The Four Basic Ontologies of Semantic Interpretation

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Abstract

This paper compares the semantic interpretation of logical, programming, and natural languages. It shows that they are based on different ontologies, and investigates the relation between the ontology assumed and the analysis of empirical phenomena such as truth, the Epimenides paradox, propositional attitudes, and vagueness. Furthermore, it shows that there is a basic difference between a metalanguage-based and a procedural semantics, and that the choice between them depends on the ontology presumed.

1 Metalanguage-based semantics

In logic, a semantic relation between the formal language and the world is established by defining the (object-)language, the world (model), and the relation between them in terms of a metalanguage definition. The theory behind this method was presented by ALFRED TARSKI (1902–1983) in a form still valid today.

In logical semantics, the task of the interpretation is to specify under which circumstances the expressions of the object language are true. The object language is the language to be semantically interpreted (e.g. quoted expressions like 'ϕ & ψ'), while the definitions of the semantic interpretation are formulated in a metalanguage. Tarski's schema for characterizing truth is the so-called T-condition.

1.1 Schema of Tarski's T-condition

T: x is a true sentence if and only if p.

The T-condition as a whole is a sentence of the metalanguage, which quotes the sentence x of the object language and translates it as p. Tarski illustrates this method with the following example:

1.2 Instantiation of Tarski's T-condition

'Es schneit' is a true sentence if and only if it snows.

This example is deceptively simple, and has resulted in misunderstandings by many non-insiders.[1] What the provocative simplicity of 1.1 and 1.2 does not express when

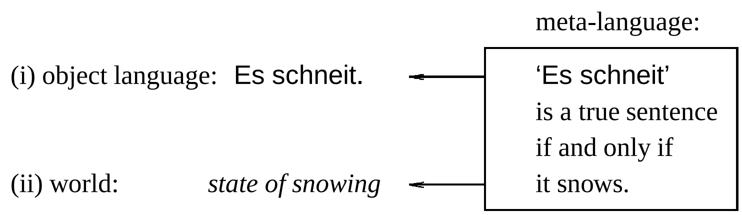
[1] Tarski 1944 complains about these misunderstandings and devotes the second half of his paper to a detailed critique of his critics.

viewed in isolation is the exact nature of the *two-level structure*, which underlies all forms of semantic interpretation.

The purpose of the T-condition is not a redundant repetition of the object language expression in the metalanguage translation. Rather, the T-condition has a twofold function. One is to construct a connection between the object language and the world by means of the metalanguage; thus, the metalanguage serves as the means for realizing the *assignment*. The other is to characterize truth: the truth-value of x in the object language is to be determined via the interpretation of p in the metalanguage.

Both functions require that the metalanguage can refer directly to (i) the object language and (ii) the correlated state of affairs in the world (model).

1.3 Relation between object and metalanguage

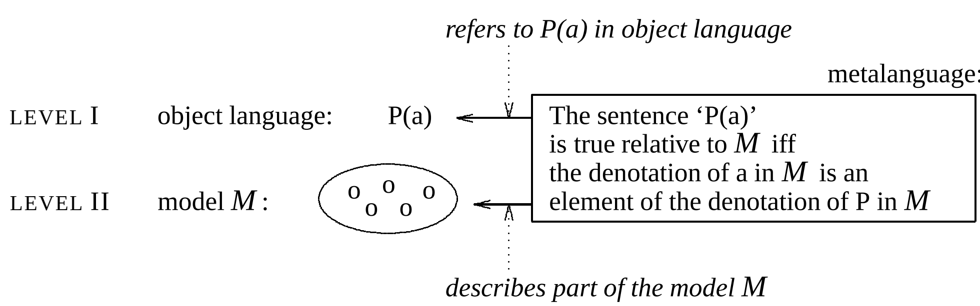


The direct relation of the metalanguage to the world is the basis of *verification*. It consists in the ability to actually determine whether p holds or not. For example, in order to determine whether Es schneit is true or not, it must be possible to determine whether or not it actually snows. Without ensuring the possibility of verifying p, the T-condition is (i) vacuous for the purpose of characterizing truth and (ii) dysfunctional for the purpose of assigning semantic objects.

According to Tarski, (i) all the basic expressions of the metalanguage must be explicitly listed and (ii) each expression of the metalanguage must have *a clear meaning* (op.cit., p. 172). This conscientious formal approach to the metalanguage is exemplified in Tarski's 1935 analysis of the calculus of classes, which illustrates his method in formal detail. The only expressions used by Tarski in this example are notions like not, and, is contained in, is element of, individual, class, and relation. The meaning of these expressions is immediately obvious insofar as they refer to the most basic mathematical objects and set-theoretic operations.

The same holds for the semantic rules in standard first-order predicate calculus, for which reason it constitutes a well-defined Tarskian semantics. Such a semantic definition is shown in 1.4 as a T-condition like 1.3.

1.4 T-condition in a logical definition



The possibility to verify the T-condition 1.4 is guaranteed by no more and no less than the fact that for any given model M anyone who speaks English and has some elementary notion of set theory can *see* (in the mathematical sense of immediate obviousness) whether the relation specified in the translation part of T holds in M or not.

In the history of mathematics, the appeal to immediate obviousness has always served as the ultimate justification:

> En l'un les principes sont palpables mais éloignés de l'usage commun de sorte qu'on a peine à tourner late tête de ce côte-la, manque d'habitude : mais pour peu qu'on l'y tourne, on voit les principes à peine; et il faudrait avoir tout à fait l'esprit faux pour mal raisonner sur des principes si gros qu'il est presque impossible qu'ils échappent.
>
> [In [the mathematical mind] the principles are obvious, but remote from ordinary use, such that one has difficulty to turn to them for lack of habit : but as soon as one turns to them, one can see the principles in full; and it would take a thoroughly unsound mind to reason falsely on the basis of principles which are so obvious that they can hardly be missed.]
>
> B. PASCAL (1623 -1662), *Pensées*, 1951:340

Tarski's method is limited to the domains of mathematics, logic, and natural science insofar as only there sufficiently certain methods of verification are available.

2 Procedural semantics

In contrast to the semantic definition 1.4, the following instantiation of the T-conditions violates the precondition of verifiability.

2.1 Example of a vacuous T-condition

'A is red' is a true sentence if only if A is red.

This example is formally correct but vacuous because it does not relate the meaning of the object language expression red to some verifiable concept of the metalanguage. Instead the expression of the object language is merely repeated in the metalanguage.

Within the boundaries of its set-theoretic foundations, model-theoretic semantics has no way of providing a truth-conditional analysis for content words like red such that its meaning would be characterized adequately in contradistinction to, e.g. blue. There exists, however, the possibility of extending the metatheory by calling in additional sciences such as physics.

From such an additional science one may select a small set of new basic notions to serve in the extended metalanguage. The result functions properly if the meaning of the additional expressions is verifiable within the extended metatheory.

In this way we might improve the T-condition 2.1 as follows:

2.2 Improved T-condition for red

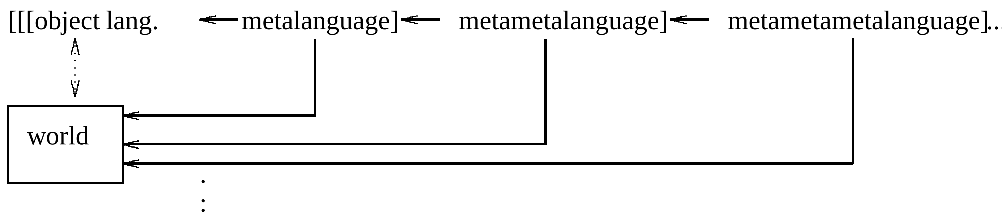
'A is red' is a true sentence if and only if A refracts light in the electromagnetic frequency interval between α and β.

Here the metalanguage translation relates the object-language expression red to more elementary notions (i.e. the numbers α and β within an empirically established frequency scale and the notion of refracting light, which is well-understood in the domain of physics) and thus succeeds in characterizing the expression in a non-vacuous way.

Examples like 2.1 show that the object-language may contain sentences for which there are only vacuous translations in the given metalanguage. This does not mean that a sentence like 'x is red' is not meaningful or has no truth-value. It only means that the metalanguage is not rich enough to provide the basis for a verification of the sentence. This raises the question of how to handle the semantics of the metalanguage, especially regarding the parts which go beyond the elementary notions of its metatheory.

Tarski's answer is the construction of an infinite hierarchy of metalanguages.

2.3 Hierarchy of metalanguages



The accuracy of this analysis of truth corresponds directly to the degree in which the expressions of the object language are related to verifiable notions of the $\{meta\}^{+}$language. That Tarski's infinite hierarchy of metalanguages makes total access to truth ultimately impossible, at least for mankind, is not regarded as a disadvantage of this construction – on the contrary, it constitutes a major part of its philosophical charm.

For the semantics of programming languages, however, a hierarchy of metalanguages is unsuitable. Consider, e.g., basic addition, multiplication, etc. The problem is not to provide an adequate metalanguage definition for them. Rather, the road from such a metalanguage definition to a working calculator is quite long, and in the end the calculator will function mechanically – without any reference to these metalanguage definitions and without any need to understand the metalanguage.

This has been called the *autonomy from the metalanguage*. It is characteristic of all programming languages. Autonomy from the metalanguage does not mean that computers would be limited to uninterpreted, purely syntactic deduction systems, but rather that Tarski's method is not the only one possible. Instead of the Tarskian method of assigning semantic representations to an object language by means of a metalanguage, computers use an operational method in which the notions of the programming language are executed automatically as electronically realized operations.[2]

3 Epimenides paradox

The next question is whether a metalanguage-based semantics would be suitable for the interpretation of the natural languages. Tarski himself leaves no doubt that a complete analysis of natural languages is impossible within logical semantics.

[2]Because the semantics of programming languages is procedural (i.e. metalanguage-independent), while the semantics of logical calculi is Tarskian (i.e. metalanguage-dependent), the reconstruction of logical calculi as computer programs usually requires profound compromises on the side of the calculus – as illustrated, for example, by the computational realization of predicate calculus in the form of Prolog.

> The attempt to set up a structural definition of the term ‘true sentence’ – applicable to colloquial language – is confronted with insuperable difficulties.
>
> Tarski 1935, p. 164.

Tarski proves this conclusion on the basis of a classical paradox, called the Epimenides, Eubolides, or liar paradox.

The paradox is based on self-reference. Its original ‘weak’ version has the following form: if a Cretan says, All Cretans (always) lie, there are two possibilities. Either the Cretan speaks truly, in which case it is false that *all* Cretans lie – since he is a Cretan himself. Or the Cretan lies, which means that there exists at least one other Cretan who does not lie. In both cases the sentence in question is false.[3]

Tarski 1935 uses the paradox in the ‘strong’ version designed by Leśniewski and constructs from it the following proof that a complete analysis of natural language within logical semantics is necessarily impossible.

> For the sake of greater perspicuity we shall use the symbol ‘c’ as a typological abbreviation of the expression ‘the sentence printed on page 5 , line 17 from the top.’ Consider now the following sentence:
>
> c is not a true sentence
>
> Having regard to the meaning of the symbol ‘c’, we can establish empirically:
> (a) ‘c is not a true sentence’ is identical with c.
> For the quotation-mark name of the sentence c we set up an explanation of type (2) [i.e. the T-condition 1.1]:
> (b) ‘c is not a true sentence’ is a true sentence if and only if c is not a true sentence.
> The premise (a) and (b) together at once give a contradiction:
> c is a true sentence if and only if c is not a true sentence.
>
> Tarski 1935

In this construction, self-reference is based on two preconditions. First, a sentence located in a certain line on a certain page, i.e. line 17 from the top on page 5 in the current Section 3, is abbreviated as ‘c’.[4]

Second, the letter ‘c,’ with which the sentence in line 17 from the top on page 5 is abbreviated also occurs in the unabridged version of the sentence in question. This permits to substitute the c in the sentence by the expression which the ‘other’ c abbreviates. There are three possibilities to avoid this contradiction in the T-condition.

The first consists in forbidding the abbreviation and the substitution based on it. This possibility is rejected by Tarski because “no rational ground can be given why substitution should be forbidden in general.”

The second possibility consists in distinguishing between the truth predicate ‘true^o’ of the object language and ‘true^m’ of the metalanguage. In this approach,

c is true^o if and only if c is not true^m.

is not contradictory, because $\text{true}^o \neq \text{true}^m$. Tarski does not consider this possibility, presumably because the use of more than one truth predicate runs counter to the most fundamental goal of logical semantics, namely a formal characterisation of *the* truth.

The third possibility, chosen by Tarski, is to forbid the use of truth predicates in the object language. For the original goals of logical semantics this third option poses no problem. Characterizing scientific theories like physics as true relations between

[3]For a detailed analysis of the weak version(s) see C. Thiel, 1995, p. 325–7.

[4]The page and line numbers have been adjusted from Tarski’s original text to fit those of this Section. This adjustment is crucial in order for self reference to work properly.

logical propositions and states of affairs does not require a truth predicate in the object language. The same holds for formal theories like mathematics.

Furthermore, for many mathematical logicians the development of semantically interpreted logical calculi was motivated by the desire to avoid the vagueness and contradictions of the natural languages. Frege 1896 (1967, p. 221) expresses this sentiment as follows:

> Der Grund, weshalb die Wortsprachen zu diesem Zweck [i.e. Schlüsse nur nach rein logischen Gesetzen zu ziehen] wenig geeignet sind, liegt nicht nur an der vorkommenden Vieldeutigkeit der Ausdrücke, sondern vor allem in dem Mangel fester Formen für das Schließen. Wörter wie >also<, >folglich<, >weil< deuten zwar darauf hin, daß geschlossen wird, sagen aber nichts über das Gesetz, nach dem geschlossen wird, und können ohne Sprachfehler auch gebraucht werden, wo gar kein logisch gerechtfertigter Schluß vorliegt.
>
> [The reason why the word languages are suited little for this purpose [i.e., draw inferences based on purely logical laws] is not only the existing ambiguity of the expressions, but mainly the lack of clear forms of inference. Even though words like 'therefore,' 'consequently,' 'because' indicate inferencing, they do not specify the rule on which the inference is based, and they may be used without violating the wellformedness of the language even if there is no logically justified inference.]

In light of this widely held view it is understandable that Tarski rejected any attempt to apply his method of semantic interpretation to natural languages.

Because the natural languages *must* contain the words true and false[5] a logical semantic interpretation of a natural (object-)language in its entirety will unavoidably result in a contradiction. Tarski's student RICHARD MONTAGUE (1930–1970), however, was undaunted by this conclusion.

> I reject the contention that an important theoretical difference exists between formal and natural languages. ... Like Donald Davidson I regard the construction of a theory of truth – or rather the more general notion of truth under an arbitrary interpretation – as the basic goal of serious syntax and semantics.
>
> Montague 1970, *"English as a formal language"*[6]

We must assume that Montague knew the Epimenides paradox and Tarski's related work. But in his papers on the semantics of natural languages Montague does not mention this topic at all. Only Davidson, who Montague refers to in the above quotation, is explicit:

> Tarski's ... point is that we should have to reform natural language out of all recognition before we could apply formal semantic methods. If this is true, it is fatal to my project.
>
> Davidson 1967

A logical paradox is fatal because it destroys a semantical system. Depending on which part of the contradiction an induction starts with, one can always prove both, a theorem and its negation. And this is not acceptable for a theory of truth.[7]

[5] This follows from the role of natural languages as the pretheoretical metalanguage of the logical languages. Without the words *true* and *false* in the natural languages a logical semantics couldn't be defined in the first place.

[6] P. 188 in Montague 1974.

[7] As a compromise, Davidson suggested to limit the logical semantic analysis of natural language to suitable consistent fragments of natural language. This means, however, that the project of a complete

4 Propositional attitudes

Another basic problem for a logical semantics of natural language are propositional attitudes. They are expressed by sentences which describe the relation between a cognitive agent and a propositional content. For example, the sentence

Suzanne believes that Cicero denounced Catiline.

expresses the propositional attitude of *belief* as a relation between Suzanne and the proposition Cicero denounced Catiline.

According to the intuitions of modal logic, a proper name denotes the same individual in all possible worlds (rigid designators, Kripke 1972). For example, because Cicero and Tullius are names for one and the same person, it holds necessarily (i.e, in all possible worlds) that Cicero = Tullius. Therefore, it follows necessarily from the truth of Cicero denounced Catiline that Tullius denounced Catiline.

However, if one of these sentences is embedded under a predicate of propositional attitude, e.g., believe, the substitution *salva veritate* is not valid even for proper names. Thus, according to intuition, Suzanne believes that Cicero denounced Catiline does not imply thatSuzanne believes that Tullius denounced Catiline. Even though the referent of Cicero is necessarily identical with the referent of Tullius, it could be that Suzanne is not aware of this. Accordingly, a valid substitution *salva veritate* would require in addition the truth of Suzanne believes that Cicero is Tullius.

Because different human beings may have very different ideas about the external reality, a treatment of propositional attitudes in the manner of Carnap and Montague would have to model not only the realities of natural science, but also the belief structures of all the individual speakers-hearers.[8] In order to determine what an individual believes, however, one is dependent on what the individual choses to report. Because it cannot be checked objectively whether this is true or not, individual 'belief-worlds' have always been regarded as a prime example of what lies outside the scientific approach to truth.[9]

The phenomenon of propositional attitudes raises the following question for a model-theoretic semantics of natural language:

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logical semantic analysis of natural languages is doomed to fail.

Attempts to avoid the Epimenides paradox in logical semantics are Kripke 1975, Gupta 1982, and Herzberger 1982. These systems each define an artificial object language (first order predicate calculus) with truth predicates. That this object language is nevertheless consistent is based on defining the truth predicates as *recursive valuation schemata*.

The technique of recursive valuation schemata is based on a large number of valuations (transfinite in the case of Kripke 1975). Moreover, recursive valuation schemata miss the point of the Epimendes paradox, which is essentially a problem of reference: a symbol may refer on the basis of its meaning and at the same time be a referent on the basis of its form.

[8] In purely formal terms one could define a 'believe-operator' B as follows:

$$B(\text{x, p})^{M,i,j,g} \text{ is 1 iff } \mathsf{p}^{M,b,j,g} \text{ is 1, whereby } b \text{ is a belief-world of x at index i,j.}$$

However, one should not be fooled by this seemingly exacting notation, which imitates Montague's PTQ. This T-condition is just as vacuous as 2.1 as long as it is not clear how the metalanguage definition should be verified relative to belief-worlds.

[9] In logical semantics, an ontological problem similar to individual belief-worlds is created by individual sensations, like a tooth ache, which do not exist in the same way as real objects in the world. The so-called *double aspect theory* attempts to make such sensations 'real' to the outside observer by means of measurings brain waves. By associating the phenomenon *pain* with both, (i) the individual sensation and (ii) the corresponding measurement, this phenomenon is supposed to obtain an ontological foundation acceptable to logical semantics. A transfer of this approach to the truth-conditional analysis of belief would require infallible lie detectors.

4.1 The basic ontological problem of model theory

Is the speaker-hearer part of the model structure or
is the model structure part of the speaker-hearer?

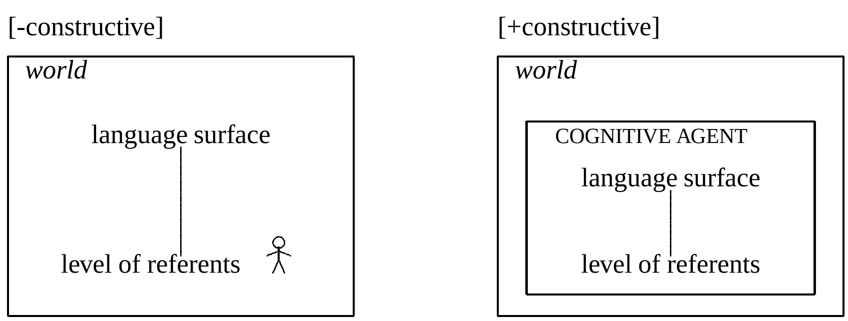
If the goal of semantics is to characterize truth, then one may use only logical meanings which are presupposed to be immediately obvious and eternal. On this approach the speaker-hearer must be part of the model structure. Thereby, the relation of truth between expressions and states of affairs exist independently of whether it is discovered by this or that speaker-hearer or not.[10]

Yet if the goal is the analysis of language meaning, then the logical system, which was developed originally for the characterization of truth based on logical meanings, is used for a new purpose, namely the description of language meanings in the form of truth conditions. In order for the meanings of language to be used in communication by the speaker-hearer they must be part of cognition. Therefore, the analysis of natural language meanings within logical semantics leads necessarily to a reinterpretation of the model structure as something cognitive which is part of the speaker-hearer.

The cognitive (re-)interpretation of the model as part the speaker-hearer is incompatible with the goals and methods of traditional theories of truth. Conversely, the 'realistic' interpretation of the model within a theory of truth is incompatible with the analysis of natural language meaning.[11]

The alternative stated in 4.1 is characterized schematically in 4.2, whereby the difference is specified in terms of the binary feature [±constructive].

4.2 Two interpretations of model theory



The [-constructive] interpretation establishes the relation between the language surfaces and the level of referents outside the cognitive agent out there in the real world. The agent is itself an object at the level of referents, who may observe this relation between language and the objects of the world.

[10]The main stream view in philosophical logic does not require that a representation of scientific truth includes the speaker-hearer as part of the model. The only reason why a speaker-hearer is sometimes added to a model-theoretic logic is the treatment of special phenomena characteristic of natural language, especially the interpretation of indexical pronouns like I and you. Thereby the speaker-hearer is in principle part of the model structure – making it impossible to provide an adequate truth-conditional treatment of propositional attitudes, for the reasons given above. A detailed critique of the outmoded 'received view' in the theory of science, as well as its alternatives, may be found in F. Suppe 1977.

[11]There are examples known in mathematics where a basic formal theory happens to allow more than one interpretation, e.g. geometry. This does not mean, however, that any formal theory may in general be used for any new interpretation desired. A case in point is logical semantics, whose formalism cannot be interpreted simultaneously as a general description of truth and a general description of natural language meaning – as shown by the phenomenon of propositional attitudes.

The [+constructive] interpretation, on the other hand, establishes the relation between the language surfaces and the level of referents solely inside the the cognitive agent. What the agent does not perceive in the world plays no role in his reference procedures, though what he feels, wishes, plans, etc., does.

Note that [–constructive] systems *must* have a metalanguage-based, while [+constructive] systems *must* have a procedural semantics. This is because scientific statements believed to be eternally valid and independent of any speaker-hearer cannot be meaningfully operationalized. Computers or cognitive agents, on the other hand, are simply useless without a procedural semantics.

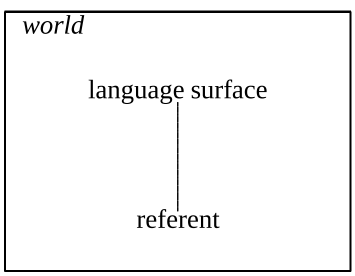
5 The four basic ontologies

Another basic distinction in systems of semantic interpretation may be represented by the feature [± sense]. It expresses whether the meaning of language is identified with the objects referred to ([–sense]), or whether meaning is characterized on a separate level as a Fregean ‘Sinn’ which is distinct from the objects referred to ([+sense]).

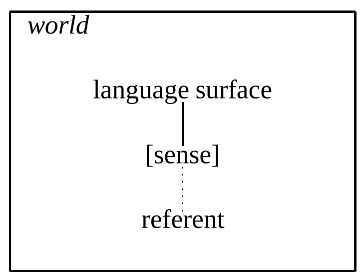
The features [± sense] and [± constructive] are independent of each other and can therefore be combined. This results in the following four types of semantic interpretation based on four basic ontologies.

5.1 Alternatives of semantic interpretation

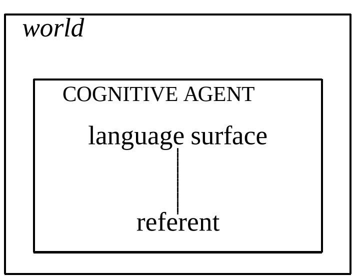
i [–sense, –constructive]
Russell, Carnap, Quine, Montague



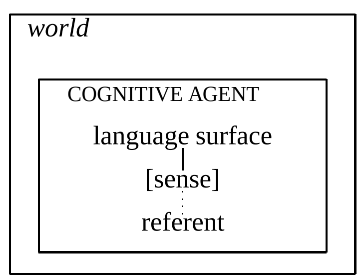
ii [+sense, –constructive]
Frege



iii [–sense, +constructive]
Newell & Simon, Winograd, Shank



iv [+sense, +constructive]
Anderson, CURIOUS, SLIM-machine



These different ontologies have been adopted by different schools of semantic interpretation.

The [–sense,–constructive] ontology (**i**) is the basis of logical semantics. Concerned with a solid foundation for truth, it uses only referents which are considered to be ontologically real. In nominalism, these are the concrete signs of language and the states of affairs built up from concrete objects. In mathematical realism, the ontology is extended to include abstract objects like sets and numbers. Both have in common that the semantics is defined as a direct, external relation between language and the world. This type of semantics has been adopted by the main stream of modern philosophical logic, from Russell via the early Wittgenstein, Carnap, Montague,[12] to Putnam.

The [+sense,–constructive] ontology (**ii**) was used by Frege in his attempt to analyze uneven (opaque, intensional) readings in natural language. For modeling the mechanics of natural language communication, this type of semantics is only half a step in the right direction. As a theory of truth, any [-constructive] semantics is incompatible with representing cognitive states.[13]

The [–sense,+constructive] ontology (**iii**) is that of the semantics of programming languages. The user puts commands (surfaces of the programming language) into the computer, which turns them directly into corresponding electronic procedures. When a result has been computed, it is communicated to the user by displaying language expressions on the screen. In this traditional use, a computer is still a far cry from a cognitive agent. But there is already the important distinction between the *task environment* in the 'world' and the computer internal *problem space*, whereby the semantic interpretation is located in the latter.

Because of their origin as conventional programs on conventional computers most systems of artificial intelligence are based – subconsciously, so to speak – on a [–sense,+constructive] ontology. This holds, for example, for SHRDLU (Winograd 1972), HEARSAY (Reddy et al. 1973) and SAM (Schank & Abelson 1977). In cognitive psychology this ontology has been used as well, for example in the *mental models* by Johnson-Laird 1983.

Within artificial intelligence, Newell & Simon 1972, p. 66, have argued explicitly against an intermediate level of sense – for purely ontological reasons. They argue that the distinction between language meanings (sense) and the computer internal referents would result "in an unnecessary and unparsimonious multiplication of hypothetical entities that has no evidential support."

A direct connection between language expressions and their referents, however, prevents any autonomous classification of new objects in principle. Therefore, a [–sense,+constructive] type of semantics is limited to closed toy worlds created in advance by the programmer.[14]. It is by no means accidental that these systems have no components of artificial perception: because they lack the intermediate level of concepts (sense) they could not utilize perception (e.g., artificial vision) to classify and to automatically integrate new objects into their domain.

The [+sense,+constructive] ontology (**iv**), finally, underlies the SLIM theory of language.[15] SLIM bases its [+sense] property structurally on the matching of the literal

[12]The intensional logic by Carnap and Montague is [–sense] because expressions refer directly to the 'world'. Apart from the definition of a few additional operators, the only difference between intensional logic and a corresponding extensional system consists in the fact that in intensional logic the world is represented not just be a single model but rather by a model structure. The model structure represents different states of the world, represented by a multitude of models which have different indices. The indices provide the formal domain for functions which Carnap calls intensions.

[13]Accordingly, Frege defended himself explicitly against misinterpreting his system as representing cognitive states, which would be what he called 'psychologistic'. Recently, 'Situation Semantics' (Barwise & Perry 1983) and 'Discourse Semantics' (Kamp & Reyle 1993) have attempted to revive the [+sense, –constructive] type of semantics. Their inherently anti cognitive point of view is clearly depicted in Barwise & Perry 1983, p. 226, in the form of diagrams.

[14]Examples are the chess board (Newell & Simon, Reddy et al.) and the blocks world (Winograd).

[15]The acronym SLIM stands for ***S****urface compositional* ***L****inear* ***I****nternal* ***M****atching*.

meaning and the context of use, while its [+constructive] property is based on the fact that this matching occurs inside the cognitive agent. In cognitive psychology, this type of semantics has been used by Anderson & Bower 1973 and 1980. They present a general psychological model of natural language understanding, which may be interpreted as an internal matching of language concepts onto a context structure.

The theoretical relation between the four alternative types of semantics may be analyzed by either emphasizing their ontological difference or their formal similarities. In the latter case, one will present one's semantics as a purely formal structure which may be assigned different interpretations without affecting the formal essence. For this, one may relate the different ontologies in terms of different degrees of specialization or generalization.

The difference between a [+sense] and a [-sense] ontology may be minimized by interpreting the latter as a simplification of the former. Assume that (i) the world is closed such that objects can neither appear nor disappear, (ii) the relation between language expressions and their referents is fixed once and for all, and (iii) there is no spontaneous use of language by the speaker-hearer. Then there is no reason for postulating a level of senses, thus leading to a [-sense] system as a special case of a [+sense] system.

Because of this simplification one might view the [-sense] system as more valid or more essential than the [+sense] system. One should not forget, however, that there are empirical phenomena which simply cannot be handled within a [-sense] ontology, such as the reference to new objects of a known type.

The difference between [+constructive] and a [-constructive] ontology may also be minimized in terms of a simplification. Assume that the cognitive agent has perfect recognition, such that the distinction between the external objects (i.e. language expressions and referents) and their internal cognitive representations may be neglected. Then there is no reason to distinguish between the external reality and its internal cognitive representation, thus leading to a [-constructive] ontology as a special case of a [+constructive] ontology.

Because of this simplification, one might view the [-constructive] system as more valid and more essential than the [+constructive] system. One should not forget, however, that there are empirical phenomena which simply cannot be handled within a [-constructive] ontology, such as propositional attitudes.

The choice between the four different types of semantics depends on the intended application. Therefore, when (i) *expanding* a given semantics to a new application or when (ii) *transferring* partial analyses from one application to another, one should be as well-informed about the structural differences between the four basic ontologies as about the potential formal equivalences based on simplifying abstractions.

6 Sorites paradox and the treatment of vagueness

The importance of ontology for the empirical analysis of a semantic phenomenon is illustrated by the phenomenon of vagueness. In logical semantics, the treatment of vagueness takes a classic paradox from antiquity as its starting point, namely the Sorites paradox or paradox of the heap.

> One grain of sand does not make a heap. Adding an additional grain still doesn't make a heap. If *n* grains do not form a heap, then adding another single grain will not make a heap either. However, if this process of adding a grain is continued long enough, there will eventually result a genuine heap.

The Sorites paradox has been carried over to the logical semantics of natural language by arguing as follows: consider the process of, e.g., a slowly closing door. Doesn't it raise the question at which point the sentence The door is open is still true and at which point it is false? Then one goes one step further by asking to which *degree* the sentence is true in the various stages of the door closing.

> Sensitive students of language, especially psychologists and linguistic philosophers, have long been attuned to the fact that natural language concepts have vague boundaries and fuzzy edges and that, consequently, natural-language sentences will very often be neither true, nor false, nor nonsensical, but rather true to a certain extent and false to a certain extent, true in certain respects and false in other respects.
>
> George Lakoff 1972, p. 183

Another situation which as been presented as an example of truth-conditional vagueness is the classification of colors. If an object is classified as *red* in context a, but as *non-red* in context b, doesn't it follow that the natural language concept *red* must be vague? If the predicate x is red is applied to the transition from red to orange in a color spectrum, the situation resembles the slowly closing door.

If these assumptions are accepted and sentences are true or false only to certain degrees, then the traditional two-valued (bivalent) logic be extended into a many-valued logic. The non-bivalent logics may be divided into two basic groups, namely the *three-valued* logics, in which a proposition can be true (1), false (0), or undetermined (#), and the *many-valued* logics, in which truth-values are identified with the real numbers between 0 and 1, e.g. 0.615. The three-values logics and the many-valued logics all suffer from the same basic problem:

> Which truth-value should be assigned to complex propositions based on component propositions with non-bivalent truth-values?

For example,what should be the value of, e.g., 'A & B' if A has the value 1 and B has the value #? Similarly in a many-valued system: if the component proposition A has the truth-value 0.615 and B has the value 0.423, what value should be assigned to 'A & B'?

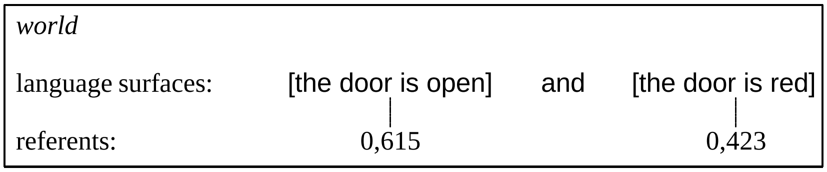
There is a wealth of possible answers to these questions. Rescher 1969 describes 51 different systems of non-bivalent logics proposed in the literature up to that date. From a history of science point of view, such a multitude of different alternatives is a clear case of an *embarrassment of riches* in combination with *descriptive aporia*. These two syndromes are an infallible sign that there is something seriously wrong with the basic premises of the approach in question.

In multivalued logic systems, the mistake resides in the premise formulated in the above quotation from Lakoff that propositions may obviously have non-bivalent truth-values. Once this premise has been accepted, one is stuck in a futile search for adequate value assignments to complex propositions, e.g. the question which truth-value should be assigned to 'A & B' if A has the truth-value 0.615 and B has the truth-value 0.423.

Instead of accepting this premise we should ask instead how such peculiar truth-values like 0.615 come about in the first place. And with this question we come back to the issue of the underlying ontology. More precisely: what impact has the structural difference between the [-sense,-constructive] and the [+sense, +constructive] ontology on the formal analysis of vagueness?

We begin with the analysis of an example within the [-sense,-constructive] ontology of logical semantics. Let's assume that 'A & B' is a proposition, where A = [The door is open] and B = [The door is red]. Furthermore, let A have the value 0.615 and B the value 0.423. Then the conjunction has the following structure:

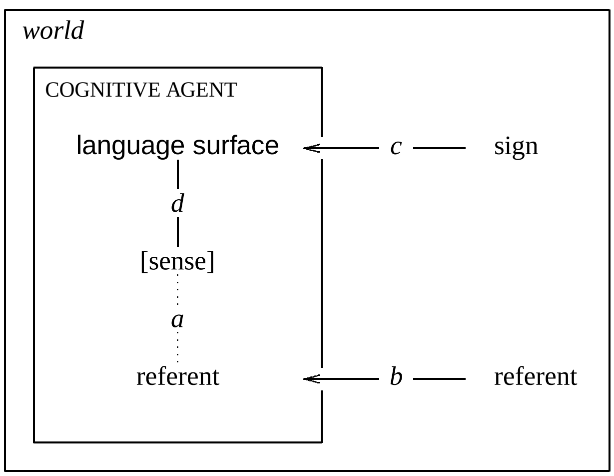
6.1 Vagueness in [-sense,-constructive] semantics



In 6.1 the propositions A and B are assigned the truth-values 0.615 and 0.423 as their referents. How these component propositions obtain their peculiar values is regarded as something outside the jurisdiction of logical theory. The artificial values of ‘A’ and ‘B’ are blindly accepted and the whole discussion is focused on the question of which truth-value should now be assigned to ‘A & B.’

A completely different analysis of this example results on the basis of a [+sense, +constructive] ontology. Its structure contains four different positions which may be postulated as a source of vagueness.

6.2 Vagueness in [+sense,+constructive] semantics



Position *d* corresponds to the vertical lines in 6.1, because there the meanings are assigned to the language surfaces. The places *a*, *b* and *c* have been added by the transition to a [+sense,+constructive] ontology. In contradistinction to position *d*, they have in common that they are interfaces based on matching.

Within a [+sense,+constructive] ontology, the most natural place for handling vagueness is *a*. This is because there a language meaning, e.g., the concept of red is matched with a restricted set of potential contextual referents. This procedure is based on the principle of *best match* within a restricted subcontext.

For example, the word red may be used to refer to a pale pink stone, provided that the other objects in the subcontext are, e.g., grey. As soon as a bright red stone is added, however, the candidate for best match changes and the pale pink stone will now be counted among the non-red objects. This is not due to a special ‘vagueness’-property of the color concept *red*, but rather to a change in the context.

Other places where vagueness may arise naturally are *b* and *c*. In *b*, vagueness is caused by imprecise perception of the task environment. In *c*, it is caused by imprecise recognition of language expressions. In either case, vagueness originates in the interaction of the cognitive agent with the external environment and may influence communication by affecting the matching procedure *a*.

Thus, the alleged vagueness of the color words does not arise in their semantics. Instead it is a normal consequence of matching a language concept and a contextual referent in the pragmatics, a procedure based on the principle of best match in a restricted context of use. This analysis of the semantics and pragmatics of the color terms can easily be realized operationally within the construction of a robot by defining concepts like red as intervals of electromagnetic frequency.

7 Absolute and contingent truth

In logic, the term proposition has acquired a special use, representing sentences which do not require knowledge of the utterance situation for their interpretation. From the viewpoint of natural language, this is problematic because it constitutes a hybrid between an *utterance* (i.e. a pragmatically interpreted or interpretable token) and an *expression* (i.e. a pragmatically uninterpreted type). This problem shows up in the distinction between absolute and contingent propositions.

Absolute propositions express scientific or mathematical contents. For example, in the proposition

> In a right-angled triangle, it holds for the hypotenuse A and the cathetes B and C that $A^2 = B^2 + C^2$

the circumstances of the utterance have no influence on the interpretation and the truth value of the sentence in question, for which reason they are ignored. The special properties of absolute propositions are reflected in logical truth, formally expressed by the metalanguage words false and true referring to the abstract set-theoretic objects $\emptyset$ und $\{\emptyset\}$, respectively, of the model structure.

Contingent propositions, on the other hand, are based on sentences with everyday contents such as

> Your dog is doing well.

Contingent propositions can only be interpreted – and thereby evaluated with respect to their truth value – if the relevant circumstances of the utterance situation are known and entered into the interpretation. This requires that the parameters of origin be known, i.e. the location, the time, the person of the speaker, and the person addressed.

The characteristic properties of contingent propositions correspond to a natural notion of truth, represented by the truth values true^c and false^c. Intuitively, a contingent proposition such as

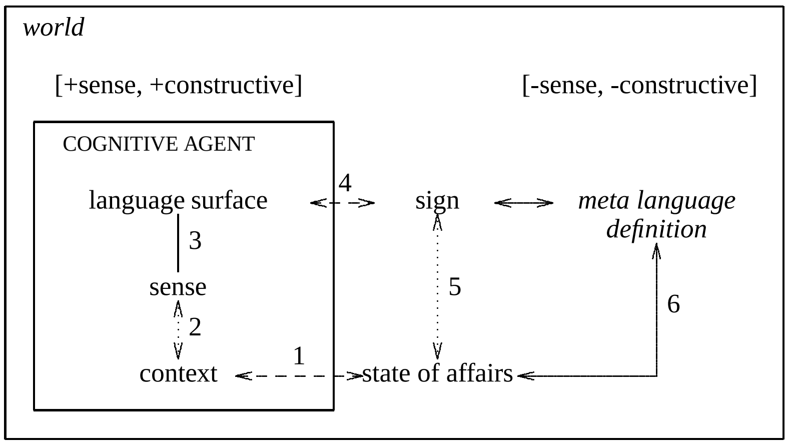
> The Persians have lost the battle

may be regarded as true^c, if the speaker is an eye witness who is able to correctly judge and communicate the facts, or if there exists a properly functioning chain of communication between the speaker and a reliable eye witness.

The natural truth values true^c and false^c have a procedural definition: A proposition – or rather a statement – uttered by, e.g., a cognitive agent (e.g. a robot) is evaluated as true^c, if all procedures contributing to communication work correctly. Otherwise it is evaluated as false^c.

The differences in the truth predicates of natural and logical semantics derive from structural difference between their respective [–sense,–constructive] and [+sense, +constructive] ontologies.

7.1 Ontological foundation of natural and logical truth



Both systems treat relation 5 between the external expression (sentence) and the external state of affairs as crucial for the truth of this type of statement. But they use completely different methods and concepts to realize this relation.

The [–sense,–constructive] system defines relation 5 directly by means of a suitable metalanguage 6. The analysis is done by the logician, who – in concord with the ontology presumed – concentrates solely on the truth relation between the expression and the state of affairs, abstracting from all structural aspects of communication. The logical model and the rule based interpretation of the expression are designed to realize formally what is assumed as obvious to begin with. The purpose of the logical system is the explicit derivation of truth values.

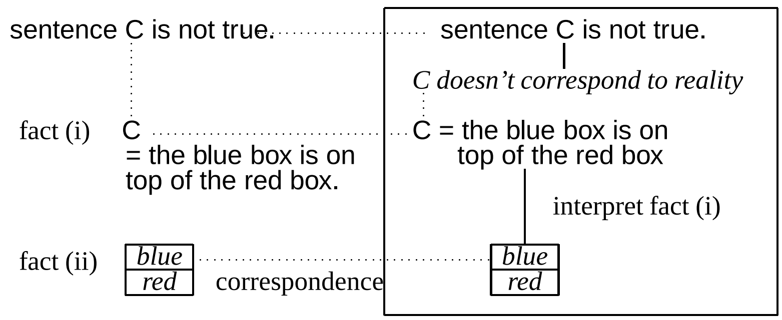
In a [+sense, +constructive] system, on the other hand, a real task environment is given. It must be analyzed automatically by the cognitive agent in certain relevant aspects, whereby a corresponding context representation is constructed internally. Relation 5 between the language sign and the external state of affairs is thus established indirectly in terms of cognitive procedures, based on the components 1 (non-verbal cognition/action), 2 (pragmatic interpretation), 3 (semantic interpretation), and 4 (verbale cognition/action). The purpose of the system is communicating contextual contents by means of language.

8 Epimenides in a [+sense,+constructive] system

The contingent truth values true^c and false^c enable a [+sense, +constructive] reanalysis of the Epimenides paradox. It permits an object-language to contain the words true and false without causing its interpretation to be inconsistent.

In preparation, let us interpret a benign use of the expression C is not a true sentence. This expression, used by Tarski to derive the Epimenides paradox, consists of a language-based abbreviation, C, and a negative truth statement. Its legitimate use within a [+sense,+constructive] system is based on the following structure.

8.1 Benign case of a language-based abbreviation



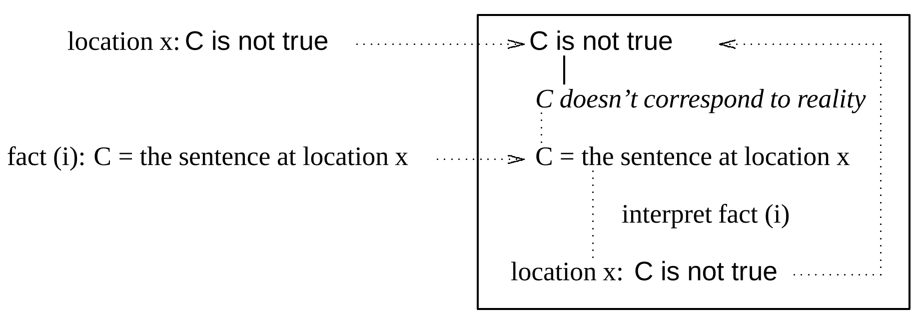
C abbreviates the expression The blue box is on the red box. It is shown in the external task environment as fact (i). In addition, the task environment contains the state of affairs described by the sentence abbreviated as C, shown as fact (ii).

When the expression C is not (a) true (sentence) is processed by a [+sense, +constructive] system, the semantics assigns to the surface a literal meaning which may be paraphrased as *C doesn't correspond to reality*. For this semantic representation, the pragmatics attempts to supply a matching contextual structure.

Thereby, it turns out that C is defined as an abbreviation of the expression The blue box is on the red box according to fact (i). The remaining part of the input expression, is not a true sentence, is processed by the pragmatic component by checking whether the content of the long version of C corresponds to reality. The literal meaning of The blue box is on the red box is matched with the corresponding subcontext, namely fact (ii), whereby it turns out that they *do* correspond. Thus the original input C is not a true sentence is evaluated as false^{c}. There are many language-based abbreviations in combination with natural truth statements which are as benign as they are normal.

A special case of a language-based abbreviation is the Epimenides paradox. Its [+sense,+constructive] reanalysis has the following structure.

8.2 Reconstruction of the Epimenides paradox



In a clearly marked location x, the robot reads C is not (a) true (sentence) and assigns to it the literal meaning *C doesn't correspond to reality*. As in 8.1, the pragmatics attempts to supply a subcontext corresponding to this literal meaning.

Taking into account fact (i), C turns out to be an abbreviation of The sentence at location x. The remaining part of the input sentence, is not true, is processed by the pragmatics by checking whether the content of what C abbreviates corresponds to reality. For this, the literal meaning of The sentence at location x is matched with a corresponding subcontext. In contrast to 8.1, where the literal meaning of The blue box is on the red box is matched with the *non-verbal* fact (ii), the literal meaning of The sentence at location x in 8.2 leads to the *verbal* referent (sign) C is not true.

At this point, the pragmatics may treat the referential object C is not true as an uninterpreted or as an interpreted sign. Treating it as an uninterpreted sign would make sense in combination with, e.g., *is printed in Helvetica*. In 8.2, however, this would make no sense. Rather, the most natural action would seem to interpret the sign – which starts the semantic-pragmatic interpretation procedure all over again.

Thus, if the external circumstances bring a [+sense,+constructive] system into the special situation of the paradox, it will get into a blind cycle and – without additional assumptions – will remain there. As shown schematically in 8.2, the C in C is not true will be replaced again and again with the corresponding sentence at location x.

Our ontologically based reanalysis of the Epimenides paradox does not result in its resolution, but rather in its transformation. What appears as a *logical contradiction* on the level of the semantics in Tarski's [–sense,–constructive] system reappears in the [+sense,+constructive] system of the SLIM theory of language as an *infinite recursion* of the semantico-pragmatic interpretation. This reanalysis disarms the Epimenides paradox, both on the level of the semantics and the theory of communication:

- In a [+constructive,+sense] system, the words true^c and false^c may be part of the object language without causing a logical contradiction in its semantics.

- The recursion caused by the Epimenides paradox can be recognized in the pragmatics and taken care of as a familiar[16] type of failing interpretation without adversely affecting the communicative functioning of the system.

The reanalysis avoids the Tarskian contradiction in the semantics because the metalanguage distinguishes between (i) the logical truth-values 1 and 0 from the T-condition, (ii) the natural truth-values true^c and false^c from the object language sentence C, and (iii) their procedural metalanguage correlates *does (not) correspond to reality*. If we were to assume for the sake of the argument that the semantic component of a [+sense,+constructive] system were a logical semantics like Montague grammar, then this reanalysis of the Epimenides paradox would not result in Tarski's contradiction

a. C is 1 if and only if C is not 1

but rather in the contingent statement

b. C is 1 if and only if C does not correspond to reality.

Version *b* does not contain a logical contradiction, in contrast to version *a*.

For the semantics of natural language, this reanalysis of the Epimenides paradox (contingent formulation *b*) is important. By avoiding Tarski's contradiction, it allows to define a *complete* semantics of natural language – that is a semantics which does not have to exclude certain sentences (i.e. those containing the words true or false).

For a logical semantics of natural language, on the other hand, the reanalysis is of little help. This is because the natural truth values true^c and false^c – necessary for avoiding Tarski's contradiction – can only be motivated conceptually and implemented procedurally within the framework of a [+constructive,+sense] ontology.

[16]It holds in general of pragmatic interpretation that a continuous repetition in the analysis of one and the same contextual object should be avoided, e.g., by means of a counter. In this way, the recursion caused by the Epimenides paradox may be recognized and stopped. Discontinuing a particular interpretation attempt in order to choose an alternative scheme of interpretation or to ask for clarification is a normal part of pragmatics.

9 Truth in natural language

Using two different notions of truth for absolute and contingent sentences would be suboptimal from the viewpoints of logic as well as linguistics. Instead, the goal is an overall system which can correctly interpret any utterance of the form C is true, no matter whether C happens to be a contingent or an absolute sentence.

The semantics of absolute and contingent statements may be unified by treating one type of statement as a special case of the other. For a [–constructive,–sense] approach it would thus be desirable, if logical semantics – geared towards absolute statements – would also allow a general treatment of contingent statements. Conversely, for a [+constructive,+sense] approach it would be desirable, if natural semantics – geared towards contingent statements – would allow a treatment of absolute statements as a special case of contingent sentences.

In logical semantics, the handling of absolute statements may be extended to contingent statements in many instances – as shown by Montague's model-theoretic analysis of English. The phenomenon of propositional attitudes (Section 4) has shown, however, that a proper semantic interpretation – that is, an ontologically justified assignment of the values 1 or 0 – is *not always* possible. Furthermore, according to Tarski, sentences of the form C is (not) true are forbidden in the object language. For these two reasons, a general treatment of contingent statements as a special case of absolute statements is excluded in principle.

In natural semantics, on the other hand, absolute statements are special only insofar as (i) they can be interpreted independently of the parameters of their origin and (ii) the cognitive responsibility for their content is transferred from individual speakers to society and its historically grown view of the world. Thus, an absolute statement like The chemical formula of water is H_2O is true^c, if there exists a correctly functioning chain of communication between the speaker and the responsible experts.[17] The true sentences of absolute scientific and logically-mathematical systems are thus reconstructed contingently by interpreting them as cognitive accomplishments of the associated human – and thus fallible – society.

From this anthropological point of view, it is quite normal that an absolute statement may be considered true^c at certain times – due to the majority opinion of the experts –, yet later turn out to be false^c. Such mishaps happened – and still happen – quite frequently in the history of science, as shown by statements like Fire is based on the material substance of phlogiston.

10 Conclusion

For the purpose of modeling communication effectively, applications of logical semantics to natural language are founded on two fallacies. One is the assumption that a formal approach designed originally as a theory of truth could be extended more or less directly to a general analysis of natural language meaning. The other is the assumption

[17] The notion of a 'causal chain' from one speaker to the next has been emphasized by Kripke 1972, especially with regards to proper names and natural classes. The central role of 'specialists' in the scientific specification of certain meanings in the language community – e.g. analyzing water as H_2O – was stressed by Putnam 1975a, but with the absurd conclusion *that meanings just ain't in the head* (op.cit., p. 227). These authors investigate meaning and reference as a precondition for the foundation of truth, but they fail to make the necessary distinctions between the semantics of logical and natural languages, between a [–sense,–constructive] and a [+sense,+constructive] ontology, and between absolute and contingent truth.

that a well-defined metalanguage-based semantics could be turned into a procedural semantics quasi routinely, as a standard engineering procedure.

The first fallacy is indicated by the need to exclude the words true and false from the object language to avoid inconsistency. This restriction is no problem as long as logical semantics is used for its original purpose, i.e. as a theory of truth for eternal sentences of science. When logical semantics is extended to analyzing the meaning of everyday language, however, this restriction constitutes a serious limitation.

The second fallacy is illustrated by the many logical systems with well-defined metalanguage definitions for which there does not and cannot exist an empirically meaningful and computationally tractable procedural realization. Again, this need not be a problem as long as logical semantics is used for its original purpose. However, when the goal is a functioning model of natural language communication, e.g. in the form of a talking robot, logical semantic analyses have to be disqualified, if their suitability for procedural realization cannot be demonstrated.

To avoid the first fallacy, logical semantics of natural language must be based on an ontology suitable for modelling communication between cognitive agents. The far-reaching consequences of ontology have been illustrated here with the Epimenides paradox, propositional attitudes, and vagueness. These phenomena are difficult in a [–sense, –constructive], but straightforward in a [+sense,+constructive] approach.

To avoid the second fallacy, Tarski's verifiability requirement for metalanguage definitions must be modified to require suitability for procedural realization. This presupposes sufficiently low computational complexity – a theoretical issue which should not be ignored in applications of logical semantics to natural language.

The effective modelling of natural communication provides a unified theoretical viewpoint, is of great practical interest, and will require a vast amount of detailed work. In order for this interdisciplinary enterprise to succeed, however, certain basic fundamentals – such as a 'cognitive´ ontology and efficient computability – must be assured from the outset.[18] Furthermore, some familiar notions must be dealt with in a new light. An example is truth: apart from the formal notion based on tautologies and axioms, a procedural notion for contingent utterances is necessary.

References

Anderson, J.R. and G.H. Bower (1973) *Human Associative Memory*. V.H. Winston, Washington, D.C.

Barwise, J. and J. Perry (1983) *Situations and Attitudes*. The MIT-Press, Cambridge, Massachusetts.

Davidson, D. (1967) "Truth and Meaning," *Synthese*, VII:304-323.

Davidson, D. and G. Harman (ed.) (1972) *Semantics of Natural Language*, D.Reidel Publishing Company, Dordrecht-Holland.

Frege, G. (1967) *Kleine Schriften*, hrsg. von Ignacio Angelelli, Wiss. Buchgesellschaft, Darmstadt.

Gupta, A. (1982) "Truth and Paradox," *Journal of Philosophical Logic*, 11:1-60.

Hausser, R. (1992) "Complexity in Left-Associative Grammar," *Theoretical Computer Science*, Vol. 103, Elsevier.

[18] That there is no difficulty to fulfill these basic standards is shown by database semantics (Hausser 1999) and left-associative grammar (Hausser 1992).

Hausser, R. (1999) *Foundations of Computational Linguistics*, Springer-Verlag, Berlin, New York.

Herzberger, H. (1982) "Notes on Naive Semantics," *Journal of Philosophical Logic*, 11:61-102.

Johnson-Laird, P.N. (1983) *Mental Models*. Harvard University Press, Cambridge, Massachusetts.

Kamp, J.A.W. and U. Reyle (1993) *From Discourse to Logic*, Part 1 and 2, Kluwer Academic Publishers, Dordrecht, Boston, London.

Kripke, S. (1972) "Naming and Necessity," in Davidson & Harmann (ed.), p.253–355.

Kripke, S. (1975) "Outline of a theory of truth," *The Journal of Philosophy*, 72:690-715.

Lakoff, G. (1972) "Linguistics and natural logic," in Davidson, D. and G. Harman (ed.) , p. 545–665.

Montague, R. (1974) *Formal Philosophy*, Yale University Press, New Haven, CT.

Pascal, B. (1951) *Pensées sur la Religion et sur quelque autre sujets*, Éditions Du Luxembourg, Paris.

Putnam, H. (1975a) "The meaning of 'meaning'," reprinted in Putnam 1975b, p. 215–271.

Putnam, H. (1975b) *Mind, Language, and Reality 2.* Cambridge University Press.

Quine, W.v.O. (1960) *Word and Object.* MIT Press, Cambridge, Massachusetts.

Reddy, D.R., L.D. Erman, R.D. Fennell, and R.B. Neely (1973) "The Hearsay Speech Understanding System: An Example of the Recognition Process," *Proceedings of the Third International Joint Conference on Artificial Intelligence*, Stanford, California.

Rescher, N. (1969) *Many-valued Logic*. McGraw-Hill, New York.

Schank, R.C. and R. Abelson (1977) *Scripts, Plans, Goals, and Understanding*. Lawrence Earlbaum, Hillsdale, New Jersey.

Scott, D. and C. Strachey (1971) "Toward a Mathematical Semantics of Computer Languages," Technical Monograph PRG-6, Oxford University Computing Laboratory, Programming Research Group, 45 Branbury Road, Oxford.

Suppe, F. (ed.) (1977) *The Structure of Scientific Theories*, University of Illinois Press.

Tarski, A. (1935) "Der Wahrheitsbegriff in den Formalisierten Sprachen," *Studia Philosophica*, Vol. I, 262–405.

Tarski, A. (1944) "The Semantic Concept of Truth," *Philosophy and Phenomenological Research* 4:341-375.

Thiel, C. (1995) *Philosophie und Mathematik*, Wissenschaftliche Buchgesellschaft, Darmstadt.

Winograd, T. (1972) *Understanding Natural Language*, Academic Press, Harcourt Brace Jovanovich, San Diego, New York.

Weyhrauch, R. (1980) "Prolegomena to a Formal Theory of Mechanical Reasoning," *Artificial Intelligence*. Reprinted in Webber & Nilsson (ed.) 1981.