MEINONGIAN SEMANTICS FOR PROPOSITIONAL SEMANTIC NETWORKS

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ABSTRACT

This paper surveys several approaches to semantic-network seman-
tics that have not previously been treated in the AI or
computational-linguistics literature, though there is a large philo-
sophical literature investigating them in some detail. In particular,
propositional semantic networks (exemplified by SNePS) are dis-
cussed; it is argued that only a fully intensional ("Meinongian")
semantics is appropriate for them, and several Meinongian systems
are presented.

1. SEMANTICS OF SEMANTIC NETWORKS.

Semantic networks have proved to be a useful data structure
for representing information, i.e., a "knowledge" representation sys-
tem. (A better terminology is *"belief" representation system*; cf.
Rapaport and Shapiro 1984, Rapaport 1984b). The idea is an old
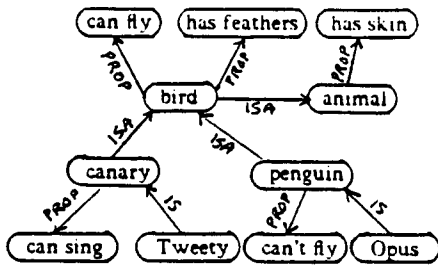one: *Inheritance networks* (Fig. 1), like those of Quillian 1968,

Fig. 1. An inheritance network.

Bobrow and Winograd's KRL (1977), or Brachman's KL-ONE
(1979), bear strong family resemblances to "Porphyry's Tree" (Fig.
2)—a mediaeval device used to illustrate the Aristotelian theory of
definition by species and differentia (cf. Kretzmann 1966, Ch. 2;
Kneale and Kneale 1966: 232). It has been pointed out that there is
nothing essentially "semantic" about semantic networks (Hendrix
1979; but cf. Woods 1975, Brachman 1979). Indeed, viewed as a
data structure, it is arguable that a semantic network is a *language*
(possibly with an associated logic or inference mechanism) for
representing information about some domain, and, as such, is a
purely *syntactic* entity. They have come to be called "semantic"
primarily because of their *uses* as ways of representing the *mean-
ings* of linguistic items.

As a notational device, a semantic network can itself be given
a semantics. That is, the arcs, nodes, and rules of a semantic
network representational system can be given interpretations in
terms of the entities they are used to represent. Without such a
semantics, a semantic network is an arbitrary notational device
liable to misinterpretation (cf. Woods 1975; Brachman 1977, 1983;
McDermott 1981). The task of providing a semantics for semantic
networks is more akin to the task of providing a semantics for a
language than for a *logic*, since in the latter case, but not in the
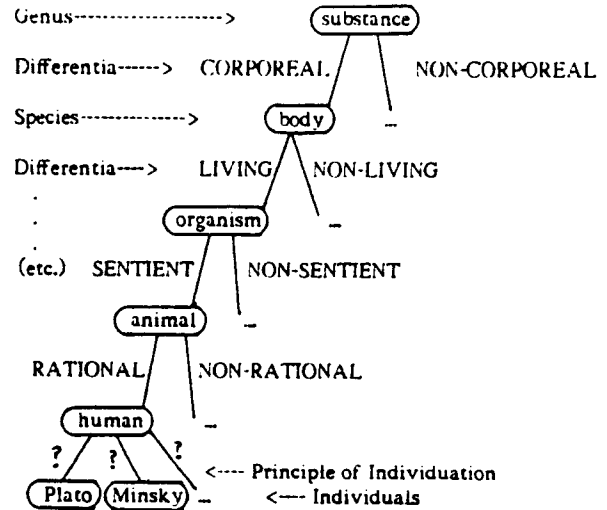

Fig. 2. Porphyry's Tree:
A mediaeval inheritance network.

former, notions like *argument validity* must be established and con-
nections must be made with axioms and rules of inference, cul-
minating ideally in soundness and completeness theorems. But
underlying the logic's semantics there must be a semantics for the
logic's underlying language, and this would be given in terms of
such a notion as *meaning*. Here, typically, an interpretation func-
tion is established between syntactical items from the language l,
and ontological items from the "world" W that the language is to
describe. This, in turn, is usually accomplished by describing the
world in another language, l_w, and showing that l and l_w are
notational variants by showing that they are isomorphic.

Recently, linguists and philosophers have argued for the
importance of *intensional* semantics for natural languages (cf. Mon-
tague 1974, Parsons 1980, Rapaport 1981). At the same time, com-
putational linguists and other AI researchers have begun to recog-
nize the importance of representing intensional entities (cf. Woods
1975, Brachman 1979, McCarthy 1979, Maida and Shapiro 1982).
It seems reasonable that a semantics for such a representational sys-
tem should itself be an intensional semantics. In this paper, I out-
line several fully intensional semantics for intensional semantic
networks by discussing the relations between a semantic-network
"language" l, and several candidates for l_w. For l, I focus on
Shapiro's propositional Semantic Network Processing System
(SNePS; Shapiro 1979), for which Israel (1983) has offered a
possible-worlds semantics. But possible-worlds semantics, while
countenancing intensional entities, are not *fully* intensional, since
they treat intensional entities extensionally. The l_w's I discuss all

have fully intensional components.

2. SNePS.

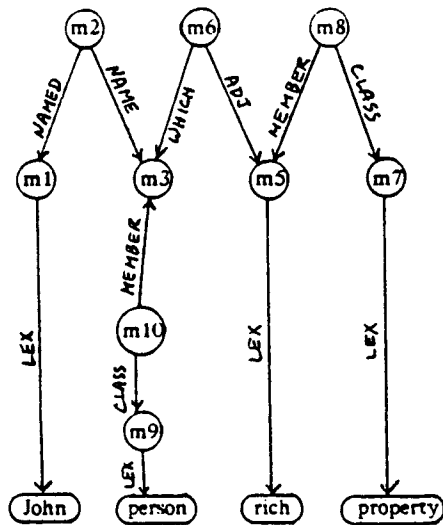A SNePS semantic network (Fig. 3) is primarily a *proposi-*

**Fig. 3. A SNePS representation for
'A person named "John" has the property of being rich.'**

tional network (see below). It can, however, also be used to represent the inheritability of properties, either by explicit rules or by *path-based inference* (Shapiro 1978). It consists of labeled nodes and labeled, directed arcs satisfying (*inter alia*) the following condition (cf. Maida and Shapiro 1982):

(S) There is a 1-1 correspondence between nodes and represented concepts.

A *concept* is "anything about which information can be stored and/or transmitted" (Shapiro 1979: 179). When a semantic network such as SNePS is used to model "the belief structure of a thinking, reasoning, language using being" (Maida and Shapiro 1982: 296; cf. Shapiro 1971b: 513), the concepts are the objects of mental (i.e., intentional) acts such as thinking, believing, wishing, etc. Such objects are intensional (cf. Rapaport 1978).

It follows from (S) that the arcs do not represent concepts. Rather, they represent binary, structural relations between concepts. If it is desired to talk *about* certain relations between concepts, then those relations must be represented by nodes, since they have then become objects of thought, i.e., concepts. In terms of Quine's dictum that "to be is to be the value of a (bound) variable" (Quine 1980: 15; cf. Shapiro 1971a: 79-80), nodes represent such values, arcs do not. That is, given a domain of discourse—including items, n-ary relations among them, and propositions—SNePS nodes would be used to represent all members of the domain. The arcs are used to structure the items, relations, and propositions of the domain into (other) propositions. As an analogy, SNePS arcs are to SNePS nodes as the symbols '→' and '+' are to the symbols 'S', 'NP', and 'VP' in the rewrite rule: S → NP + VP. It is because no propositions are represented by arcs that SNePS is a "propositional" semantic network (cf. Maida and Shapiro 1982: 292).

When a semantic network such as SNePS is used to model a mind, the nodes represent only intensional items (Maida and Shapiro 1982; cf. Rapaport 1978). Similarly, if such a network were to be used as a notation for a fully intensional natural-language semantics (such as the semantics presented in Rapaport

1981), the nodes would represent only intensional items. Thus, a semantics for such a network ought itself to be fully intensional.

There are two pairs of types of nodes in SNePS: constant and variable nodes, and atomic (or individual) and molecular (or propositional) nodes. (Molecular individual nodes are currently being implemented; see Sect. 7, 8. For a discussion of the semantics of variable nodes, see Shapiro 1985.) Except for a few pre-defined arcs for use by an inference package, all arc labels are chosen by the user; such labels are completely arbitrary (albeit often mnemonic) and depend on the domain being represented. The "meanings" of the labels are provided (by the user) only by means of explicit rule nodes, which allow the retrieval or construction (by inferencing) of propositional nodes.

3. ISRAEL'S POSSIBLE-WORLDS SEMANTICS FOR SNePS.

David Israel's semantics for SNePS assumes "the general framework of Kripke-Montague style model-theoretic accounts" (Israel 1983: 3), presumably because he takes it as "quite clear that [Maida and Shapiro] ... view their formalism as a Montague type type theoretic, intensional system" (Israel 1983: 2). He introduces "a domain *D* of possible entities, a non-empty set *I* (... of possible worlds), and ... a distinguished element *w* of *I* to represent the real world" (Israel 1983: 3). An *individual concept* is a function *ic* : *I* → *D*. Each constant individual SNePS node is modeled by an *ic*; variable individual nodes are handled by "assignments relative to such a model". However, predicates—which, the reader should recall, are also represented in SNePS by constant individual nodes—are modelled as functions "from *I* into the power set of the set of individual concepts." Propositional nodes are modelled by "functions from *I* into {*T*, *F*}," although Israel feels that a "hyperintensional" logic would be needed in order to handle propositional attitudes.

Israel has difficulty interpreting MEMBER, CLASS, and ISA arcs in this framework. This is to be expected for two reasons. First, it is arguably a mistake to *interpret* them (rather than giving rules for them), since they are arcs, hence arbitrary and non-conceptual. Second, a possible-worlds semantics is *not* the best approach (nor is it "clear" that this is what Maida and Shapiro had in mind—indeed, they explicitly reject it; cf. Maida and Shapiro 1982: 297). Israel himself hints at the inappropriateness of this approach:

if one is focussing on propositional attitude[s] ... it can seem like a waste of time to introduce model-theoretic accounts of intensionality at all. Thus the air of desperation about the foregoing attempt ... . (Israel 1983: 5.)

Moreover—and significantly—a *possible*-worlds approach is misguided if one wants to be able to represent *impossible* objects, as one *should* want to if one is doing natural-language semantics (Rapaport 1978, 1981; Routley 1979). A fully intensional semantic network demands a fully intensional semantics. The main rival to Montague-style, possible-worlds semantics (as well as to its close kin, situation semantics (Barwise and Perry 1983)) is *Meinongian semantics*.

4. MEINONG'S THEORY OF OBJECTS.

Alexius Meinong's (1904) theory of the objects of psychological acts is a more appropriate foundation for a semantics of propositional semantic networks as well as for a natural-language semantics. In brief, Meinong's theory consists of the following theses (cf. Rapaport 1976, 1978):

(M1) *Thesis of Intentionality*: Every mental act (e.g., thinking, believing, judging, etc.) is "directed" towards an "object".

There are two kinds of Meinongian objects: (1) *objecta*, the individual-like objects of such a mental act as thinking-of, and (2)

objectives, the proposition-like objects of such mental acts as believing(-that) or knowing(-that). E.g., the object of my act of thinking of a unicorn is: *a unicorn*; the object of my act of believing that the Earth is flat is: *the Earth is flat*.

(M2) Not every object of thought exists (technically, "has being").

(M3) It is not self-contradictory to deny, nor tautologous to affirm, existence of an object of thought.

(M4) *Thesis of Aussersein*: All objects of thought are *ausserseiend* ("beyond being and non-being").

For present purposes, *Aussersein* is most easily explicated as a domain of quantification for non-existentially-loaded quantifiers, required by (M2) and (M3).

(M5) Every object of thought has properties (technically, "*Sosein*").

(M6) *Principle of Independence*: (M2) and (M5) are not inconsistent. (For more discussion, cf. Rapaport 1984c.)
   Corollary: Even objects of thought that do not exist have properties.

(M7) *Principle of Freedom of Assumption*:
   (a) Every set of properties (*Sosein*) corresponds to an object of thought.
   (b) Every object of thought can be thought of (relative to certain "performance" limitations).

(M8) Some objects of thought are incomplete (i.e., undetermined with respect to some properties).

(M9) The meaning of every sentence and noun phrase is an object of thought.

It should be obvious that there is a close relationship between Meinong's theory and a fully intensional semantic network like SNePS. SNePS itself is much like *Aussersein*; Shapiro (personal communication) has said that all nodes are implicitly in the network all the time. In particular, a SNePS base (i.e., atomic constant) node represents an *objectum*, and a SNePS propositional node represents an *objective*. Thus, when SNePS is used as a model of a mind, propositional nodes represent the objectives of beliefs (cf. Maida and Shapiro 1982, Rapaport and Shapiro 1984, Rapaport 1984b); and when SNePS is used in a natural-language processing system (cf. Shapiro 1982, Rapaport and Shapiro 1984), individual nodes represent the meanings of noun phrases and verb phrases, and propositional nodes represent the meanings of sentences.

Meinong's theory was attacked by Bertrand Russell on grounds of inconsistency: (1) According to Meinong, the round square is both round and square (indeed, this is a tautology); yet, according to Russell, if it is round, then it is *not* square. (2) Similarly, the existing golden mountain must have all three of its defining properties: being a mountain, being golden, and existing; but, as Russell noted, it *doesn't* exist. (Cf. Rapaport 1976, 1978 for references.)

There have been several formalizations of Meinongian theories in recent philosophical literature, each of which overcomes these problems. In subsequent sections, I briefly describe three of these and show their relationships to SNePS. (Others, not described here, include Routley 1979—cf. Rapaport 1984a—and Zalta 1983.)

5. RAPAPORT'S THEORY.

On my own reconstruction of Meinong's theory (Rapaport 1976, 1978—which bears a coincidental resemblance to McCarthy 1979), there are two types of objects: *M-objects* (i.e., the objects of

thought, which are intensional) and *actual objects* (which are extensional). There are two modes of predication of properties to these: M-objects are *constituted* by properties, and both M- and actual objects can *exemplify* properties. For instance, the pen with which I wrote the manuscript of this paper is an actual object that *exemplifies* the property of *being white*. Right now, when I think about that pen, the object of my thought is an M-object that is *constituted* (in part) by that property. The M-object *Jan's pen* can be represented as: <belonging to Jan, being a pen> (or, for short, as: <J, P>). *Being a pen* is also a *constituent* of this M-object: P c <J, P >; and 'Jan's pen is a pen' is true in virtue of this objective. In addition, <J, P > *exemplifies* (ex) the property of *being constituted by two properties*. There might be an actual object, say, α, corresponding to <J, P >, that *exemplifies* the property of *being a pen* (α ex P) as well as (say) the property of *being 6 inches long*. But *being 6 inches long* ¢ <J, P >.

The M-object *the round square*, <R, S >, is constituted by precisely two properties: being round (R) and being square (S); 'The round square is round' is true in virtue of this, and 'The round square is not square' is false in virtue of it. But <R, S > exemplifies neither of those properties, and 'The round square is not square' is *true* in virtue of *that*. I.e., 'is' is ambiguous.

An M-object *o* exists iff there is an actual object *a* that is "Sein-correlated" with it: *o* exists iff ∃α[αSCo] iff ∃α∀F[F c o ↔ α ex F]. Note that incomplete objects, such as <J, P >, can exist. However, the M-object *the existing golden mountain*, <E, G, M >, has the property of existing (because E c <E, G, M >) but does not exist (because ¬ ∃α[α SC <E, G, M >], as an empirical fact).

The intensional fragment of this theory can be used to provide a semantics for SNePS in much the same way that it can been used to provide a semantics for natural language (Rapaport 1981). SNePS base nodes can be taken to represent M-objects and properties; SNePS propositional nodes can be taken to represent M-objectives. Two alternatives for networks representing the three M-objectives: R c <R, S >, S c <R, S >, and <R, S > ex *being impossible* are shown in Figs. 4 and 5. (The second can be used to avoid "Clark's
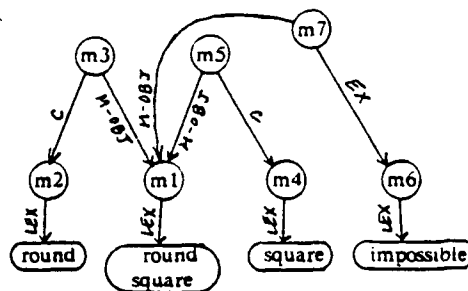

Fig. 4. A SNePS representation of
'The round square is round', 'The round square is square',
and 'The round square is impossible' on Rapaport's theory.

paradox"; see Rapaport 1978, 1982.) Actual (i.e., extensional) objects, however, should not be represented (cf. Maida and Shapiro 1982: 296-98). To the extent to which such objects are essential to this Meinongian theory, the present theory is perhaps an inappropriate one. (A similar remark holds, of course, for McCarthy 1979.)

6. PARSONS'S THEORY.

Terence Parsons's theory of nonexistent objects (1980; cf. Rapaport 1976, 1978, 1985) recognizes only one type of object—intensional ones—and only one mode of predication. But it has two
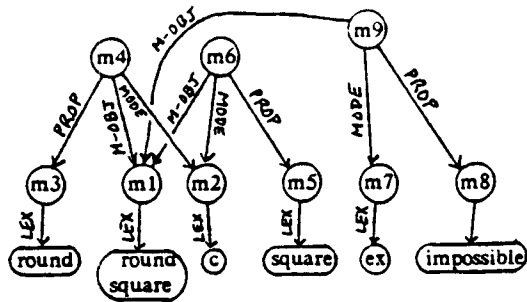
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Fig. 5. An alternative SNePS representation of 'The round square is round', 'The round square is square', and 'The round square is impossible' on Rapaport's theory.

types of properties: *nuclear* and *extranuclear*. The former includes all "ordinary" properties such as: being red, being round, etc.; the latter includes such properties as: existing, being impossible, etc. But the distinction is blurry, since for each extranuclear property, there is a corresponding nuclear one. For every set of nuclear properties, there is a unique object that has only those properties. Existing objects must be complete (and, of course, consistent), though not all such objects exist. For instance, *the Morning Star* and *the Evening Star* don't exist (if these are taken to consist, roughly, of only two properties each). *The round square*, of course, is (and only is) both round and square and, so, isn't non-square; though it is, for that reason, impossible, hence not real. As for *the existing golden mountain, existence* is extranuclear, so the set of these three properties doesn't have a corresponding object. There is, however, a "watered down", nuclear version of existence, and there *is* an existing golden mountain that has *that* property; but *it* doesn't have the extranuclear property of existence, and, so it doesn't *exist*.

Parsons's theory could provide a semantics for SNePS, though the use of two types of properties places restrictions on the possible uses of SNePS. On the other hand, SNePS could be used to represent Parsons's theory (though a device would be needed for marking the distinction between nuclear and extranuclear properties) and, hence, together with Parsons's natural language semantics, to provide a tool for computational linguistics. Fig. 6 suggests how this might be done.
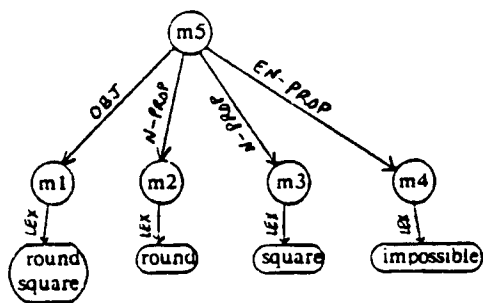

Fig. 6. A SNePS representation of 'The round square is round, square, and impossible' on Parsons's theory.

7. CASTAÑEDA'S THEORY.

Hector-Neri Castañeda's theory of "guises" (1972, 1975a-c, 1977, 1979, 1980) is a better candidate. It is a fully intensional theory with one type of object: *guises* (intensional items corresponding to sets of properties), and one type of property. More precisely, there are properties (e.g., *being round, being square, being*

blue, ...), sets of these (called *guise cores*; e.g., {*being round, being square*}), and an ontic counterpart, *c*, of the definite-description operator, which is used to form *guises*; e.g., *c*{*being round, being square*} is the round square. Guises can be understood, roughly, as things-under-a-description, as "facets" of (physical and non-physical) objects, as "roles" that objects play, or, in general, as objects of thought.

Guise theory has two modes of predication: *internal* and *external*. In general, the guise *c*{... *F* ...} is-internally *F*. E.g., the guise (named by) *the round square* is-internally only round and square. The two guises *the tallest mountain* and *Mt. Everest* are related by an external mode of predication called *consubstantiation* (*C**). Consubstantiation is an equivalence relation that is used in the analyses of (1) external predication, (2) co-reference, and (3) existence: Let $a = c\{... F...\}$ be a guise and let $a[G] =_{df} c\{... F ...\} \cup \{G\}$. Then (1) a is-externally G (in one sense) if $C^*(a, a[G])$. For instance, 'the Morning Star is a planet' is true because $C^*(c\{M, S\}, c\{M, S, P\})$; i.e., *the Morning Star* and *the Morning Star that is a planet* are consubstantiated. (2) Guise a "is the same as" guise b if and only if C^*ab. For instance, 'the Morning Star is the same as the Evening Star' is true because $C^*(c\{M, S\}, c\{E, S\})$. And (3) a exists if and only if there is a guise b such that C^*ab.

Another external mode of predication is *consociation* (C^{**}). This is also an equivalence relation, but one that holds between guises that a mind has "put together", i.e., between guises in a "belief space". For instance, C^{**}(Hamlet, the Prince of Denmark).

C^* and C^{**} correspond almost exactly to the use of the EQUIV arc in SNePS. Maida and Shapiro (1982: 303) use the EQUIV case-frame to represent co-reference (which is what C^* is), but, as I have suggested in Rapaport 1984b, EQUIV more properly represents *believed* co-reference—which is what C^{**} is. It should be clear how guise theory can provide a semantics for SNePS. Fig. 7 suggests how this might be done. Some problems remain, however: in particular, the need to provide a SNePS correlate for internal predication and the requirement of explicating external predication in terms of relations like C^*. Note, too, that nodes m3, m5, and m8 in Fig. 7 are 'structured individuals'—a sort of molecular base node.

8. CONCLUSION.

It is possible to provide a fully intensional, non-possible-worlds semantics for SNePS and similar semantic network formalisms. The most straightforward way is to use Meinong's theory of objects, though this theory has the disadvantage of not being formalized. There are several extant formal Meinongian theories that can be used, though each has certain disadvantages or problems. Two lines of research are currently being investigated: (1) Take SNePS as is, and provide a new, formal Meinongian theory for its semantic foundation. This has not been discussed here, but the way to do this should be clear from the possibilities examined above. My own theory (stripped of its extensional fragment) or a modification of Castañeda's theory seem the most promising approaches. (2) Modify SNePS so that one of the extant formal Meinongian theories can be so used. SNePS is, in fact, currently being modified by the SNePS Research Group—for independent reasons—in ways that make it closer to Castañeda's guise theory, by the introduction of structured individuals—"base nodes" with descending arcs for indicating their "internal structure".
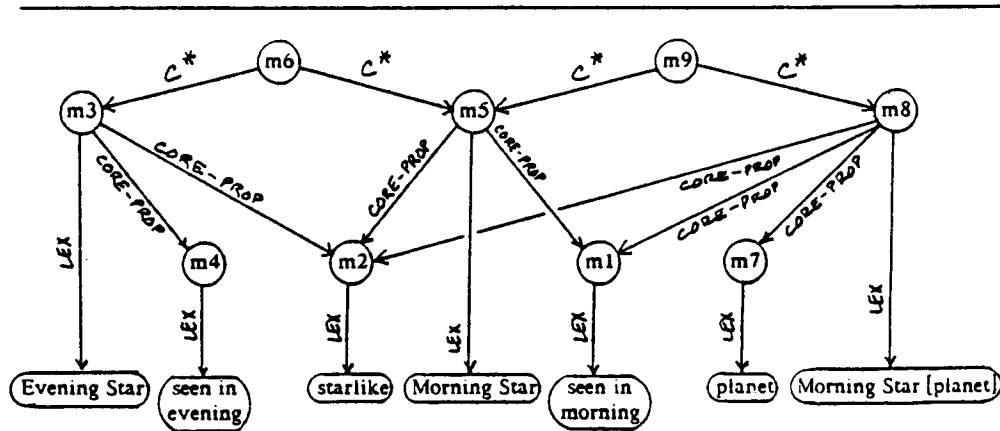
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Fig. 7. A SNePS representation of 'The Morning Star is the Evening Star' (m6)
and 'The Morning Star is a planet' (m9) on Castañeda's theory.

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