x)])$

(8a) and (8b) are not equated in PTQ via meaning postulate (16) —in contrast to (3a) and (3b)— due to the presence of the intensional predicate *seek*. Meaning postulate (15), however, does apply to (8a) and (8b), lowering *unicorn′* to the 'extensional' *unicorn′*$_*$.

The IL_1-E_1 analysis described above renders precisely the same truth conditions for (3) and (8) as PTQ. It does so, however, without the use of any meaning postulates and in a simpler logic that avoids switching between intensional and extensional levels. As an illustration of how the truth conditions of IL_1 guarantee the required extensions in (23)/(25) consider the following 'interpretation sketch':

(26) $({}^{\vee}\vee x[unicorn'(x) \wedge find'(j, x)])^{@,i,j,g}$ is 1 if and only if

$({}^{\vee}[\text{unicorn}'(x) \wedge \text{find}'(j, x)])^{@,i,j,g'}$ is 1 for at least one g'.

$({}^{\vee}[\text{unicorn}'(x) \wedge \text{find}'(j, x)])^{@,i,j,g'}$ is 1 if and only if
$({}^{\vee}[\text{unicorn}'(x)])^{@,i,j,g'}$ is 1 and $({}^{\vee}[\text{find}'(j, x)])^{@,i,j,g'}$ is 1.

$({}^{\vee}[\text{unicorn}'(x)])^{@,i,j,g'}$ is 1 if and only if
$({}^{\vee}\text{unicorn}'_{*})^{@,i,j,g'}\ ({}^{\vee}x)^{@,i,j,g'}$ is 1 (since *unicorn′* is listed as an extensional predicate, condition (18b-ext.) applies).
(And similarily for $({}^{\vee}[\text{find}'(j, x)])^{@,i,j,g'}$.)

The indicated IL_1-E_1 analysis of *seek* and *find* extends naturally to all intensional (and extensional) contexts of natural language. For example, in order to handle the celebrated example (27)

(27) The temperature is ninety and rises.

we expand the lexicon as follows:

(28) $\text{temperature}' \in ME_{\langle s, \langle\langle \overset{\uparrow}{s}, e\rangle, t\rangle\rangle} \longrightarrow \text{temperature} \in B_{t//e}$
 $\longrightarrow \text{temperature}' \in ME_{\langle s, f(t//e)\rangle}$

(29) $\text{ninety}' \in ME_{\langle s, \langle\langle \overset{\downarrow}{s}, e\rangle, t\rangle\rangle} \longrightarrow \text{ninety} \in B_{t//e}$
 $\longrightarrow \text{ninety}' \in ME_{\langle s, f(t//e)\rangle}$

(30) $\text{rise}' \in ME_{\langle s, \langle\langle \overset{\uparrow}{s}, e\rangle, t\rangle\rangle} \longrightarrow \text{rises} \in B_{t/T}$
 $\longrightarrow \lambda P(P\lambda x(\text{rise}'(x))) \in ME_{\langle s, f(t/T)\rangle}$

Note that instead of indicating extensional versus intensional argument positions in the roots by means of the newly introduced sub-types ↓ and ↑ (which in turn control whether rule (18b-ext) or (18b-int) is applicable for the interpretation, we could have treated these distinctions simply in the definition of the specific functions denoted by the different roots. Both solutions are compatible with our strictly intensional translation of, e.g. (27), which is given in (27′) below:

(27′) $\vee y(\wedge x(\text{temperature}'(x) \leftrightarrow x = y) \wedge \text{ninety}'(x) \wedge \text{rise}'(x))$

Let us finally turn to verbs of propositional attitude. The example (31)

(31) John believes that Cicero denounced Catiline.

intuitively does not entail (32):

(32) John believes that Tulli denounced Catiline.

The reason is that John might not know that Cicero is Tulli. But in PTQ (32) does entail (33), due to the rigid designator analysis of proper names (Kripke, 1972). We may accommodate verbs of propositional attitudes in a formal model theory, however, by relativizing the interpretation of an expression not only to a possible world $i \in I$ and a moment of time $j \in J$, but also to a speaker $a \in A$. The verb ***believe*** could then be analyzed as follows:

(33) lexical analysis of ***believes***:

$$\text{believes} \in B_{(t/T)/t}$$

$$\text{believe}' \in ME_{\langle s, \langle\langle s,t\rangle, \langle\langle s,e\rangle,t\rangle\rangle\rangle} \rightarrow \lambda p \lambda P(P \lambda x(\text{believe}'(x, p)))$$

(34) denotation condition for ***believe′***:

$\text{believe}'^{@,g}$ denotes a function from $A \times I \times J$ to $D_{\langle f((t/e)/t)\rangle, A, I, J}$ such that $({}^{\vee}\text{believe}'(x, p))^{@,a,i,j,g}$ is 1 iff $({}^{\vee}p)^{@,a',i,j,g}$ is 1, where a' is $({}^{\vee}x)^{@,a,i,j,g}$.

Thus, in the same sense that modal operators may be formally treated in terms of denotation conditions referring to possible worlds and tense operators may be treated in terms of moments of time, we may provide a truth conditionally satisfying formal analysis of propositional attitude predicates in terms of possible speakers. According to the analysis indicated, (31) would entail (32) only if 'Cicero is Tulli' is true for John (and provided that proper names are defined as functions which are constant only relative to possible worlds and moments of time, but may have different extensions relative to different speakers).

Since our denotation conditional treatment accounts for the failure of substitutivity with regards to (a) equivalent propositions and (b) equivalent proper names in the complement of verbs of propositional attitude, our reanalysis of PTQ provides a formal solution to both problems raised against Montague semantics in Partee (1978). But the question is: how compatible is the relativization of the extension of expressions to possible speakers with the ontology of model-theoretic semantics?

As long as meaning is defined as a direct relation between expressions and a model regarded as a substitute for reality, the use of possible speakers in the index would clearly be ojectionable on ontological grounds; though for slightly different reasons than the use of possible worlds. While the basic objection to possible worlds for the extensional approach is that they cannot be real, the natural objection to possible speakers is that it would follow from their general use in the index (motivated by our treatment of propositional attitudes) that nothing in the model structure would have the status of an independent reality anymore. Our treatment of propositional attitudes assumes that all extensions are speaker dependent—a conclusion *unacceptable* to most philosophers except perhaps the most extreme sceptic *as long as extensions are regarded as real objects.* In other words, assuming the standard approach according to which the model structure is interpreted as a representation of reality, our treatment of propositional attitudes results in a model structure comparable to the 'brain in a vat' case described by Putnam (1979). In that case, Putnam ponders the question of how to argue against the view that we are all brains in a vat and what we believe to be real is nothing but an illusion fed to the brains by a sophisticated simulator.

Such arguments are not relevant, however, if we assume our constructive approach to model theory (c.f. section 3) where the model structure is defined as a lexical space, serving as part of a speaker (or a speaker simulation device (SID)), in which tokens are synthesized rather than 'checked' relative to a model structure which is defined in advance and viewed as a substitute for reality. Questions of reality arise in our alternative approach only in connection with the formal build-up of a *context*, which is assumed to be what the speaker perceives and remembers at a given moment. Thus, as far as our model-theoretic *semantics* is concerned—and the indicated pragmatics in terms of token/context-matching as well—, we may remain completely neutral with regards to the controversy between nominalists, empiricists, positivists, realists, and sceptics: even though our approach is inherently speaker-relative,—which makes it compatible with our formal treatment of propositional attitudes—, the possibility or likelihood of the existence of an objective, independent reality outside the speaker or the SID is neither precluded nor presumed.

7. Concluding remark

Before we turn in the appendix to the formal definition of a strictly intensional logic let us return once more to the characteristic differences between an intensional and an extensional logic. A system may be called extensional if it either

i) allows unrestricted substitution of equivalent expressions, or
ii) fails to treat the difference between intensional and extensional contexts, or
iii) avoids the use of possible worlds.

The system advocated in this paper and defined in the appendix is intensional in the sense of (ii) and (iii), i.e. it treats the difference between intensional and extensional contexts in terms of different denotation conditions, and it uses the notion of possible worlds. However, since according to our approach the model-structure is part of the SID (in contrast to the standard approach, where the speaker/hearer is part of the model-structure), we interpret possible worlds intuitively as belief-states of the SID and not as possible states of the universe. We thus use the term possible world in a technical sense in order to maintain the traditional definition of the model operators and intensions. A similar reinterpretation holds of our notion of an extension, which we interpret in the sense of 'value of an intension function' but not in the sense of 'object of SID-external reality'. Note that with respect to (i), our strictly intensional logic may be called extensional in that it allows unrestricted substitution of equivalent expressions. The reason is that expressions always denote intensions in our logic, defined as functions from world-time-speaker triples to extensions.

Another 'extensional' feature of our strictly intensional logic is the absence of an intension operator '^'. Mathematically speaking, this is probably the most interesting property of our system. It simplifies the logic in that it removes one of the two restrictions on lambda conversion (cf. Gallin, 1975: 18 and 19, AS4), according to which $\lambda x_\alpha[A_\beta(x)]B_\alpha \equiv A_\beta(B_\alpha)$ is not valid if x lies within the scope of ^ (unless B is modally closed). For a more extensive discussion of this particular feature of extensional systems with intension- and lambda-operator (like PTQ) see Link (1979, 106 and 158).

8. Appendix: definition of the strictly intensional logic IL_1

The strictly intensionalized logic presented below is a revised version of IL_1, defined in Hausser (1978b, section 1.7, 1-3). Besides some improvements in the formulation of the rules, the present version differs from the earlier definition in that intensions are defined as functions from speaker-world-time triples, rather than world-time pairs, to extensions, and in that the believe-operator B is defined.

1. The Il_1-Lexicon

1.1. Types

Let e,t, and s be three objects (0, 1, and 2) that are distinct and not an ordered pair or triple. The TYPE, or set of types of IL_1 is the smallest set Y such that

(1) $e, t \in Y$;

(2) whenever $a, b \in Y$, $\langle a, b\rangle \in Y$, and

(3) whenever $a \in Y$, $\langle s, a\rangle \in Y$.

1.2. Basic Expressions

We shall employ denumerably many variables and infinitely many constants of each type. In particular, if n is any natural number and $A \in$ TYPE, we understand by $v_{n,a}$ the n^{th} variable of type a, and by Con_a the set of constants of type a.

2. The IL_1-Interpretation

2.1. Possible Denotations

Let A, I, J be any sets, which we may regard as the set of entities (or individuals), the set of possible worlds, and set of moments of time, respectively. In addition let *a* be a type. Then $D_{a,A,I,J}$ or the set of possible denotations of type *a* corresponding to A,I, and J may be introduced by the following recursive definition:

$$D_{e,A,I,J} = A$$
$$D_{t,A,I,J} = \{0, 1\}$$
$$D_{\langle a,b\rangle,A,I,J} = D_{b,A,I,J}^{\;D_{a,A,I,J}}$$
$$D_{\langle s,a\rangle,A,I,J} = D_{a,A,I,J}^{\;A\times J\times I}$$

2.2. Interpretation or Intensional Model

By an interpretation is understood a quintuple (A, I, J, $\leqslant$, F) such that

(1) A, I, J are non-empty sets, $a_0 \in A$, $i_0 \in I$, $j_0 \in J$, where a_0, i_0, and j_0 are regarded as the speaker, the utterance world, and the utterance moment, respectively;

(2) $\leqslant$ is a simple (that is, linear) ordering having J as its field;

(3) F is a function having as its domain the set of all constants, and

(4) whenever $a \in TYPE$ and $\alpha \in Con_a$, $F(\alpha) \in D_{a,A,I,J}$

2. 3. Intension and Extension

Suppose that ⓐ is an interpretation having the form $\langle A, I, J, \leqslant, F\rangle$. Suppose also that g is an ⓐ assignment (of values to variables), that is, a function having as its domain the set of all variables and such that $g(u) \in D_{a,A,I,J}$ whenever u is a variable of type a. If α is a meaningful expression (i.e. a member of the set ME to be defined below) and α is of type $\langle s, a\rangle$, we shall understand by $\alpha^{@,g}$ the intension of α with respect to ⓐ and g; if $\langle a, i, j\rangle \in A \times I \times J$, then $\alpha^{@,g}(\langle a, i, j\rangle)$ is to be the extension of α — that is the function value of the intension of α when applied to the point of reference $\langle a, i, j\rangle$.

3. The Syntax and Semantics of IL_1

The set of meaningful expressions ME of IL_1 is recursively defined in the clauses (1-12), while the corresponding denotation conditions are recursively defined in clauses (1′-12′):

(1) Every constant of type $\langle s, a\rangle$ is in $ME_{<s,a>}$.

(1′) If α is a constant of type $\langle s, a\rangle$, then $\alpha^{@,g}$ is $F(\alpha)$.

(2) Every variable of type $\langle s, a\rangle$ is in $ME_{<s,a>}$.

(2′) If α is a variable of type $\langle s, a\rangle$, then $\alpha^{@,g}$ is $g(\alpha)$.

(3) If $\alpha \in ME_{<s,a>}$, then $({}^{\vee}\alpha) \in ME_a$.

(3′) If $\alpha \in ME_{<s,a>}$ and $\langle a, i, j\rangle \in A \times I \times J$, then $({}^{\vee}\alpha)^{@,a,i,j,g}$ is $\alpha^{@,g}(\langle a, i, j\rangle)$.

(4) If $\alpha \in ME_{<s,a>}$ and a variable of type $\langle s, b\rangle$, then $\lambda u\alpha \in ME_{<s,<<s,b>,a>>}$.

(4′) If $\alpha \in ME_{<s,a>}$ and u is a variable of type $\langle s, b\rangle$, then $(\lambda u\alpha)^{@,g}$ is that function h from $A \times I \times J$ to $D_{a,A,I,J}{}^{D_{<s,b>A,I,J}}$ such that whenever x is in the domain of $D_{<s,b>,A,I,J}$, $h(\langle i, j\rangle)(x)$ is $({}^{\vee}\alpha)^{@,a,i,j,g'}$, where g′ is the ⓐ-assignment like g except for the possible difference that g′(u) is x.

(5) If $\alpha \in ME_{<s,<<s,b>,a>>}$ and $\beta \in ME_{<s,b>}$, then $\alpha(\beta) \in ME_{<s,a>}$.

(5′) If $\alpha \in ME_{<s,<<s,b>,a>>}$ and $\beta \in ME_{<s,b>}$, then $\alpha(\beta)$ is a function from $A \times I \times J$ to $D_{a,A,I,J}$ such that $({}^{\vee}(\alpha(\beta)))^{@,a,i,j,g}$ is $({}^{\vee}\alpha)^{@,a,i,j,g}(\beta)^{@,g}$.[14]

[14] Since the specification of extensional versus intensional sub-types is required only for unanalyzed IL_1-constants, and since each of these IL_1-constants will ultimately require its own definition (i.e. the 'Zuordnungsbestimmung' of the function denoted) we state only the the intensional clause of the rule of function application (i.e. (18b-int), and assume that the role of the extensional clause (18b-ext) is carried out in the definition of each extensional constant. Thus the postulation of sub-types (c.f. (17)) is not essential to our solution.

(6) If $\alpha, \beta \in ME_{<s,a>}$, then $(\alpha = \beta) \in ME_{<s,t>}$.

(6′) If $\alpha, \beta \in ME_{<s,a>}$, then $(\alpha=\beta)^{@,g}$ is a function from $A \times I \times J$ to $D_{t,A,I,J}$ such that $({}^{\vee}(\alpha=\beta))^{@,a,i,j,g}$ is 1 if and only if $({}^{\vee}\alpha)^{@,a,i,j,g}$ is $({}^{\vee}\beta)^{@,a,i,j,g}$.

(7) If $\phi \in ME_{<s,t>}$, then $\sim\phi \in ME_{<s,t>}$.

(7′) If $\phi \in ME_{<s,t>}$, then $(\sim\phi)^{@,g}$ is a function from $A \times I \times J$ to $D_{t,A,I,J}$ such that $({}^{\vee}\sim\phi)^{@,a,i,j,g}$ is 1 if and only if $({}^{\vee}\phi)^{@,a,i,j,g}$ is 0.

(8) If $\phi, \psi \in ME_{<s,t>}$, then $(\phi \wedge \psi)$, $(\phi \vee \psi)$, $(\phi \rightarrow \psi) \in ME_{<s,t>}$.

(8′) If $\phi, \psi \in ME_{<s,t>}$, then $(\phi \wedge \psi)^{@,g}$ is a function from $A \times I \times J$ to $D_{t,A,I,J}$ such that $({}^{\vee}(\phi \wedge \psi))^{@a,i,j,g}$ is 1 if and only if $({}^{\vee}\phi)^{@,a,i,j,g}$ is 1 and $({}^{\vee}\psi)^{@,a,i,j,g}$ is 1; and similarily for $\vee$ and $\rightarrow$.

(9) If $\phi \in ME_{<s,t>}$ and u is a variable, then $\vee u\phi$ and $\wedge u\phi \in ME_{<s,t>}$.

(9′) If $\phi \in ME_{<s,t>}$ and u is a variable of type $\langle s, a\rangle$, then $\vee u\phi^{@,g}$ is a function from $A \times I \times J$ to $D_{t,A,I,J}$ such that $({}^{\vee}\vee u\phi)^{@,a,i,j,g}$ is 1 if and only if there exists $x \in D_{<s,a>,A,I,J}$ such that $({}^{\vee}\phi)^{@,a,i,j,g'}$ is 1, where g′ is as in (4); and similarily for $\wedge u\phi$.

(10) If $\phi \in ME_{<s,t>}$, then $\Box\phi \in ME_{<s,t>}$.

(10′) If $\phi \in ME_{<s,t>}$, then ${}^{\vee}\Box\phi^{@,g}$ is a function from $A \times I \times J$ to $D_{t,A,I,J}$ such that $({}^{\vee}\Box\phi)^{@,a,i,j,g}$ is 1 if and only if $({}^{\vee}\phi)^{@,a,i',j',g}$ is 1 for all $i' \in I$ and $j' \in J$.

(11) If $\phi \in ME_{<s,t>}$, then $W\phi$ and $H\phi \in ME_{<s,t>}$.

(11′) If $\phi \in ME_{<s,t>}$, then $W\phi^{@,g}$ is a function from $A \times I \times J$ to $D_{t,A,I,J}$ such $({}^{\vee}W\phi)^{@,a,i,j,g}$ is 1 if and only if $({}^{\vee}\phi)^{@,a,i,j',g}$ is 1 for at least one j′, $j' > j$; and similarily for H.

(12) If $p \in ME_{<s,t>}$ and $\alpha \in ME_{<s,e>}$, then $B(\alpha, p) \in ME_{<s,t>}$.

(12′) If $p \in ME_{<s,t>}$ and $\alpha \in ME_{<s,e>}$, then $B(\alpha, p)^{@,g}$ is a function from $A \times I \times J$ to $D_{t,A,I,J}$ such that $({}^{\vee}B(\alpha, p))^{@,a,i,j,g}$ is 1 if and only if $({}^{\vee}p)^{@,a',i,j,g}$ is 1, where a′ is $({}^{\vee}x)^{@,a,i,j,g}$.[15]

Nothing is in any set ME_a except as required by (1–12). If ϕ is a formula (that is, a member of ME_t), then ϕ is true with respect to ⓐ,a,i,j if and only if $\phi^{@,a,i,j,g}$ is 1 for every ⓐ assignment g.

In line with the synthesizing approach outilned in section 0∼3 above, let us assume that ⓐ is a lexical model of a given SID which partially specifies the denotation of any two IL_1-constants of equal type in terms of inclusion, overlap, etc. of their extensions according to the 'lexical intuition' of the SID. An IL_1-sentence ϕ is a *syntactic*

[15] The analysis of believe-contexts in the present paper treats a sentence like "John doesn't believe that Zombies dream and John doesn't believe that Zombies don't dream" (or "John neither believes that Zombies dream nor does he believe that they don't dream") as a contradiction, i.e. it is not possible to express in the present logic that someone has no opinion about something. This deficiency is naturally resolved, however, if we admit undefined denotations. For a definition of a presuppositional logic in Montague Grammar see Hausser (1976a).

tautology, if no lexical model ⓐ can be defined in which a model structure satisfying [$^{\vee}\sim\phi$] can be constructed. A sentence ϕ is a *lexical tautology* in a given lexical model ⓐ, if no model structure satisfying ($^{\vee}\sim\phi$) can be constructed in ⓐ and ϕ is not a syntactic tautology. And similarily for syntactic and lexical contradictions.

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