MEMORY FOR WORD AND SENTENCE MEANINGS: A SET-FEATURE MODEL

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Aan het tot stand komen van dit proefschrift hebben de leden van de Vakgroep Psychologische Funktieleer een belangrijke bijdrage geleverd, niet alleen door mee te werken aan de uitvoering van de experimenten maar ook door talloze malen te discussiëren over theoretische vraagstukken.

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This online version (December 2011) contains the original text of the dissertation. The only modifications are reformatting and repagination, and corrections of typos and a few infelicitous formulations. However, the OCR procedure may have introduced new "typos" that I failed to recognize. The brief postscriptum on p. 87 aims to rectify an incorrect formulation of one of the design features of the set-feature model.

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INTRODUCTION

In the present study a model for the memory representation of word and sentence meanings is developed. The focus is on the organization of what we call the meaning memory, which is part of the human language mechanism. We pursue an essentially psychological strategy but, since semantic-linguistic theories ultimately aim at specifying structural properties of the same language mechanism, we cannot refrain from considering these theories and their empirical foundation. Seen from a linguistic point of view, the model includes a set of proposals with regard to the semantic representation of sentences.

As has often been pointed out, the term "meaning" itself has many different meanings. Generally, three domains may be delimited. First, a word refers to, or is applicable to, a set of objects which is called its denotation or extension. The second type of meaning is affective (connotative) meaning, indicating the emotional dispositions or reactions elicited by a word. Third, each word contracts circumscribed relationships with other words in the language (cf. the definition of a word). Together, these relations constitute the intension (sense, designation) of that word. The terms Evening Star and Morning Star, denoting the same entity but having distinct senses, form a well-known example. The present model which we shall tersely refer to as the setfeature model, is mainly concerned with intensional meaning.

The development of the set-feature model has been governed by the following principles. (1) Because we conceive of the meaning memory as the store of verbal conceptual knowledge, we have to ascribe to it a structure enabling logical operations to be performed upon its content. Thus, fundamental logical notions such as set, relation, inclusion, intersection, etc., will be indispensable theoretical and descriptive tools, (2) The model has to be compatible with the experimental evidence gathered within the framework of psychological theories of meaning. (3) The memory representations must exhibit a semantically acceptable structure. The set-feature model attempts as far as possible to fulfill these logical, psychological and semantic requirements.

Chapter I gives a concise survey of the most important theories and methods developed in the psychological study of meaning. Included is a discussion of some trends in semantic theorizing which have strongly influenced recent psychological theories of meaning. Then we present the organization of the meaning memory in a set of statements about the types of information stored in its memory locations (Chapter II). The specific way in which word meanings and linguistic constructions are represented in this structure, forms the content of Chapter III. Chapter IV compares these memory representations to alternative ones reported in the literature and examines the extent to which the set-feature model is able to account for experimental data in the field of word and sentence recall. Finally, in Chapter V we report a series of five experimental studies, most of them centering around an essential aspect of the setfeature model: the distinction between what we have called hierarchical and relational structures and their realization in the meaning memory.

Chapter I

CURRENT PSYCHOLOGICAL CONCEPTIONS OF MEANING

In this chapter we shall briefly pass in review the most influential psychological meaning theories. Because of the great impact it exerted upon subsequent psychological theorizing, we include a discussion of the linguistic theory initiated by Katz and Fodor (1963).

In general we shall distinguish between holistic and componential theories, the predicate "holistic" being not more than a short-hand expression for "noncomponential". The term componential applies to theories which conceive of meanings, not as unanalyzable wholes, but as bundles of some kind of elements or features. Holistic theories were dominating up to about 1963; from then onwards the trend has been increasingly componential.

§1. Holistic approaches

A. Word meaning

The meaning theories outlined in the present section originate from general theories of learning and incorporate their steadily growing conceptual apparatus. Earlier accounts of learning were phrased in terms of associations between overt stimuli and responses, later ones also include unobservable mediating r-s chains and r-r and s-s connections. Osgood's (1968) division of meaning theories, which has been adopted here, reflects this increasing complexity. Creelman (1966) gives a survey of numerous experimental studies to which these theories and their subsequent modifications gave rise. In order to illustrate the various points of view we shall repeatedly use the same simple example: the way in which subjects learn (part of) the meaning of the word-form *danger*. A general discussion of these theories is postponed until §3, B.

I. Single-stage theories

1 Pavlovian classical conditioning

An originally neutral stimulus (the word-form *danger*) acquires meaning by repeated pairing in temporal contiguity with an unconditioned stimulus (e.g. pain). In the long run the sound *danger* (now called conditioned stimulus) provokes the responses that previously only followed on the pain stimulus. These conditioned responses, then, represent the meaning of the word-form *danger*.



2. Skinnerian operant conditioning

The subject is motivated to escape from painful and dangerous situations. To the behavioral repertory he has learnt in the past belongs the operant "running away", elicited by the motive mentioned; this operant leads to reinforcement (escape from pain). The sound *danger*, if perceived in temporal contiguity with the painful stimulation, becomes a "discriminative stimulus", an occasion which evokes the operant. This operant is then called "discriminated" operant under the control of the stimulus event *danger*.



Skinner (1957) calls such verbal learning processes "tacts". The tact is only one of the procedures that, according to him, lead to complete language acquisition.

II. Two-stage theories

These theories differ from the preceding ones in that they add an unobservable intermediate r-s stage.

1. Representational mediation theory

The sound *danger* that has been paired repeatedly with the pain stimulus does not elicit the total pain reaction, but only an unobservable part of it: "some reduced portion of the total behavior made to the thing signified [...] The sign comes to elicit those most readily and least interfering components of the total behavior to the significate" (Osgood 1961).



2. Non-representational mediation theory

The term "non-representational" indicates that the postulated mediating response is not a representation (not a part) of R_T (Bousfield 1961). Nevertheless, "representational r-s sequences" play an important part in this theory. Repeated presentation of a stimulus comes to elicit a representational response (R_{rep}) which is a proper part of the total reaction to the stimulus. In the case of a vocal stimulus (a word-form) the representational response consists of the subject's repeating the word subvocally or aloud. To the feedback stimulation (s_{rep}) following upon such a r_{rep} , new responses are conditionable.

Thus the mediational response involved in learning the meaning of a word-form presentational responses to the word-form itself (see figure). Bousfield suggests that the meaning of a word-form does not exclusively have to be seen as the relation between a speech-sound and a R_{rep} to its referent (H₃ see figure). Mainly for practical reasons (experimental observability), he pleads the use of information given by interverbal associations (H₂). To illustrate the formation of these interverbal associations we shall now divide the process of learning the meaning of *danger* into two stages.

Stage (i). Presentation of the pain stimulus elicits a representational response (R_{rep}). After repeated presentations of the sound *bad.*, this stimulus elicits an r_{rep} — s_{rep} sequence which, in turn, elicits R_{rep} , after some pairings with the pain stimulus.



Stage (ii). In this stage a higher-order conditioning process takes place. The CS *bad* now acts as US and is repeatedly presented in temporal contiguity with a new CS, the word-form *danger*.



Although Deese (1962, 1965) does not explicitly base his work on such a theory, he arrives at a similar strategy. By means of spontaneous interverbal associations he tries to gain an insight into the structure of what he calls "associative meaning". The basic assumption in his extensive study is that the similarity of the associative meanings of two words can be expressed as the proportion of common associations to these words. Factor analysis of these similarity indices reveals meaningful structures (cf. p. 17).

Numerous studies have proved the predictive value of distributions and hierarchies of associations. Here, we shall only make reference to the volume edited by Dixon and Horton (1968) where a great number of such studies are reviewed, commented upon and criticized.

III. A three-stage theory

In 1963 Osgood adds to his meaning model (cf. II.1) cortical s-s and r-r "integrational" mechanisms. The external stimulus (a word-form) stimulates sensory receptors which, in turn, activate the corresponding cortical projection systems. Here, integration of this information takes place on the basis of contiguity and redundancies in past experience (s-s). Thus a "mirror of 'what ought to be" is brought about. These integration patterns constitute the input to the previously learnt mediation processes (r_m — s_m). Only at this level can there be any question of attaching meaning to the stimulus object. Osgood uses the term "intention" to describe the s_m elicited by r_m ; this leads to the execution of an integrated (r-r) reaction pattern which takes account of the significate. In this way he is able to circumvent the mechanistic character inherent in two-stage models. The above cortical processes are "meaningful", as distinct from the lower level, automatic, reflex-like reactions to the word-form (dotted lines in the figure).



B. Sentence meaning

As early as 1954 Mowrer tried to apply the paradigm of classical conditioning (p. 7) to sentence meaning. An essential feature of the sentence is "predication", the combination of two or more signs into an assertion. He considered a sentence to be a "communicative act in which we are not transferring meanings from person to person so much as we are transferring meanings *from sign to sign* within a given person, within a single mind [...] The communicative act, in its most salient and significative aspect lies rather in the combination, juxtaposition or association of the meanings thus aroused in *novel, informative ways.*" Mowrer illustrates this concept of the sentence as a conditioning device with the aid of the rudimentary sentence *Tom is a thief.* The separate words of this sentence acquired their distinctive meanings by being associated with "Tom" and "thieves" as real persons. Hearing the sentence *Tom is a thief* triggers off in the subject a conditioning process in which the reactions that initially followed only on the word *thief* are transferred to *Tom*, just as in a conditioning experiment CS evokes the reactions which previously only followed on the US.

Osgood (1963) summarizes his objections to this theory in the following way:

"1. It doesn't explain how we understand momentarily the meaning of the novel utterance *Tom is a thief*, without necessarily believing it, on a single presentation or trial.

It doesn't take grammatical structure into account——simple conditioning in the sentence *Tom is a perfect idiot* should lead to cancellation of the *Tom is perfect* and *Tom is an idiot* effects.
 It doesn't account for the fact that the predicate may be modified as much or more than the subject, as in the sentence *President Kennedy favors a test-ban treaty.*"

As an alternative, Osgood proposes the Congruity Hypothesis: "Whenever two signs are related by an assertion, the mediating reaction characteristic of each shifts toward congruity with that characteristic of the other, the magnitude of the shift being inversely proportioned to the intensities of the interacting reactions." In order to be able to introduce grammatical relationships he distinguishes associative (affirmative) and dissociative (negative) assertions, and proposes that in the first instance the mediating reactions shift into the same, compatible direction and in the second instance into contrary, reciprocally antagonistic direction. This theory is capable of giving fairly good predictions of the meaning (measured by the Semantic Differential Technique) of e.g. adjective-noun and intensive adverb-adjective combinations from the meaning of their components (e.g. *listless nurse, very charming*).

According to Osgood, the Congruity Principle is also applicable to whole sentences. His example is *The clever young thief was severely sentenced by the rather grim-faced judge*. He summarizes the meaning interactions ("shifts") which occur in the course of processing this sentence, as follows:

- (a) *thief* modified by *young* and *clever*
- (b) *sentenced* modified by *severely*
- (c) *judge* modified by *grim-faced* and by "topic"
- (d) grim-faced modified by rather.

As far as we can see from this example, Osgood assumes that (1) nouns are modified by adjectival and nominal predicates and (2) verbs and adjectives by adverbs, thus crediting traditional grammatical theory. Some issues, however, remain obscure. Why are not *judge* and *thief* somehow modified by the main verb *to sentence*? A second difficulty is that "modifiers" (adjectives, adverbs) are not themselves modified by the words they modify. This seems to be in contradiction to the Congruity Principle.

§2. Componential approach

A. Semantic theory within generative grammar

In 1963 Katz and Fodor published their well-known article entitled "The Structure of a Semantic Theory". This study had a great impact on the development of the compo-

nential approach to the problem of meaning within psychology. In subsequent publications (Katz and Postal 1964, Katz 1964a, 1964b, 1966, 1967) this linguistic theory was elaborated and modified. Our discussion is based upon Katz 1967 and is only concerned with psychologically relevant aspects. This last limitation is possible because the theory implies definite psychological commitments.

Katz presupposes the form of grammar presented by Chomsky (1965). The syntactic division of grammar contains two parts: the base component and the transformational component. The base generates deep structures; surface structures are generated by transformational rules applied to deep structures. Besides the syntactic component, generative grammar contains two interpretative components: a phonological component which provides surface structures with phonetic representations, and a semantic component which takes deep structures as its input and gives them semantic interpretations. In this way, phonetic representations (sound waves) are paired with semantic representations (meanings). Deep structures¹ consist of strings of formatives with an associated structural description in the form of a phrase-marker.

All of the formatives inserted into the phrase-markers as terminal elements occur in a lexicon as lexical items. For each lexical item (identified by some phonological notation) the lexicon specifies all syntactic and semantic properties. Only the semantic characterization will be our concern, here. The phrase-markers associated with a string of formatives describe the syntactic relations between the constituents of the string, the formatives themselves being the ultimate constituents of the string.

To illustrate this, we shall consider the generation of the sentence *the boy reads the old book*. Two deep structures are involved:



¹ By way of illustration we mention one advantage of the introduction of deep structures into linguistic descriptions. The syntactic ambiguity of phrases like *the shooting of the hunters* can easily be accounted for if they are seen as the transformational outcome of two different deep structures: one where *hunters* is subject, one where it is object of *shoot*.

Among the formatives we find (in orthographic notation) *the, Present, be, book*; among the larger constituents are Noun Phrase (NP) and Verb Phrase (VP). Between NP and VP, which are immediately dominated by the same symbol S(entence), holds the relationship Subject of S - Predicate of S; the syntactic relations between *boy, read* and *book* in (1) are different from those between *book, be* and *old* in (2).

The first transformation to be applied embeds (2) in the position of Sentence' in (1). Then, by a number of steps, the resulting sequence of formatives is transformed to *the boy Present read the old book*. Finally, *Present* is substituted by the formative S and permuted with *read* to yield the surface structure *the boy read S the old book*. Interpretation by the phonological component results in the required sentence.



According to Katz, the semantic component, which provides deep structures with semantic interpretations, consists of two parts, one of them being the above lexicon (dictionary) and the other a set of projection rules. Apart from characterizations of phonological and syntactic features, the lexicon assigns a limited number of lexical readings to each lexical item. These readings correspond to the different senses of the item (the "submeanings" of a word, if the word has more than one meaning). Three types of semantic information go into lexical readings: semantic markers, distinguishers, and selection restrictions.

Markers and distinguishers are the elements meanings can be decomposed into. Comparing *father* to *mother*, *boy* to *girl*, *stallion* to *mare*, *drake* to *duck*, one immediately sees that in all pairs the same opposition *male-female* is involved. The semantic element present in *book*, *water*, *tree* and *pope*, but absent from *psy-chology*, *freedom*, *creativity* and *love* can be characterized as *Physical Object*. These meaning components are raised to the status of semantic *markers* if they represent systematic relationships between lexical items; if they do not reflect such systematicity, they are *distinguishers*. For instance, English color adjectives only serve to distinguish between the otherwise lexically identical meanings of words like *emerald*, *ruby* etc. The third type of semantic information, called *selection restrictions*, specifies the conditions for semantically acceptable combinations of lexical items. The subject of *drink*, for example, must contain the semantic marker *Living* (maybe even *Animate*), the object must be a *fluid* substance.

This, however, does not suffice as a description of Katz's conception of semantic markers and distinguishers. According to Katz, linguistic theory attempts to explain the complex system of rules enabling man to communicate in a natural language, i.e. to encode his inner thoughts, ideas, concepts into phonetic signals so that the hearer, decoding these signals on the basis of the same system of rules (his linguistic competence), experiences the same thoughts, ideas, or concepts. "Although the semantic markers are given in the orthography of a natural language, they cannot be identified with the words or expressions of the language used to provide them with suggestive labels." (Katz 1966; 156). Semantic markers² refer to classes of ideas, to concepts. Thus, (Male) labels an idea, a conceptual component shared by the idea-complexes (meanings) we think of when hearing words like *boy, priest, stallion, bull.* In the same vein, selection restrictions serve to preclude combinations of incompatible or incongruous concepts.

Distinguishers, on the other hand, are not labels for concepts, but for perceptual properties. If we were to try to define the meanings of *emerald* or *ruby* exclusively in terms of cognitive components, their lexical readings would be identical. Only by adding the purely perceptual distinction between [green] and [red] can their meanings be kept apart. The fact that a natural language, being primarily the vehicle of private thoughts and ideas, makes only unsystematic use of distinguishers, corresponds to their property of reflecting perceptual distinctions. Connected to this is a further difference between markers and distinguishers: selection restrictions contain markers, but never distinguishers. This provides us with an indirect check upon the correctness of a classification of certain semantic components into markers and distinguishers: as soon as a lexical entry is found where a putative distinguisher is included within the selection restrictions, we have to raise this element to the status of marker.

The second division of the semantic component of grammar consists of a set of *projection rules*. As we have seen above, the input into the semantic component consists of deep structures. Associated with the lexical items of each deep structure is a phrase-marker that specifies the syntactic relations holding between them. Projection rules use this syntactic information in order to combine the readings of individual into so-called *derived readings*. To each syntactic relationship specified by deep structure phrase-markers corresponds one projection rule. For instance, there are separate rules for modifier-head, subject-predicate, verb-object, etc., constructions. The modifier-head projection rule applies to various cases of attribution (adjective-noun, adverb-verb adverb-adjective) and takes the union of the sets of semantic markers and distinguishers provided by the readings for head and modifier. The subject-predicate projection rule, however, does not take the union of the individual readings, but embeds the subject reading into the subject-slot of the predicate reading.

As an illustration of this we shall consider the semantic interpretation of the sentence *Bachelors chase spinsters*. All of the words of this sentence have several

² Following Katz's notational conventions we enclose (markers) within parentheses, [distinguishers] within text brackets and <selection restrictions> within triangular brackets.

senses, i.e. several lexical readings, but we shall restrict ourselves to one reading for each word. Katz proposes the following readings:

 bachelor³
 ------ (Physical Object), (Living), (Human), (Male), (Adult), (Never Married); <selection restrictions>.

 chase
 -------((Activity of X) (Nature:(Physical))) ((Motion) (Rate:(Fast)) (Character:(Following Y)) (Intention: (Trying to catch ((Y) (Motion))))); <selection restrictions>.

 spinster
 same reading as bachelor but (Female) instead of (Male).

The reading for *chase* requires some explanation. The marker (Activity) classifies *chase* as an activity verb along with *speak*, *eat* and distinguishes *chase* from state verbs (*sleep*, *wait*) and process verbs (*grow*, *freeze*). "(Nature: (Physical))" indicates the physical character of this activity, as distinct from mental activities such as *think* and *remember*. X and Y indicate the slots into which the readings for subject and object, respectively, are embedded. "((Y) (Motion))" reveals that the object of *chase* is itself moving.

In order to arrive at a derived reading for the sentence⁴, the verb-object projection rule embeds the *spinster* reading into the Y-slot, and the subject-predicate rule embeds the *bachelor* reading into the X-slot. This is possible, here, because, as we may assume, no selection restrictions preclude these embeddings.

So far, this sketch of Katz's conception of semantic theory will suffice. In §3A we shall formulate some criticisms.

B. Componential approach within psychology

Following the linguistic tendency towards componential treatment not only of semantic, but also of syntactic and phonological phenomena (here the components are usually labeled syntactic markers and phonological distinctive features), a number of psychologists came to advocate explicitly componential meaning theories.

Osgood (1963) summarized the results of numerous studies in which affective word meanings were measured by means of the Semantic Differential as follows: "We have been able to demonstrate three bipolar factors or dimensions, which account for a large share of the variance in affective meaning and appear to be common to all people, regardless of differences in both language and culture." To this he adds the conclusion that representational mediation processes are "just as complexly componential as the total behaviors from which they are derived. My general suggestion is this: *In a fashion strictly analogous to the way a phoneme is defined as a bundle of simultaneous phonetic features, so may a meaning be defined as a bundle of simultaneous semantic features.*"

 ³ In his 1964b and 1966 publications, Katz does not mention distinguishers and lists *Never Married* as a marker, although, in previous publications, this component was a distinguisher.
 ⁴We abandon concern with tense, number etc.

In his later work Osgood (1968) continues this componential approach. He endeavored, again with the aid of factor analytic techniques, to discover features of cognitive rather than affective word meaning from the judgments of subjects on the compatibility of word combinations (e.g. adjectives with nouns; verbs with adverbs).

In this same paper Osgood reformulated, albeit in a tentative way, his 1963 model of the process of sentence understanding. At first the subject reduces the perceived sentence to its deep structures. Every deep structure contains a Subject Phrase and a Verb Phrase; possibly a Verb Phrase will be decomposed into Verb and Object Phrase. Each of these components (words from various syntactic categories) stimulates a set of semantic features conditioned to these components. As a metaphor to describe this encoding process Osgood used dials which are set in a certain position (e.g. + , 0 or -). Every component of a deep structure sets a number of dials in one of the three possible positions. These codes are stored in memory. In order to be able to explain the recognition of semantically or syntactically anomalous sentences, transitional dependencies have to be built into this coding mechanism. For example, after encoding of a Subject Phrase with such features as -Human and +Plural, encoding of *shout* or *breaks* is experienced as anomalous by the hearer.

Deese (1968), too, arrived at the hypothesis that word meanings are stored in memory as sets of semantic features. Retrieval from memory of a word item is not to be regarded "as the retrieval of a single source item but as the intersection of some set of distinctive source features which, in turn, enables the production of a single item." He does not explicitly formulate a procedure for the determination of these features, but it seems reasonable to see the technique which he used in "The Structure of Associations in Language and Thought" (1965) as a start towards this. This technique proceeds through four stages:

- (i) Collection of the associations to a certain stimulus word
- (ii) Presentation of these association words and the stimulus word to a new group of subjects; collection of the associations to these words
- (iii) Determination of the associative overlap of these words (roughly the proportion of response words which are in common)
- (iv) Factor analysis of the overlap (similarity) matrix.

It does not become clear whether or not Deese identifies the extracted factors with the semantic features in the above quotation. At any rate, the "associative laws" which, according to him, are able to explain a great deal of associative data, are, too, defined in terms of features (or, more exactly, of attributes). Words are associatively connected (1) if they are antonymous, i.e. occupy the opposite poles of one dimension (attribute), and (2) if they share two or more attributes. It will be evident from this discussion, that Deese views the meaning memory as a structure of features and sets of features. Revealing the exact nature of this structure forms the object of further study. In fact, the set-feature model (Ch. II) is an attempt towards this.

Another theory of word memory, superficially looking rather different from the foregoing ones, has been drafted by Mandler (1967, 1968). He proposed that this

memory consists of hierarchically ordered categories. Each word is localized in one category and each category contains about 5 words. This is the lowest level of the hierarchy. At the next level, a limited number of basic categories (again, maximally 5) are grouped together to form a new category. Thus, each superordinate category in the structure subsumes a number of lower-order categories. Mandler gives an idio-syncratic example of a subsection of this structure: the memory organization of the names of acquaintances.



Mandler does not seem to regard his hierarchic model as being in accordance with componential approaches. As far as the meaning of the stored words are concerned, this view is not tenable. Mandler's hierarchic structure can immediately be translated into a feature structure by attaching to each word a complex symbol containing a list of features, each feature being a category label in Mandler's sense. For instance, in terms of the previous example: person A \rightarrow [acquaintance, social, old], person B \rightarrow [acquaintance, professional, peer] etc. The hierarchical organization intended by Mandler can be reconstructed from this storage model (only acquaintance occurs in all of the complex symbols and, therefore, represents the highest level, etc.). Formulated in this way, the model would be highly inefficient because of the frequent repetition of the features. This can easily be accommodated, as is done by our setfeature model (Ch. II).

In this context it suffices to stress the close relationship between the notions of feature and set (or category). One way to define a set is to indicate a property which is common to all the elements of the set. If A has property B, then A belongs to set B. Replacing "property" by "feature", we get: if A has feature B, then A belongs to set B. Or, applied to word meanings, if B is one of the features of word meaning A, then A belongs to set B.

§3. Comments and discussion

A.. Katz's semantic theory

Essential to Katz's notion of semantic markers is that they are "theoretical constructs introduced into semantic theory to designate language invariant but language linked components of a conceptual system that is part of the cognitive structure of the human mind" (Katz 1967; 129). The semantic marker is the link that connects deep structures to an extra-linguistic realm of ideas, concepts, that is, to human cognitive apparatus.

In order to preclude objections that ideas are not necessarily open to either introspective or public observation and, therefore, that ideational meaning theories lack empirical support (Alston 1964), Katz argues that ideas and concepts are hypothetical constructs of linguistic theory and comparable to such constructs of natural science as photons or certain evolutionary events that are not accessible to direct observation either:

"The linguist, like the physicist or biologist, achieves understanding of the phenomena with which he is concerned by constructing a theory of the unobservable system. If the consequences of the theory lead to correct predictions about the observable effects of the underlying system and would not do so if the theory were changed and if, moreover, the theory is the simplest one that enables the scientist to derive the known facts and predicts the unknown ones as consequences of the hypothesized system, then the scientist can say that the theory accounts for the observable behavior in terms of the functioning of an unobservable but causally efficient system and that the theory correctly represents the structure of this unobservable system. In this way, the linguist can empirically support the claim that his mentalistic theory of meaning describes a real, though unobservable, system that is the basis of the speaker's ability to communicate with other speakers and that causally underlies the observable speech events that occur in such communication" (1966; 182).

Katz's semantic theory, together with syntactic and phonological theories, form a theory of the unobservable system enabling man to communicate in a natural language, and we agree with the claim that linguistic theory provides empirically testable hypotheses concerning *part* of man's language mechanism. But Katz neglects one of the conditions he imposes upon an adequate theory of an unobservable system, namely that changing such a theory must immediately reduce its power in predicting observable events.

If, then, the ideas designated by semantic markers are replaced by something else, no matter whether it be internal physiological reactions or complex conditioned responses, in other words, if markers do not designate ideas but other types of inner processes, then the predictions of Katz's semantic theory with respect to observable speech events will be left wholly unchanged. Therefore, Katz's decision to let ideas correspond to semantic markers is linguistically unmotivated and arbitrary. As long as we are without compelling philosophical, psychological or physiological arguments as to what happens when we "think of" meaning components, we can more economically conceive of them as just words in a natural language, or, if one accepts that a theory is a special kind of language, as constructs (but without any ideational connotations) of semantic theory.

Our next criticism deals with the projection rules (cf. pp. 15-16) as proposed by Katz in his publications 1964b, 1966 and 1967. According to him, different grammatical relations between the formatives occurring in deep structures correspond to different projection rules. Actually, Katz describes three of these rules⁵, namely those for attribution, for the subject-predicate and the verb-object relations. The attribution rule, applying to modifier-head constructions (*hot summer, speak loudly, very charming*) and to copula sentences (*water is dangerous, children are rascals*) takes the union of the sets of semantic markers (and distinguishers) that are formed by the lexical readings for each word in the construction. The readings for verbs (cf. p.15) always have a dummy marker X, and, if transitive, also a symbol Y indicating the positions into which the readings for subject and object are embedded by application of, respectively, the subject-predicate and the verb-object projection rules. In this way, the derived readings for *cats chase mice* and *mice chase cats* are appropriately differentiated from one another.

Katz (1967) repeatedly underlines the distinction between the union and embedding operations performed by the various projection rules. Within his general framework, such a discussion is, indeed, necessary; accounting for subject-predicate and verbobject phrases in terms of the union operation would result in identical derived readings for cats chase mice and mice chase cats. However, this decision leads to undesirable consequences. If we compare (1) John was an employer to (2) John was a bachelor, then we have to apply the subject-predicate rule to (1), but the attribution rule to (2). This follows from the syntactic consideration that (1) is transformationally derived from a deeper structure John employed someone (cf. Katz and Postal 1964). Such a transformation has not been applied to (2). There does not seem to be any semantic motivation for applying different projection rules to (1) and to (2). The difficulty even increases for pairs of sentences that should receive at least one identical semantic interpretation, as for example John is an airman and John is a flyer. As a solution to this problem one might suggest that into the reading for airman a complex marker ((X) (flies)) be inserted, in this way approximating the deep structure underlying John is a flyer. But, when this type of complex markers is allowed for nouns, there is no objection against changing markers like (Male), (Physical Object) etc. into ((X) (is a male)), ((X) (is a Physical Object)), in other words, against the application of the embedding operation to attribution rela-

⁵ We renounce discussion of the other rules presented in Katz and Fodor (1963), because, later on, Katz changed his views with regard to some of the projection rules outlined there.

tionships. To take another example, we could replace the marker (Never Married) occurring in the reading for *bachelor* (p.15) by ((X) (did never marry)) in order to bring it in line with such markers as ((X) (flies)). But, then, we are consistent only if we also change (Living) to ((X) (is living)) or even ((X) (lives)), etc.

The same problem arises with regard to the verb-object projection rule. Here we have *John is an employee, The wheel is an invention*, derived from verb-object deep structure relationships. We may conclude that Katz's distinctions between various projection rules and the operations they perform upon lexical readings, are not consistently related to the syntactic framework which is presupposed. Our set-feature model leads to a conception of how lexical readings are combined into derived readings (cf. Ch. III) in which this difficulty is circumvented.

B. Psychological theories of meaning

Katz's accentuation of ideas or concepts corresponding to semantic markers illustrates a typical aspect of many meaning theories: their attempt to grasp the nature of the processes going on when we realize meanings of words or sentences, or to account for our capacity to find the right words in the right situation. (See our reviews of Skinner's, Osgood's and Bousfield's hypotheses with respect to this.) However, at the present moment no conclusive evidence is available. Moreover, those theorists who have in fact been engaged in empirical studies of meaning, all state the meaning of a word in interverbal terms, i.e. as its *sense* (cf. p. l).

We might ask whether another possibility is available. Suppose we know that upon hearing the word dog a circumscribed (nonverbal) complex process takes place, and that animal elicits a process which is a proper part of the dog-process. We would have compelling evidence, then, that animal is a component of the meaning of dog. In describing these facts we would have to use such expressions as "dog elicits processes a, b, c, and d; animal elicits a and b" or "the animal-processes are included under the dog-processes". These statements, however, provide hardly more semantic information than the every-day assertion that animal is a component of the meaning of *dog*. Certainly, knowledge about the processes which constitute meaning would be an important and independent tool in the search for exact characterizations of meanings. However, should an unknown processual component x of word y be detected, we would only be satisfied after having ascertained which word exclusively elicits the x-process; if such a word would not actually exist we would even create a fitting neologism. All this boils down to the conclusion that, although it is most important to search for meaning constituting processes, it is justified to develop meaning theories that are neutral with respect to these processes, not only within linguistics, but also within philosophy and psychology.

If one agrees upon the vacuity of the claim that some type of conditioned responses constitutes the meaning of words, he not necessarily has to do away with the notion of conditioning as a construct of a psychological theory of meaning. But he will soon become aware of the fact that this construct has no explanatory power at all in this field. Chomsky (1959) has shown very convincingly that most of the concepts occurring in conditioning theories (reinforcement, motivation, discriminative stimulus) are, at best, metaphors when applied to language behavior. What remains, then, is the assertion that meanings are interverbal associations, but this reveals nothing more about the structure of memory than, for instance, the principles of electricity about the working of TV sets. Needed, of course, are more concrete specifications of the "structure of associations" (Deese 1965).

We emphasize the following (interrelated) requirements to be put on this structure. It should be able to handle grammatical relations (cf. above discussion). It should provide a basis for Deese's Laws of Association. Moreover, as is pointed out by Frijda and Meertens (1967): it has to allow for logical operations upon its content. Various types of semantic data have to be taken into consideration, too (componential structure of meaning, paraphrase relationships, synonymy, homonymy, etc.). These constraints provide the basis for the meaning memory model developed in this study.

Chapter II

THE SET-FEATURE MODEL

The set-feature model is a set of assumptions about the structure of the *meaning memory*, the store containing meanings of words and sentences. Here we only describe the formal properties, the frame of this structure without reference to actual contents, although a limited number of examples is indispensable. The following chapters will show how the set-feature model is able to account for semantic data both from a linguistic and a psychological point of view.

§1.The language mechanism

The language mechanism is able to decode speech sounds into meanings and viceversa. Because the meaning memory is part of this mechanism, some very general—and at present hardly testable—assumptions with regard to its complex functioning are unavoidable. It seems plausible to delimitate three types of functions that run more or less parallel to the tripartition of linguistic study into phonologymorphology, syntax and semantics. Analogously, we assume three divisions within the language mechanism: (1) the *word-form memory*, (2) the *syntactic operator* and (3) the *meaning memory*. In addition, we make the—economic—assumption that these divisions take part in both speech processing (decoding sound waves into meanings) and speech production⁶ (encoding meanings into sound waves). Our concern, in this study, is only with the structure of the meaning memory, but a global outline of the functions of these divisions and the connections between them is needed.

In the word-form memory, recognition of input strings of words takes place, as does the control of the production of articulatory patterns during speech. It contains phonological characterizations for all words known to the speaker-hearer. Although the structure of this store is not clear for the moment, we may most easily think of it as some list of word-forms (see Morton 1968 and Thomassen 1970 for more elaborate models). The output from the word-form memory (a string of recognized word-forms) enters the syntactic operator that contains, for each of the word-forms listed in the word-form memory, a set of syntactic features. We suppose that the syntactic operator, on the basis of the syntactic information available, is able to decompose the string into *hierarchies of minimal propositions*. It would be premature, now, to dwell on this notion (see Ch. III) but it suffices here to say that a minimal proposition (MP) is the simplest possible subject-predicate construction (*John is ill*; *children play*). By virtue of its connections with the *memory locations* of the meaning memory, the syntactic operator *activates* one location for every minimal proposition in the hier-

⁶ Motor theories of speech perception make similar assumptions as regards what we call, here, the word-form memory.

archy. These three stages being minimally necessary for understanding utterances, during speech production the reversed sequence is followed. As soon as a hierarchy of meaning memory locations is activated, either under the influence of activities in parts of the brain outside the language mechanism or by other, previously activated locations of the meaning memory, the syntactic operator determines a string of wordforms which subsequently are realized by the articulatory apparatus. Of course this general structure is supplemented by feedback loops, short-term memories etc.

So far, this is an utmost global sketch of a very complex process. In this study, we shall not go into the details of the syntactic operator and the word-form memory but restrict ourselves to the meaning memory. In line with our conclusion of Chapter I, we, too, refrain from making any assumptions about the relations between the meaning memory and other, sensory, memories (visual, acoustic, etc.). We leave open the possibility that some memory locations (perhaps all) contain references to visual, acoustic, tactile, etc., imaginations but, for the present purpose, this is not essential. We are concerned with intensional rather than denotative and connotative meaning (cf. p. 23),

§2. The structure of meaning memory

The meaning memory consists of a large number of memory locations. Each of these locations contains several kinds of information. We shall discuss their nature and function under separate headings. For purposes of illustration, we shall often use the sentence *Pascal invented the calculator*.

1. Memory locations containing identical set-indicating labels belong to the same set.

The meaning of a word can be represented as a bundle or set of components (features). Among the semantic features of *Pascal* are *philosopher*, *human*, *French*, *male*, *author*; for *calculator* we have *artifact*, *counter*, *mechanical*, *object*. One memory location (ML) specifies one semantic feature. All MLs that contain features of a certain word are identified by bearing identical *labels*. To indicate which are the features of this word, each ML has a second label referring to another word that is a meaning component of the former word. This second label is the "identifying" label of the second word (see figure).



We see that the meaning of a word is represented as a set of features, and that features, being themselves words, are sets, too. MLs, therefore, form *intersections* between two sets. Another way of describing the content of MLs is to say that an ML contains one *minimal proposition* (MP). Thus, the intersection in the figure states that *Pascal is a philosopher*.⁷

2. Memory locations optionally specify which of the two labels represents the including, which the included set.

From the above figure alone it does not become clear whether *Pascal* is included within the set of *philosophers* or conversely (cf. *philosophers are humans* vs. *humans are philosophers*). We adopt the convention of using *arrows* directed to the larger, including set. (Not all MLs have to contain arrows: see p. 28, footnote.)

3. Memory locations have activation thresholds.

Not all features of a word are equally prominent. When hearing *horse*, one probably thinks of *animal* faster than of *hairy*. Introduction of activation thresholds can account for this differential retrieval probability.

What has happened when a subject, after having been presented with the stimulus *horse*, produces the response *animal*? As soon as the word-form memory has recognized the stimulus as the entry *horse* in its word-form list, then by virtue of connections running from this entry over the syntactic operator to the identifying labels of a circumscribed set of MLs, these MLs are aroused and some of them effectively activated. If the ML that forms the intersection between the sets for *horse* and *animal* has the lowest activation threshold, then the animal-label in this ML is immediately activated, and a connection from this label to the word-form *animal* induces the subject to pronounce the word *animal*.⁸

⁷ It will be clear from this that we do not make any fundamental distinction between word meaning and sentence meaning: each feature of a word meaning is a minimal proposition.

⁸ In this description we have neglected the fact that *horses* as a noun has several submeanings

We may note here that, although there is only one activation threshold associated with an ML, the probability of retrieving *animal* as a response to *horse* is not necessarily equal to the chance that *horse* is given as the first response to the stimulus *animal*. In both cases, the same ML is involved, but whether it will be the first to be activated also depends upon the thresholds of the other labels aroused after presentation of *horse* and *animal* respectively.

If the syntactic operator produces a minimal proposition, which always contains two content words as its output (e.g. *horses are animals*), then the sets of MLs corresponding to each of the content words are aroused and, if allowed by their activation thresholds, effectively activated. However, this process must result in activation of at least one ML forming an intersection of the two sets (e.g. the ML bearing labels corresponding to *horse* and *animal*). If such an ML already existed beforehand, then we assume that its activation threshold is somewhat lowered; in the case of its not existing, an ML with the appropriate labels is formed. In this way, new meaning components are added to sets of old ones just by verbal training.

It is possible to introduce more specific learning principles by postulating that the activation threshold depends upon the number of times it has been activated, upon recency and decay. But these notions are controversial and form no essential part of the model.⁹

Before concluding this section we wish to emphasize that our notion of labels only serves to simplify discourse but is, properly speaking, superfluous. Saying that MLs contain two labels corresponding to the content words of MPs is equivalent to the assertion that MLs are the places where these words are linked together. Necessary characteristics of these links are provided under the headings 3,5, and 6. Broadly stated, the meaning memory is a kind of wiring diagram—whose formal structure is the object of this study —originating from and recurring back to the entries of the wordform list, with the syntactic operator as a mediating and regulating instance. This is an immediate consequence of our decision to conceive of meaning as *sense* as a system of interverbal relationships (cf. p. 23). But see the next section.

Memory locations optionally contain references to contents of sensory memories.

It is evident that people, to a greater or lesser extent, can imagine the content of a heard utterance. Whether this imagery, or various types of conditioned mediating responses, constitute the quintessence of the process of understanding sentences or whether they are merely accompanying phenomena, is a question we leave open. But, at all events,

⁽senses) and that there exists a verb *to horse*, too. Generally, in order to account for the obvious fact that one sense of a word is activated before other ones, we can invoke differences between momentary activation thresholds of MLs of different senses. The same principle can apply to the sets of syntactic features within the syntactic operator. Of course, when a word is embedded in a sentence, additional syntactic constraints prevail, which is a totally different matter.

⁹ We assume that the syntactic operator enters MLs by their identifying labels. Then, all information in the ML is directly accessible.

we must suppose connections between the meaning memory and visual, acoustic, motor, etc., memories. We insert these connections as optional information units into MLs, hereby also opening the possibility that sensory events activate meaning memory locations which, in turn, induce speech production.

5. *Memory locations contain information about their position relative to other memory locations in the same set.*

As will be shown in the next chapter, it is desirable to hypothesize that antonymous words *(small-big₃ good-bad)* activate the same set of memory locations, but, are connected to the opposite poles of this set. This requires introduction of an ordering principle.



The figure shows some of the MLs in the *big-small* set. We might locate the intersection of *giant* with this set into an ML at the *big—pole*, while that of *dwarf* near the *small-pole*. We partition the set into *equivalence classes* (E_1 - E_5 in the figure); MLs within the same equivalence class can be said to have indiscriminable values on the dimension, that is, indicate the same degree of *bigness* or *smallness*. In logical terminology, they engage in a transitive, symmetric and reflexive relation. Over equivalence classes we define a proper inequality relation (transitive, asymmetric and irreflexive) enabling one to say, for instance, that *giants are bigger than dwarfs*. For many words there is only one equivalence class, so that their MLs are, in fact, unordered.

6. Each memory location contains a space (filled or empty) for reference to one other ML that has the former ML as one of its labels.

This type of information is of utmost importance because it enables the formation of *hierarchies of minimal propositions* necessary to account for complex sentences. As an example we take the sentence (1) *Pascal invented the calculator* that can be paraphrased to (2) *Pascal is (was) the inventor of the calculator* and (3) *The calculator is (was) an invention of Pascal.* From (2) and (3) we see that (1) contains, among others, the MPs (a) *Pascal-inventor* and (b) *calculator-invention.* Both of them express the inclusion of an element (subset) under a set. This, however, does not exhaust the meaning of (1); what has to be added is a *relation* (in logical sense) between the elements of the sets.¹⁰

We now hypothesize that (1) requires a third ML, (c), that receive labels referring to (a) and (b). At the same time, the empty spaces in (a) and (b) are both filled with the

¹⁰ For a discussion of the linguistic acceptability of this notion, see Ch. III.

symbol (c), which indicates that they are labels of ML (c). The following two figures picture this process:



From the latter figure¹¹ we see that (c) remains with an empty space, so that it can serve, in turn, as a label for one other ML. In this way, complicated hierarchies of MLs (MPs) can be built up. In chapter III we shall discuss how various kinds of linguistic constructions are analyzable into such hierarchies. Here, we only note that letting MLs be labels for other MLs constitutes a recursive principle making possible the generation of an infinite number of sentences and imposing no upper limit to their length.¹²

In the next two chapters we shall investigate the extent to which the set-feature model provides plausible accounts for meaning, both from linguistic and psychological points of view. The last chapter will be devoted to experimental tests of a number of hypotheses that can be derived from this model but are incompatible with some alternative theories.

In the following chapters we shall use "storage schemes" to picture the hypothesized MLs and their interrelations. Sets are represented by continuous lines, MLs by intersecting lines, cross-reference between MLs by dotted lines. E.g. the storage scheme for (1):



That the crosses are asymmetric has to do with the postulated ordering of MLs in many sets. ¹² See also the Postscriptum on p. 87 which was added to the 2011 on-line edition.

¹¹ Because MLs where a two-place relation has been stored, do not specify the inclusion of one set under another, they do not contain the arrow-symbol (cf. p. 25). We assume that all other MLs indicate inclusion-relationships and, therefore, have arrows pointing to the including set.

Chapter III

LINGUISTIC STRUCTURES AND THE SET-FEATURE MODEL

In this chapter we describe the analysis of various types of linguistic constructions into hierarchies of minimal propositions. Our proposals concerning these hierarchies, primarily required for the derivation of experimentally testable hypotheses from the set-feature model as a *performance* model, may be considered a set of statements about the semantic representation of sentences as part of linguistic theory. This implies that *competence* data constrain the range of possible alternative proposals and also may provide evidence pro or contra.¹³ However, the main object of this study is collecting performance evidence in support of the set-feature model. We assume that the semantic representations outlined below are tenable from a linguistic point of view; supplying detailed competence data in support of this assumption, however, should form the object of further study.

§1. Nouns, pronouns, and articles

Nouns can be said to denote two different collections of objects: (a) the whole collection of objects to which the noun applies, and (b) an element or subject of this collection. The former case may be termed *generic* use *(cars are vehicles, water is a liquid, a horse is an animal)*, the latter one *particular* use *(the car is out of order, the water is rising, I saw a horse)*. It goes without saying that this distinction does not apply to proper names referring to individual entities *{Homer, Venus, Fido)*. As is shown by the examples, generic or particular use of nouns is indicated by the article in combination with singular and plural forms. Without entering into the details, we assume that the syntactic operator determines the way a certain input-noun is used. In cases of particular function of this noun, the syntactic operator arouses a set of MLs which intersects the set of MLs aroused when the same noun has generic function.



The arrow in the figure indicates that, of the two intersecting sets, *car* (generic) is the including, *car* (particular) the included set. This proposal is in line with our general treatment of "lower" concepts as belonging to the set of features of "higher" concepts (cf. p. 25). When, in normal connected discourse, a new instance of the collection of

¹³By *performance* we mean language behavior, by *competence* the underlying system of linguistic rules and relations (Lyons 1968; 52).

cars is introduced, the syntactic operator builds up a new set of MLs and assigns all that is asserted about this *car* to this set, not to the "generic" set.

By means of (personal, demonstrative, possessive etc.) pronouns it is possible to refer to preceding or following nouns and phrases (*The burglar broke into the villa; he* ...; or *it* ...). Pronouns also can serve to add semantic features to a foregoing noun(-phrase), e.g. if this noun is unmarked as *male* or *female* (... *my neighbor; she* ...; cf. McCawley 1968). It is difficult to explain these facts in terms of the framework of our model as outlined in the previous chapter, because additional short-term memories have to be postulated. Pronouns are borderline cases between syntax and semantics, and a complete account presupposes elaboration of the presently unknown structure of the syntactic operator. We confine ourselves to remarking that pronouns do not have straightforward connections to sets of the meaning memory and, in the process of syntactic analysis, are somehow replaced by the nouns or nounphrases they refer to (sometimes adding markers, such as *male* or *female*).

We conclude this section with some general remarks about synonymy, homonymy and polysemy. We assume that each of the readings (cf. p. 14) of a homonymous or polysemous word-form is represented by a separate set of MLs in the meaning memory. Thus, the word-form *ball* is connected with one set for the reading which includes the feature *globular*, with one for *ball* as a social activity, and perhaps with yet other ones. It would be premature, here, to outline a mechanism that determines which of the ML sets connected to a particular homonymous or polysemous wordform is aroused in a given context (cf. *The boy is playing with the ball* and *The girls visited the ball*. See Katz and Fodor (1963) for the notion of selection restriction.) As for synonymy, synonymous words are different word-forms which, via the syntactic operator, arouse the same set of MLs in the meaning memory.

§2. Verbs

Our assumption that MLs may be labels for other MLs enables us to introduce *relations* between elements of the same or different sets (cf. p. 27). Using the traditional term *modification*¹⁴, we say that in a minimal proposition a word A is modified by another word B, and vice-versa. In the same way, an ML into which a relation has been stored, represents a minimal proposition, but, here, the modifiers are not single words, but two minimal propositions.

Transitive verbs express relations between two noun-phrases, between their subject and object. As indications for the sets involved in those relations, two transformational forms are available: present and past participles. For example, we represent *John kills Bill* and *Bill is killed by John* by the following MPs: MP₁: *John-killing*, MP₂: *Bill-killed*, MP₃: *MP*₁-*MP*₂. Many verbs allow another pair of derivatives which may serve as set indicators: *inventor-invention*, *employer-employee*, *writer-writing*, *producer-product*. Intransitive verbs only require one MP and,

¹⁴However, we use it in a sense different from, although related to, the traditional one.

thus, one set-indicating participle form (John laughed \rightarrow MP: John — laughing; for the implications of this analysis of verb-constructions with regard to constituent structure, see p. 61).

Syntactically little related but synonymous constructions such as *I liked the play* and *The play pleased me* (Chomsky 1965) can easily be handled by taking into account the synonymy of the participles *liking* and *pleased* on the one hand, and of *liked* and *pleasing* on the other. The MPs involved can be represented by MP₁: I - *liking (pleased)*, MP₂: *play - liked (pleasing)*, MP₃: *MP₁-MP₂*. A similar phenomenon has been observed in connection with many indirect objects: *John sold the book to Bill* has the same meaning as *Bill bought the book from John*. The following MP hierarchy represents this pair of sentences¹⁵:



Verbs like *to marry, to resemble* show the particular property that their subjects and objects are interchangeable without alteration of sentence meaning *(John married Mary* vs. *Mary married John)*. These verbs express *symmetrical* relations. This property is reflected in MP hierarchies by the inclusion of both subject and object under one unordered set.



The verbs *to be* and *to have* require special consideration. Lyons (1968: 389) distinguishes between four functions of *to be*:

¹⁵ It is characteristic for indirect objects that an alternative MP_4 : MP_2 - MP_3 is equally plausible. We did not meet this difficulty for other types of prepositional phrases (p. 35).

- (1) existential (God is; There are lions in Africa)
- (2) identifying (*That man is John*)
- (3) attributive (Apples are sweet; Catholics are Christians)
- (4) locative (including temporal) (John was in Central Park; The demonstration is on Sunday).

He summarizes the status of this verb as "a grammatical element, devoid of meaning, which serves only to 'carry' the markers of tense, mood and aspect in the surface structure of sentences". In line with this conclusion we propose one MP for (the simplest possible) sentences with *be* as identifying or attributive (*apples are sweet* —> MP: *apples - sweet*). Existential *be*-constructions require an MP: (subject) - *existing*. For a discussion of prepositional complements in these as well as in locative constructions we refer to §4.

As Lyons (1967, 1968) points out, *have* as a main verb and, in general, possessive constructions, are often used as locatives: *I have the book (with me, at home)*; *Where is the book? John has it; the number of this page*. These cases may be treated as prepositions when it is unambiguously clear for which preposition *have* has been substituted. But, this is not always so: From *Houses have rooms* and *Houses have chimneys* we see that the subject of *have* only indicates a broad localization which leaves unmarked the actual spatial relationship (*in, upon houses)*. For these instances we propose the following hierarchy: MP₁: (subject)*localization*, MP₂: (object)*-localized*, MP₃: *MP*₁-*MP*₂. The genuine possessive meaning of *have* probably requires different analysis, e.g. in terms of *possess, own*, but, admittedly, the transition from locative to possessive functions is not clearly marked.

Our decision not to assign a separate set of MLs to the verb *be* may be extended to the verb *have*. When we inspect the MLs which have two other MLs as their labels (mostly indicated by MP₃: *MP*₁-*MP*₂), we see that these MLs can always be considered semantic representations of "possessive" constructions, that is, they might be replaced by *have*, *of* or genitive in surface structure. E.g. the hierarchy MP₁: *Johnemployer*, MP₂: *Bill- employee*, MP₃: *MP*₁-*MP*₂ for *John employs Bill* corresponds to the - awkward and redundant - sentence *John as an employer has Bill as an employee*, or, preferably, *John is Bill's employer* and still other possessive paraphrases. This means that, except in cases of *have* as possessive and as locative (see above), *have* expresses the fact that two MPs engage in a relation (in logical sense), whereas *be*, (except *be* as existential), expresses the intersection of two sets of MLs. This conception of *have*-constructions simplifies the analysis of various other constructions to a considerable extent (e.g. verb-adverb, p. 47).

Questions and imperatives are sentences implicitly containing the verbs *to question* and *to come* (*Come*! vs. *I order you to come*; cf. Lakoff, in press). This leads to the following MP hierarchies for *Come*! and *Does he come*?, respectively:¹⁶

¹⁶The MPs: *I*-(verb)*ing* are not necessary and may be deleted (together with the MPs at the bottom of both figures. For similar proposals with respect to sentences containing the nega-



§3. Adjectives

Polarity and dimensionality are pregnant characteristics of adjectives and form the basis for comparative constructions (Bierwisch 1967; Campbell and Wales 1969). Any meaning memory model should somehow assign a closer connection between antonym pairs such as *wet* - *dry* or *high* - *low* than between *wet* and *high* or *dry* and *low*. How this is done in the set-feature model has been presented at p.30 - 31 and need not be repeated here.

We distinguish between two basic comparative constructions: equivalence and inequality. Equivalence is in order when the compared noun phrases intersect the ML set corresponding to the antonym pair in the same equivalence class. This can be expressed by the *as* ... *as* construction: *A is as big as B*. In cases of inequality, the intersection is located in different equivalence classes. Here the *than*-construction is in place: *A is bigger than B* or *B is smaller than A* (see figure).

tion element *not*, see §4. A complete account of verb constructions should include the aspects of tense and mood, modal auxiliaries etc. For the present moment we leave them out of consideration but hypothesize that they might be represented in some way analogous to questions and imperatives.



Superlatives are special cases of *inequality:* A is bigger than B is transformationally related to Of A and B, A is biggest. The proposition phrase Of ... may be deleted but is always presupposed: I am the greatest (of all people, boxers). Implicit comparatives are provided by John is tall which may be paraphrased into John is tall for a man or John is a man taller than the average man (Bierwisch 1967):



Adjectives as well as relative clauses have either a restrictive (attributive) or nonrestrictive (appositive) function. In *The naughty children were punished, naughty* is appositive when the speaker intends to say that the whole collection of children was punished; it is restrictive when not all of the children but only the naughty ones received punishment. Sentences containing an appositive adjective can be paraphrased into two coordinated sentences: *The children were naughty; the children were punished.* This possibility does not exist for restrictive adjectives. The following figures show the MP hierarchies.



§4. Prepositions, conjunctions, adverbs and quantifiers

Prepositions and conjunctions have a common characteristic: they do not activate just one set of MLs in the meaning memory, but two sets simultaneously. In this respect they resemble transitive verbs (§2) that are connected to the sets corresponding to present and past participle forms and thus express two-place relations between subject and object.

Prepositions, too, express relations. In order to substantiate this view we may point out the frequent possibility of paraphrasing prepositional phrases into transitive verb constructions:

- (1) There is water in the bottle The bottle contains water
- (2) John eats with a spoon John uses a spoon to eat (Lakoff 1968)
- (3) *The houses of my father The houses owned by my father*
- (4) The cafe opposite the police office The cafe facing the police office
- (5) That book is about some unsolved problems That book treats ...

Although, perhaps, the pairs are not completely synonymous, they readily demonstrate the relational property of prepositions. Therefore, the MP hierarchy for prepositions has to be formally identical to that for transitive verbs. Sentence pairs (1) and (2) are represented as follows:



In many cases, the choice of a transitive verb expressing exactly the relation intended by the preposition will be either impossible or arbitrary (e.g. *on*, *under*). Because of this, we shall delete such paraphrases and confine ourselves to just *with*₁ and *with*₂ or *in*₁ and *in*₂ as indications of the pair of sets simultaneously activated by the syntactic operator upon presentation of a preposition. In order to account for the synonymy of *in*₂ and *contained (content)* or *with*₁ and *using*, we assume that the syntactic operator assigns the members of each pair to the same set of MLs.¹⁷

Synonymy is also exemplified by the sets corresponding to *before* and *after*, *over* and *under*, where we have to assume that *before*₁ (of time) and *after*₂ are identical to *after*₂ and *before*₁, respectively. From the obvious connections between *before* (of time) and *earlier than* on the one hand, and between *after* and *later than* on the other, we have to conclude that *before*₁ (= *after*₁) and *after*₁ (= *before*₂) actually activate opposite poles of the same set. See the MP hierarchy for *John arrived before Bill*:

¹⁷It will be clear that not only the digits 1 and 2, but also the present and past participles are just convenient marks. For instance, we do not assume that the syntactic operator, in effect, carries out transformations yielding the participle forms of input-verbs. Instead, transitive verbs (and prepositions) are connected to two sets and differ in this respect from other word-classes, e.g. nouns and adjectives, which activate only one set.


Subordinating *conjunctions (because, after, if,* but not *that*) are handled in essentially the same way as prepositions (or transitive verbs: *because* expresses the same relation as *to cause, if* as *to condition* etc.). The coordinating conjunction *but,* mostly expressing the symmetrical relation *opposite to,* also fits in with this scheme. The conjunction *that* does not receive a separate semantic representation; see the hierarchy for *I saw that Bill arrived*:



And and or show more complicated patterns of use. We do not consider cases where and just replaces full stop or semicolon (John went home and ... and). Next, we distinguish between (conjunction or disjunction of) factual statements and generalizing statements. Examples of the former kind are (Either) I stay or I go home, (Both) John and Bill are sleeping. Such cases of explicit (stressed) conjunction or disjunction require subsumption of the coordinated propositions under sets labeled joint and disjoint (incompatible), respectively:

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In generalizing statements, and and or are often interchangeable (Lakoff, in press). During his vacations John always visited Rome {and,or} Paris is open to three readings: (1) With and: John visited both cities during each vacation; (2) with or: John did not visited both cities during any vacation; (3) with and or or: Rome and Paris form the set of cities John visited during all of his vacations, but nothing is asserted about combinations within one vacation. Readings (1) and (2) have to be dealt with as real conjunctions and disjunctions¹⁸ (see above). The fact that reading (3) is allowed by both and and or requires some explanation. From (a) Children are boys or girls and (b) Boys and girls are children, we can see that (a) describes properties of individual members of the class of children, whereas (b) specifies the membership of the class of children. In other words, or focuses individual entities or subsets, while and focuses the larger subsuming class. This, of course, applies to unions of sets in general: If $A \cup B = C$ and $A \cap B = \emptyset$, then each element of C is a member either of A or of B, and C consists of the elements of A and B. Without entering into further details we shall assume that this is a sufficient explanation why and and or may be interchangeable. If this is correct, then no special provisions are needed for these occurrences of and and or. Both (a) and (b) may be pictured as



In order to set up MP hierarchies for *adverbial* constructions we make use of the relationship between adjectives and "abstract" nouns {*free-freedom, ill-*

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¹⁸Here, of course, *and* and *or* are not interchangeable. Another instance of *and* not replaceable by or in generalizing or factual statements is provided by symmetrical relations: *Mary and Nelly combed each other's hair, A and B are interchangeable*. For the MP hierarchies associated with these constructions, see p. 31.

illness) and between verbs and their nominalized forms (*the boy plays - the boy's playing* or *the boy's play*). We will assume that both groups of nouns receive, in the meaning memory, ML sets which are different from the sets allotted to the corresponding adjectives and verbs. (Thus these nouns are not considered transformational derivatives of adjectives or verbs.) In the sequel, we shall refer to the sets corresponding to nominalized verbs by their infinitive forms (*play, give*) in order to avoid confusion with the present participles (*playing, giving*) that already serve a different purpose.

We delimit a group of adverbs which modify the sets connected to abstract nouns and nominalized verbs. E.g. *John is seriously ill* and *Mary dances beautifully* are represented as follows:



Constructions with this type of adverbs are paraphrasable into possessive constructions, *{John's illness is serious* and *Mary's dancing is beautiful*) where it is clear that the adverbs (now adjectives) modify the abstract nouns or nominalized verbs (cf. the remark on p. 32 with regard to the relational function of *have*).

In the case of another group of adverbs, this paraphrase leads to a change of meaning. E.g. John is rarely ill differs from John has a rare illness. This shows that rarely and, by similar argument, also not, perhaps, seldom, certainly etc. cannot be said to modify the ML sets connected with abstract nouns or nominalized verbs. Instead, we assume that these adverbs modify minimal propositions or hierarchies of MPs (cf. Kraak 1966, p. 163). We illustrate this point of view with the negation element not, hereby supposing that the past participle negated arouses the same ML set as not (cf. p.40 for analogous MP hierarchies for imperatives and questions). The figure (for John did not eat with a spoon) shows that negated can be attached to the structure as a whole or embedded at some place in the structure. In the latter case, the scope of the negation is limited (in the figure, the embedded *ne-gated* only covers *with a spoon*).



As for quantifiers, we limit ourselves, here, to mentioning Jackendoff⁴s (1968) analysis of quantifiers (number names, *some, many, a group of,* etc.) as nouns plus the preposition *of.* In line with this proposal we could represent *two horses* as:



§5. Semantic representations of sentences: phrase-markers or hierarchies of minimal propositions

In several recent articles (McCawley 1968, McCawley (in press) and Lakoff (in press), a fundamental revision of the conception of transformational grammar is proposed. (For criticisms, see Chomsky (in press).) The separation between the various components (semantics, syntax with base and transformational divisions, phonology; cf. Ch. I) are broken down and, instead, the generation of a sentence is seen through a series of transformational steps, beginning with a phrase-marker P₁, along intermediate stages P_{*i*}, P_{*i*+1}, etc., ending with a phrase-marker P_n. Each P_{*i*} is a phrase-marker into which, broadly speaking, a certain structural change is introduced by a transformational rule, resulting in P_{*i*+1}. This process goes on until P_n is reached, the structure that receives a phonological interpretation. P₁, called the semantic representation of the sentence, is

interpreted in terms of extralinguistic entities whose nature is left untouched. But it is stressed that set-theoretical notions and rules play an important role in the formation of semantic representations.

Associated with the grammar is a lexicon which assigns, to each entry, sets of semantic, syntactic and phonological features. Insertion of lexical items into portions of phrase-markers (lexical transformations) does not necessarily take place in a block, but may be distributed over several stages in the process $P_1 \dots P_n$. This makes deep structure a superfluous notion, because it presupposes blockwise insertion of the lexical material (at the terminal modes of trees generated by the base component of syntax). Also, a separate semantic component with various types of projection rules in the sense of Katz (cf. Ch. I) is explicitly (at least by Lakoff (in press)) or implicitly rejected, because the semantic representations (P_1) are unambiguously and immediately interpretable by the hypothesized extralinguistic system.

The latter conclusion may be questioned on the following ground. The semantic representations are phrase-markers labeled with syntactic symbols which serve to indicate the grammatical relations between constituents. This is necessary because, otherwise, *The cat chases the mouse* would be equivalent to *The mouse chases the cat.* This means that, as a next step, a theory is needed about how exactly the extralinguistic interpreting system responds to these syntactic symbols. We immediately agree that such a theory does not properly belong to the task of linguistics, but we disagree with a linguist's claim that introduction of symbols such as Subject (agens) or Object (patiens) into the semantic representation of a sentence exhausts the semantic analysis of this sentence. He also has to define the notions of Subject, Object etc.,—in other words, to give their semantic analysis. Only after this has been accomplished, has the semantic analysis of the sentence been completed. Therefore, in addition to P₁, a separate "semantic component" is needed where the semantic functions of grammatical relations is defined.

As soon, then, as one attempts to circumscribe the meaning of grammatical relations, for instance of Subject, it is unavoidable (1) to go back to one, more basic, grammatical relation, namely that of modification (or, rather, the relation between the nominal phrases in a NP-*be*-NP construction; in set-theoretical terms: inclusion) and (2) to invoke other words of a language to characterize the relation. If we suppose that Subject might be satisfactorily defined as *agent*, then the subject of *The cat chases the mouse* would be represented as *cat is the agent*. Consequently, the phrase-marker serving as the semantic representation for this sentence is partitioned into several subtrees for *cat is the agent* (and, say, *mouse is patiens*):



One sees now that the coherence of the sentence is lost: S dominates coordinated subsentences (S' and S'') and a verb, so that S' and S'' might be interpreted as totally unrelated sentences. The coherence could, perhaps, be restored by inserting the preposition *of*, resulting in something like *cat is agent of chase and* ..., but this only replaces the problem to the semantic analysis of *of*. The next problem, of course, is an old one: Is it possible to find sufficiently general definitions of Subject, Object, etc.

Both difficulties are avoided by the set-feature model: It only uses the basic grammatical relation of modification which, in virtue of the conception of two-place relations as the mutual modification of two other modifications, is applicable to a variety of grammatical functions, as outlined in this chapter.¹⁹

¹⁹We note, here, that it is possible to depict (but not more than that) MP hierarchies as binary trees, by turning the MP figures upside down, replacing crosses (X) with non-terminal branching nodes (Λ), and labeling all non-terminal nodes with MP. These "trees", however, differ from phrase-markers in at least one important respect: They imply no left-to-right order of constituents.

Chapter IV

PSYCHOLINGUISTIC IMPLICATIONS: MEMORY REPRESENTATION OF WORD AND SENTENCE MEANINGS

The hierarchies of minimal propositions developed in the previous chapter are hypotheses not only with regard to the semantic representation of a variety of linguistic constructions, but also with regard to the way these constructions are stored in the meaning memory. The latter point of view makes the set-feature model comparable to other theories on the memory representation of word and sentence meanings. Here, the set-feature model is confronted with these alternative psycholinguistic theories and their supporting evidence. As such, this chapter prepares for the next one which is devoted to some critical experiments.

§1. Word meaning

According to the set-feature model, word meanings are represented in the meaning memory as sets of MLs, and each ML contains exactly one MP. An exhaustive enumeration of all MPs in a set would provide us with a complete inventory of the meaning of the corresponding word. In order to approximate such an inventory one could have a subject write down all he knows about the meaning of given stimulus words in short sentences and, afterwards, reduce them to their MP hierarchies along the lines indicated in the previous chapter. Of course, MLs with high activation thresholds are hardly accessible and, therefore, will tend to be excluded from the inventory.

It is evident, now, that most of the sentences cannot be analyzed into simple MPs but into hierarchies of them. For example, the circumscriptions obtained for *clock* will include not only *clocks tick, a clock is an instrument* (simple MPs), but also *clocks indicate time, clocks have cogwheels,* etc. The nouns of both latter sentences are distributed over different MPs (e.g. MP₁: *clock-indicating,* MP₂: *indicate-time*, MP₃: MP_1 - MP_2 . This means that *time* and *cogwheels* do not properly belong to the ML set for *clock* but are indirectly related to it (via MP₃). We shall make a sharp distinction between both types of sentence-responses and shall label *instrument* and *tick* as *set responses,* but *cogwheel* and *time* as *non-set responses*. Correspondingly, we may define set responses as *simple* semantic features, whereas phrases containing non-set responses (*have cogwheels*) may be referred to as *complex* semantic features.

The sentence generation procedure—in combination with the analysis into MP hierarchies—seems to be a natural way to arrive at inventories of word meanings because it appeals to the common-sense notion of meaning as "definition" or "circumscription". A second advantage of this technique is its free-response characteristic: because, within the limits imposed by the instruction, the subjects are free to respond with whatever they like, it does not preclude any semantic feature from showing up in the sentences. The latter aspect enables a direct comparison with another procedure

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used in the study of meaning: eliciting one-word free associations (Deese 1965).²⁰

The responses produced in word-association sessions closely depend on the instructions supplied to the subject. He may be asked to respond with one word per stimulus (Deese 1965), with as many words as possible in a limited interval of time (Noble 1952), with continuous associations (Pollio 1966) or with instances of a category (Bousfield, quoted from Deese 1965). Because there are hardly any semantic considerations urging towards the adoption of one variation instead of another, choice between alternatives is difficult. Deese (1965; 42) opts in favor of collecting one-word free associations because "these are the most direct and immediate responses elicited by the linguistic forms which serve as stimuli". This is reasonable in the light of his general definition of meanings as "*the potential distribution of responses*". This distribution comprises all learned responses (including nonverbal ones, e.g. imagery) and thus it is important to leave the subject as free as possible.

However, it is evident that all current association techniques preclude an important class of responses, namely utterances consisting of two or more words. With the aid of the analysis of these utterances into MP hierarchies this constraint may be removed. The result is not an unmanageable heap of sentences but a structure of words. It seems likely that there is a high degree of overlap between the words produced in the sentence generation technique and the one-word free association responses. But, unlike the free association method, the sentence generation technique immediately reveals the logical relations between these words (superordinate and subordinate concepts, relations between elements of different sets). This goal seems unattainable by any single-word association technique, if not in principle, then at least in practice.

The sentence generation method has at least one disadvantage. Suppose that the following structure has been stored in the meaning memory of some subject



and that he writes down the sentence *canaries are animals*. From the sentence alone we would have to conclude that it is derived from an ML containing the MP: *canary - animal* which, in fact, does not exist. Generally, this means that many higher concepts will, erroneously, be included under the ML sets of stimulus words. Collins and Quillian (1969), indeed, have shown that, given the structure depicted in

²⁰Comparison with two methods developed by Osgood is much more difficult. In both his semantic differential and his word-compatibility judgment method (cf. p. 16) the experimenter presents a limited set of words to the subject so that the set of potential responses is determined by the experimenter's choice of these words (cf. Deese 1965, p. 70-71). We do not enter into a discussion of these methods.

the figure, the reaction time needed to confirm the truth of *a canary is a bird* is shorter than for *a canary is an animal*. In Ch. V \$ and 2 we present two experimental studies where a simplified version of the sentence generation technique has been applied.

In the survey of componential meaning theories within psychology (Ch. I, §2,B) we mentioned Mandler's (1968) proposals with regard to the hierarchical organization of verbal memory and showed that hierarchically ordered word categories can be reformulated as structures consisting of sets of features. The sets mentioned there, however, show a lot of redundancy (e.g. acquaintance occurs in all of the sets). It will be clear that, by means of the arrow-device (p.28) this inefficiency can be circumvented. The translation into sets of features is also motivated by the following argument. Mandler's hierarchical structure precludes the possibility that words are classified under different hierarchies without repeating them for each hierarchy in which they participate. For instance, someone who has classified a certain person as one of his acquaintances, might, at the same time, subsume him somewhere in the category of artists. Now, a strictly hierarchical system would require that the name of this person is mentioned separately in both categories, so that there are two unrelated occurrences of that name in the memory organization. It would be less uneconomical if the name occurred at one place in the memory with tags referring to the sets acquaintance and artist, as is realized in the set-feature model.

§2. Sentence meaning

The development of transformational-generative grammar gave the impulse to a large amount of research into the "psychological reality" of linguistic constructs. We delimit, here, *two* fields of study: the performance correlates of (a) syntactic transformations and (b) phrase-structure rules (linguistic segments). A third line of research stems from Yngve's (1960) model of language structure. We shall discuss these fields in turn and place emphasis upon memory rather than perception experiments.²¹ The main conclusion will be that most of the experimental data which are interpretable as demonstrating performance correlates of *syntactic* constructs, can plausibly be accounted for in terms of *semantic* factors, that is, in terms of the meaning memory representations of the experimental sentence materials.

²¹We do not give a complete survey of the literature available. Rather, we restrict ourselves to theories that are directly comparable to the set-feature model. A number of studies report the influence of variables absent from the theoretical vocabulary of our model. Of course, we do not deny the impact of these factors.

A. Syntactic transformations

The general assumption is that deep structures, not surface structures are the units stored in memory after sentences have been perceived and understood. The hearer is supposed to decode surface structure by tracing back the sequence of transformations according to which the sentence has been generated in the first place, until he arrives at the level of deep structure. From this it follows that transformationally more complex sentences (e.g. passives) are less easily understood than transformationally less complex sentences (e.g. actives) transmitting the same semantic content. They are also more difficult to remember because, if the experimental situation requires verbatim recall of the presented sentences, the subject has to store independently the transformational steps yielding the correct sentence. It is also assumed that the transformations described in some version of transformational-generative grammar (Chomsky 1957, 1965).

In the case of certain supposed transformations, these hypotheses lead to counterintuitive predictions. Adjective-noun phrases (the red house) seem more easily processed and stored than the noun-relative clause constructions from which they are derived (the house which is red; cf. p. 14; Fodor and Garrett 1967). In a number of studies, transformational complexity has been confounded with semantic content and sentence length. The finding that negative, interrogative, emphatic sentences impose a higher load upon memory than the corresponding affirmative ones (Savin and Perchonok 1965; Mehler 1963) may also be ascribed to their more complex semantic content (cf. Osgood 1968). Moreover, Matthews (1968) points out that the recall scores of the Savin and Perchonok study are equally well predicted by sentence length (rho =.85) as by number of transformations (rho =.83). In two experiments devised according to the technique developed by Savin and Perchonok (p. 66), Wright (1969a) shows that passives are remembered less well than actives. She envisages the possibility that mere sentence length, not transformational complexity, caused the difference, but rejects this interpretation because of Savin's finding that who-questions (who saw the man?) were more difficult than active affirmative sentences (the girl saw the man), although they were shorter by one word. However, this seems to be a weak argument because it is likely that whosentences are semantically more complex than simple affirmative ones. Although we would agree with an opponent's claim that these alternative explanations remain arbitrary without specification of the empirical functions relating ease of recall to both semantic content and sentence length, we maintain that in these experiments at least three factors have to be taken into account: not only transformational complexity, but also semantic content and sentence length.

Another study by Wright (1969b) throws further doubt upon the general assumption that before a subject is able to grasp the meaning of a sentence, he has to trace back the transformational history, that is, to derive the deep structure. She presented subjects with active and passive sentences (e.g. *The cat watched the bird*). Each presentation was followed by a question asking for the subject part, the verb or the

object part of the sentence. The questions were phrased in either the active or the passive voice {What was watched by the oat?; What did the cat watch?). Four combinations were possible: (1) active sentence-active question, (2) passive-active, (3) active-passive, and (4) passive-passive. The transformational hypothesis would predict, among other things, that condition (1) is easier than all of the other ones, because it does not require any reduction of passive to active voice. For similar reasons, (4) was expected most difficult. However, the number of incorrect answers in conditions (2) and (3), where sentence and question had different voices, turned out to be significantly higher than in (1) and (4) where sentence and question were matched as to voice. Thus, not number of transformational steps, but matched vs. mismatched was the relevant dimension. These data show that understanding and storing sentences is possible without going back to deep structure.

If these considerations are valid, than we are free to assume that the syntactic operator starts activating sets of MLs as soon as the first content words of the sentence have been recognized in the word-form memory. The resulting MP hierarchy is determined by the syntactic information in the sentence. This assumption would have been precluded when the evidence was consistently in favor of the transformational hypothesis. If it were true that subjects perform syntactic transformations upon the input sentence in order to derive its deep structure, then semantic interpretation could start only after the whole sentence had been perceived.

B. The depth hypothesis

In 1960 Yngve proposed the notion of "depth" as a measure of the memory load imposed by sentences- As soon as a speaker has uttered the first word of a sentence, he commits himself to continue in a certain way. E.g. when the first word is an article, then, the sentence must also contain a noun; the first noun-phrase must be followed by a verb-phrase. Each of these commitments has to be stored in memory and retrieved at the appropriate time. In order to determine the number of commitments involved one constructs a binary tree and counts the number of left branches (=depth) leading to each word (see figure; e.g., *the* "ties" the speaker to completing the noun-phrase and to following it by a verb-phrase).



In a number of studies "mean depth" (number of commitments divided by number of words) appeared to be a good predictor of sentence recall. However, these experi-

ments failed to control for semantic content and sentence length (Perfetti 1969, Wright 1969a). As an alternative measure Perfetti proposes lexical density (the proportion of *content* words occurring in the sentence). Using an experimental design that allowed for independent variation of mean depth and lexical density without affecting sentence length, he showed that lexical density, not mean depth, was the critical factor involved. Thus, we have to conclude, again, that semantic complexity is a potent, but easily overlooked variable in sentence retention.

C. Immediate constituent analysis

The term *immediate constituent analysis* refers to the common linguistic procedure of segmenting sentences into word groups (phrases), word groups into smaller word groups etc. E.g., the first constituents within *The man reads the old book* are *the man* and *reads the old book*. The latter constituent is segmented, in turn, into *reads* and *the old book*, etc. The result of this procedure may be represented as

(((the)(man))((reads)((the)((old)(book))))).

Generally, the main boundary within a sentence is placed between subject and predicate (but see Uhlenbeck 1963).

The psychological reality of this major boundary has been substantiated by means of a variety of techniques. Two of them will be discussed here: one using probe latencies (Suci, Ammon and Gamlin 1967; Suci 1969; Wilkes and Kennedy 1969), the other using transitional error probabilities (Johnson 1965).

Probe latency studies consist of two stages. First, subjects listen to a sentence carefully or, alternatively, learn it to a criterion of perfect recall. Second, they are presented with one of the words occurring in the sentence and asked to respond as quickly as possible with the next word of the sentence. The general hypothesis is that the reaction time (latency) will be longer, when the constituent boundary between stimulus and response words is more important (as indicated by the number of brackets between them). More particularly, the longest latency is predicted between subject noun and main verb in subject-verb-object sentences. This is borne out by the data very clearly.

In Johnson's experiment, subjects learned sentences of the types *The tall boy* saved the dying woman and *The house across the street is burning* as responses in a common paired-associate procedure with one-digit numbers as stimuli. As soon as a number appeared, subject had to respond with the corresponding sentence. For each pair of adjacent words (n, n+1). Johnson computed a transitional error probability, that is, the proportion of cases where *n* could be correctly recalled but not n+1. Again, the results were in good agreement with linguistic constituent structure, and the highest error probabilities coincided with subject-verb boundaries (*boy-saved* and *street-is*) and with the transition from noun to preposition in the second sentence type (*house-across*).

Although these data lend convincing support to the psychological relevance of the phrase-structure boundaries, we shall show that these phenomena can be accounted for in terms of the set-feature model, that is, in terms of meaning. In the figure we give the MP hierarchies for both sentence types.



We make the following assumptions, that are needed independently (see Ch. V for supporting evidence):

- 1 (a) When presented with a word indicating a relation (transitive verbs and prepositions; cf. pp. 30/31 and 35/36) the syntactic operator activates (at least) two MLs simultaneously, namely one for each noun entering into the relation.
 - (b) A word-form expressing a relation can only be produced (pronounced) when both MLs between which the relation holds, have been activated.
- 2 The probability that a certain response is produced after a certain stimulus depends on their distance in the MP hierarchy.

Assumption l(b) accounts for the high error probabilities at the transitions *house-across* and *boy-saved*: The relation-expressing words can only be uttered after the second term of the relation has been retrieved (*street* and *dying woman*, or perhaps, other nouns for which the relations with *house* and *boy* hold). Assumption (2) explains the high error rate between *street* and *is* (*burning*); for their distance see the figure.

As for the noun-main verb transition, we note, here, that l(b) only applies to verbs followed by an object phrase. In the case of an intransitive verb, production of this verb as a response to the subject noun does not require simultaneous activation of two MLs. In Ch. V, §5 we present a probe latency study confirming this expectation. This result suggests that the main constituent boundary is located *to the right of intransitive verbs*; incompatible as this is with most conceptions of phrase-structure, it follows directly from the set-feature model.

We conclude that semantic factors may be substituted for a variety of supposedly syntactic factors. This does not necessarily imply that syntactic factors are unimportant in sentence retention, but, more probably, that the frontiers between syntax and semantics have been overstated, not only in the realm of competence (cf. Ch. III, §5), but also of performance.

Chapter V

EXPERIMENTAL EVIDENCE

The experiments which we report here, test a number of hypotheses derived from the hierarchies of minimal propositions set up in Ch. III. Selection of hypotheses and design of the experiments were determined by the following considerations. First, the predicted outcomes must be incompatible with the alternative theories reviewed in Ch. IV. The experiments in Sections 1 and 2, dealing with one-word free associations, test the set-feature model against other models of verbal memory (cf. Ch. IV, \$1); Sections 3 through 5 present data which cannot be predicted from the sentence retention models which we discussed in Ch. IV, §2. Second, the hypotheses tested in the experiments must bear upon those assumptions which are most typical of the setfeature model. These are, in our opinion, the memory representations of two-place relations (cf. p. 30) as opposed to hierarchical structures (higher and lower concepts, words modifying one another). Of course, this implies that the below experiments do not cover the set-feature model as a whole. Because all of the experiments, in one way or another, draw upon the MP hierarchies elaborated in Ch. Ill and test performance correlates predictable from them, we do not pretend to offer direct evidence for the abstract structure of the meaning memory as postulated in Ch. II. That is, we do not factually show that memory locations are organized into sets, that they contain order information with regard to other MLs in the set, that they have activation thresholds, etc., and we keep open the possibility of devising a different meaning memory structure which generates the same set of predictions.

§1. Associative reaction time as a function of the distance between stimulus and response words in meaning memory

Theory

Although little is known definitely with regard to the way subjects retrieve from memory the response words during a free association session, we hypothesize that they trace one of the MP hierarchies of which the stimulus word is a part, in search of a response word meeting certain requirements. If, afterwards, these subjects are able to reproduce the search process in the form of a written sentence expressing the passed-through hierarchy, then we have, in principle, a measure of the distance covered while going from the stimulus to the response word. This measure is the number of MLs between both words in the MP hierarchy set up for the sentence. If, now, we place the subjects under an appropriate time pressure, we expect that they will produce many more "near" than "remote" responses, and also that remote associations take longer reaction times than near ones.

So far, this seems fairly clear-cut, but we emphasize that this way of defining distance is wholly different from the usual definitions in terms of frequency of the response: It is possible that two associations to a certain stimulus have equal associative frequency but, nevertheless, different distances as measured by the number of intervening MLs.

In order to arrive at a manageable and reliable design we decided to split the distance continuum into two parts; short-distances (0-1 intervening MLs) and longdistance (2 or more). By way of illustration, if we designate stimulus and response by *A* and *B* respectively, then zero distance means that *A* and *B* modify each other in the same ML (MP: *A-B*). A distance of one ML is exemplified by the patterns MP₁: *A-C*, MP₂: *B-C*; or MP₁: *A-C*, MP₂: *MP*₁-*B*. The hierarchy MP₁: *A-C*, MP₂: *MP*₁-*MP*₃, MP₃: *B-D* (typical of relational structures) counts as a distance of two MLs.

As we already noted at p.53, sentences produced by subjects as descriptions of word meanings (in the present experiment: of the meaning relation between stimulus and response words) do not necessarily mirror the stored memory structure. If, for example, a subject associates to the stimulus *animal* with the response *lion*, he might, afterwards, write down the sentence *lions are animals*. But the possibility remains that what has been stored is not the MP: *lion-animal* but *lion-mammal* and *mammal-animal*, so that we would erroneously count a factual distance of one ML as zero. For this reason we decided to group zero- and one-ML distances together.

The same difficulty may incidentally lead to wrong classification of a response as "short" instead of "long" when, for instance, the higher and lower concepts are separated by two MLs. Because of the time pressure prevailing we may assume that such responses will not often occur. Moreover, their inclusion within the short-distance responses tends to work against the experimental predictions and, thus cannot invalidate results confirming these predictions. This remark applies to other types of wrong classifications as well. But, in the absence of a better alternative, we have to rely upon the sentences offered by the subjects.

Summarizing, we predict that short-distance responses (zero or one MLs intervening) will have shorter associative reaction times than long-distance responses (separated from the stimulus word by two or more MLs), and that this difference also holds for response words of equal associative frequency.

Procedure

As stimuli we used 88 Dutch substantives, verbs and adjectives. The number of words per class of words was approximately equal (some words allowed of classification into more than one word-class). They were sampled from the word-count by van Berckel et al.(1965) in such a manner that words from the whole frequency range were represented in equal degree. The words were printed on six sheets of paper. Order of sheets was randomized for every Subject); sequence of words per sheet was identical for all *S*s.

The stimulus words were pronounced by E(xperimenter). A digital counter was started off by the sound of E's voice and stopped by S's voice (one association word). S was instructed to respond as quickly as possible with the first word occurring to him after presentation of the stimulus word. Associative reaction times (ARTs) were measured in milliseconds. In a preliminary training, Ss learned to respond with sufficient voice volume and to avoid making any other noise. The maximal permitted latency was 10 seconds. E recorded response words and ARTs on the sheets of paper, so that Ss could begin immediately after delivery of 88 response words with writing down the sentences. Only after delivery of all associations did the Ss learn that, for each S-R pair, they were to give a sentence that rendered as concisely as possible the essential meaning relationship between stimulus and response word. The sentence had to contain both stimulus and response. Although we have no absolute guarantee that this sentence reflects the MP hierarchy traced during the association phase of the experiment, we rely upon it, because it seems the best approximation within the limits of what is experimentally feasible. Moreover, the mere fact that a certain hierarchy has been passed through under free association instructions, makes it highly probable that it is the easiest way to go from stimulus to response. And even if S traced different hierarchies in the two phases of the experiment, then it is still unlikely that this leads to a wrong classification: e.g. the stimulus-response pair car-street can be connected by several words (prepositions, transitive verbs) but then street will invariably be classified as a long-distance response. (Of course, sentences like Cars and streets are physical objects (short-distance) are possible, but seem highly implausible).

Twenty undergraduate psychology students at the University of Nijmegen served as subjects in individual sessions.

Results

The maximal number of association words could total 1760 (20x88). 27 of these were blanks, i.e. either no response within 10 seconds, or a response to low to stop the counter. 75 association words were classified as "common expressions" (e.g. *bibliotheek (library)* as response to *openbaar (public)*> or *rooms (Roman)* as response to *katholiek (Catholic)*. We did not include them in the final analysis because they are parts of overlearned word sequences comparable to single word-forms.

The remaining response words were classified as either short or long-distance responses. The following lists contain some instances. Stimuli are printed in capitals, responses in italics.

Short-distance associations

Ik ben FOTOGRAAF (I am a PHOTOGRAPHER)

TEVREDEN mensen zijn *blije* mensen (CONTENTED people are *happy* people)

Die *dokter* kan goed OPEREREN (That *doctor* can OPERATE well)

VERS brood is heerlijk (FRESH bread is delicious)

GRAAN en *koren* zijn landbouwprodukten (CORN and *wheat* are agricultural products)

Wanneer je iemand beDANKT moet je hem iets *zeggen* (When you THANK someone, you must *say* something)

ONDERZOEKEN is een voorname bezigheid van een *psycholoog* (TESTING is an important part of the work of a *psychologist*)

BALANCEREN is *moeilijk* (BALANCING is *difficult*) POLITIEK is *saai* (POLITICS are *boring*)

Een *paspoort* is een gangbaar identiteitsBEWIJS (A *passport* is a generally accepted DOCUMENT for identification)

Een HOOFD is een zeer attractief object om te *schilderen* (The HEAD is a very attractive object to *paint*)

Een ARBE1DER behoort te Werken (A LABOURER is supposed to work)

LOPEN is een vorm van reizen (WALKING is a form of travelling)

Je NEEMT appels om ze op te eten (You TAKE apples to eat)

Een schommel ZWAAIT heen en weer (A swing SWINGS to and fro)

ENORM *veel* geeft een soort overtreffende trap aan. (TREMENDOUSLY *much* indicates a kind of superlative)

Er kan lang GEAARZELD worden (It is possible to HESITATE long).

Long-distance associations

Er zijn veel *mode*-FOTOGRAFEN (There are many *fashion* PHOTOGRA-PHERS)

Na het eten DANKT men met een *gebed* (After the meal one THANKS with a *prayer*)

BONNEN krijg je in een winkel (You get STAMPS in a shop).

WIELEN draaien snel als een auto rijdt (WHEELS turn fast when a car drives)

De VINGER is een deel van de hand (A FINGER is a part of the hand)

Bij een VERZOENING zijn op zijn minst twee *partijen* betrokken (In a RECON-CILIATION at least two *parties* are involved) De meeste MEDEDELINGEN worden op papier verstrekt (Most MESSAGES are provided on paper).

Onkundig wassen heeft KRIMPEN tot gevolg (Careless washing results in SHRINKING)

Bij een VERZOENING komt liefde op hoger niveau (In a RECONCILIATION love reaches a higher level)

Een pan is KEUKENgerei (A saucepan is a KITCHEN utensil)

Een ORGANIST bespeelt een orgel (An ORGANIST plays an organ)

De minister voert een BELEID (The Minister pursues a POLICY)

Op straat worden auto's GEPARKEERD (Along the street, cars are PARKED)

It will be clear that this classification follows the MP hierarchies developed in Ch. III. Sometimes we paraphrased sentences into shorter forms; e.g. the above psychologist example was scored as a short response because it may be rephrased as psychologists test. Not classified were 58 responses. This was partly due to carelessness on the part of the Ss (e.g. Een lamp werkt op elektriciteit (A lamp uses electricity), although ELEKTRISCH (ELECTRIC) was the stimulus word). Sometimes the response was nearly identical to the stimulus word (e.g. Een operatie doen is OPEREREN (Doing an operation is to OPERATE)).

The total number of short-distance responses was much higher than the number of long-distance associations (Table 1). Table 2 presents the ART data. In accordance with the prediction we see that the average ART for all long-distance associations together exceeds the average ART of all short-distance reactions by 323 msec. For 16 out of the 20 Ss the difference between the average ART for long and that for shortdistance responses was in the predicted direction; this yields a significance level of p=.006 (sign test, one-tailed). For each of 82 stimulus words separately, we calculated average ARTs for both reaction types and found for 66 words smaller short-distance ARTs (6 of the 88 stimulus words did not elicit any long-distance response).

Reaction types Ν % Short-distance responses 1087 61.8 29.1 Long-distance responses 513 Unclassified 58 3.3 Common expressions 75 4.3 Blanks 27 1.5 1760 100.0 Total

Table 1. Number and percentages of different reaction types

Marbe's law states a negative relationship between the frequency of an association and its average ART. The more often a given word is produced as an association to a given stimulus by a group of *Ss*, the shorter the latency of the response. Because, in this experiment, the number of short-distance responses is higher than the number of long-distance reactions, this law could account for our ART data. In order to discredit this explanation we calculated the average ARTs for unique responses, that is, association words which, within our group of *Ss* were given only once upon representation of a certain stimulus and, thus, have (more or less) equal associative strength (cf. the second prediction on p. 52). Table 3 shows that the difference between the ARTs for long- and short-distance responses is fully maintained for the unique responses separately, so that Marbe's Law fails for the present data.

Table 2. Average ARTs for all short and long-distance responses

Reaction types	Average	N
	ART (ms.)	
All short-distance responses	2029	1087
All long-distance responses	2352	513
Difference	323	

Table 3. Average ARTs for only the unique (once occurring) shortand long-distance responses

Reaction types	Average	Ν
	ART (ms.)	
Unique short-distance responses	2294	477
Unique long-distance responses	2635	270
Difference	341	

Discussion

It is possible to interpret these results in a slightly different way. The short-distance responses refer to higher or lower concepts in comparison with the stimulus word (inclusion, subsumption), whereas long-distance associations are members of a two-place relation with their stimuli as the other member of the relation (cf. our discussion of prepositions and transitive verbs on pp. 30/31 and 35/36). This means that the present data do not necessarily support the specific characteristics of the set-feature model as a whole. But, at least, they point out the necessity of making a sharp distinction, in any semantic memory model, between the memory representations of higher and lower concepts on the one hand, and two-place relations on the other. This requirement is not fulfilled by meaning memory models which conceive of word meanings as sets of features (or as word hierarchies; cf. Deese (1968) and Mandler (1968)) without a theoretical device for representing relations, nor by models trying to state *all* interverbal connections in terms of two-place relations (Frijda 1969).

Two problems remain unsolved. First, why do people produce long-distance associations at all? Second, what is the cause of the remarkable variation in the number of short-distance responses elicited by the stimulus words? (We observed a range of 1 to 20.) At present, we cannot provide the answers. As to the first question, perhaps *Ss* restricted many of their responses to words of the same syntactic class as the stimulus word (noun-noun, adjective-adjective, etc.); this strategy will often suppress relation-indicating words (prepositions, transitive verbs). Other response suppressing factors are easily conceivable; all of them keep *Ss* from doing what they are asked, namely to give the first association word.

§2. Clustering in free recall of association words as a function of their distance from the stimulus word

Theory

In free recall experiments, subjects are free to reproduce the previously memorized materials, often single words, in whatever order they prefer. This order of emission gives important clues as to the nature of the organization imposed upon the materials by the subjects. For instance, if the items to be memorized are exemplars of well-known categories (colors, towns, animals) and if they are presented to the subjects in some scrambled order, then the subjects will reproduce clusters of words belonging to the same category. Also more subtle determinants of subjective organization in free recall have been studied intensively. One factor is the frequency according to which the list items are elicited as associations to the category names, another the associative strength between the items (see Cofer 1965 and Tulving 1968 for surveys of the literature). Both factors point to the role of associative mechanisms determining the amount of clustering.

In the above ART experiment we found distance between associatively connected words to be a factor independent of associative strength. We predict an analogous distance effect upon the clustering tendency of association words in the free recall paradigm. Suppose we collect associations to a certain stimulus word, classify them as long or short-distance responses and group them according to associative frequency. The words classified as short-distance responses, then, not only are closer to the stimulus word but also close to each other, whereas the long-distance responses will probably, although not necessarily, be more remote from one another. Stated differently, all short-distance responses to a stimulus word necessarily belong, together with the stimulus, to the same hierarchy of including and included concepts, as is represented in the model by the arrow-device (See also Discussion of §1, p. 56). On the other hand, since long-distance responses are connected to the stimulus via a relational word, they belong to hierarchies different from that of the stimulus word. This does not preclude the possibility that a given set of long-distance responses has been taken from one hierarchy, but this would be a matter of chance, whereas it is necessary in the case of short-distance responses. This leads to the prediction that short-distance responses, embedded in some list of words, will more often be reproduced in clusters than long-distance responses, even when the two types of associations were equally well elicited as free associates to the stimulus word.

This forms the basis for the design of the present experiment, that went through four stages: (l) collections of free associations to a sample of nouns, (2) collection of sentence responses to these nouns for the purpose of distance classification, (3) composition of two lists, one containing short-distance^ the other long-distance responses, and (4) the free recall test.

Procedure

(1) For 50 Dutch nouns sampled from the whole frequency range in van Berckel et al.'s (1965) word count and judged to be well-known to the *Ss* (45 first-grade high-school students, about 12 -13 years of age), we collected one-word free associations. The stimuli had been printed in small booklets, one word on every page. We used two different orders of stimuli. *Ss* were free to move ahead at their own rate. We listed the obtained associations and eliminated 10 stimuli which, apparently, had not been understood.

(2) The remaining 40 words served as stimuli for another group of 44 Ss (students of the same grade at the same school) who were instructed to write down, for each word, three concise sentences that had to include the stimulus noun, "in order to tell us what you know about …". *E* gave one example (orally) and insisted upon spontaneity of responding. The words had been printed in booklets, five words on each sheet. Here, we used one random order. Because of the limited time available (40 minutes), no *S* finished the whole book; we could analyze the responses to 22 words for which we obtained a complete set of sentences from 36 *Ss*. By taking different, but comparable, groups of Ss for stages (1) and (2) we were better able to select those semantic features which are invariant over *Ss*, that is, to collect response words which are either short-distance or long-distance responses for all *Ss*.

(3) Again, we had to discard two nouns, because they were often used as verb or adjective. The sentences elicited by the remaining 20 nouns underwent an analysis into MP hierarchies (cf. p. 53-55) if they contained one or more of the free associates collected from the former group of *Ss*. In this way we could classify part of these associations as either short- or long-distance responses (not all of these associations recurred in the sentences). A few response words received a double classification so that we had to discard them. Since we preferred lists of nouns for the final test, we did not process words of other syntactic classes.

We were left with 140 classified free associates from which the test lists had to be composed. The choice possibilities, however, were limited because we needed pairs of one short- and one long-distance response which had equal associative frequency (in the first group of 45 Ss). Moreover, for each stimulus word at least two such pairs were necessary. Some stimuli allowed for more than one possible set of pairs; in these case we chose according to a random system. Table 4 presents the resulting words. Because of the many selectional restrictions, average associative frequency is fairly low.

We listed both groups of items in two different random orders (one for each presentation in the test phrase) in such a way that the short- and long-distance members of each pair occupied the same place in the two lists. Words belonging to the same stimulus were separated by at least three other items.

(4) The final test took place two and three weeks after phases (2) and (1), respectively. *Ss* were 111 first-grade students of the above-mentioned school, distributed over four classes; students in three of these classes already had participated in stages (1) or (2). Each class was divided into two groups (left vs. right halves) and received booklets containing two lists of either short- or long-distance responses. Each list was followed by an empty sheet for writing down the recalled items. In the first class participating in the experiment, the long-distance list was assigned to the left half, in the second class, to the right half, etc. Ss were instructed to memorize the word-list and, immediately after a signal, to reproduce as many of the words as possible. *E* emphasized that order of recall was unimportant and that the words should be written down (below one another) as soon as they were remembered. Ss were allowed two trials; each trial comprised 60 seconds of study and 90 seconds for responding.

Results

The number of Ss in the long- and short-distance conditions were 56 and 55 respectively. Each *S* delivered two lists of recalled words. We computed (1) the number of correctly reproduced items and (2) the number of clusters. A cluster is defined as a contiguous reproduction of two nouns which belong to the same stimulus word (Table 4). For instance, when a *S* wrote down *ruiter (jockey)* and *wei (meadow)* one below the other, this constituted an instance of clustering, because these words, both being associates to *paard (horse)* had not been contiguously presented in the test lists. Here, we mention only the results summed over both trials; they most clearly represent the general picture (Table 5).

In accordance with the prediction, we see that the number of clusters is highest in the short-distance condition. However, the lower total score (for the short-distance list as compared to the long-distance list (17.82 vs. 19.43) is counter to expectation, because difficulty of a word list closely depends on its level of organization. This deviation from the general rule is certainly due to non-randomness in the assignment of Ss to conditions (left vs. right halves of classes). In one class, where we found the total short-distance score exceeding that of the long-distance group (20.50 vs. 19.00), the number of clusters in the conditions differed extremely: 2.71 (short-distance) vs. .77 (long-distance). Probably, the clustering difference between conditions would have been larger than the one mentioned in Table 5, if we had applied a better subject-to-condition assignment rule.

Stimulus	Association words		Associative
words	Short-distance	Long-distance	frequency
paard	dier (animal)	ruiter (jockey)	3
(horse)	pony (pony)	wei	2
		(meadow)	
maan	ster (star)	landing (landing)	3
(moon)	hemellichaam	heelal (universe)	1
	(celestial body)		
gevangene	bandiet (bandit)	rechter (judge)	1
(prisoner)	misdadiger	tralie (bar)	1
	(criminal)		
parel	edelsteen (jewel)	snoer (string)	3
(pearl)	namaak	schelp (shell)	1
	(imitation)		
bloem	tulp (tulip)	meel (flour)	2
(flower)	anjer	water (water)	1
	(carnation)		
geld	munt (coin)	vrek (miser)	1
(money)	briefje	koning (king)	1
	(note)		
grens	scheiding	paspoort	2
(border)	(separation)	(passport)	
	einde (end)	grenswachter	1
		(border guard)	

Table 4. Words occurring in the final lists (second and third columns). Associative frequencies (rightmost column) from a group of 45 *S*s.

Table 5. Average scores summed over two trials

	Short-distance list (N=55)	Long-distance list (N=56)	Significance level (Median test)
Mean number of correctly repro-	17.82	19.43	p<.01 (two-tailed)
Mean number of clusters	2.36	1.14	p<.0005 (one-tailed)

Discussion

These outcomes are not very surprising when one inspects the words making up the test lists (Table 4), and it seems possible to "postdict" the data in terms of inter-item associative strength or overlap between associations elicited by the list-items (cf. pp. 56 and 17). However, as a matter of fact, we did not collect this kind of data but, instead, applied MP hierarchy analysis. Thus, from the standpoint of association theory,

the observed differences are sheer coincidence. We kept constant the associative connections between list items and original stimulus words and, solely on this basis, association theory cannot predict any difference between short and long-distance conditions. Actually, the set-feature model is not contrary to association theory, insofar as it is permissible to replace the term association by connection. The set-feature model specifies various types of connections between verbal items: connections within hierarchical structures, connections within relational structures, etc. But all these different types may be called associations.

§3. Clustering in free recall of sentence pairs with identical objects or adverbial modifiers

Theory

The hypothesis explored in the previous section can be tested more directly by studying the clustering tendency of sentences having different MP hierarchies but (almost) identical constituents. In (1) Ze typten de "twee" (They typed the "two") and (2) Ze veranderden de "twee" (They changed the "two"), the ML sets of the verb both intersect the ML set corresponding to the symbol two. On the other hand, this intersection is not present in (3) Ze typten het tweemaal (They typed it twice) and (4) Ze veranderden het tweemaal (They changed it twice).

In the figure (see next page) we represent *tweemaal (twice)* in accordance with adverbs such as *often, sometimes, certainly*, etc. (p. 39). We see that, even if we delete the object-MPs (*it*), the adverbial ML set does not intersect the set corresponding with the verbs. This implies that, in the meaning memory structure, the distance between verb and object representations is smaller than the distance between verb and adverbial modifier representations. Notice, however, that in spoken or printed representations the verb is equally remote from object and adverbial phrase.

We therefore hypothesize that object sentences of the above type will show a greater clustering tendency than sentences with an adverbial modifier when they are embedded in lists of sentences having similar structure and if the other sentences, pairwise, contain other number names. We collected a list of 10 verbs which all allow number names as objects. They were allotted five number names as object or adverbial modifier, so that two verbs were followed by the same number. The resulting sentences were scrambled and presented to two groups of subjects: One group received the object sentences, the second the sentences with an adverbial. This is the global design of the present experiment.



We have to admit that the sentences sound rather peculiar, but we needed objects and adverbial modifier of maximal lexical similarity. Moreover, it is necessary to have objects and adverbials which fit all of the verbs occurring in the lists. If we had chosen different objects and adverbials and if, for instance, the objects had been compatible with half the verbs occurring in the list, but the adverbials with all of them, then the hypothesis would probably have been confirmed, even in the absence of the hypothesized processes.²² It is difficult to find other material fulfilling these requirements.

Procedure

We chose 20 verbs which allowed number names as objects: *schrijven* (*write*), *veranderen* (*change*), *vertalen* (*translate*), *nemen* (*take*), *kiezen* (*choose*),

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²²This applies to any experiment where *S* is asked to recall a list of sentences which has been presented as a whole. Perhaps, this factor is responsible for the occasionally conflicting results in experiments studying prompted recall of sentences, in those cases where the prompt words (subjects, verbs, objects) had different ranges of compatibility.

bedekken (cover), verdoezelen (blur), onderstrepen (underline), tekenen (draw), vermenigvuldigen (multiply), raden (guess), tellen (count), vragen (ask), spellen (spell), berekenen (calculate), krijgen (receive) omcirkelen (encircle), voorspellen (predict), verdienen (earn), and typen (type). The 10 former verbs were assigned the numbers one through five, the 10 latter ones the numbers six through ten. The adverbials were tweemaal (twice), tienmaal (ten times) etc. In this way we obtained two lists of 10 object sentences (Ze schrijven ae twee) and adverbial phrase sentences (Ze schrijven het tweemaal). All verbs were in the present tense and always preceded the same number name.

The sentences were put in random order in such a way that no sentence followed another with equal number name. They were tape-recorded with normal intonation, except that the speaker pronounced the words according to a rhythm of one word per second. In this way, the temporal separation between onset of the verb and onset of object or adverbial modifier was always two seconds. There was no special pause between sentences, except for a short tone of high pitch.

As *S*s served 30 undergraduate psychology students. Fifteen were presented with object, the other half with adverbial modifier sentences. They were alternatingly assigned to one of the conditions in order of participation. *E* instructed them to listen to the sentence list carefully and, immediately thereafter, to recall as many whole sentences as possible, in any order. Before actually starting, *S* received preliminary training with other types of sentences. Reproduction was oral and started immediately after the last sentence had finished (as indicated by a double tone) and lasted for maximally 90 seconds. Every *S* underwent four such trials (two for each list). All responses were tape-recorded and, afterwards, written out in order of production. On these protocols we performed the statistical analysis.

Results

For each group, we computed (1) the average number of completely correct sentences, (2) the average number of correctly recalled verbs, and (3) the average number of clusters. A cluster is a contiguous reproduction of two verbs which, in the presented list, preceded the same number name. We did not require perfect recall of the clustered sentences because their occurrences were rather rare (16 in the object, eight in the adverbial condition). Table 6 presents the data summed over four trials.

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Condition	Sentences	Verbs	Clusters			
	recalled	recalled				
Object	16.93	23.47	2.20			
Adverbial modifier	14.80	21.27	.93			

Table 6. Average scores summed over four trials

Although the object group recalled somewhat more complete sentences and verbs, this difference is negligible (Mann-Whitney tests give U=95 for recalled sentences and U=91.5 for recalled verbs, which is not significant. Median tests yield χ^2 values of .54

(p<.50) and .13 (p<.75). The difference between number of clusters is significant: the Kruskal-Wallis test yields H=5.02 (corrected for ties) which corresponds to a one-tailed p<.015. (Mann-Whitney test without correction for ties: U=64.5; this just misses the value (64) required for p<.025.) In the object condition, the number of clusters is more than twice as high as in the adverbial modifier condition; this confirms our expectation.

Discussion

The hypothesis we were able to confirm is in agreement with the linguistic intuition according to which the adverbial modifier used in this experiment are constituents with a more "independent" character than objects (cf. p. 39). This is sometimes reflected in phrase-markers by a separate branch leading from S(entence) directly to Prep(ositional) P(hrase) or Adverbial Phrase, so that the latter constituents do not belong to V(erb) P(hrase).

The psychological sentence production model developed by Johnson (1966) starts from the assumption that a subject (1) decodes higher order constituents into two lower ones (e.g. S into NP plus VP), (2) stores the rightmost constituent in short-term memory and (3) goes on decoding the leftmost constituent into lower ones (e.g. NP into Article plus Noun) until the first concrete word has been reached. Then, (4) he retrieves the most recently stored constituent from short-term memory and starts decoding it, etc., until the last word in the sentence has been produced (cf. p. 65 for a further discussion). It is not clear how this type of theory could account for the present data. Most of Johnson's predictions derived from this model are based upon the number of decoding steps leading from the production of one unit to production of the following one. We counted the number of steps between the production of the verb up to production of object or adverbial modifier in binary trees for the sentence of this experiment, but did not find a larger number of steps for adverbial phrases.

The required difference can be obtained if we drop the condition of binary trees and construct phrase-markers with *three* branches originating from S (branches leading to NP, VP and Adverbial Phrase nodes). But then the theory runs into another difficulty because it must assume short-term memory storage of *two* constituents (VP and Adverbial Phrase); however, the model offers no criteria for deciding which of these is the first to be retrieved. It seems fair to conclude that the present data are hardly compatible with Johnson's sentence generation model.

§4. Memory storage of subject-verb-object sentences

Theory

If we inspect the following four SVO sentences and their MP hierarchies:

- (1) *The man killed the girl* (MP₁: *the man-killing*, MP₂: *killed-the girl* MP₃: *MP*₁-*MP*₂.
- (2) The man killed someone (MP₁:the man-killing, MP₂: killed-Y, MP₃: MP₁-MP₂.
- (3) Someone killed the girl (MP₁: X-killing, MP₂: killed-the girl, MP₃: MP₁-MP₂)
- (4) Someone killed someone (MP₁: X-killing, MP₂: killed-Y, MP₃: MP₁-MP₂)

we immediately see that the following relations hold between their semantic contents:

$$(1) > (2), (3) > (4), \text{ and } (1) + (4) = (2) + (3)$$

or, equivalently,

$$(4) = (2) + (3) - (1).$$

In terms of the memory effort required for storing these sentences we would expect the same relationship to hold between the retention scores. Johnson's (1966) model (cf. pp. 49 and 64), however, predicts a different outcome when retention is measured as we measured it in the present experiment.

In *The tall boy saved the dying woman, tall* and *boy* belong to the same higherorder unit, but not *boy* and *saved*. As soon as a Subject has produced, i.e. decoded from a higher order unit, the response *tall*, he will proceed to decoding *boy*. However, the decoding operation following upon *boy* does not generate *saved* but a higherorder unit, VP, which only after some further operations is decoded into *saved*. From this, Johnson deduces the prediction that preliminary training with the association *tall-boy* will have a facilitating effect upon subsequent learning of the whole sentence, but not pretraining with the association *boy-saved*. His results confirm this expectation. Transferred to the four sentences above, Johnson's model leads to the prediction that pretraining with (4) will have equal facilitating effect upon subsequent learning of (1) as pretraining with (2), provided, of course, that familiarity with individual words is controlled for. Hence :

$(1) > (3) > (2) \sim 4$ and (1) + (4) > (2) + (3).

That in Johnson's experiment pretraining with word pairs *boy-saved* did not significantly reduce the transitional error probability (cf. p. 59) from *boy* to *saved*, is probably due to ambiguities in six out of eight noun-verb pairs in the pretraining list. *Wants* in *family-wants* can also be a noun; *lady* and *sisters* in *lady-told* and *sisters-liked* were perhaps not seen as logical subject but as logical object. Party-was is not even a minimal proposition. Did, was and had in person-did, party-was and girl-had can function not only as main verbs but also as auxiliaries. These objections do not apply to the adjective-noun combinations (new-person, *last-party, young-girl*). Because the present experiment not only aims at deciding between the alternative models, but also at testing the additivity hypothesis ((4) = (2) + (3) - (1)), we could not repeat Johnson's procedure but, instead, applied a modified version of the "archimedic" method developed by Savin and Perchonok (1965). This technique is based on the principle that in a given time interval a fixed amount of material can be stored in memory. Bringing in additional material results either in the forgetting of it or, if it is remembered, in forgetting another part of the material. In this experiment we presented the *S*s in each trial with one SVO sentence and, after a pause of five seconds, with a string of 8 single words. *S*s were instructed to memorize the sentence and as many single words as possible. The number of these words that were reproduced after correct recall of the sentence, counts as a measure for the memory space (effort) needed for storage of the sentence content.

In the preliminary training, groups A, B, C and D learnt six sentences of types (1), (2), (3) and (4), respectively. Subsequently, each of the subjects underwent six trials with complete SVO sentences (type (1)). If we indicate the mean number of single words correctly reproduced by groups A, B, C and D during six trials by a, b, c, and d, then the set-feature model predicts d = b + c - a.

Procedure

The experiment comprised three stages. In stage I the *Ss* underwent 16 practice trials to become familiar with the experimental situation. In stage II the *Ss* memorized the sentences, or parts of the sentences, which, so they were told, would recur in stage III. In stage III measurement was made of the memory space needed for the retention of the sentences wholly or partly memorized in stage II.

The experiment was performed in groups in two fifth-grade and two sixth-grade classes of an elementary school. Each class was divided at random into four groups: A, B, C and D; the total numbers of *S*s in these groups were 24, 20, 22 and 23, respectively. The four groups from a given class took part in the sessions simultaneously, so that their treatment was identical except for the material they had to study during stage II.

The sentences and the strings of single words for stages I and III were presented by means of a tape recorder. Sentences had been recorded with normal intonation and speed, the strings of eight words at the rate of one word per second. Between the sentences and the strings of single words there was a five-second pause.

In total 22 sentences and strings had been recorded; 16 were designed as practice trials in stage I, six as the material for stage III. The six experimental sentences were the following:

De soldaat grijpt het geweer (The soldier grabs the gun)

De inbreker begraaft de diamant (The burglar buries the diamond)

De piloot drinkt de koffie (The pilot drinks the coffee)

De dorpelingen huldigen de burgemeester (The villagers welcome the mayor)

De minister verbrandt de handdoek (The minister burns the towel)

De agent regelt het verkeer (The policeman controls the traffic)

All 22 sentences were in present tense, but subjects and objects could be singular or plural.

The 22 word strings were composed from eight clusters of five words, each cluster being a well-known category of words: parts of the body, animals, vehicles, colors, temporal periods, garments, weather types and pieces of furniture. For each string the sequence of categories was identical, but the specific words had been chosen at random.

In a preliminary experiment we noticed that writing out in full all the words from the sentences and strings cost too much time. We therefore decided to make a modification in the sense that *S*s only had to write the initial letters of the words. In order to make a reliable scoring possible, the five words of each category were chosen such that their first letters were all different. The six subjects, verbs and objects also had different first letters. *S*s recorded their answers immediately on sheets of paper ruled with nine columns and eight rows. The leftmost column was wide so that it would provide enough space for filling in the five initial letters of the sentence words. In the remaining eight columns, which were narrower, stood the names of the categories. These names occurred in every row, rows corresponding to trials.

Ss were instructed to make sure they could reproduce the sentence, and after that as many separate words as possible. They first had to write down the sentence in the leftmost column, and then, in any order, the single words. For writing down the answers, 45 sec. per trial was allowed.

The material for stage II was different for each group. Group D was presented with the words from the six experimental sentences printed one beneath the other; at the top the subjects, in the middle the verbs, and below, the objects, all in a random order, with subjects and objects preceded by the definite article. The verbs were preceded by *hij (he)* or *ze (they)* and followed by *het (it)* or *hem (him)* (type (4) sentences). We chose these additions instead of *iemand (someone)* and *iets (something)* because we judged they would more successfully prevent *Ss* searching for concrete subjects and objects than would the indefinite pronouns.

Ss of group C received a sheet of paper on which, one beneath the other, the experimental sentences were printed; the subjects, however, were replaced by *he* or *they*. The subjects had been printed at the bottom of the sheet, preceded in each instance by the definite article. These *Ss* memorized type (3) sentences during stage II. Group B was given the experimental sentences with the objects replaced by *him* or *it* (type (2)). Here the objects had been printed at the bottom of the paper. Group A, finally, learned the experimental sentences in exactly the same form as that which they were to be presented in stage III (type (1).

The instruction was the same for all groups: to study the material printed on the sheet of paper by copying it once and afterwards reading it carefully. *Ss* were told that these materials would help them in memorizing the sentences in stage III. Total learning time was 4 minutes for all groups. Notice that as a result of this procedure *Ss* of all groups were familiar with all words of the experimental sentences.

Results

For calculating the average group scores we used only the trials in which the sentence was correctly reproduced. (Number of sentence errors was very small.)

Table 7. Average group scores (number of correctly recalled words after perfect reproduction of the sentences) and standard deviations

Groups	Ν	Average	Standard
		score	deviation
А	24	4.070	1.18
В	20	3.759	1.20
С	22	3.771	1.42
D	23	3.412	1.05

From table 7 it appears that the average scores fit in very closely with our prediction (d = b + c - a). Predicted d-value is 3.460, empirical d-value is 3.412; the difference is only .048 words. The a priori probability that our prediction is right grows larger the nearer the group averages approach each other. The difference between a and d is, however, significant (t - 1.717, p <.025 (one-tailed); Mann-Whitney U-test: z = 1.93, p = .027). All remaining differences are not significant (standard deviations being relatively large).

Discussion

The closeness of the average scores for groups B and C makes an interpretation in terms of Johnson's (1966) theory, which would predict that $a > c > b \approx d$, highly implausible, although the difference between b and d is not significant.

However, another very simple model is in perfect agreement. A theory in terms of "chunks" (cf. Wright 1968) would describe the memory load imposed by a sentence as the number of well-integrated and overlearned parts (chunks) out of which the sentence has been composed. Now, the number sof chunks for groups A, B, C and D were 1, 2, 2 and 3 respectively; these numbers correspond to the number of fragments into which the experimental sentences had been divided in stage II. Recalling a sentence during stage III, therefore, required retrieval of 1, 2, 2 and 3 chunks; this offers a complete account for the data.

However, the notion of chunking is too weak as a general explanation of sentence retention phenomena: it is unable to predict patterns of cohesion (e.g. different patterns of transitional error probabilities or probe latencies) between presumed chunks (e.g. words) when sentences are memorized to some criterion of performance. The extent to which this can be accomplished by the set-feature model, we will investigate in the next section.

§5. Probe latencies in sentences with transitive and intransitive verbs

Theory

In our discussion of the performance correlates of linguistic constituent structure (p. 48) we noticed that most experiments directed at these phenomena, studied sentences with the general structure x-relation-y where x and y are nouns or noun phrases connected by a word expressing a two-place relation (transitive verb, preposition). As a possible explanation for the observation that the transition from x to the relational word is more difficult than that from the relational word to v we hypothesized that the syntactic operator allows for production of a relational word-form only after the other term of the relation has been retrieved from meaning memory (p. 49). This requires additional processing time and increases error probability because two ML sets must be aroused. If, however, the first word of the second constituent is not a relational word, but, for instance, an intransitive verb, then the transition to the second constituent should no longer impose extra problems. This hypothesis can be tested by having Ss learn sentences with transitive and intransitive verbs and afterwards measuring probe latencies with the subject noun as probes. We expect that the latency will be longer when the response word is a transitive verb than when an intransitive verb is the correct answer.

Procedure

Two groups of five Ss (undergraduate students, alternatingly assigned to one of the conditions in order of participation) memorized sets of six sentences. The sentences were identical except that the fourth word was either a noun (object group) or an adverb (adverb group). They read as follows:

- Jonge apen eten [noten/zelden] onder bomen (Young monkeys [seldom] eat [nuts] under trees)
- Onze vrienden leren [teksten/prettig] achter tafels (Our friends learn [texts/comfortably] behind tables)
- Deze mensen stelen [platen/altijd] tijdens feesten (These people [always] steal [records] during parties)
- Hippe vrouwen roken [pijpen/gretig] zonder schaamte (Hippie women smoke [pipes/eagerly] without shame)
- Oude vrijers zingen [liedjes/tevens] over moeders (Old bachelors [also] sing [songs] about mothers)
- Slimme knapen spelen [poker/gaarne] tegen gasten Clever guys [like playing/play poker] with guests)

The verbs were identical in both conditions, so that, during probe latency measurement, exactly the same responses served as responses to the subject noun for the object and adverb groups. Because each of the *Ss* learnt only one type of sentence, we judged they would not hesitate between transitive and intransitive readings.

The sentences were memorized as responses to one-digit numbers as stimuli according to the usual anticipation paired-associate procedure. We used the maximum time interval allowed by the memory drum: four sec. for stimulus alone, four sec. for stimulus plus response. The sentences were exposed in four different orders; order of object and adverb sentences was identical. Learning went on until the criterion of one correct trial (all six sentences correctly reproduced) was reached.

The individual words of the sentences (36 in each condition) had been taperecorded; the interval between successive words amounted to eight seconds. The words occurred four times each, so that it was possible to obtain reliable latency scores. Word order in the adverb condition was identical to that in the object condition, except that adverbs had been replaced by object nouns. Latencies (milliseconds) were measured by a digital counter which was started by the tape signals (words taped) and stopped by S's voice. E instructed Ss to listen carefully to the words played by the recorder and to respond as soon as possible with the next word of the sentence from which the probe word had been taken. When the probe was the last word of a sentence, S had to react by "*punt*" (full stop). Before actually starting, S learnt to react with sufficient voice volume to stop the counter. After 72 words, a short resting pause was inserted. E checked correctness of the responses and recorded latency times; because of the limited time available until onset of the next probe, he deleted latencies longer than 4500 msec. All words in the sentences had two syllables. We took this measure in order to eliminate effects of duration of the taped stimulus words as much as possible.

Results

The numbers of learning trials in object (14.30) and adverb (12.00) conditions were nearly equal (median test: $\chi^2 = .40$, p < .50). So were the numbers of omissions (latencies not registered): 68 (8) and 66 (9) in adverb and object groups, respectively. (The numbers between brackets indicate omissions in the subject noun-verb transition.) Omissions were due to (1) latencies longer than 4.5 sec, (2) incorrect responses and (3) no or too low responses.

Table 8 shows the average latencies calculated over all registered responses, together with the levels of significance (Mann-Whitney test, one-tailed, except p < .004 which is two-tailed). We see that the subject-verb transition is much more difficult when the verb has transitive function than when it is intransitive. In fact, we observed, for this transition, no overlap between the mean latencies measured for individual *Ss* in the two conditions. This strongly supports the hypothesis. Also in agreement with the theory is the shorter latency for the verb-object transition compared with the verb-adverb transition. Presentation of the transitive verb directly activates the ML set

which intersects the set corresponding to the object noun. To this difference, however, should not be attached too much importance, because the responses in this transition involved very different word-classes.

Transition:	Det./Mod	l. Noi	un Ve	rb Obje	ct/ Prep	o. No	un St	op
Adverb								
Object condit	ion 1	407	2365	1447	1473	1560	1732	
Adverb condi	tion 1	419	1705	1755	2160	1614	1567	
Significance l	level	n.s.	p<.002	p<.025	p<.004	n.s.	n.s.	

Table 8. Average latencies (msec.) for the transitions

We did not anticipate the extremely large difference at the fourth transition. A possible explanation could be that, because of the independent character of most of the adverbs used (cf. pp. 64-65), they are not very helpful in locating the sentences they had been taken from (weak "cueing power", cf. Horowitz and Prytulak 1969; see also p. 62, footnote).

Discussion

These data emphasize the importance of distinguishing between relational and attributive function of verbs, and show that, at least in probe latency tasks, this distinction has more weight than constituent boundaries, unless one were to move the main constituent boundary to the right of intransitive verbs (cf. Uhlenbeck 1963).

Two difficulties remain to be discussed. Two of the six adverbs *(prettig (com-fortable)* an *gretig (eager)*) belong to the word-class of adjectives and it is most appropriate to represent their MP hierarchies as follows:

MP₁: *friends-studying*, MP₂: *study-comfortable*, MP₃: MP_1-MP_2 (for the notation, see p. 39). It is not clear whether the arguments we put forward in order to account for the greater difficulty of transitions to relational words, also apply to cases like *study comfortably*. Here, we need further experimentation and, perhaps a correction of the MP hierarchies proposed for this type of adverb.

The fourth transition (to prepositions) is a transition to a relational word, too. We might expect, here, an increased latency similar to that for the subject-verb transition. This is borne out by the adverb condition, but not by the object group data. As already indicated, differential cueing power of the adverbs and object nouns which, here, served as probes, is, perhaps, a sufficient explanation.

§6. General discussion

The line of reasoning leading to the above set of experiments may be summarized as follows. First, we postulated an abstract structure of the meaning memory consisting of memory locations in which different types of information are contained. Next, we showed that this structure accepts hierarchies of minimal propositions, and that both

word and sentence meanings are describable in terms of such hierarchies. As a following step, these hierarchies were compared to the memory representations developed within the framework of alternative theories, and the conclusion arose that much of the experimental data supporting these theories are compatible with the set-feature model. However, in a number of cases the predictions from the set-feature model are in conflict with those derivable from the other theories. The experiments reported in this chapter demonstrate that in these cases the set-feature model is supported.

We attach most importance to the outcomes of §§1 and 2 because they imply that any meaning memory model must make a fundamental distinction between the memory representation of hierarchical structures (of superordinate and subordinate concepts) on the one hand and relational structures (of words connected via a relationindicating word) on the other, and to §5 where the necessity is demonstrated of assigning, somehow, a more complex memory representation to transitive verbs as one type of relation-indicating words. Both properties derive from the set-feature model and provide the basis for postulating hierarchies of minimal propositions. In §§3 and 4 more specific consequences entailed by these hierarchies were studied.

This experimental evidence must be interpreted with some caution. Although the data, covering a fairly heterogeneous set of language behaviors, are in good agreement with the predictions, it might be objected that they do not necessarily support the structure of the meaning memory postulated in Ch. II. More specifically, the data support part of the proposals concerning the semantic representation of sentences which we outlined in Ch. III, but this does not imply that the memory organization of Ch. II is the only one compatible with these semantic representations. This necessitates experimentation aiming more directly at the postulated meaning memory structure.

Further research will also have to deal with the following issues. First, the hierarchies of minimal propositions elaborated in Ch. III must be evaluated in the light of more detailed semantic information, especially of a larger array of paraphrase relations than we took into account in this study. Second, the formal properties of a syntax which takes hierarchies of minimal propositions as its input need to be studied. For, if after further semantic and psycholinguistic research the notion of hierarchies of minimal propositions still proves to be a useful one, then the following step will be to investigate the working principles of the syntactic operator. Finally, seeing the recent advances in the field of computer simulation of human memory, and the potential practical usefulness engendered by computer storage and retrieval of verbal information, it is desirable to explore the extent to which the set-feature model lends itself to computer simulation. (For a recently published survey of the literature, see Frijda 1970.) Such an attempt will also lead to a more exact formulation of the structure of the meaning memory.
SUMMARY

The present study is concerned with that part of the human language mechanism in which the meanings of words and sentences are stored. Our aim is the formulation and testing of a descriptive model for the memory representations of word and sentence meanings. In the development of this model, the following considerations have taken prime of place. (1) Word and sentence meanings are regarded as systems of interverbal relationships (intensional meaning). Consequently this study does not deal with extensional (denotative) or connotative meaning. (2) The representations of word and sentence meanings must show a logical structure so that logical thinking with the contents of the "meaning memory" is, in principle, possible. (3) These representations must not be in contradiction to already available experimental data on verbal (long-term) memory. (4) The memory representations of word and sentence meanings need to agree with available semantic-linguistic knowledge. This implies (a) that the representations of word meanings must show a componential structure, that is, can be regarded as sets of features, and (b) that the meaning relationships between sentence constituents (words, phrases) and between sentences (e.g. paraphrase relationships) must be adequately represented. In other words, memory representations of sentence meanings, as semantic representations of sentences, must be able to form part of a (to be constructed) competence model (grammar) in which sentences are generated from their semantic representations.

In Chapter I we present a concise survey of the most important psychological theories of meaning and of Katz's semantic theory because this has exerted great influence on the development of componential meaning theories in psychology. Some theories (Skinner, Osgood, Katz) make explicit assumptions concerning the relationship between verbal items and non-verbal processes considered necessary for the understanding of meanings, while others (Deese, Mandler) hold open the possibility of, or deliberately restrict themselves to, defining meanings as networks of interverbal relationships (cf. (1)). However, the available empirical studies in the field of meaning, in actual practice, investigate and determine structures of interverbal relations. Moreover, the nature of non-verbal meaning-related processes has not been established, nor has it been demonstrated that they are essential for understanding meanings. Therefore, our proposed model remains confined to interverbal relationships in meaning memory. We hereby take into account as far as possible the requirements made under points 2, 3 and 4.

Chapter II expounds the structural properties of this memory. The set-feature model presupposes a tripartition of the human language mechanism: word-form memory in which words of the language are phonologically represented; meaning memory which contains a great number of memory locations specifying connections of different kinds among word-forms in the word-form memory and among memory locations in the meaning memory itself; and the syntactic operator which acts as mediator between both the other parts, and among other things contains the syntactic information belonging to the word-forms. The organization of word-form memory and syntactic operator is not considered in this study.

Every location in the meaning memory constitutes a connection between (a) two word-forms, (b) one word-form and one memory location, or between (c) two memory locations. If we let A and B stand for the connected entities, then memory locations of the types (a) and (b) also enclose a symbol indicating which of the following relationships holds: $A \subset B$ or $B \subset A$. Type (c) is reserved for indicating two-place relations (see below) and does not contain an inclusion symbol. Each word-form in the word-form memory is connected with a set of memory locations; each of these locations stands for one feature of the meaning of that word (see consideration 4a in the first paragraph of this summary). Presentation of a word to a language user results in activation of a subset of the set of memory locations connected to that word, and via this subset, of a number of other word-forms in the word-form memory. Which locations belong to this subset depends on their activation thresholds.

Chapter II is devoted to the memory representation of sentences of various syntactic structures, Sentences are considered as being built up from basic units which we have called minimal propositions (MPs). Examples of MPs which always include two content words are e.g. subject with nominal or adjectival predicate or with a verbal predicate based on an intransitive verb, an adjective-substantive or an adverb-verb construction. In the meaning memory, these occupy one memory location of the (a) type. Combinations of such constructions require memory locations of both the (a) and the (b) type, as, for example, the construction adjective-substantive construction, and one (b) location which is connected to this (a) location and to the intransitive verb. We presume that all words belonging to the word classes mentioned above, have as their denotation sets of objects, and that the above-mentioned constructions specify subsets of sets; this is expressed by the inclusion symbol in both (a) and (b) locations.

A special group of words (transitive verbs, prepositions, conjunctions) express twoplace relations, that is, bring two subsets of the same or different sets in correspondence. This requires two memory locations of type (a) for the specification of sets and subsets. and one location of type (c) where the correspondence is registered. For example, the verb *invent* in *Pascal invented the calculator* is connected with two sets of memory locations, viz. those which are also connected with the words *inventor* and *invention*. The sentence specifies *Pascal* and *calculator* respectively as subsets of these sets (represented by two (a) locations) and moreover the relation (correspondence; type (c)). Combinations of all these constructions in more complex sentences give rise in the meaning memory to hierarchical structures which represent "hierarchies of minimal propositions".

In Chapter IV the relationships between the set-feature model and alternative theories on memory for words and sentences is investigated. With reference to work by Deese it is observed that the experimental determination of word meanings by means of collecting free associations (a specific type of interverbal relations) entails the limitation that the nature of the semantic relationships between stimulus and produced associations cannot show up. To meet this objection we suggest a procedure whereby the Subjects produce as responses short sentences which indicate aspects of the meaning of the stimulus word. After this, the sentences can be analyzed into MP hierarchies. It is furthermore borne out that the hierarchical memory structure proposed by Mandler is realized in a specific manner in the set-feature model.

As regards the retention of sentences, we show that a number of phenomena that are generally ascribed to syntactic factors (transformational complexity, syntactic depth, constituent boundaries) either do not show up consistently or may be the result of non-syntactic—more specifically, of semantic factors. Emphasis is laid on experiments that support the psychological reality of constituent boundaries (Johnson); most of these data are meaningfully interpretable in terms of the set-feature model.

Chapter V contains five experiments in which are tested hypotheses that derive from the set-feature model but are at variance with alternative theories. The experiment of §1 is an association study which demonstrates that there is a relationship between the number of memory locations that have to be passed through from a given stimulus word to reach a certain response, and the associative reaction time. This phenomenon still stands if we regard only associations with equal associative frequency. As the basis for estimating the number of passed-through memory locations (distance) we make use of short sentences in which the subject had to render the meaning relationship between stimulus and response words. In fact, a classification is made into "short" and "long" distances, and this classification coincides with the distinction between hierarchic and relational structures respectively. If a sentence expresses that stimulus and response belong to the same hierarchy of higher (including) and lower (included) concepts, then we speak of a hierarchic structure (this requires passing through at least one (a) location; short-distance). If stimulus and response in this sentence are connected via a relation-indicating word (this requires at least three passed-through locations: (a)-(c)-(a)), then we speak of a relational structure.

The difference in associative reaction time between stimulus-response pairs embedded in hierarchical and relational structures respectively is complemented in §2 by a difference between the two types of association with respect to the tendency to clustering in "free recall". Here, too, the associative frequency was held constant. Both experiments lend support to an essential aspect of the set-feature model: the distinction between the memory representation of hierarchical and relational structures.

With the aid of the same free-recall paradigm it is demonstrated in §3 that verbs in sentence pairs with the same object show a stronger tendency to clustering than the verbs in sentence pairs with equal adverbial modifier. The sentences (apart from object and adverbial phrase) were identical. This result is predicted by the memory representation of both types of sentence: The distance in terms of the number of intervening memory locations is smaller for verb and object than for verb and adverbial phrase.

In §4 it is established, with the help of a modified version of the "archimedic" method developed by Savin and Perchonok, that the memory effort necessary for simultaneously retrieving the information from both (a) locations occupied by sentenc-

es of the structure subject-verb-object, is equal to the sum of the effort required for retrieving the information from each of the (a) locations separately (viz. one for the combination subject-verb and one for the combination verb-object). The experiment moreover demonstrates that memorizing the combination subject-verb (one (a) location) has a facilitating influence on subsequent retention of a sentence in which this combination is embedded. This is in conflict with Johnson's theory.

The experiment in §5 is concerned with the difference between transitive and intransitive verbs. Subjects memorize sentences containing a transitive or an intransitive verb; afterwards they are presented with the individual words and instructed to name as quickly as possible the next word of the sentence concerned (probe latency technique). (In the intransitive condition the object-noun was replaced as an adverb.) In connection with the double representation of transitive verbs (cf. the above example *invent*) the set-feature model predicts that after presentation of the subject-noun the reproduction of the verb will demand more time if this is transitive than if it is intransitive. This prediction is verified.

The results of the first two investigations point to shortcomings in theories by Deese and by Mandler on verbal memory; the last three experiments (especially §5) are hard to interpret with Johnson's model, and, more generally, with models based on "immediate constituent analysis". On the other hand, they provide a good empirical basis for the set-feature model.

We conclude that the set-feature model is a suitable basis for further research in the field of word and sentence meanings. Efforts should hereby be concentrated on research that, in comparison with the experiments reported here that took as starting point the memory representation of sentences, is more immediately directed towards the structural properties of meaning memory.

SAMENVATTING

Deze studie heeft betrekking op dat deel van het menselijke taalmechanisme waarin de betekenissen van woorden en zinnen zijn opgeslagen. Doel is het formuleren en toetsen van een descriptief model voor de geheugenrepresentaties van woord- en zinsbetekenissen. Bij de ontwikkeling van dit model hebben de volgende overwegingen vooropgestaan . (1) Woord- en zinsbetekenissen worden opgevat als systemen van interverbale relaties (intensionele betekenis). Deze studie handelt derhalve niet over extensionele (denotatieve) of connotatieve betekenis. (2) De representaties van woord- en zinsbetekenissen moeten een logische structuur vertonen, zodat logisch denken met behulp van de inhouden van het "betekenisgeheugen" in principe mogelijk is. (3) Deze representaties mogen niet in strijd zijn met de reeds beschikbare experimentele gegevens over het verbale (lange-termijn) geheugen. (4) De geheugenrepresentaties van woorden zinsbetekenissen dienen overeen te stemmen met voorhanden zijnde semantisch-linguïstische inzichten. Dit impliceert (a) dat de representaties van woordbetekenissen een componentiële structuur moeten vertonen, d.w.z. op te vatten zijn als verzamelingen (sets) van kenmerken (features), en (b) dat de betekenisrelaties tussen zinsconstituenten (woorden, zinsdelen) en tussen zinnen (o.a. parafraserelaties) adequaat gerepresenteerd moeten zijn. Anders geformuleerd, de geheugenrepresentaties van zinsbetekenissen moeten als semantische representaties van zinnen onderdeel kunnen zijn van een (nader uit te werken) competentiemodel (grammatica) waarin zinnen worden gegenereerd vanuit hun semantische representaties.

In Hoofdstuk I geven we een beknopt overzicht van de belangrijkste psychologische betekenistheorieën en van de semantische theorie van Katz omdat deze grote invloed heeft uitgeoefend op de ontwikkeling van componentiële betekenistheorieën in de psychologie. Sommige theorieën (Skinner, Osgood, Katz) maken expliciete assumpties omtrent de relatie tussen verbale items en non-verbale processen die nodig zouden zijn voor het begrijpen van betekenissen, terwij1 andere (Deese, Mandler) de mogelijkheid openhouden van, of zich bewust beperken tot, het omschrijven van betekenissen als netwerken van interverbale relaties (vgl. (1)). Echter, de beschikbare empirische onderzoekingen op het gebied van betekenis onderzoeken en bepalen in de praktijk structuren van interverbale relaties. Bovendien is de aard van non-verbale betekenis-gerelateerde processen niet vastgesteld en is evenmin aangetoond dat deze onmisbaar zijn voor het begrijpen van betekenissen. Daarom blijft het door ons voorgestelde model beperkt tot interverbale relaties in het betekenisgeheugen. Hierbij houden we zoveel mogelijk rekening met de eisen gesteld onder punten 2 t/m 4.

Hoofdstuk II bevat een uiteenzetting van structuureigenschappen van dit geheugen. Het set-feature model vooronderstelt een driedeling van het menselijk taalmechanisme: het woordvorm-geheugen waar de woorden uit de taal fonologisch gepresenteerd zijn; het betekenisgeheugen dat een groot aantal geheugenlocaties bevat die verbindingen van verschillende aard tussen woordvormen in het woordvormgeheugen tussen geheugenlocaties in het betekenisgeheugen zelf specificeren; de syntactische operator die fungeert als mediërende instantie tussen de beide andere onderdelen en, onder meer, de syntactische informatie bevat behorende bij de woordvormen. De organisatie van woordvormgeheugen en syntactische operator blijft in deze studie buiten beschouwing.

Elke geheugenlocatie in het betekenisgeheugen vormt een verbinding tussen (a) twee woordvormen, (b) een woordvorm en een geheugenlocatie, ofwel (c) tussen twee geheugenlocaties. Als we de verbonden entiteiten aanduiden met A en B, dan bevatten geheugenlocaties van de typen (a) en (b) tevens een symbool dat aanduidt welke van de volgende logische relaties geldt: $A \subset B$ of $B \subset A$. Type (c) is voorbehouden voor het weergeven van tweeplaatsrelaties (zie beneden) en bevat geen inclusiesymbool. Iedere woordvorm uit het woordvormgeheugen is verbonden met een verzameling van geheugenlocaties; elk van deze locaties vertegenwoordigt een kenmerk van de betekenis van dat woord (zie 4a). Presentatie van een woord aan een proefpersoon heeft tot gevolg dat een subset van de set van geheugenlocaties die met dat woord zijn verbonden, geactiveerd wordt en via deze subset, een aantal andere woordvormen uit het woordvormgeheugen. Welke locaties behoren tot deze subset hangt af van hun activatiedrempels.

Hoofdstuk III is gewijd aan de geheugenrepresentatie van zinnen van uiteenlopende syntactische structuur. Zinnen worden opgebouwd gedacht uit basiseenheden die we minimale proposities (MPs) noemen. Voorbeelden van MPs, die altijd twee inhoudswoorden bevatten, zijn o.a. onderwerp met naamwoordelijk gezegde of met een werkwoordelijk gezegde op basis van een intransitief werkwoord, een adjectief-substantief- of een adverbium-adjectiefconstructie. Deze bezetten in het betekenisgeheugen een geheugenlocatie van het type (a). Combinaties van dergelijke constructies vereisen geheugenlocaties van zowel type (a) als (b), zoals bijv. de constructie adjectief-substantief- intransitief werkwoord. In dit voorbeeld: een (a)-locatie voor de adjectief-substantief constructie, en een (b)-locatie die verbonden is met deze (a)-locatie en met het intransitieve werkwoord. We veronderstellen dat alle woorden die tot de hier genoemde woordsoorten behoren, verzamelingen van objecten als denotatie hebben en dat de vermelde constructies deelverzamelingen van verzamelingen specificeren; dit wordt uitgedrukt door het inclusiesymbool in zowel (a)- als (b)-locaties.

Een speciale groep van woorden (transitieve werkwoorden, preposities, voegwoorden) drukken tweeplaatsrelaties uit, d.w.z. brengen twee deelverzamelingen van dezelfde of verschillende sets met elkaar in correspondentie. Dit vereist twee geheugenlocaties van het type (a) voor specificatie van verzamelingen en deelverzamelingen, en een locatie van het type (c) waar de correspondentie wordt vastgelegd. Bijv. het werkwoord *uitvinden* in *Pascal vond de rekenmachine uit* is verbonden met twee verzamelingen van geheugenlocaties, namelijk die welke tevens verbonden zijn met de woorden *uitvinder* en *uitvinding*. De zin specificeert resp. *Pascal* en *rekenmachine* als deelverzamelingen van deze verzamelingen (gerepresenteerd door twee (a)-locaties) en bovendien de relatie (correspondentie; type (c)). Combinaties van dergelijke constructies in complexere zinnen leiden in het betekenisgeheugen tot hiërarchische structuren die "hiërarchieën van minimale proposities" representeeren. In Hoofdstuk IV wordt het verband onderzocht tussen het set-feature model en alternatieve theorieën over het geheugen voor woorden en zinnen. Met betrekking tot het werk van Deese wordt vastgesteld dat de experimentele bepaling van woordbetekenissen door middel van het verzamelen van vrije associaties (een specifieke soort van interverbale relaties) de beperking inhoudt dat de aard van de semantische relaties tussen het stimuluswoord en de geproduceerde associaties niet aan de dag kan treden. Om aan dit bezwaar tegemoet te komen stellen we een procedure voor waarbij de proefpersonen als responses korte zinnen produceren die aspecten van de betekenis van het stimuluswoord weergeven. Deze zinnen kunnen daarna worden geanalyseerd in MP-hiërarchieën. Verder blijkt dat de hiërarchische geheugenstructuur voorgesteld door Mandler op een specifieke wijze in het set-feature model gerealiseerd is.

Met betrekking tot het onthouden van zinnen tonen we aan dat een aantal verschijnselen die worden toegeschreven aan syntactische factoren (transformationele complexiteit, syntactische diepte, constituentsgrenzen) ófwel niet consistent optreedt ófwel het gevolg kan zijn van niet-syntactische, en wel met name semantische factoren. Nadruk wordt gelegd op experimenten die de psychologische realiteit van constituentsgrenzen ondersteunen (Johnson); een groot deel van deze gegevens kan zinvol worden geïnterpreteerd door het set-feature model.

Hoofdstuk V bevat een vijftal experimenten waarin hypothesen worden getoetst die afgeleid worden van het set-feature model en die in strijd zijn met alternatieve theorieën. Het experiment van §1 is een associatiestudie die aantoont dat er een samenhang bestaat tussen het aantal geheugenlocaties dat moet worden gepasseerd om vanuit een gegeven stimuluswoord een bepaalde response te bereiken, en de associatieve reactietijd. Dit verschijnsel blijft optreden als we alleen associaties met gelijke associatieve frequentie in de berekening betrekken. Als basis voor de schatting van het aantal gepasseerde geheugenlocaties (afstand) maken we gebruik van korte zinnen waarin de proefpersoon de betekenisrelatie tussen stimulus en responsewoorden moest weergeven. In feite wordt een indeling gemaakt in "korte" en "lange" afstanden, en deze classificatie valt samen met het onderscheid tussen resp. hiërarchische en relationele structuren. Wanneer de zin uitdrukt dat stimulus en response behoren tot dezelfde hiërarchie van hogere (insluitende) en lagere (ingesloten) begrippen, dan is sprake van hiërarchische structuur (dit vereist het passeren van minimaal één (a)locatie; korte afstand). Wanneer stimulus en response in de zin worden verbonden via een relatie-aanduidend woord (dit vereist minimaal drie gepasseerde locaties: (a)-(c)-(a)) dan spreken we van een relationele structuur.

Het verschil in associatieve reactietijd tussen stimulus-response paren opgenomen in respectievelijk hiërarchische en relationele structuren wordt in §2 gecompleteerd door een verschil tussen de twee typen van associaties met betrekking tot de tendens tot groepering (clustering) in "free recall". Ook hier werd de associatieve frequentie constant gehouden. Beide experimenten verlenen steun aan een essentieel aspect van het set-feature model: het onderscheid tussen de geheugenrepresentatie van hiërarchische en relationele structuren. Met behulp van hetzelfde free-recall paradigma wordt in §3 aangetoond dat de werkwoorden uit zinsparen met gelijk object een sterkere groeperingstendens bezitten dan de werkwoorden uit zinsparen met gelijke adverbiale bepaling. De zinnen waren (behoudens object en adverbiale bepaling) identiek. Deze uitkomst wordt voorspeld door de geheugenrepresentatie van beide typen zinnen: de afstand in termen van bet aantal tussenliggende geheugenlocaties is kleiner voor werkwoord en object dan voor werkwoord en adverbiale bepaling.

In §4 wordt aan de hand van een gemodificeerde vorm van de "archimedische" methode van Savin en Perchonok vastgesteld dat de geheugeninspanning die nodig is om de informatie uit beide (a)-locaties die worden bezet door zinnen van de structuur onderwerp-persoonsvorm-lijdend voorwerp tegelijkertijd op te halen, de som is van de inspanning vereist voor het ophalen van de informatie uit elk van de (a)-locaties afzonderlijk (nl. één voor de combinatie onderwerp-persoonsvorm en één voor de combinatie persoonsvorm-lijdend voorwerp). Bovendien laat dit experiment zien dat het leren van de combinatie onderwerp-persoonsvorm (een (a)-locatie) een faciliterende invloed heeft op het onthouden van een zin waarin deze combinatie is ingebed. Dit is in strijd met de theorie van Johnson.

Het experiment van §5 heeft betrekking op het verschil tussen transitieve en intransitieve werkwoorden. Proefpersonen leren zinnen van buiten die een transitief of een intransitief werkwoord bevatten, en krijgen dan de afzonderlijke woorden aangeboden met de opdracht zo snel mogelijk het volgende woord uit de zin op te noemen (probe latency techniek). (In de intransitief-conditie werd het object-substantief vervangen door een adverbium.) In verband met de dubbele representatie van transitieve werkwoorden (vgl. bovenstaand voorbeeld *uitvinden*) voorspelt het set-feature model dat na aanbieding van het onderwerp-substantief de reproductie van het werkwoord meer tijd zal vergen wanneer dit transitief is dan wanneer dit intransitief is. Deze predictie wordt bevestigd.

De resultaten van de twee eerste onderzoekingen wijzen op tekortkomingen in de theorieën van Deese en Mandler over het verbale geheugen; de laatste drie experimenten (vooral §5) zijn moeilijk te interpreteren met het model van Johnson en, meer in het algemeen, met modellen die gebaseerd zijn op "immediate constituent analysis". Anderzijds verschaffen ze een goede empirische basis aan het set-feature model.

We concluderen dat het set-feature model een geschikte basis vormt voor verder onderzoek op het gebied van woord- en zinsbetekenissen. Hierbij moet gestreefd worden naar onderzoek dat, in vergelijking met de hier gerapporteerde experimenten die geheugenrepresentaties van zinnen als uitgangspunt namen, meer rechtstreeks gericht is op de structuureigenschappen van het betekenisgeheugen.

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STELLINGEN

Ι

In de totnutoe ontwikkelde theorieën over het verbale geheugen wordt onvoldoende onderscheid gemaakt tussen hiërarchische en relationele opslagstructuren.

Π

Het verdient de voorkeur semantische representaties in de vorm van *n*-plaatsrelaties, zoals deze in de generatieve semantiek recentelijk zijn ontwikkeld, te vervangen door hiërarchische systemen van een- en tweeplaatsrelaties.

III

De psychologische realiteit van de grens tussen het subjekt en het predikaat van een zin is in haar algemeenheid niet overtuigend aangetoond.

IV

Experimenteel onderzoek naar de invloed van syntaktische faktoren op het waarnemen en onthouden van zinnen wordt ernstig bemoeilijkt door het feit dat deze faktoren vrijwel niet los te koppelen zijn van semantische en informatietheoretische faktoren.

V

De resultaten die verkregen werden met computersimulatie van het semantische geheugen kunnen richting geven aan voortgezet onderzoek naar efficiënte systemen voor computeropslag van wetenschappelijke informatie en naar de daarbij passende ophaalstrategieën.

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VI

In de nederlandse taalkunde is te weinig aandacht geschonken aan de mogelijkheid om het meewerkend voorwerp van een zin onderwerp te maken via een transformatie die gebruik maakt van de antonymierelatie tussen de werkwoorden *geven* en *krijgen*.

VII

Onvoldoende beheersing van de fonologische component van de taal waarin het kind leert lezen, moet opgevat worden als de hoofdoorzaak bij het ontstaan van legasthenie.

VIII

Op korte termijn dient binnen de faculteit der sociale wetenschappen een interdisciplinaire afstudeerrichting Onderwijskunde ingesteld te worden die toegankelijk is voor kandidaten in de psychologie, pedagogiek en sociologie.

IX

Het psychologieonderwijs op niet-universitair niveau is aan grondige vernieuwing toe omdat het vaak gegeven wordt door ondeskundigen en omdat de beschikbare leermiddelen over het algemeen sterk verouderd zijn.

Х

Het oud-christelijke gebod dat men iedereen lief moet hebben is door latere moralisten zo geïnterpreteerd dat men ieder een lief moet hebben.

Nijmegen, 12 juni 1970

G. Kempen

POSTSCRIPTUM ADDED TO THE 2011 ONLINE VERSION

The set-feature model as described in §2 of Ch. II includes the following design feature (mentioned on p. 27): "Each memory location contains a space (filled or empty) for reference to one other ML that has the former ML as one of its labels". This description embodies an inadvertent restriction to "one other memory location". The intended description should read as follows: "Each memory location contains a space (filled or empty) for reference to <u>one</u> <u>or more other MLs</u> that have the former ML as one of its labels". This corrected version, which does not invalidate other aspects of the model, allows one and the same ML to enter into several different relations with other MLs. For example, the ML Pascal—inventor now can serve as label not only for a "higher order" ML that has ML calculator—invention as its second label, but also for another higher-order ML whose labels are ML Pascal—inventor and ML (hydraulic-)press—invention". Levelt (1970) pointed out this mistake in his review of my dissertation, fearing that correcting it would require a major overhaul of the model—quod non.

Levelt, W.J.M. (1970). Het semantisch weefgetouw. *Studia Neerlandica*, issue *4*, 81-88.