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A NEW TREATMENT OF CONTEXT IN MODEL THEORY

0. *Introductory remarks*

In standard model-theoretic semantics, the notion « denotation » and « reference » are used as synonyms, while the model is regarded as a substitute for reality. In this paper, an alternative approach is developed by relativizing model-theoretic semantics to a *speaker*. The idea is that the denotation of a sentence is the model-theoretic structure (or set of structures) which would make the sentence true. Instead of reading the denotation conditions as instructions to find out whether a sentence is true relative to a model and an index, we read the denotation conditions as instructions to synthesize the denotation of a sentence in a lexical space. Otherwise the logic remains completely unchanged. Reference, on the other hand, is treated as the pragmatic process of matching the denotation with a context. A context is regarded as what the speaker perceives and remembers at a given moment. Formally, a context is treated as a model-theoretic structure synthesized in the same lexical space as the denotation of surface expressions.

After discussing the assumptions of the standard approach to model-theoretic semantics in section 1, we turn in section 2 to the problem of treating context-dependent expressions within the standard system (coordinates approach to indexicals). In section 3, the unified treatment of indexical and anaphoric pronouns based on context-variables of Hausser 1979 (« How do pronouns denote? ») is summarized. In this earlier paper a context is defined as a *stage description*, i.e. a regimented description of the utterance situation. While stage descriptions provide a far more structured treatment of context than the coordinate approach (and thus allow a linguistically more satisfactory analysis of pronouns), the earlier system still remains within the standard model theoretic approach insofar as the model continues as a substitute of reality, no distinction is made between denotation and reference, and the speaker has no function beyond the interpretation of first person pronouns. After presenting the generalized model-theoretic semantics in section 4, it will be shown in what sense the generalized model theory affects the linguistic analysis of pronouns of the earlier paper.

1. *Reference and Denotation on the standard semantic approach*

The standard semantic approach, as represented in various stages by, e.g., Frege (1892), Russell (1905), Carnap (1947), Kripke (1963), and Montague (1974), proceeds on the assumption that the meaning of an expression consists roughly in the relation between the expression and the object it denotes or refers to. The paradigmatic case of this approach is the logical concept of a *proper name*. Frege extended this concept to declarative sentences, which he analyzed as names of truth values. This proposal developed into the view that the meaning of a sentence may be equated with its truth conditions, defined relative to a formal model.

On the standard semantic approach, the formal model is viewed as an objectively given substitute of reality, and the denotation conditions (truth conditions) are read as if it were the purpose of the formal interpretation to find out whether a formula is 1 or 0 relative to a model and an index. By defining meaning as a direct relation between expressions and states of affair, the standard approach eliminates the use aspect of language and abstracts from the role of the speaker.

While this abstraction, which is based on the apparent fusion of meaning (denotation) and use (reference) in the case of declarative sentences in their literal meaning, has provided for the development of a rigorously formal semantics, it is at the same time responsible for certain fundamental limitations and problems of the standard model-theoretic approach. The point is that the lexical and the referential aspect of meaning are not separated in the definition of the standard model. For example, when we define a model in order to interpret the sentences *John walks.* and *John sits.* we should make sure that the extension of *walk* and *sit* do not overlap at an index — because one cannot sit and walk at the same time. This is what I call the lexical aspect in the definition of a model. On the other hand, we are free to define the extension of *John* to be either contained or not to be contained in the set denoted by *walk* at an index, thus making the sentence *John walks.* true or false depending on how we define the model. This is what I call the referential aspect in the definition of a model.

In summary, the standard approach collapses the notions of denotation and reference, where the denotation of an expression is regarded as the formal model theoretic object characterizing the literal meaning of the expression (including the semantic interdependencies induced by the word meanings), while reference is regarded as the process of matching the meaning of an expression with a certain situation. It seems to me that the discussion, starting with Frege and Russell, on whether logical expressions should be restricted to denote only real objects, or whether the model should be allowed to include also possible individuals (and possible worlds, etc.) is grounded precisely in the fusion of reference and denotation inherent in the standard approach.

2. Treating indexicals on the standard approach

One problem created by the double function of the model to assign *meanings* to constants and at the same time to serve as a substitute of *reality* is the treatment of indexicals.

« An indexicals word or sentence is one of which the reference cannot be determined without knowledge of the context of use; an example is the first person pronoun “I” » (Montague 1974, chapter 4, p. 119). Compare for example (1) and (2):

- (1) Bill saw Mary at the station
- (2) I saw you there

In (1) the truth value depends on the denotation of the constants *Bill*, *see*, *Mary*, and *at the station*, as specified by the model. In particular, *Bill*, *Mary*, and *at the station* are to be defined as denoting particular individuals and particular places, respectively. In (2), on the other hand, the situation is quite different insofar as it would be intuitively wrong to assign fixed denotations to the indexicals, *I*, *you*, and *here*.

How can indexicals be treated on the standard approach? The most widely accepted proposal is the so-called *coordinates* approach (Montague 1974, chapter 3; Lewis 1972): in addition to the coordinates specifying a possible world and a moment of time, additional coordinates are defined for each context-dependency aspect to be treated. Lewis (1972), for example, defines different coordinates for possible speakers (pronoun *I*), possible hearers (pronoun *you*), possible places (pronoun *here*), possible indicated objects (pronoun *this*), and even for possible previous discourses, respectively. In short, the coordinates approach allows to maintain the standard approach in a technical sense by defining a context of use as an extended point of reference.

The coordinates approach clearly highlights the problem arising from the fusion of denotation and reference on the standard approach. Since the model is intuitively regarded as a representation of reality, specifying a state of affairs at an index, one would expect that this state of affairs serves as the context. Instead, the coordinates approach introduces a second reference mechanism: while the denotation of regular constants is specified over the denotation function, the denotation of indexicals is specified over the additional context-coordinates.

To define the context as an arbitrary n -tuple of external coordinates fails to capture the highly specific interaction between context-dependent expressions and referents provided by the utterance situation. And we cannot expect that a theory will render linguistically satisfactory formalizations of contextual phenomena if the grammar operates on a smaller basis of contextual information than the speaker does in daily life. In the following section, we will discuss context-dependent expressions from a linguistic point of view.

3. *Anaphoric versus indexical pronouns*

The class of context-dependent expressions in English (and other natural languages) falls into several groups, among them *pronouns* like *I, you, my, mine, this, there, then, one, etc.*, *definite descriptions* like responsiveness (non-redundant answers) such as *John*, (which has different truth values relative to an interrogative like *Who left?* versus *Who came?*). In the following we will be mainly concerned with pronouns and definite descriptions.

Note that pronouns arise in various different syntactic categories. Thus *I, you, he, she, it, we, you, they* are pronouns of category T (for term, i.e. they are noun phrases), while *here, there, then, etc.* are pronouns of category t/t or IV/IV (i.e. sentence or predicate adverbials). The pronouns *my, your, his, etc.*, on the other hand, are pronouns of category T/CN (i.e. determiners). The only pronouns that are really *nouns* are *one, ones*, which are of category CN. Thus the name « pronoun » is unfortunate and should be replaced by something like pro-expression.

The crucial fact for an analysis of context dependency is that pronouns of different categories may have the *same aspect of context dependency*. For example, *I, my, mine, myself* are of different categories, but share the same aspect of context-dependency (i.e. first person). The transformational literature on pronouns, however, has not much concentrated on the difference in categories and the shared aspects of context-dependency in various pro-expressions, but instead limited attention to a syntactic treatment of the *anaphoric* (as opposed to *indexical*) use of pronouns. Consider for example (3):

(3) After John came home, *he* read a book

On the anaphoric reading, *he* is coreferential with *John*, while on the indexical reading, *he* refers to some other person in the context of the utterance. Anaphoric expressions are regarded as those which derive their denotation from a « full » expression in the same sentence, called *antecedent*, while indexical pronouns depend on contextual information for their proper interpretation.

In transformational grammar, as well as in Montague (1974, chapter 6 and chapter 8), anaphoric pronouns are treated on the basis of *syntactically stipulated coreference* (c.f. Hausser 1979). Thus a principled contrast between indexical and anaphoric pronouns is construed. It should be noted, however, that anaphoric pronouns do not constitute a welldefined natural class. While the pronouns *I, you^{pl}, we, and you^{pl}* have only indexical interpretations, *he, she, it, and they* may be used either anaphorically or indexically.

A *uniform* syntactico-semantic treatment of anaphoric and indexical pronouns, on the other hand, is proposed in Hausser (1979), which is based on *context-variables*. Context-variables are distinct from regular variables (and constants). Context variables are interpreted in terms of *contextual reconstruction*, i.e. they are replaced by denoting expressions derived from the con-

text (indexical interpretation) or the sentence in which they occur (anaphoric interpretation). Different context-variables represent different aspects of context-dependency in terms of their characteristic reconstruction conditions. The reconstruction conditions specify possible values for a context variable mainly in terms of their position (in the context or the sentence under interpretation).

On the basis of context-variables, we may characterize different pronouns semantically in terms of the following translations into intensional logic:

- (4) *I* translates into $\lambda P \lambda x \in [\Gamma_1(x)]^1 P(x)$
 (5) *you* translates into $\lambda P \lambda x \in [\Gamma_2(x)]^1 P(x)$
 (6) *he* translates into $\lambda P \lambda x \in [\Gamma_3(x) \wedge \text{male}'(x)]^1 P(x)$

The formulas in (4-6) exemplify « restricted quantification » (Hausser 1976), which characterizes the pronouns under discussion as « existential presupposition inducers ». $\lambda x \in [f(x)] g(x)^{d,i,j,g}$ (where d is a model, i a possible world, j a moment of time and g a variable assignment) is undefined if there is no variable assignment g' for which $f(x)^{d,i,j,g'}$ is 1 (failure of existential presupposition). Otherwise the value assignment of restricted quantification resembles the corresponding non-restricted quantification, e.g. $\lambda x [f(x) \rightarrow g(x)]$. The superscripts ¹ in (4-6) indicated that the quantifier restrictions are unit-sets (because we are dealing with singular pronouns). For example, (7)

- (7) $\lambda x \in [\Gamma_1(x)]^1 \text{walk}'(x)$ (which translates « I walk »)

may be read as « All x in the unit set the elements of which have the property of first person have the property of walking ».

The difference between the pronouns in (4,5,6) resides in the presence of different context variables Γ_1 , Γ_2 , and Γ_3 , which represent different aspects of context dependency. Note that on this approach, pronouns are not derived from « underlying » noun phrases. Instead they are treated as *basic* definite descriptions. Compare for example (6) and (8):

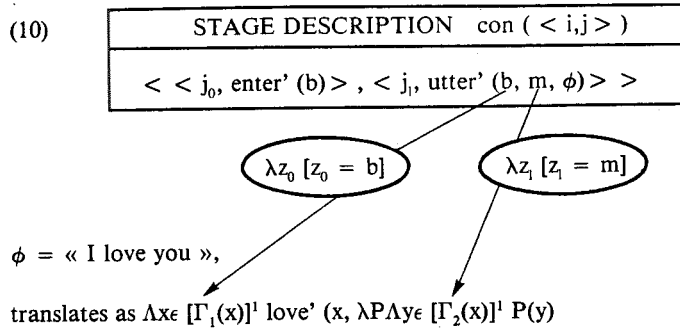
- (8) the man $\rightarrow \lambda P \lambda x \in [\text{man}'(x) \wedge \Gamma_{0..}(x)]^1 P(x)$

The different context-dependency aspects expressed by different context-variables are formulated in terms of restrictions on the possible places of their values. The interpretation is further restricted by the requirement of *semantic compatibility*, i.e. a reconstruction is regarded as successful only if it does not lead to a presupposition failure. For example, reconstructing *the cat* as *the cat which is a dog that barks* will in most models lead to a presupposition failure.

In Hausser (1979), a context is defined as a *stage description*, i.e. a sequence of *moment specifications* $\langle j, \phi \rangle$, where j is a moment of time and ϕ a sentence of the context language IL_1 ; ϕ is interpreted as a description of the moment j . A stage description like

(9) $\langle \langle j_0, \phi_0 \rangle, \langle j_1, \phi_1 \rangle, \dots, \langle j_n, \phi_n \rangle \rangle$

associated with a point of reference (i,j) is regarded as a history of the time intervall leading up to that point of reference. The values for an indexical interpretation (« external » reconstruction) of a context-variable are provided by the Π_1 -sentences in the stage description. Consider the following illustration.



Reconstruction of Γ_1 and Γ_2 in ϕ :

$\Lambda x \epsilon [\lambda z_0 [z_0 = b] (x)] \text{love}'(x, \lambda P \Lambda y \epsilon [\lambda z_1 [z_1 = m] (y)]^1 P(y))$

This reconstruction reduces via lambda conversion to (11):

(11) $\Lambda x \epsilon [x = b]^1 \text{love}'(x, \lambda P \Lambda y \epsilon [y = m]^1 P(y))$

Thus « I love you » uttered by Bill towards Mary is reconstructed into a formula equivalent to « Bill loves Mary ».

Contextual reconstruction assimilates the interpretation of context-dependent expressions to that of regular constants: once a context-variable is contextually reconstructed relative to a stage description associated with an index in a context-model, the interpretation runs standard (for the pertinent definitions see Hausser 1979). Since context-variables may also be reconstructed relative to the sentence in which they occur, the interpretation of anaphoric and indexical pronouns is unified. Furthermore, it can be shown that the indicated analysis succeeds in treating a number of traditional puzzles, such as Bach-Peters sentences, the donkey-sentence, and the paycheck sentence, which so far have eluded a coherent formal analysis.

In « proper » context-models, the formulas in the stage description are required to be 1 relative to the model and the respective index. This imposes an additional coherency condition on the definition of the denotation of constants in the model (additional to the « meaning postulates », c.f. Montague

1974, chapter 8). But on the whole the indicated approach remains firmly within the realm of the standard approach, as discussed in section 1 and 2 above. Thus the relation between an expression and the « world » is direct and there is no distinction between reference and denotation. The model is regarded as an objectively given substitute of reality, and beyond the interpretation of first person pronouns the speaker has no intrinsic role.

4. *The role of context in a generalized model theory*

The coordinates approach (c.f. section 2) and the reconstruction approach (c.f. section 3) have in common that they constitute *external* parameters or restrictions which are added to the original model structure. Thus the fusion of the lexical aspect and the referential aspect characteristic of the standard approach (c.f. section 1) remains unresolved on either treatment of context-dependency. Let us turn now to an alternative approach which is compatible with the linguistic analysis of the reconstruction approach but separates the lexical aspect of meaning from the referential aspect by treating

- (11i) *literal meaning* in terms of model-theoretic synthesis in a lexical space;
- (11ii) *context* in terms of a model theoretic synthesis of what the speaker perceives and remembers at a given moment;
- (11iii) *reference* in terms of matching the synthesized literal meaning with the synthesized context.

The lexical space is defined as a partially specified model, which determines the denotation of constants insofar as to accommodate the speaker's intuition with regards to the semantic interdependencies of words in their literal meaning. The meaning of complex expressions is *synthesized* in the lexical space by setting the constants of the translation formula into certain function-theoretic relations as specified by the logical operators in the formula. The meaning of *Bill walks*, for example, is synthesized by setting *b* as an element of *walk'*. Since the interdependencies of word meanings are treated directly in the lexical space, there is no need for meaning postulates.

The formal logic, i.e. the syntax and semantics of the translation language, however, is not affected by this switch to model-theoretic synthesis. Rather than reading the denotation-conditions as instructions to find out whether a sentence is true or false relative to a model and an index (interpretive mode), we read them as instructions to synthesize the set of *model theoretic structures relative to which the sentence would be true* (synthesizing mode). These synthesized model-theoretic structures are regarded as the denotation of an expression, representing its literal meaning.

But what about cases like (12):

(12) The square circle rises

On the one hand, the lexical model specifies the denotation of *square* and *circle* as disjoint (extensionally speaking). The logical operators reflecting the syntactic structure of (12), on the other hand, instruct the system to set the denotation of *square* and *circle* as intersecting. Rather than postulating that in the case of contradictory expressions like (12) there is no synthesis at all, let us assume that the system synthesizes the denotation of expressions like (17) to the extent possible — leaving the discrepancies where they arise. The reason is that expressions for which there is no consistent synthesis can still be successfully used, for example metaphorically. Note that the specification of word meanings (or rather of the logical constants serving in the translation of surface words) does not represent the natural language under investigation as a whole, but rather the idiolect of the presumed speaker.

The treatment of literal meaning (denotation) in terms of synthesis in a lexical space is complemented by a treatment of context in terms of model theoretic synthesis of what the speaker perceives and remembers. As an example of a possible context-representation consider (13):

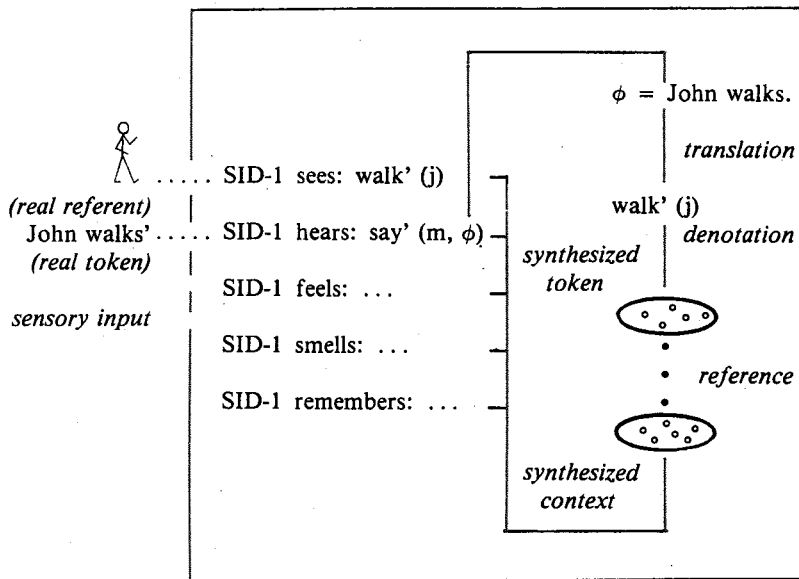
(13) at (i,j) SID-1 sees: [walk' (j) \wedge talk'(m)]
 hears: [[speak' (m, ϕ)] \wedge (ϕ = « John walks »)]
 feels: ...
 smells: ...
 remembers: ...

The formulas in (13) are stated in term of the same context-language used in the definition of the stage descriptions of Hausser (1979), i.e. an extension of intensional logic. Thus the formulas in (13) are model-theoretically interpretable.

But relative to which model and which index should these formulas be interpreted? Again, it is not the purpose of the denotation conditions associated with these formulas to find out whether the formulas are true or false. After all, the formulas are assumed to represent what the speaker SID-1 perceives to be the case at the index (i,j). For this reason we interpret the denotation conditions associated with the context-language likewise as instructions to model-theoretically synthesize the meaning of the formulas — in the same lexical space as the token meanings.

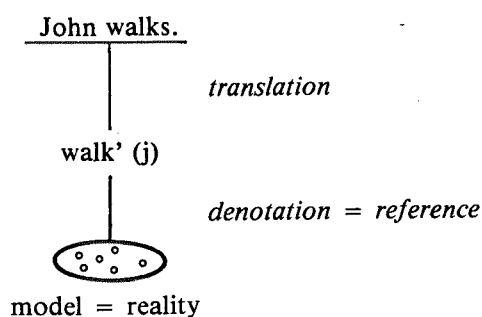
Let us illustrate the interaction of the synthesized token meaning with the synthesized context in the lexical space by picturing our system as a speaker simulation device.

(14) Generalized model:



In (14) we distinguish between *denotation* and *reference*. Denotation is the model-theoretic structure serving as the formal meaning of the token under analysis, i.e. a certain function synthesized in the lexical space. Reference, on the other hand, is the process of matching the denotation with the synthesized context. This separation of denotation and reference will be crucial for treating different types of reference (literal reference, vague reference, metaphoric reference, etc.) in terms of different types of matching. In the standard system illustrated in (15) below, on the other hand, reference and denotation are collapsed. Thus different kinds of reference require different kinds of denotations, which explains why the standard approach must appeal to alleged *ambiguities* in order to handle instances of non-literal reference.

(15) standard system:



The crucial difference between the generalized system and the standard system is the relativization of the generalized system to a speaker. It is the relativization to a speaker which permits to interpret the denotation as a *synthesized* model structure rather than a substitute of reality. Apart from the switch to the synthesizing mode, however, nothing changes: the standard system reappears as a crucial part of the generalized system. The relativization to a speaker allows furthermore to complement the synthesized token meaning with a context that is a model-theoretically synthesized picture of reality rather than reality itself.

The systems illustrated in (14) and (15) are both compatible with the idea that meaning is the relation between an expression and its referent. But (15) pictures this relation directly between the expression and a supposedly real object. In (14), on the other hand, the relation is taken apart into several steps - due to the relativization to a speaker. According to the generalized model illustrated in (14), the speaker may use, e.g. the name *John* to refer to a real person, but the reference process is located in the speaker's head. (14) accommodates the fact that successful reference depends on what the speaker perceives and remembers.

Our new system represents a generalized form of model-theoretic semantics insofar as the classical notion of truth as the correspondence between what is said and what is (Aristotle, *Metaphysics*) reappears as a special case, namely the case where (i) the sensory input or memory are faithful to reality and (ii) the reference type is literal reference, i.e. there is a complete match between the synthesized token meaning and the synthesized context.

5. Indexical pronouns revisited

The generalized model illustrated in (14) has a number of important consequences. The definition of a lexical space provides a realm for the systematic

empirical study of word meaning. The concept of model-theoretic synthesis provides for a formal characterization of literal meaning which applies to complete as well as incomplete expressions and to declarative as well as non-declarative expressions (for the respective analysis of non-declaratives see Hausser 1978).

The definition of a synthesized speaker context provides for the systematic empirical study of context structures. Furthermore, it provides for the study of the *use of literal meaning* relative to the context, i.e. pragmatics. Different types of reference, for example, are treated in terms of different types of matching the synthesized token meaning with the synthesized context. How the types of matching are to be defined is an empirical question within pragmatics (apart from the case of literal reference where we assume complete correspondence). The relativization of the context to a speaker also provides the basis for the systematic study of speech acts within our system.

In the present paper, however, we are especially interested in the interpretation of pronouns relative to the synthesized context. One notable fact about our new system is that the context illustrated in (13) and (14) has a lot more inherent structure than the stage descriptions proposed in my earlier pronoun paper. This should facilitate the definition of the reconstruction conditions for indexical pronouns. The crucial difference between the stage descriptions of section 3 and the synthesized context of section 4, however, concerns the distinction between reference and denotation. In the standard model, the stage descriptions serve to restrict the definition of denotations in the model structure; there is no distinction between reference and denotation. Thus stage descriptions define the context essentially in terms of the context *language* and the contextual reconstruction of indexicals is essentially reconstruction relative to another language. In the generalized model of section 4, on the other hand, the context is regarded as a model-theoretic structure and the formulas describing the sensory input and memory of a speaker are merely a means to present these structures.

While the denotation (= referent) of indexicals in the standard model (c.f. section 3) is determined via contextual reconstruction, the context-variables of indexically interpreted pronouns in the generalized model are defined to *refer directly*. Take for example the pronoun *I*. On the earlier analysis using stage descriptions, the *denotation* of *I* at an index would be specified by replacing the context-variable with a name or description of the speaker. On the new approach using a synthesized context, on the other hand, the partially specified denotation of the pronoun *I* is not completed in terms of reconstructing the context-variable in the translation formula, but the context-variable is instead defined as a pointer to the speaker as represented in the synthesized context. Thus Kaplan's (1977) idea of direct reference is formally accommodated.

Analyzing indexical interpretations of context-variables in terms of direct reference serves an important function in the analysis of matching a synthesi-

zed token with a synthesized context. While ordinary denoting expressions are almost always open to metaphorical or other non-literal interpretations, this does not hold for indexicals. Contextual reconstruction of indexicals would obscure and neutralize this crucial difference between normal constants and indexicals. Direct reference, on the other hand, captures the anchoring function of indexicals in the process of reference, i.e. the process of matching a synthesized token with a synthesized context.

For the anaphoric interpretation of context-variables, however, direct reference is not suitable. Since pronouns on their anaphoric interpretation do not depend on the context but rather on their surface antecedent, we continue to analyze anaphoric interpretations in terms of contextual reconstruction. Thus the linguistic analysis of pronouns in Hausser (1979) remains unchanged. A sentence like (16), for example,

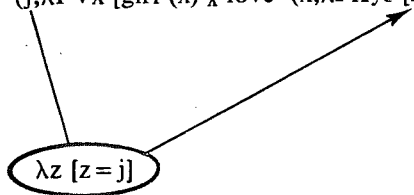
(16) John sees the girl who loves him

translates unambiguously into (17)

(17) $see'(j, \lambda PVx [girl'(x) \wedge love'(x, \lambda P\Lambda y \epsilon [\Gamma_3(y) \wedge male'(y)]^1 P(y))])$

The anaphoric interpretation of (17) may be indicated as follows:

(18) $see'(j, \lambda PVx [girl'(x) \wedge love'(x, \lambda P\Lambda y \epsilon [\Gamma_3(y) \wedge male'(y)]^1 P(y))])$

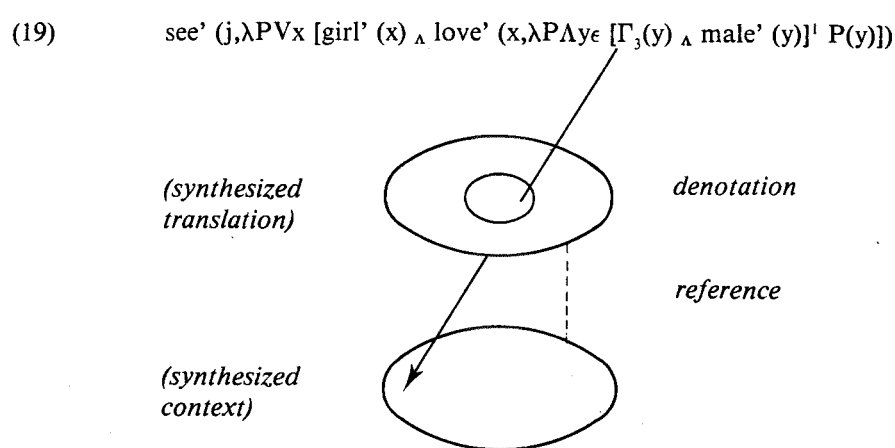


reconstruction:

$see'(j, \lambda PVx [girl'(x) \wedge love'(x, \lambda P\Lambda y \epsilon [(y = j) \wedge male'(y)]^1 P(y))])$

Thus the contextual reconstruction of (17) renders a formula equivalent to « John sees a girl who loves John ».

The indexical interpretation of (17), on the other hand, where *him* refers to a person in the context, may be illustrated as follows:



The denotation of the pronoun in (19) is only partially specified insofar as the denotation of the context-variable is not given beyond the domain/range structure determined by the semantic type of the context-variable. Instead the *referent* of the pronoun (or rather the context-variable) is determined directly over a "reference condition" for Γ_3 .

Our analysis follows Hausser (1979) in that the difference between the indexical and the anaphoric interpretation of (16) is not treated in terms of a syntactico-semantic ambiguity, but rather in terms of alternative interpretations of the context-variable Γ_3 . However, while the rules of contextual reconstruction (which continue to apply in the anaphoric interpretation of pronouns) are defined as part of the semantic interpretation according to Hausser (1979), the interpretation of indexicals in terms of direct reference must be classified as part of pragmatics. Thus our present analysis recognizes a greater theoretical difference between anaphoric and indexical interpretations of pronouns than my earlier paper. But the distinction is still on the level of semantico-pragmatic *interpretation* and not on the level of syntactico-semantic analysis. In summary: anaphorically interpreted pronouns denote (once they are reconstructed) while indexically interpreted pronouns refer directly.

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