CHAPTER 7

Language

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This chapter confines itself to what might be called 'General Psychology of Language'. By this we mean the psychological study of language and language use as observable in normal adults. Thus, it deals with the language function itself, not with the speaking person or with individual differences in language usage nor with its development.

The modern psychology of language (psycholinguistics) has its roots in various scientific developments that took place in the 19th and 20th centuries. In the first part of this chapter, the main historical backgrounds of general psycholinguistics will be outlined. Here, two lines of thought stand out with regard to the empirical data that are the object of research and theory construction. One research tradition is based upon the intuitive judgment of the language user, while the other focuses on primary language behavior, i.e., speaking and understanding. These two domains of research are the topics of the second and the third parts of this chapter, respectively.

1. Historical roots of psycholinguistics

Nineteenth-century idealism

This language research tradition leads from Kant to Von Humboldt (1836), Marty (1876) and Steinthal (1881). It is characterized by analysis of intuitive experience, with the objective to gain insight into the cognitive structures (called *ergon* by Von Humboldt) which give rise to the manifold cognitive activities (*energeia*) of man. Such structures were supposed to reflect innate rules of thought and judgment as well as variations imposed upon these rules by the *Weltanschauung* (world view) inherited by the people living in a given cultural community. This world view was thought to be under the influence of the rules of word and sentence construction: Von Humboldt was the first to offer a formulation of what is now known as the *linguistic relativity hypothesis* (Whorf, 1956).

Nineteenth-century empiricism

The first scientific 'laws' of linguistics were diachronic: they described systematic language changes in consecutive temporal stages (cf. the vowel and consonant shifts of Grimm and Rask). Empirically, diachronic research is based upon a host of objectively verifiable morphological and phonological data. Theoretically, it was strongly influenced by evolution theory (Schleicher, 1863), at least initially. Later explanations of diachronic phenomena, especially by the so-called *Junggrammatiker* (Paul, Leskien), were increasingly put in terms of simple psychological principles of association and analogy (see also Whitney, 1875). The same principles were used to explain speech behavior. By a sentence, according to Paul (1886), a speaker signifies that in his mind a number of ideas have formed associations among themselves. In the hearer the sentence arouses the same associations. Linguistics receives a psychological foundation. In the Netherlands, Van Ginneken (1904, 1905), who was strongly influenced by Wundt, and later also Reichling (1935) were prominent representatives of a 'psychological linguistics'.

The first experimental psycholinguistic study of the principle of analogy was performed by Thumb and Marbe (1901). They systematically studied the phenomenon of free word-association, and not only showed that the syntactic category of the association word was analogous or similar to that of the stimulus (paradigmatic association), but also found the first psycholinguistic 'law' (Marbe's Law). This states that the more frequent (or the more effective, *E)* a response, the shorter the associative reaction time (t) for such a response: $E = (f + t)^{-1}$. In 1910, Kent and Rosanoff published their famous list of word association norms. No wonder that, even in those early days of the empiricist tradition, much attention was given to statistical description of linguistic data. This was done by Markov (1913) in particular.

Wundt's psycholinguistics

Undoubtedly, Wundt was the most important psycholinguist around the turn of the century. His principal work *Die Sprache* (1900) represents a certain integration of idealist and empiricist ideas, although his inclination was towards the former. Thus, he rejected Paul's conception of the sentence. The sentence is, according to him, not the expression of an association of ideas (mental images). Apart from the 'passive' process of forming associations, Wundt borrows an active principle from idealism: apperception, which, controlled by motives and intentions, is able to attend to specific mental images and complexes of mental images. This apperceptive mechanism, then, will analyze a complex into parts and relationships between parts ('apperceptive analysis'). Which parts and which relationships will result from this analysis depends, among other things, on the vocabulary and the grammatical relations ('subject', 'object') in the language of the speaker.

Despite the strongly intuitive aspects of his psycholinguistics (he was sometimes blamed for theorizing too much), Wundt did not consider introspection a valid method. He also held the view that experimental investigation of language, as well as of other 'higher' processes, is not very practicable. Language can only be studied indirectly, by observing the mind's language products as can be found in language communities. Here, observation plays the same role as in Darwin's study of natural history.

Semiology

At the end of the 19th century, C.S. Pierce and F. de Saussure put new life into the general theory of signs, which was called 'semiotics' by the former and 'semiologie' by the latter. Pierce tried to set up a classification of signs from the viewpoint of the relation sign-significate. De Saussure emphasized the arbitrariness of this relation, at least as far as linguistic signs are concerned. Even if arbitrary, the relation between sign and significate cannot be handled at will by the individual language user. It is determined by the structure of the sign system as a whole, which, in turn, is based upon social convention. (This is the tenet of later structuralism.) Consequently, the study of language and language use remains incomplete without a study of the structure of the language system as it is at a given point in time. In this way De Saussure contrasted the usual diachronic research with a synchronic approach to language. Furthermore, De Saussure made a sharp distinction between the socially determined sign system ('langue') and its use by the individual speaker/hearer ('parole'). This distinction is akin to Von Humboldt's ergon/energeia on one hand, and to Chomsky's competence/performance on the other.

The psychologist Bühler (1934) explicitly placed his semiological studies within this Saussurian framework. Language is a tool (organon) which derives its significance from the functions it fulfills in the triangle transmitter-receiver-topic of conservation. With respect to the transmitter, the linguistic sign has a so-called symptom function; with respect to the receiver it has a signal function, and a symbol function with respect to the conversational topic (the significate). Bühler tried to explain human language behavior by analyzing these functions. For criticism of Bühler's work see Reichling (1935) and Duijker (1946). Kainz (1941-1969) has continued Bühler's functionalism.

Behaviorism

In the beginning of the 20th century a strong behavioristic tradition in psycholinguistics was born in America. It originated from the work of Stumpf's student Max F. Meyer (1911), who was crusading against introspective methods, though without denying the meaningfulness of mentalistic notions. The latter was done by his student Weiss (1929) who, in turn, so strongly influenced Bloomfield, the linguist, that he entirely revised (Bloomfield, 1933) his originally Wundtian position (Bloomfield, 1914). Bloomfield, the father of American structuralism, banished all mentalistic notions from linguistics which he purported to base upon behavioristic psychology but, nevertheless, developed quite independently. Psycholinguistic work in the behavioristic tradition was mainly concerned with learning word meanings. The theoretical principles used here were either classical conditioning (Razran, 1949), mediation (Osgood, Suci and Tannenbaum, 1957; Mowrer, 1954), or an instrumental conditioning model (Skinner, 1957).

The technology of communication

This development was at first unrelated to psychology and linguistics. With the growth of telephone communication, the technical question of how to use the communication channels as efficiently as possible, while preserving sufficient speech intelligibility, became more and more urgent. This led to the gathering of fundamental data about the relation between speech-intelligibility on one hand, and band-width, amplitude, masking, interruptions, etc., on the other. It was discovered that speech is indeed not a very economical code, but one which stands up excellently against all sorts of disturbances, because the information is distributed, as it were, over the entire signal. Due to the development of mathematical communication theory (Shannon and Weaver, 1949), it became possible to calculate accurately the various sources of redundancy in speech. To this purpose, one had to determine relative frequencies of speech sounds, syllables, words and word-sequences. For all these forms of verbal context one tried to assess the influence upon speech-intelligibility (see Miller, 1951; Cherry, 1957). A typical result is given in fig. 1. It shows the effect of variation in vocabulary size, i.e., of the relative frequency of individual (monosyllabic) words, upon the intelligibility of speech. The larger the vocabulary (2-1000 words), the worse the intelligibility.

Historically, this whole development is closely related to Markov's original work. One was aware of this connection, but the great similarity with Bühler's transmitter-receiver theory eluded everyone. Literally as well as metaphorically, one spoke different languages.

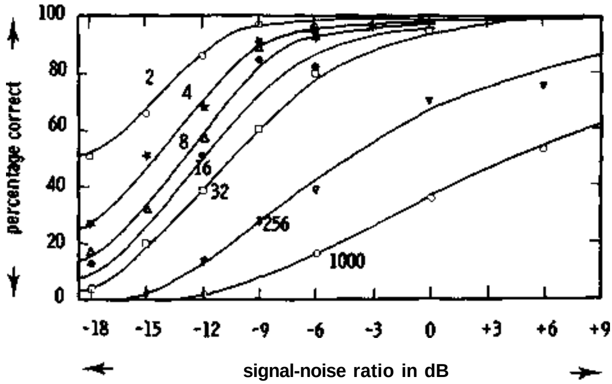


Fig 1. Percentage of correctly identified words as a function of the number of alternatives and of the signal-noise ratio (from: G.A. Miller et al., The intelligibility of speech as a function of the context of the materials. J. of Exp. Psychol., 41, p. 333. Copyright 1951 Amer. Psychol. Ass. Repr. by permission).

Transformational linguistics

Originating from the work of Harris (1951) and Chomsky (1957, 1965), transformational linguistics profoundly affected psycholinguistics. Especially the work of Miller and his group at Harvard University was responsible for this. The new impulses were mainly in the following areas:

(a) explicit study of the psychological validity of linguistic notions such as 'transformation', 'constituent', 'deep structure', etc.;

(b) new attention to the sentence as object of psychological laboratory research;

(c) emphasis on the biological-genetic basis of human language use (Lenneberg, 1967);

(d) the replacement of a behavioristic conceptual framework by a mentalistic one;

(e) renewed integration of linguistics and psychology, particularly the emphasis on linguistic intuition as a source of information about the human language capacity.

Artificial Intelligence

Since the late fifties, the area of 'artificial intelligence', as part of computer science, has developed strongly. A body of programming principles and techniques has grown which increasingly enables the computer to behave intelligently, for instance to recognize visual forms and speech sounds, to solve thinking problems, to prove mathematical theorems, etc. In the area of artificial language behavior, three subdomains have made most progress:

(a) parsing: discovering sentence structure (in most programs this includes both syntax and semantic content);

(b) semantic or conceptual representation: coding the meaning of sentences and of texts in such a way that the computer is able to handle this knowledge in an intelligent fashion (e.g., for deriving conclusions, executing commands, answering questions);

(c) sentence production: the conception of a semantic content and its expression in an intelligible utterance. All these aspects are discussed in Schank and Colby (1973). For subdomain (b), see Frijda (1972).

The list of backgrounds is certainly not complete, but it shows how diverse the scientific approaches to human language behavior are. This applies to both past and present: as yet, the various approaches are hardly integrated so that a systematic treatment of present-day psycholinguistics seems impossible. Therefore we decided to prepare a selection of topics. As the point of departure for making our choices we took the empirical issues psycholinguistic theory has tried to cover. Here, two orientations stand out. The first is directed towards describing what is commonly called 'linguistic intuitions'. They express themselves in intuitive judgments of the language user about aspects of his language. This theoretical orientation is in line with the idealist tradition, Wundt's psycholinguistics, with Bühler's experimental method of systematic introspection, and especially transformational linguistics.

According to the second approach, the empirical domain of psycholinguistics is primary language skills, i.e., speaking and understanding language utterances. In this view, language is a communicative tool the adult handles more or less skillfully, thanks to special information-processing capabilities. This viewpoint relates to the position of the *Junggrammatiker,* to the functionalistic organon theory of Bühler, to the behavioristic tradition in psycholinguistics, and to artificial intelligence research.

However, the two orientations are not incompatible. One only needs to realize that linguistic judgments are also language utterances, which may be strongly influenced by ideas about one's own language behavior.

2. The study of linguistic intuitions

2.1. Model and data

Linguistic intuitions, as represented in judgments of grammaticality, paraphrase, ambiguity, similarity of sounds and of meanings, etc., are suitable data on which to base a psycholinguistic model. Although the researcher is completely free in constructing models or theories, he must, ultimately, be confronted with the empirical data. Two things are needed for this: first, the empirical data must be unambiguous and reliable; second, they must explicitly be linked up with relationships specified within the theory. The latter is often called the interpretation problem (Bar-Hillel, 1970). In the study of language, this will pertain to the relation between sentence (theory) and expression (data), between grammaticality (theory) and acceptability (judgmental data), between cohesion of sentence elements (theory) and relation strength (as judged by subjects). Sometimes the problem is trivial, namely, if enough clear data are available whose relation with the theory is direct and obvious. These are called *'clear cases'* (Chomsky, 1957). In such conditions, the investigator can freely engage in model construction. This situation has long been characteristic of transformational linguistics. In the following paragraph (2.2) we shall briefly go into the models developed within this framework. Then (in 2.3) we discuss some cases that give rise to interpretation problems. It is especially psychologists who have tackled such problems.

2.2. Some linguistic models

In the fifties, Chomsky developed a number of mathematical models for describing natural language. Initially, these were mainly concerned with morphology and syntax. Later on, the transformational models were extended to phonology (Chomsky and Halle, 1968) and semantics, the latter with less success and more conflicts (cf. Chomsky, 1971; Lakoff, 1971).

Syntactic models

According to the intuitive point of view, a syntactic theory must describe two kinds of linguistic intuitions. The first is the grammaticality intuition. The language user is consciously aware that some sequences of words are sentences of his language (e.g., *the book is too thick),* whereas other sequences are not (e.g., *too the book thick is).* As for *clear cases* (there are unclear cases as well: sentences of dubious grammaticality), the syntactic model must be able to distinguish the grammatical sequences from the ungrammatical ones (cf. the discussion of enumerability and decidability, in Vol. I, chapter 4). If the theory is able to do that it is called *'observationally adequate'.* The second kind of intuition might be called structure intuitions. These are intuitions which have to do with relations between and within sentences. The paraphrase judgment concerns relations between sentences, namely, that in some respect they have the same interpretation ('reading'; e.g., *the arrow hits the target* and *the target is hit by the arrow).* The ambiguity intuition concerns relations within the sentence: the same sentence has two or more readings (e.g., *the shooting of the hunters was terrible).* The cohesion judgment also has to do with relations within the sentence (e.g., in *I'll ring him up, up* belongs to *ring).* The model must predict which sentences are paraphrases, which are syntactic ambiguities, and which elements of a sentence belong together. If this meets with success, the model is called *'descriptively adequate'.*

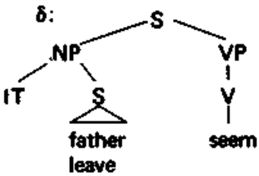
Chomsky (1956, 1957) investigated the extent to which regular, context-free and context-sensitive grammars (see Vol. I, chapter 4 for definitions) are adequate for describing natural language. It appeared there were strong reasons for assuming that regular grammars cannot lead to observational adequacy. (This 'proof made a strong impression, because it freed linguistics from the finite-state automata (Markov sources) that were so popular in communication theory.) From the point of view of descriptive adequacy, strong arguments could be put forward against the sufficiency of context-free and context-sensitive grammars as models of natural language. These so-called constituent grammars were fashionable in linguistics, mainly because they are very suitable for representing how a sentence can be hierarchically analyzed into bigger and smaller constituents (word groups). Before that, no one had explicitly dealt with the formal structure of this type of sentence analysis.

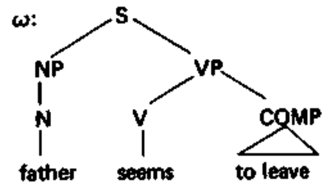
Without giving up the advantages of such constituent grammars, Chomsky extended these models with a new type of rule, the transformation. Whereas the rules of constituent grammars have *strings* as input and output (they are string-expanding rules), transformations have hierarchical structures *{phrase-markers)* as input and output (they are structure-modifying rules). They can change, delete or add parts of a phrase-marker. Put more generally, a transformational grammar may be considered as a system TG = (B, T). B is the base grammar, a constituent or equivalent type of grammar, which generates phrase-markers that are called base structures. The transformational component, T, is a set of transformations which convert some base structures, called the deep structures (δ), into derived or surface structures (ω). If the grammar is adequate, it produces for every sentence of the language a pair $= (\delta, \omega)$ of a deep and a surface structure. is called the structural description of the sentence. Therefore, contrary to the usual constituent description, it consists of two phrase-markers.

By way of illustration, a few simplified examples of such pairs follow below (simplified, because tenses are not represented in the deep structures, and because parts of the phrase-markers remain incompletely specified). It goes without saying that the deep structures in the examples can be generated by suitable context-free rules, such as S -> NP + VP, NP -> IT + S (see Vol. I, chapter 4). Derivation of the corresponding surface structures requires adding, reordering and deleting parts of the phrase-marker. The transformational rules needed cannot be mentioned here (see, e.g., Jacobs and Rosenbaum, 1968; Levelt, 1974b). The examples are numbered (1) through (6).

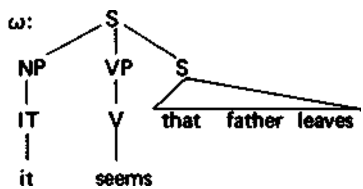
Although, following Chomsky, a constituent grammar is most often used as base grammar B in (psycho)linguistics, this is not necessary at all and not always to be recommended. There are other, more or less equivalent, types of grammar which often represent psychological or linguistic phenoma better and more simply.

(1) Father seems to leave

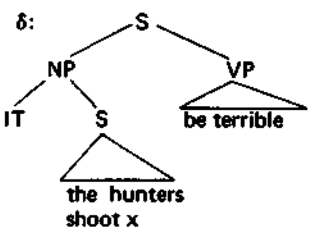


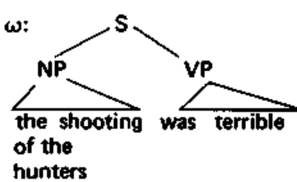


(2) It seems that father leaves
δ: see (1)

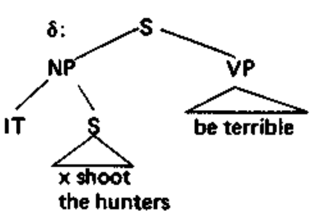


(3) The shooting of the hunters was terrible (a)



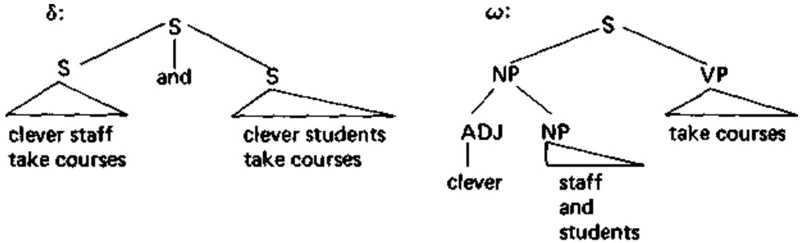


(4) The shooting of the hunters was terrible (b)

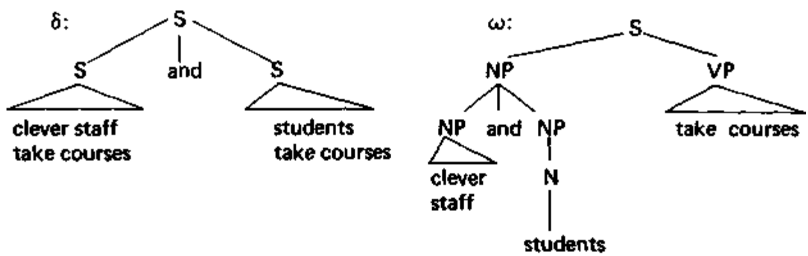


ω: see (3)

(5) Clever staff and students take courses (a)



(6) Clever staff and students take courses (b)



In this context we mention adjunction grammars, developed by Harris (1968) and Joshi (1972), categorial grammars (Ajdukiewics, 1935; Bar-Hillel et al., 1960), which are often used for semantic purposes, and dependency grammars (Tesnière, 1959; Gaifman, 1965; Robinson, 1970) which are especially suited to treatment of case relationships (such as direct and indirect object, agent, locative).

Finally, we mention that at present there are also variations of TG's with constituent base in which rules of B and T are applied in some sort of alternation (Lakoff, 1971; McCawley, 1968), which makes it difficult to speak of *the* deep structure of a sentence. It is always true, however, that a TG assigns more than one structural description to a sentence, and this allows for adequate representation of various types of structural intuitions. Usually, this is done in the following way. One structure in is put into close correspondence with the interpretation of the sentence (δ) and the (an-) other (ω), especially with its phonetic form. Now, we will demonstrate this for paraphrase, ambiguity and cohesion intuitions, respectively.

Two sentences are paraphrases of each other if they have a common interpretation *(Father seems to leave* and *It seems that father leaves).* In terms of the model, this can be interpreted as follows. Two sentences S_1 and S_2 with structural descriptions $\Sigma_1 = (\delta_1, \omega_1)$ and $\Sigma_2 = (\delta_2, \omega_2)$ are paraphrases if and only if $\delta_1 = \delta_2$. Compare examples (1) and (2).

A sentence is ambiguous if it has (at least) two interpretations. In the model, syntactic ambiguity can be given the following interpretation: a sentence S is ambiguous if it has two structural descriptions $\Sigma_1 = (\delta_1, \omega_1)$ and $\Sigma_2 = (\delta_2, \omega_2)$, where $\delta_1 \neq \delta_2$. There are two possibilities:

(a) $\omega_1 = \omega_2$. In this case we use the term *deep structure ambiguity* (only the deep structures are different). Examples of such sentences are: *the shooting of the hunters was terrible; flying planes can be dangerous.* Compare examples (3) and (4). Because $\omega_1 = \omega_2$, the phonetic form of the two readings is the same; it is impossible to hear which of the two readings is intended.

(b) $\omega_1 \neq \omega_2$. Because there is only one sentence the terminal strings of ω_1 and ω_2 must be the same. However, the constituent structures are different. If the constituent structures do differ, one can hear which of the meanings is the intended one, at least when the sentence is pronounced carefully (Levelt, Zwanenburg and Ouweneel, 1970). The sentences, then, are ambiguous in written form only. Such ambiguities are called surface structure ambiguities. Examples are *He hit the dog with the bone, Clever staff and students take courses;* compare examples (5) and (6).

For cohesion intuitions, the relation with is somewhat more complicated (see 2.3), but here we already note that such intuitions are best interpreted in terms of deep structures. When two sentences are paraphrases, the cohesion between corresponding elements will be equally strong. Example: the relation between *rang* and *up* is equally strong in the following two sentences: *John rang up his girl friend and John rang his girl friend up.* The same must apply to the relation between *father* and *seems* in examples (1) and (2). Because of the equivalences which exist between various types of grammar (they often are intertranslatable), the choice of a specific formalism strongly depends upon pragmatic circumstances. For instance, the demand for automated syntactic analysis in artificial intelligence research has stimulated the development of the so-called augmented transition network (ATN) grammars (Woods, 1970). These grammars are equivalent to the transformational grammars discussed above; translation both ways is quite feasible.

These grammars offer interesting psychological possibilities, one example of which will be given in section 3.4.

Phonological models

Present-day phonological models are predominantly based on the intuitive judgments of the linguist and the informant, respectively. Of old, phonology has tried to describe and explain the sound system of vowels and consonants (phonemes) of languages, the characteristic sound contrasts between phonemes, the limitations as regards possible phoneme sequences, the origin of phonemes and their contrasts, etc.

In first instance, a phonological description of speech sounds is abstract. One tries to classify the speech sound in a way which is at the same time intuitively satisfying and economic (somewhat comparable to Mendeleev's periodic table of chemical elements). A phonological intuition is, for instance, that the words *van* and *fan* have the same sound contrast as *zeal* and *seal,* or as *dip* and *tip;* the contrast can be labeled voiced vs. voiceless. For reasons of economy one aims at a classification based on a small number of - preferably dichotomous - features on which phonemes or larger speech segments take contrasting values, and by which the phonological rules (see below) become as simple as possible.

Bridging the gap between such an abstract representation and a more complete description of the speech sound as perceived or articulated (a so-called phonetic description), requires a system of rules, that is, a phonological model. The phonological rules not only complete the description of each individual phoneme but also indicate how consecutive phonemes, syllables, or larger segments influence each other. Therefore, it must follow from the phonological rules of Dutch that the 'f' in *af* sounds as 'v' in *afdak* (assimilation), that the 'g' and the 'r' of *groot* are pronounced simultaneously, not one after the other (coarticulation), that *kerststal* sounds as [kerstal], that voicing is lost before a word boundary (/paarden/ vs. /paart/), that a long vowel (as in *maat)* is shortened when more syllables follow (as in *mateloze),* that the stress pattern depends on suffixes *(pádvinder* vs. *padvinderij),* etc.

A powerful device for investigating whether such intuitive phonetic judgments are correctly represented in the phonological model is called *'automatic speech synthesis-by-rule'.* The phonological rules are translated into a computer program that converts an abstract phonological description into audible speech (see, e.g., Ladefoged, 1971; Mattingly, 1971). The correctness of the chosen phonological rules is then judged direct from hearing. Notice that, in this procedure, the empirical basis for phonological theory is still provided by intuitive judgments: 'this is/isn't pronounced correctly'.

The scope of this chapter does not permit a more detailed treatment of phonological theory and phonetic description. See, however, the references and Vol. I, chapter 8. Here we confine ourselves to describing the most important sound oppositions or 'distinctive features' which are used for the phonological classification of English vowels and consonants (table 1). The meaning of most features will be self-evident ('coronal' means 'articulated by the tip of the tongue'). In broad outlines this classification follows the scheme of Chomsky and Halle (1968).

Table 1
Some distinctive features of English vowels and consonants.

Vowels	/i/ beat	/u/ book	/ε/ pen	/e/ take	/ð/ the	/o/ boat	/a/ father
Feature							
front [– back]	+	–	+	+	–	–	–
high [– nonhigh]	+	+	–	+	–	–	–
low [– nonlow]	–	–	+	–	–	–	+
rounded [– nonrounded]	–	+	–	–	–	+	–

Consonants	/k/	/p/	/t/	/b/	/d/	/f/	/s/	/v/	/z/	/g/	/n/	/m/	/ng/
Feature													
voiced [– voiceless]	–	–	–	+	+	–	–	+	+	+	+	+	+
spirant [– nonspirant]	–	–	–	–	–	+	+	+	+	–	–	–	–
nasal [– oral]	–	–	–	–	–	–	–	–	–	–	+	+	+
coronal [– noncoronal]	–	–	+	–	+	–	+	–	+	–	+	–	–
front [– back]	–	+	+	+	+	+	+	+	+	–	+	+	–
continuant [– stop]	–	–	–	–	–	+	+	+	+	–	–	–	–

Semantic models

Often a distinction is made between *reference* and *meaning*. Reference (denotation, extension) concerns the relation between word (respectively lexeme, word group) and nonlinguistic object (things, actions, events, mental images, etc.). This aspect of semantics will not be discussed here at all. Meaning (sense, designation, intension) concerns the relation between word and concept. Two words may have the same denotation, but different meanings (evening star and morning star). Important (though not all) aspects of meaning express themselves in systematic relations between words. Such relations (mediated by concepts) between verbal elements (lexemes, words, word groups) are called 'sense relations'. In this section we limit our discussion to some sense relations. Some important intuitions in this field are synonymy (e.g., *spectacles* vs. *glasses),* homonymy *(bank-river* vs. *bank-money),* antonymy *(big* vs. *small),* hyponymy *(chair* and *table* vs. *furniture),* presupposition and assertion (see below). We shall briefly go into these intuitions.

One of the main problems of semantics is to specify the relation between the interpretation of sentence or word group on the one hand, and the meanings of the constituent elements on the other. Of course, the syntactic relations between those elements play an essential part. Without going deeply into this matter, we already note that meaning distinctions are essentially context-dependent. Synonymy, for example, does not imply that in all sentence contexts, two words can be interchanged without affecting the interpretation. Hyponymy is also context-dependent. This can be formulated as follows. Element *x* is a hyponym of element *y* in a given sentence context $\mathbf{S}_{\Delta}$ (where Δ is a variable lexical element), if the sentences S_x and S_y which are formed by giving Δ the the value *x* and y respectively (i.e., by copying x and y, respectively, at the place indicated by Δ), are intuitively assigned the following implicative relation: $\mathbf{S}_x \supset \mathbf{S}_y$. Example: *canary* and *bird* are hyponyms in the context *here is a* Δ because the sentence *Here is a canary* implies *Here is a bird.* Notice that the converse is not true. Two elements *x* and *y* are synonyms in context S if they are hyponyms of each other in that context, that is, if both $\mathbf{S}_x \supset \mathbf{S}_y$ and $\mathbf{S}_y \supset \mathbf{S}_x$ ('$\supset$' stands for 'implies'). Two words which usually are hyponyms become synonyms in some contexts. For example, *bitch* is a hyponym of *dog,* but in the context *the A has puppies, bitch* and *dog* are synonyms.

As the most influential definition of presupposition, we mention Strawson's (1952). S_2 is a presupposition of S_1 if S_1 as well as its negation $(\neg S_1)$ intuitively imply S_2, that is $(\neg S_1 \supset S_2) \wedge (S_1 \supset S_2)$. Example: S_1 = *the King of France is bald;* S_2 = *There is a King of France.* The assertion of an affirmative sentence is that aspect of the sentence which does change its truth value under negation. In the example the assertion is: *the King is bald.* There are problems with this definition of presupposition. Firstly, the definition implies the universal truth of S_2, since either S_1 or $\neg S_1$ whereas what is really intended is to say 'both S_1 and $\neg S_1$ are interpretable only if S_2'. Secondly, this interpretability does not depend on the existential truth of S_2 (i.e., the King of France exists), but only on the conceptual availability (i.e., one can imagine a king of France, although one knows that he doesn't exist).

As S_2 is a condition on interpretability, S_1 does not need to be a proposition. For example, the imperatives S_1 = *close the door* and $\neg S_1$ = *don't close the door* both presuppose S_2 = *the door is open.* Such presuppositions play an important role in verbal communication, just because they are not pronounced. We come back to this in section 3.5. We can apply the notion of presupposition as condition on interpretability to word meaning in the following way. Suppose S_x and S_y are sentences which merely differ in the elements *x* and *y* (see above). If S_y is presupposition of S_x in the above sense, then we say that *y* is presupposition of *x* in the context S. Example: the sentence *she is a mother* as well as the sentence *she isn't a mother* presuppose: *she is a woman.* Therefore *woman* is presupposition of *mother* in the context *she is a* Δ. The assertion of *mother* is 'to have a child', for this is what is denied by the negative sentence.

Finally, we mention the existence of various kinds of meaning opposition. One variety is the relation between mutually exclusive co-hyponyms, for example, the pieces of furniture *table, chair, bed,* etc. A special case presents itself if there are exactly two co-hyponyms *(man/woman, brother/sister).* An important type of meaning opposition is antonymy. This concerns pairs of words indicating a value upon a dimension *(big/small, warm/cold).* Three striking characteristics of antonyms are noted here. First, assertion of one member of a pair implies denial of the other (something *big* is not *small)* whereas the opposite is not necessarily true (something which is not *big* need not be *small).* Second, one member of the pair can mostly be used unmarked. This member then applies to the whole dimension: we ask *how heavy is the book?* even though we know it is *light.* If the answer is *heavy,* then *heavy* is, in this case, marked (namely, contrasting with *light).* Finally, there is always an implicit or explicit standard. *The whale is small* means that *the whale* is small in comparison with some standard size of *whales.* The standard may be considered a presupposition. Therefore, the sentence *the small whale is big* has two presuppositions: (1) that *whales* normally have size such-and-such, and (2) that *animals* normally have size such-and-such.

Just as in phonology, one has tried to construct in semantics a classificatory model from contrasts, in this case, contrasts between concepts. Efforts have been made to derive distinctive features of meaning *(semantic markers)* which, in turn, can serve as the basis for a classification of concepts. This is called 'componential analysis'. For instance, there is an intuitive analogy between the contrasts *man/woman, bull/ cow, rooster/hen,* etc. All these can be reduced to an abstract feature-dichotomy : *male/female.* Other features are, for instance, *full-grown/not fully grown (horse/foal, lion/cub), human/non-human, concrete/abstract, causal/non-causal,* etc. On this basis, one may devise a classification of concepts. Unlike phonology, it seems that there is hardly any limit to the number of features which is needed. The only safe conclusion is that some features - like the ones just mentioned - are very general, whereas others contribute little to differentiation or are only applicable to specific conceptual domains. In componential analysis, therefore, one mostly restricts oneself to such limited domains, called *semantic fields.* For example, color names, animal names, kinship terms, motion verbs, time indicators, etc. The next step is to derive from the classification within such a semantic field the various intuitions with regard to conceptual relations. For instance, suppose: *x* is a hyponym of *y* if the set of features of *y* is a subset of the set of features of *x: table* has all features *of furniture, child* has all the features of *man* (human being), etc. It follows then, that *x* and *y* are synonymous if they have the same feature-set. However, we have already noted that such relations are fundamentally context-dependent; a word usually has few features which are maintained over all contexts. The phenomenon of *presupposition* suggests that negation can only affect one or a few features of the word. *She isn 't a mother* only denies the feature *to have a child,* not the feature *female.* The various features will therefore be assigned different status in the componential analysis of a word (Miller, 1969).

The structure of a semantic field is determined by the relations between features. A hierarchical taxonomy will arise when the features of a field have implicative relations with each other. To some extent, this is true for animal names: *ruminant* implies the feature *mammal,* which in turn implies *vertebrate* (whether this is intuitively very salient, is questionable; see Henley, 1969.) Kinship terms lend themselves better for cross-classification of features, especially the features *generation, male/female* and *colinearity* (see Wallace and Atkins, 1960; Romney and d'Andrade, 1964). Time indicators seem to have a circular organization (days of the week, months of the year); see Miller (1969). The latter is perhaps also true of the names of the primary colors. Primary colors, in turn, have hyponyms: *blue* has *turquoise* and *azure* as hyponyms, etc.

The study of semantic fields has taught us that the relations between concepts are essentially more complex than the relations between phonemes. The feature analogy is only superficial. While a phoneme can be described by a small number of features (nasality, voice, etc.), this is absolutely insufficient for a componential description of word meaning. Apart from one-place-relations, such as *male (x)* or *concrete (x),* more-place-relations must be introduced as components. Compare, for instance, the conceptual components *parent (x, y)* or *child (y, x)* which, respectively, are parts of, among other things, the concepts of *father* and *son.* It also happens that nesting of components is needed: complete propositions, that is, relational components in which *x, y* are bound variables, must, in turn, be able to function as argument of relational components. The verb *kill* could be analyzed in terms of the relation *cause (x, y)* and *dead (x)*; *a kills b* is then represented by *cause* [*a, dead* (b)]. From such analyses it is sufficiently clear that the distinction between concept and feature (or component) is rather arbitrary. *Cause* is by itself a concept which, nevertheless, may be considered a component of the meaning of *kill.* Efforts are made to represent such complex relations between the concepts of a semantic field by means of conceptual networks.

By *conceptual network* we mean a directed graph where each node is labeled by the name of a concept and each edge (arrow) by a relation term. Logical relations (such as inclusion, implication), various case-relations (such as agent, object, instrument), etc. can serve as relation terms; their number is, however, relatively small. The structure of a concept, represented as a node in the network, is brought out by the relations which the node maintains with other nodes of the network. For example, the triplet *poodle* $\subset$ *dog,* which consists of two nodes and one relation (inclusion), says that all meaning components of *dog* also apply to *poodle*. What the features of *dog* are can be seen from the relations of this node with its neighboring nodes.

As an illustration, we choose an example from Schank's (1972) so-called 'conceptual dependency theory'. The meaning of the concept 'give' is represented in the following piece of conceptual network:

$$give: X \Leftrightarrow \text{trans} \overset{o}{\leftarrow} Y \overset{r}{\leftarrow} \left[\begin{array}{l} \rightarrow Z \\ \leftarrow X \end{array}\right.$$

where X is human
Y is physical object
Z is human

Here X, Y and Z are open slots for nominal concepts, whereas *trans* is an action concept denoting 'transfer of possesion'. The relations between these nodes are the agent relati$\Leftrightarrow$, object relation $\overset{o}{\leftarrow}$ and the recipient-relation $\overset{r}{\leftarrow}\left[\begin{array}{l} \rightarrow \\ \leftarrow \end{array}\right.$, which is two-pronged because both entities involved in the transfer of possession must be mentioned. This is also shown by the network for *take:* the conceptual act is the same, only the recipient variables are interchanged:

$$take: X \Leftrightarrow \text{trans} \overset{o}{\leftarrow} Y \overset{r}{\leftarrow} \left[\begin{array}{l} \rightarrow X \\ \leftarrow Z \end{array}\right.$$

Other designers of conceptual networks are Quillian (1967), Rumelhart et al. (1972) and Kintsch (1972).

It is easy to see now that conceptual networks are able to represent not only word meanings, but meanings of word groups and sentences as well. One only needs to fill the slots which are reserved for cases, with names of concepts. For example, to represent *mothers give clothes to children,* the nodes X, Y and Z must be supplied with pointers to the concepts *mother, clothes* and *child.* For more extensive discussions of conceptual networks consult Frijda (1972), Simmons (1972), Tulvin and Donaldson (1972) and Schank and Colby (1973).

2.3. Psychological research on linguistic intuitions

Linguistic intuitions are not always 'clear cases'. In fact, some isolated studies (Levelt, 1972; Kempen, 1972) show that linguistic judgments are often unreliable, individually different and strongly context-dependent. This also applies to many intuitions theory construction has hinged on. Therefore, systematic collection of linguistic judgments under standardized experimental conditions is no luxury. To make things even worse, the relation between theory and data often remains in the dark. We called this the 'interpretation problem' (2.1). The phenomenon of semantic anomaly may serve as an example *(lazy stone, married bachelor).* The componential model states that anomaly arises when modifier and head take opposite values on the same feature. The model, however, says nothing about *degree* of anomaly - something data are easy to obtain for. The interpretation theory, now, should indicate how (at least) a rank order of anomaly degrees can be related to the model. One could, for instance, assume that anomaly is a monotonous function of the number of opposite features, and one could add to this that features form a hierarchy of importance, so that violation of one feature outweights violation of others, etc. Thus, rejection or confirmation of a linguistic model will also be dependent on the interpretation theory chosen. It is deplorable that the interpretation problem receives so little attention in the literature. This causes untenable linguistic models to be maintained unnecessarily long. Without aiming at completeness, we now mention briefly some experimental research with regard to linguistic intuitions - research which often went hand in hand with clarification of assumptions about the relation between model and data.

Syntactic intuitions

It is mainly grammaticality, paraphrase and cohesion that have been experimentally studied. Grammaticality research started with the study of Maclay and Sleator (1960), followed by many others (a.o., Marks, 1965; Quirk and Svartvik, 1965; Levelt, 1972a; Greenbaum, 1973). The main objectives of these studies were to examine the reliability of grammaticality judgments and to differentiate this judgment from other judgments such as meaningfulness, acceptability, etc. An explicit interpretation theory was formulated in two cases (Marks, 1965 and Chomsky, 1964). The latter will be mentioned briefly.

Compare the ungrammaticality of sentences such as (1) and (2); (2) is more ungrammatical then (1).

(1) *the driver laughs the car*
(2) *the driver stone the car*

In order to explain such differences, Chomsky states that there is a hierarchy of syntactic categories. The first subdivision (C_1) is, for instance, the division into nouns, verbs, adjectives and other categories. Each of these is subdivided at the next level (C_2); for example, verbs into transitives (V_t) and intransitives (V_i) In case of category violation during the application of linguistic rules, ungrammaticality will arise. Now, according to the syntactic model, the category sequence for (1) as well as (2) should be: ANV_tAN, while the actual sequences are respectively ANV_iAN and ANNAN. For (1), the category violation concerns C_2, for (2) it is C_1. The higher in the hierarchy the category violation, Chomsky states explicitly, the more ungrammatical the sentence. Moore (1972) investigated this model experimentally and could not verify it. Finally, we note that a considerable amount of research has been done on the grammaticality of adjective orders (*the big white house* vs. *the white big house).* See Bever (1970b), Martin (1970), Danks and Glucksberg (1971), Ertel (1971).

Paraphrase research has been carried out by Gleitman and Gleitman (1970) and Honeck (1971), among others. The first to do this were Clifton and Odom (1966), however, who also gave an interpretation theory for degrees of paraphrase, that is, about meaning similarity between sentences. We have seen (2.2) that in a TG-model S_1 and S_2 can be called paraphrases when $\delta_1 = \delta_2$. Clifton and Odom hypothesized that meaning similarity between S, and S, is a decreasing function of the number of transformations on which ω_1 and ω_2 differ from each other. Thus, a passive interrogative sentence differs more from the corresponding kernel sentence than a passive affirmative sentence. The authors used this interpretation rule for comparing two linguistic models: Chomsky (1957) and Katz and Postal (1964). The latter theory states (contrary to the first) that the negative interrogative is not a combination of two transformations (negative and interrogative) but is derived by one transformational step. The experimental results confirmed the theory of Katz and Postal.

Cohesion was experimentally studied by Levelt (1967a, 1969, 1970, 1974c), Levelt and Schils (1971) and Martin (1970), and for aphasic patients by Zurif et al. (1972). Explicit interpretation theories for various linguistic models (constituent grammar, TG with constituent basis, TG with dependency basis) can be found in Levelt (1974c). The experimental results tend to contradict Chomskian TG with constituent base and clearly point to a TG with dependency base.

Phonological and phonetic intuitions

We have seen in section 2.2 that phonological models are largely based on phonological intuitions (such as intuitions about opposition and classification of phonemes in a language) and phonetic intuitions (such as This is (or isn't) correctly pronounced')- Thanks to automatic speech synthesis-by-rule, it is possible - much more so than in the past

- to experiment on phonetic intuitions and to draw conclusions with regard to correctness of phonological rules as well as the abstract phonological sound classification. This means that the rather elusive phonological intuitions can, in turn, be tested by confronting them with much more reliable phonetic judgments. Moreover, speech synthesis-by-rule enables phonetics to help abstract phonology in those areas where the linguist or informant is simply short of intuitions. The latter point in emphasized especially by Lindblom (1972).

In this section we only mention one example of experimentation on phonetic intuitions. Nooteboom (1972) investigated intuitions related to 'vowel duration'. In this study subjects had to adjust, by turning a knob, the duration of a vowel in an acoustically presented word, in such a way that the word sounded as natural as possible. The subjects made the sound 'grammatical', so to speak. They could express their intuition, or internal criterion, with regard to vowel duration in a normal linguistic context. The average results (three subjects, ten measures each) for the Dutch words *maat, mate, mateloos,* and *mateloze* are shown in fig. 2. Nooteboom found that the criterion for vowel duration is strongly context-dependent. Specifically, the duration of a stressed vowel decreases with the number of syllables that follows in the word, *and* with the number of syllables that follows up to the next (secondary) stress. Fig. 2 shows the combined effect of both factors. These intuitions proved to be in very good agreement with the way the words are normally articulated. From this, Nooteboom derives conclusions with regard to the rules governing duration of Dutch vowels.

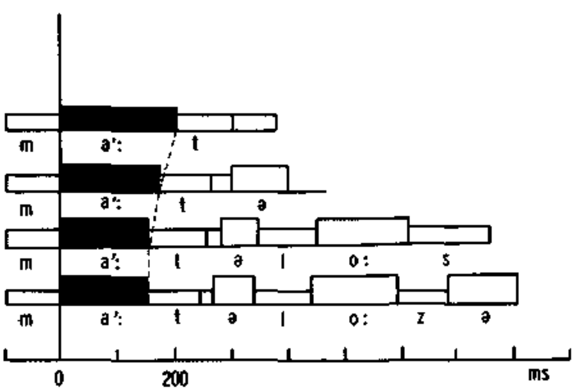


Fig. 2. Adjusted vowel duration for *maat, mate, mateloos* and *mateloze* (after: Nooteboom, 1972).

Semantic intuitions

Here we confine ourselves to the study of intuitions on word meanings. Psychological experimentation in this field has concentrated on the development of discovery procedures, i.e. methods for discovering (abstract) semantic features or components. To this purpose, subjects usually had to react to stimulus words taken from the semantic field under study, in such a way that their reactions are interpretable as similarity or distance measures between the stimulus words. The resulting distance matrix was then analyzed by means of a multidimensional scaling technique, factor analysis or cluster analysis. The obtained dimensions/factors/clusters were interpreted in terms of semantic components.

The methods differed mainly with respect to the method of data collection. We distinguish two groups here. In the first group of methods the words to be analysed are judged by similarity. There is a broad range of possibilities for eliciting these judgments. We refer to Miller's (1969) so-called 'sorting method', and to Fillenbaum en Rapoport (1971) for a survey of other methods. They also present the results of a series of experiments they carried out on various semantic fields. In the second group, a judgment about the relation between the stimulus word and a set of reference words is elicited. The best-known example is Osgood's (1957) Semantic Differential technique, where stimulus words are given values on dimensions specified by pairs of antonymous adjectives. For a survey of SD-research we refer to Snider and Osgood (1971) and Osgood et al. (1975).

This second group also includes studies where subjects are asked whether or not a given word can be combined with a reference word or word group, cf. *lazy nurse* vs. *lazy stone* or *they received the growth* vs. *they received the present.* This method, developed by Osgood (1968), leads to the so-called 'intersection-matrix', an asymmetrical data matrix where each entry is a measure of combinability of a stimulus with a reference word. The analysis of such an intersection matrix entails special problems and is strongly dependent on the interpretation theory which is chosen. If degrees of combinability (or anomaly) are brought into relationship with the number of common meaning components of stimulus and reference word (see Levelt, 1967c) then the data must be analyzed differently than in the case where data are considered dichotomous, and oppositeness in just one component is regarded as justifying the judgment *'anomalous'.* The latter model was used by Noordman and Levelt (1970) for verb/object-combinations. The three most important components found in that study were concrete/abstract, living/nonliving, and generic/nongeneric.

It is hardly possible, though, to make general statements about the results of these discovery procedures. The only absolutely reliable and universal result is obtained by the SD-technique: there are the three 'affective' meaning components: *evaluation, potency* and *activity* (Osgood et al., 1975). Furthermore, it appears that the components and their organization strongly depend on the semantic domain (see Fillenbaum and Rapoport, 1971), on the reference words used, on the judgment procedure and the technique of data analysis (see Levelt, 1972b). The conclusion seems appropriate that the investigator cannot but make blind decisions here without detailed hypotheses about the structure of the word domain under study. In other words: the experimental research on semantic intuitions should be hypothesis-testing rather than explorative. Examples of hypothesis-testing research can be found mainly in anthropologically oriented literature. We mention the work by Romney and d'Andrade (1964) on kinship terminology and by Rosch-Heider about color names in English and in Dani (New Guinea). See Heider (1972), Rosch (1973), Rosch-Heider and Olivier (1972).

3. Language as skill

In this part we shall deal with the skills of primary language use: speaking and understanding language. Despite their essential role in civilized language use, reading and writing must be left out of systematic consideration (see Vol. I, chapter 8, however). It must be noted, though, that the materials used in psycholinguistic experimentation are frequently presented in writing, and that written responses are often required. Considering the communicative function of language skills, it is impossible to draw a line between linguistic and nonlinguistic aspects of behavior. *What* is being communicated is usually the result of nonverbal, perceptual, intellectual or emotional activity. The limited space available forces us to an extremely restrictive treatment of these matters. So, except in a brief final section (3.6), we will discuss either investigations where the stimulus material has a predominantly nonlinguistic character or models mainly concerned with nonlinguistic information processing. For these topics we refer the reader to other chapters of this handbook and to the literature quoted there.

3.1. The hierarchical structure of language skills

All complex human skills show a hierarchical organization: successfully carrying out some action is almost always dependent on the correct performance and timing of partial actions. This is especially true of speaking and understanding language. Speaking is possible thanks to timely retrieval of words from memory, precisely timed performance of certain articulations, etc. Many of such partial activities are completely automated, which, for that matter, is true of any skill (cf. Herriot, 1970 and Levelt, 1975, for further comparisons of language and other skills). According to systems theory, the best procedure for analyzing such extremely complex processes is to describe the system in terms of subsystems and relations between subsystems. In this section we shall make use of a *stratified* hierarchical systems description (Mesarovic et al., 1970). By this we mean that the same input-output system is described at various levels of detail. At the most elementary level the language user can be considered a system that receives and emits speech sounds. This level represents *phonological skills.* If the unit of description for the same input and output is chosen to be somewhat larger, then the language user can be considered a system operating with morphemes or words: at this level we focus on *lexical skills.* But words are not produced in random sequences; they are organized as syntactic units, and this is accomplished by *syntactic skills.* The largest units discernable in the input and output of language users are complete messages; they are composed by what we shall call *textual skills.* It is evident that carrying out a textual task (for example, telling or understanding a story) implies correct and well-timed performance of syntactic subprocedures. The way in which these subprocedures are linked up with the main procedure is called an *'intervention relation'.* Similarly, intervention relations must be assumed to exist between the syntactic and the lexical levels and between the lexical and the phonological levels. Fig. 3 summarizes this way of description.

It is unlikely that the organizational principles of one level could be borrowed from another level. According as the level is higher (i.e., is concerned with larger units) will behavior be less automated and decision times slow down, will feedback control increasingly occupy central mechanisms of attention instead of peripheral closed circuits, and will behavior show more variability and divergence. The latter will make theoretical formalization rather cumbersome. The following sections discuss the various levels of skill in turn.

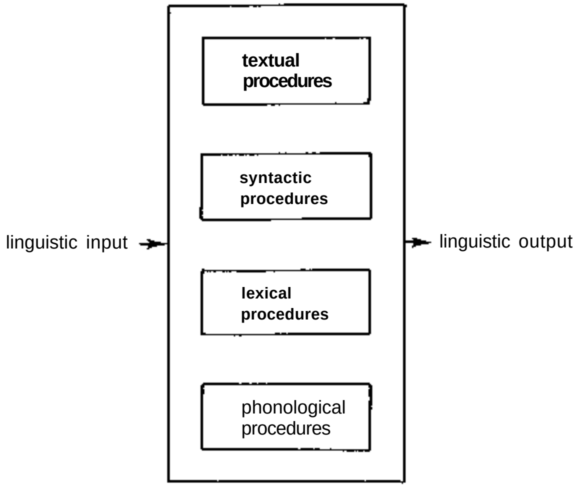


Fig. 3. Stratified hierarchical description of the language user.

3.2. Phonological skills

The formation and recognition of speech sounds (phonemes, syllables) is controlled by a multitude of processes. This section briefly presents a few examples showing that, even at this most elementary level, very complex integrated activity is going on. First we choose a specimen of speech production research; then we will make a few remarks on speech perception.

If speaking is viewed as the execution of an articulatory program, then the organization of that program might be studied by analyzing speech errors in normal subjects. Although this approach has been applied for a long time (Merlinger and Mayer, 1895; Freud, 1901; Staal, 1946; Kainz, 1956), present-day speech research has renewed its interest for speech errors. Cohen (1965) published an analysis of 787 Dutch speech errors. The same material was further examined by Nooteboom (1967) and, among other things, extended with experimentally produced reading errors (1969). These studies were replicated by MacKay (1970a) for the English language. The relevance of speech errors for testing speech production models was especially emphasized by Fromkin (1971). For an anthology of speech error studies, see Fromkin (1973).

Speech errors may be classified in various ways. With respect to their temporal organization, they can be divided into perseverations and anticipations. A perseveration is, for instance, *corkical* instead of *cortical;* an anticipation is an error such as *hinch hit* instead of *pinch hit.* Some anticipations have the form of a permutation, for example, *heft lemisphere* instead of *left hemisphere.* From his collection of speech errors, Cohen derived the time distribution of Fig. 4.

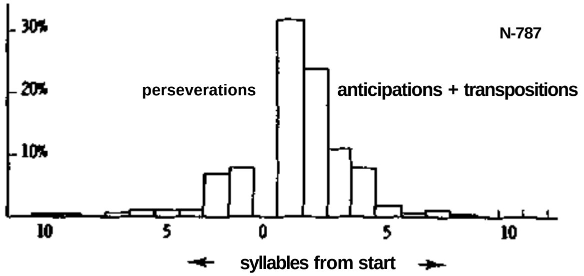


Fig. 4. Distribution of speech errors in time (after: Cohen, 1965).

It is clear that most speech errors are anticipations that come a maximum of seven syllables ahead of time. This gives some idea of the moment of time articulations are programmed. The maximum of seven syllables corresponds to an anticipation time of approximately one second. By far the most speech errors are additions, replacements, order reversals and deletions of phonemes (individual vowels or consonants). This indicates that, despite the continuous nature of articulation, there is a level of programming which controls the temporal order of individual phonemes. We would have no evidence for this if only syllables or complete words were misplaced in speech errors.

Although vowels and consonants are the smallest phonological segments, we have seen in section 2.2 that they, in turn, can be considered simultaneous bundles of distinctive features. There is evidence that the speech program adjusts these features relatively independent of each other and, consequently, that the phoneme is not the smallest unit of planning. This is supported by two aspects of speech errors. First, there are transpositions which do not concern whole phonemes but only one feature, so that two new phonemes appear. Examples: *Cedars of Lebanon* -> *Cedars of Lemadon* (transposition of nasality) and *clear blue* *sky* -> *glear plue sky* (transposition of voice). Second, the chance of transposition of two phonemes decreases as they differ by more features (Nooteboom, 1967; MacKay, 1970). It should be remarked, however, that errors which are interpretable as substitution of a distinctive feature are relatively rare.

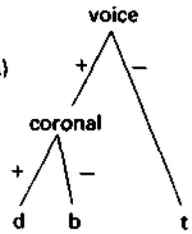
The hierarchical organization of speech skills does not only appear from the fact that greater units are also involved in speech errors, such as syllables *{infantry men* -> *intrymen* and words *{my father's other remark* -> *my other father's remark)* but also from the fact that the prosodic pattern - which is determined by larger units - is maintained. An example is *how bad things are* -> *how things bad are.* In such cases of transposition, the vowel does *not* take its intonation (stress) along with it. They are good examples of what we have called intervention relations: the realization of a smaller unit (in this case, the vowel) is also dependent on decisions made with regard to larger units (stress pattern of the word or intonation pattern of the sentence).

In speech perception, too, distinctive features play a role. Miller and Nicely's classical experiment (1955), where subjects had to recognize spoken phonemes which had been degraded by noise or frequency filtering, showed that identification errors are not random. Usually, the response missed the stimulus by just one or two distinctive features *{m* instead of *n, d* instead of *t,* etc.). Later experiments confirmed this and added that in memorizing phonemes, features are forgotten relatively independent of each other (Wickelgren, 1906; cf. chapter 7).

That articulatory factors are at work in speech perception has been demonstrated several times. The discrimination between *b* and *d* is much better than that between two variants of *b* whose acoustic-physical differences are greater (Liberman et al., 1967). The former belong to different articulatory categories, the latter to the same. According to a widely accepted view, there is feedback between perception and articulation. The hearer identifies the perceived sound by checking which articulatory instruction would enable him to produce a sound which is sufficiently similar to the perceived sound. There are many versions of this theory, among them *the analysis-by-synthesis theory* (Stevens, 1960), *the servo-theory* (Fairbanks, 1966), and the *motor-theory* developed in the Haskins laboratories (see Liberman et al., 1967). However, one can speak of 'internal imitation' only in an abstract sense. Certain cortical midbrain lesions make speech articulation impossible. Children who had this disorder (anarthria) from birth onwards and could never learn to articulate, can nevertheless acquire perfect speech perception (Lenneberg, 1967). The articulatory codes must be very abstract, then, or based on the visible articulation pattern of others (lipreading).

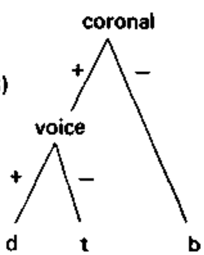
Little is known about the *process* of speech recognition. Campbell (1974) showed that in recognizing individual speech sounds, the hearer does not process the various features simultaneously, but in quick succession. Moreover, he does not process more features than are necessary for discriminating the speech sound from alternatives. The decision process has the form of a tree structure such as diagram A which represents the choice between the responses *d, b* and *t.* The decision 'voiceless' is sufficient for identifying the *t;* for *d* and *b* a second feature (coronal) must be tested, however. Both error analysis and reaction times strongly support this successive elimination theory.

(A)



The order of testing the features is determined by discriminability. For example, voice is more audible than coronality. It is less visible, however. In lipreading, where the subject only sees the speaking face but does not hear anything, the discriminability is reversed and the decision tree takes the form of diagram B.

(B)



To what extent these results are generalizable to situations where units larger than CV-syllables are recognized is not clear. But it is likely that, also in listening to continuous speech, only those features are processed which are strictly necessary in order to distinguish the speech sound from probable alternatives, and that the most discriminable properties are tried first.

The recognition of individual speech sounds is heavily dependent on the context in which they appear. Here, too, many experimental demonstrations of intervention relations are available; recognition as a function of context has been studied by Miller, Heise and Lichten (1951) and Broadbent and Gregory (1963), in particular.

3.3. Lexical skills

The everyday use of words betrays a multitude of lexical skills. Of these, only a few have been studied to some extent, and even fewer can be discussed in the space we have available. Just think of the following examples: rapidly finding the right word during speaking, correctly and rapidly recognizing a word spoken or written by someone else, recognizing sound as well as meaning relationships between words, the efficient use and understanding of metaphorical expressions, learning new words and relations between words, the production of free or directed associations. Of old, psychological research was mainly concerned with word association and word recognition; more recently, recognition of semantic relations between words was added. In this paragraph we shall briefly discuss both latter topics. Word association research, though very extensive, is marked by a lack of models for underlying processes. It always strongly adhered to the psychometric tradition: the search for independent semantic factors/components (2.3; cf. Deese, 1965). Nevertheless, the importance of a descriptive approach to word association should not be underestimated: in many psycholinguistic experiments, associative strength is an important variable to be controlled. Word association norms are an indispensable tool here.

3.3.1. Word recognition

Word-frequency is an essential variable in word recognition experiments. Frequent words are faster and better recognized, acoustically as well as visually, than infrequent words (cf. Solomon and Postman, 1952; Broadbent, 1967; Kempen et al., 1969; Nieuwenhuyse, 1970). Furthermore, word recognition is a function of the number of alternative words in the recognition vocabulary, of the signal/noise-ratio under which the word is presented (see the curves in fig. 1), of the context in which the word appears (see, among others, Tulving et al., 1964), of the interval since the last recognition of the same word (cf. Meyer, 1973) and of visual properties of the word (see Bouma, 1973 and Vol. I, chapter 8).

Morton (1969,1970) has proposed a model describing these and other phenomena of word recognition. As yet, the iogogen' model is the best-developed theory on word recognition, also with respect to its mathematical elaboration, which we cannot present here. Fig. 5 gives a diagram of the model.

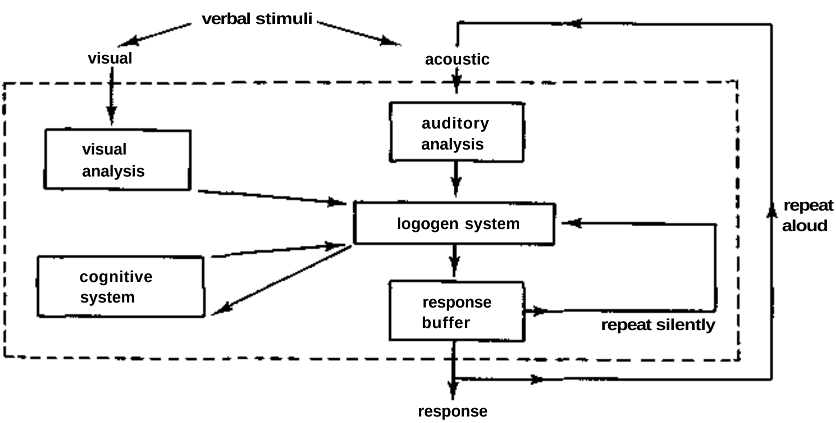


Fig. 5. Diagram of the logogen model (after: Morton, 1970).

The model departs from the assumption that it is always the same unit which activates a certain verbal response, whatever the information which selected that unit in the first place. The response *cat* may come up in a free word association task where the stimulus is *dog*, but also in a sentence-completion task where the stimulus is *Miaow said the...*, and in various other ways. It is always the same unit which makes the word *cat* available. Such a unit is called a *Iogogen.* A logogen is characterized by the phonological properties of its specific response, plus a number of acoustic, visual and semantic attributes. The latter are the most important ones. Homonyms have the same acoustic (and sometimes also visual: in written form) attributes but, nevertheless, correspond to different logogens because of the meaning difference.

A logogen is a counter. Each time an attribute is sent into the logogen system, irrespective of whether it results from acoustic, visual or cognitive-semantic analysis, this fact is registered by all logogens which have that attribute in their characteristic set. Cumulative counting of the number of attributes that are registered by a logogen within given period of time produces a number that we call the arousal level of the logogen. Without new input, the arousal level of a logogen decreases rapidly. Then the count must start again from the beginning. This 'refreshing process' takes a maximum of one second. As soon as the arousal level exceeds a certain value, the logogen releases its response. That value is called the threshold value of the logogen. Many things may happen to that response: it could be uttered as an overt response via the response buffer; it could also be rehearsed internally, or passed on to the cognitive system. Several or all of these things may happen simultaneously.

When a logogen has just responded, the threshold value decreases temporarily and returns slowly to its normal value. This explains why a word is more easily recognized just after it was given as a response (see Neisser, 1954). The return to the normal value remains incomplete even after longer periods of time. If a response is frequently given this leads to permanent threshold lowering for the corresponding logogen. This explains the word-frequency effect. A frequent word is more easily recognized because less activation is needed to exceed the lower threshold. In terms of signal-detection theory: the word-frequency effect is not brought about by better discriminability, *d'*, of frequent words, but by an easier criterion, *c* (see Vol. I, chapter 6). Experiments by Broadbent (1967) and Morton (1968) support this position. The results of Goldiamond and Hawkins (1958) and of Zajonc and Nieuwenhuyse (1964), who studied 'word-recognition' when only noise was presented, are also in perfect agreement: the more frequent a word, the greater the chance it is given as a response. The latter experiments, however, presuppose a mechanism which is able to lower the threshold of all logogens simultaneously and to the same degree until a response comes free.

In case a stimulus has, indeed, been presented, and it is an infrequent word (e.g., the printed word *swath)*, the chance of an incorrect answer (e.g., *smalt)* may be higher than of the correct response. This happens when the two logogens have so many attributes in common that the low threshold of the frequent word is already exceeded, but not yet the (high) threshold of the correct but infrequent word. Many experiments (Pillsbury, 1897; Savin, 1963; Morton, 1964), support this prediction. It also follows that rare words are more easily identified if they have few features in common with frequent words (Havens and Foote, 1963). Morton (1964) was also able to give a complete mathematical description of the data of fig. 1 of Miller et al. (1951) by assuming that if the response alternatives in a recognition task are known, the threshold values of the corresponding logogens are reduced by an equal amount.

The context (words, word-groups, sentences or other stimuli presented earlier or later), that is, semantic attributes, also affects the count, and an important prediction of the model is that context information influences recognizability independently of stimulus information. An analysis of the data of Mandler et al. (1968) shows that this is indeed the case. Research by Osgood and Hoosain (1974) supports the view that the units corresponding to logogens are single words and not syllables or morphemes.

The results mentioned here are not nearly the only ones describable by the logogen model; the reader can consult the original publications. We give one more word-recognition phenomenon that, perhaps, is also explicable in terms of Morton's model. It is the so-called 'homograph effect' (Rubenstein et al., 1970, 1971). Subjects are repeatedly presented with letter strings, and each time they have to decide whether or not the string makes up a word of the language. It now appears that homographs (such as *bear* or *like)* require less decision time than non-homographs of comparable language frequency (by the frequency of a homograph we understand the sum of the frequencies of the separate meanings). Meyer and Schvaneveldt (1971) and Schvaneveldt and Meyer (1973) discovered an interesting phenomenon in this "lexical decision task". They presented the subjects, not with one but two letter strings at the same time, asking them to decide as quickly as possible whether both strings were words or not. It appears that the decision is faster if the two words are strongly associated *(sky - blue)* than if they are not *(sky - bone).* According to the authors, this points to 'spreading of excitation': semantically related logogens communicate their excitation to each other, if not directly, then via the cognitive system (cf. fig. 5).

3.3.2. Verification of semantic relationships

Since 1968 many reaction time studies have been carried out on semantic relationships between words or, for that matter, about the structure of the mental lexicon. The following methods are in use:

(1) Landauer and Freedman (1968) had their subjects judge, under time pressure, whether a stimulus word (e.g., *poodle)* denotes an exemplar of a previously specified category (e.g. *dog* or *animal).*

(2) Schaeffer and Wallace (1969) presented pairs of words which had to be compared. The subjects had to respond with 'same' or 'different' depending on whether or not both members of a pair (e.g., *oak* and *tulip)* belonged to a prespecified class (e.g., *tree* or *plant).*

(3) Collins and Quillian (1969) measured verification times for sentences which expressed inclusion and property relations such as *a canary is a bird and a canary has a skin.* These paradigms have stimulated many further investigations whose main traits we shall summarize here. For partial surveys see Landauer and Meyer (1972), Collins and Quillian (1972a) and Rips et al. (1973).

A phenomenon which consistently shows up in the latter two procedures is the 'semantic distance effect'. Two words for which the semantic relationship to be verified is indeed true - so that the answer 'yes' or 'same' is the correct one - require a longer decision time according as their semantic distance increases. For false semantic relationships (response 'no' or 'different') the inverse rule holds. For instance, it is easier to confirm the correctness of the statement *oaks and beeches are plants* than *oaks and tulips are plants,* but negation of *oaks and tulips are trees* is more difficult than *oaks and starlings are trees* (Noordman-Vonk and Noordman, 1973). Correspondingly, Collins and Quillian (1969) found that affirmation of a *canary is a bird* takes less time than of a *canary is an animal,* whereas negation of *a canary is an ostrich* takes longer than of *a canary is a fish.*

We have intentionally omitted a definition of the notion of 'semantic distance'. If, following Collins and Quillian, we think in terms of conceptual networks, we may express the semantic distance between two words in terms of the number of nodes on the shortest route between the concepts corresponding to those words. In the so-called set model (Meyer, 1970) inclusion relations are represented by pairing each category name with a list of exemplar names. The semantic distance between two category names corresponds to the number of exemplars which do not belong to both sets: for the pair *canaries-animals* this number is greater than for *birds-animals.* But, independently of these taxonomic distance criteria, the factor 'representativeness' is at work: how representative, how typical is an exemplar of the class it belongs to. For a number of mammals and birds, Rips et al. (1973) collected judgments about their similarity to and their representativeness of the categories of mammals, birds and animals. The distance values calculated by means of a multi-dimensional scaling method were shown to correlate considerably with the verification times. For instance, these investigators found that the calculated distance between *hawk* and *bird* is smaller than between *goose* and *bird,* and that the inclusion relation between the members of the first pair takes less verification time than of the last pair. What kind of lexical information determines the degree of representativeness is an unsolved problem as yet (see below).

Collins and Quillian's (1969, 1972a) interpretation of the semantic distance effect falls into separate parts for affirmative and negative answers. What is common to both is only the beginning of the decision process. The conceptual network is traversed, starting from the nodes which correspond with the content words of the sentence to be verified, in search of a path connecting the nodes. The reaction time, which for affirmative answers goes up with increasing semantic distance, is accounted for by the duration of this search phase. It takes longer as the nodes are farther from each other. As for negative answers, it is assumed that the search phase reveals paths which, after more careful examination, prove incompatible with the relation expressed in the sentence. As the semantic distance of the content words is shortened, the probability of such misleading paths increases as well as the time needed to diagnose them as wrong. For example, *saucers have ears* will be more difficult to reject than *saucers have legs* since *saucer,* via *cup,* has a closer connection with *ear* than with *leg.*

The set model predicts only half the semantic distance effect: the reaction time has to increase with increasing distance, both for affirmative and negative responses (Landauer and Meyer, 1972). Within the category of the predicate noun, for example, *dogs* in the sentence *poodles are dogs,* an exemplar is looked for which has the name of the sentence's subject. In the smaller set of *dogs* the exemplar name *poodle* will be easier to find than in the more extensive category of *animals.* This makes it easier to categorize *poodles* as *dogs* than as *animals,* but the same applies to false exemplar names such as *tulip.* For, the negative response can only be given after the whole category has been searched through for the exemplar name *tulip.* As a matter of fact, such results - that are incompatible with the 'negative part' of the semantic distance effect - have sometimes been found in paradigm (1) mentioned above. Why this paradigm behaves differently is not clear (cf. Collins and Quillian, 1970; Landauer and Meyer, 1972). Category size, i.e., the number of exemplars of a category, must perhaps be regarded as a factor which functions independently of semantic distance.

In discussing the network interpretation we did not yet talk about the criteria on which to base negative answers. In principle, there are two possibilities. First, the answer 'no' is produced in case *of failure* to find confirming evidence for the assertion-in-question with the help of the available search procedures. Second, the negation is given as soon as the search procedures have discovered a *contradiction* between the assertion-in-question and the relationship in the conceptual network. As a measure against excessively long decision times, we must build in some 'short-circuit' facility which stops the search procedures after a predetermined maximum period of time, or - in the second case - one which accepts data that only suggest but do not gurantee a contradiction.

Collins and Quillian (1972b) outline a possible heuristic for use in the verification of inclusion relations, for example, *volleyball is badminton:* look up, for both nouns, the values they have on a number of attributes and decide 'no' if the number of unequal values exceeds a critical value; e.g., *volleyball* and *badminton* have unequal values for the attributes 'object played with' and 'measures of the net'. Similar mechanisms might be responsible for the representativeness effect. Rips et al. (1973) suggest the possibility that the memory representations of category names contain specific values which do not apply to all exemplars. *Bird,* for instance, has a specific value for the dimension *wild-domesticated,* a value which is closer to the one for *hawk* than for *goose.* Collins and Quillian (1972b) also show that subjects do not easily base their 'no' on the absence of confirming evidence but preferably on (actual or putative) contradiction. This is also a kernel assertion in the model developed by Noordman-Vonk and Noordman (1973) for the measurements they carried out according to paradigm (2) mentioned above.

3.4. Syntactic skills

The development of transformational grammar (TG) has led to a renewed interest in the problem of how people analyze and construct syntactic structures while listening and speaking. In fact, before 1962 no experimental research of any importance had been done on this topic. It was Miller and his collaborators who, in the beginning of the sixties, introduced experimentation on syntactic structures into psychology. For a complete survey of this work until 1966 we refer to Levelt (1966a, b). The objective of this research was the development of perception, memory and production models for sentences on the basis of a transformational linguistic theory. The originally implicit point of departure was that the model of the language user would turn out to be largely isomorphic to the linguistic theory.

The first aspect to become explicit was the so-called 'coding hypothesis' : presented with a sentence, the hearer is supposed to try and derive its deep structure *(5):* the internal representation is isomorphic to δ. Only later (about 1965) people realized having assumed a second and stronger form of isomorphism, namely, the "derivational complexity hypothesis". While decoding a sentence, the hearer is supposed to carry out a series of operations which are, one by one, reflections of the linguistic rules (especially the transformation rules) involved in the generation of the sentence. Hence, the more complex the linguistic structure of the sentence, the more complex (more difficult, more time consuming) the comprehension process. Since 1967, both versions of the isomorphism hypothesis were gradually abandoned. The position with respect to TG became more and more unprejudiced, without slowing down the new upsurge of experimental research on perception of sentences. In this section we confine ourselves to some aspects of perception and retention of sentences.

3.4.1. The perception of sentences

In order to understand a sentence, the hearer must be able to derive the semantic relations which exist between the elements of a sentence. How are these relations represented in a spoken sentence? In 1886 already, Paul listed the 'linguistic devices' for expressing the combination of ideas: (1) grouping of words; (2) the sequence of these words; (3) stress or accent; (4) modulation of pitch (intonation); (5) variations of speed and pauses between the words; (6) function words such as prepositions, conjunctions, auxiliaries; (7) inflection of words such as for expressing gender, number and case. In 1922, Bühler remarked: "Ich glaube nicht dasz heute jemand imstande ist, den sieben Hilfsmitteln ein neues hinzuzufügen oder ein altes abzustreichen" (quotation after De Groot, 1949).' Yet, the experiments of Fodor and Garrett (1967), see also Levelt (1967a), led to the addition of the eight possibility: the lexical structure of verbs. The idea is that the language user knows, for each verb, in which deep-structure configurations it can occur. Thus, the word *persuade* has an obligatory subject constituent, an optional direct object and an optional prepositional phrase introduced by *(in) to* (e.g., *I persuaded him (in) to a dinner-party)* or complement construction (e.g., *I persuaded him to leave).* As soon as the main verb of the sentence is heard the perceiver tries to insert the identified and to-be-identified partial constructions into the open places of the deep-structure configuration.

That the hearer uses each of these eight sources of information during sentence perception has, since 1967, been shown in a great variety of experiments. Especially Bever's (1970a, b) work has stimulated this research. He coined the term *'perceptual mapping rules'* ('perception strategies') for indicating the operations the hearer performs in order to extract semantic/syntactic relations from such information sources. Here, we mention some of the important experiments on the eight syntactic devices.

(1) and (2). The left-to-right arrangement of words sometimes leads to an immediate temporary interpretation. Levelt (1974c) mentions experiments where paraphrase latencies were measured for Dutch sentences of type (a) and (b):

(a) Het jongetje merkte dat het vlees lekker smaakte.
(The boy thought that the meat deliciously tasted)
(b) Het jongetje merkte dat het vlees lekker vond.
(The boy thought that the meat delicious found)

The (b) sentences lead to much longer latencies and to interpretation errors. Subjects take *het vlees* directly as a noun phrase. In (a) this is all right, but in (b) it is wrong because, now, *het* is a personal pronoun referring back to *het jongetje {the boy).* The strategy seems to be: interpret

[1] "I don't believe that anybody today is able to add a new linguistic device or to erase an old one".

every occurrence of *de*, *het* or *een* as an article (A) first; check whether A is followed by a noun (N), interpret A + N as a noun phrase. Fodor et al. (1974) mention as a very fundamental strategy the *'canonical sentoid strategy'*: each time a sequence of the form NP + V(+NP) occurs, assume that these units are respectively subject, verb and object of a deep structure clause. For English, this strategy almost always leads to the correct interpretation. Its functioning can be experimentally demonstrated in cases where this is not so, such as in sentence (c) which must be interpreted as (d).

(c) The editor authors the newspaper hired liked lughed.
(d) The editor the authors the newspaper hired liked laughed.

Subjects persistently interpret the *editor, authors* and *newspaper* as subject, verb and object, so that they do not know what to do with the last three verbs in the sentence. Fodor et al. (1974) mention some further related experiments. The difference in the level of difficulty between active and passive sentences is also ascribed to the inapplicability of this strategy to passive sentences.

(3), (4), (5). The effectiveness of prosodic characteristics for interpreting word groups and sentences has been shown many times. We mention an experiment by Bolinger and Gerstman (1957), where small variations in pausing time sufficed to distinguish *light housekeeper* from *lighthouse keeper*. Levelt et al. (1970) showed that hearers were able to give the correct interpretation to spoken surface-ambiguous French sentences by using prosodic characteristics:

(e) On a tourné ce film intéressant pour les étudiants.

In a follow-up experiment (Zwanenburg et al., 1976) this also applied to ambiguities as in (f), (g) and (h).

(f) le livre est tout vert/le livre est ouvert.
(g) il parlait du nombre/il parlait d'une ombre,
(h) elle avait ses amants/elle avait seize amants.

(6). The role of function words is already clear from the effect of the article in examples (a) versus (b) and (c) versus (d). Fodor and Garrett (1967) showed that omitting the relative pronoun from sentences like

(i) makes them more difficult to understand. Compare (i) and (j).

(i) The pen which the author whom the editor liked used was new.
(j) The pen the author the editor liked used was new.

This result has been replicated in various ways (Hakes and Cairns, 1970; Hakes and Foss, 1970). Hakes (1972) found considerable RT-delay by omitting the conjunction *that* in the beginning of a complement clause:

(k) While he was studying his data, the young astronomer noted (that) something odd had happened.

(7). The experimental study of the role of inflection, suffixes and affixes has almost exclusively made use of nonsense material of the sort that is found in Lewis Carroll's Jabberwocky poem.

'Twas brillig, and the slithy toves
Did gyre and gimble in the wabe:
All mimsy were the borogoves,
And the mome raths outgrabe.'

From a series of investigations, starting with Epstein (1961), it appeared that sequences of nonsense words are considerably easier to perceive and to memorize if they are changed into quasi-syntactic structures by adding various kinds of morphemes (syntactic devices). (See O'Connell (1970) for methodological criticism of these studies.) But, unfortunately, little is known about the role of these devices in the perception of meaningful material. We note here in passing that the syntactic analysis program of Thorne et al. (1968) is largely controlled by this sort of information. For most types of words, no category information was stored in the computer memory. The syntactic category of a word was derived, in particular, from bound morphemes such as -*ly*, -*ness*, etc. Whether the human language user, too, prefers to derive category information in this manner is an open question.

(8). That the lexical structure of the main verb is a possible determinant of the complexity of a sentence was made plausible in a series of experiments by Fodor et al. (1968). Among other things, they compared verbs which admit only a noun phrase as direct object (example: *pay),* with verbs which also admit a sentential complement (e.g., *prefer).* Replacement of the lexically simple verbs by the lexically complex ones made sentences containing them more difficult to paraphrase:

(1) The tiger the natives the hunter paid hated was fierce.
(2) The tiger the natives the hunter preferred hated was fierce.

However, we must add here that Hakes (171) did not find this contrast in a phoneme monitoring task. The subjects had to press a reaction button as soon as possible after hearing a word beginning with a previously specified phoneme. Under the assumption that processing a sentence makes use of the same central channel of attention as phoneme recognition, it may be expected that the two tasks will interfere with each other. Processing sentences having the critical phoneme in a complex verb must, then, produce longer RT's than sentences with the phoneme in a simple verb. Hakes found no such difference. Holmes and Forster (1972), however, could partially confirm the original result.

Generally, it is not a great problem to demonstrate the effectiveness of the various syntactic devices. It is quite a different matter to build and to test processing models. One may speak of perception strategies, but as long as one does not know under which conditions they are applied, how the various strategies interact, what their priorities and probabilities are, what their temporal characteristics are, etc., one still has no model of perception but only a list of devices for use by the hearer. As yet, the perception process itself remains rather obscure. It is probable that processing largely proceeds in a clause-by-clause fashion. At the end of each clause, a more or less definitive decision is taken with regard to its semantic interpretation.

This is clearly borne out by experiments of Jarvella (1971) and Jarvella and Herman (1972). They had subjects listen to short stories which were interrupted unexpectedly. The task, then, was to reproduce verbatim the last part of the story. It appeared that the last clause, i.e., the interrupted one, was almost always reproduced correctly, in contrast with the relatively bad reproductions of the immediately preceding clause, of which only the meaning but not the literal form was available. Caplan (1972) demonstrated the same point by means of a word recognition task. The transition from clause to clause also appears to play a critical role in the numerous click-experiments. During the sentence a click is presented; afterwards the subject has to indicate at which moment of the sentence the click was heard. The general finding is that the click is mislocated and tends to move towards the boundary of clauses (Bever et al., 1969; Holmes and Forster, 1970). For a survey of 'clickology', see Fodor et al. (1974). Reber and Anderson (1970) and Reber (1973) showed that the click results may be a consequence of response bias. Subjects preferably localized a purportedly 'subliminal' click, that actually did not exist however, at the boundary between clauses. These findings do not contradict the idea that sentence interpretation proceeds clause-by-clause.

Arguments for this idea can also be derived from numerous studies on the perception of ambiguous sentences (see, especially, the relevant chapter in Flores d'Arcais and Levelt, 1970, and Fodor et al., 1974). The main issue has always been whether the hearer determines both interpretations of the sentence and, subsequently, rejects one of them, or whether he determines one interpretation in the first place and derives a second one only if necessary. The first view is supported by experiments of Mackay (1966, 1970) and Foss (1970) on sentence completion and phoneme monitoring. They found longer reaction times when the clause concerned was ambiguous. An experiment by Lackner and Garrett (1972), too, points to the simultaneous presence of both interpretations. In a dichotic listening task, subjects paid attention to an ambiguous sentence presented to one ear. At the same time, disambiguating information was presented to the other ear in so low a voice that the subjects could not recognize it. It appeared that the subjects, practically without exceptions, adopted the interpretation suggested by the non-shadowed channel.

Opposing these results are those obtained by Foss et al. (1968) and Carey et al. (1970) during verification tasks. After having read a sentence which was either ambiguous or unambiguous, the subject looked at a picture that was a true or false depiction of one (the) interpretation of the sentence. The reaction times showed that, at the moment of verification, the subject had available only one interpretation.

The solution of this seeming contradiction, again, is to be found in the realization that sentence interpretation proceeds clause-by-clause. If reaction times are measured before the end of the ambiguous clause, an effect of ambiguity is obtained. When the measurements are taken after completion of the clause, the effect of ambiguity has disappeared. This is systematically shown by Bever et al. (1973).

Though we have seen now, that subjects decide on an interpretation at the end of a clause, the question of how the interpretation process is carried out has not been answered yet. Kaplan (1972) has offered several suggestions. He showed that Bever's strategies are elegantly formalizable in terms of augmented transition network grammars (ATNs). We shall briefly describe how such a grammar can account for the canonical sentoid strategy mentioned above. Fig. 6 contains a partial transition network. It looks much like the transition diagram of a finite automaton (see Vol. I, chapter 6). The nodes (circles) are states whose names indicate the constituent being analyzed, as well as the partial constituent already finished (to the left and to the right of '/', respectively).

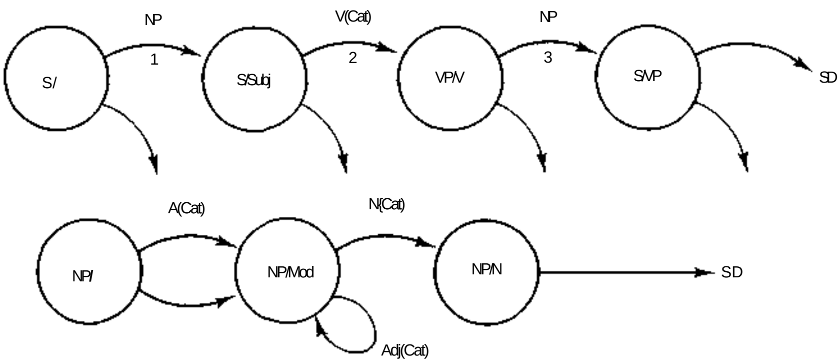


Fig. 6. A transition network grammar.

Conditions	*Operation*
1. None	Put structural description of NP in subject register
2. V is a finite verb; there is person agreement between V and the NP in the subject register	Put V in verb register
3. V is transitive	Put structural description of NP in object register

The arrows in fig. 6 are possible transitions between states. They sometimes have labels indicating under which conditions the transition may be made. Numbers may add further restrictions and operations to be applied while making the transition. It is this addition of various types of conditions and operations which enables such networks to exceed the power of finite automata and, in principle, makes them equivalent to Turing machines (see Vol. I, chapter 6). We have not stated all conditions and operations because this would lead into too much detail.

Now, let us look at some steps in the analysis of the sentence *The little girl broke her arm.* The starting state is S/. Because NP is not a word category (Cat), an NP-subroutine must be carried out first. To this purpose, a jump is made to state NP/. The first transition from here is permitted because *the* is of the category A (article). The transition N (Cat) is not possible but Adj(Cat) is, so that *little* is accepted. Then, N(Cat) is possible and *girl* is accepted. The arrow SD now means that a structural description is built of the form (NP(A *the)(*Adj *little)(*N *girl)),* which completes the NP-subroutine and enables the transition to S/Subj. The number 1 indicates that the transition can be made unconditionally and that the structural description must be placed into a so-called 'subject register'. As *broke* is of the category V, and the conditions that V is finite and in person agreement with *the little girl* being fulfilled, V can be placed into the verb register and state VP/V is reached. Then, again, a jump to the NP-subroutine is made since the condition 'V is transitive' is fulfilled. After thus having prepared a structural description for *her arm,* this is placed in the object register. Finally, a structural description for the whole sentence is constructed of the form (S (Subj...) (VP (V...) (Obj...)). Notice that this procedure treats the words in order of arrival and produces structural descriptions clause-by-clause, which, as we have seen, is psycholinguistically very attractive.

Attractive, too, is the capacity of this formalism to represent 'wrong tracks', such as in examples (b) and (c), and the difficulty of processing certain sentence types, such as the passive. If, for example, the sentence is *The little girl was treated expertly,* then the first part of the analysis process is not different from what we saw above, in particular, *the little girl* is registered as subject. Only at transition 2, condition V(Cat) is violated and another transition is tried. If *was* is accepted, the following operation is performed: move the content of the subject-register to the objectregister. This takes some extra time, of course. Thus, the greater complexity of the passive is accounted for. The priority of the alternative operations is indicated by arranging them clockwise. Furthermore, transition networks are easy to make probabilistic, so that the chance of blockings such as in (b) and (c) can be predicted.

It be noted here that, as far as its syntactic analysis system is concerned, Winograd's 'artificial language user' (1972) has been modeled after such augmented transition networks. Simmons and Slocum (1972) use these grammars as a language production model.

3.4.2. Sentence memory

Contrary to what was assumed in the sixties, sentences are not stored in memory in their syntactic form (cf. Flores d'Arcais, 1974). This is shown, among other things, by the high frequency of confusions between sentences which have similar meanings but differ as to syntactic structure. Examples are (a) vs. (b) (Johnson-Laird and Stevenson, 1970) and (c) vs. (d) (Fillenbaum, 1973):

(a) John liked the painting and bought it from the Duchess.
(b) The painting pleased John and the Duchess sold it to him.
(c) If you do that I'll hit you.
(d) Do that and I'll hit you.

Nevertheless, several effects of syntactic structure upon memory for sentences have been obtained and these need to be explained. A well-known example is the 'constituent boundary effect' expressing itself in a higher percentage of transition errors on the boundary *between* constituents than *within* constituents (Johnson, 1965) and in longer probe reaction times on these boundaries (Kennedy and Wilkes, 1968). Transition errors are measured during memorization and are defined as incorrect reproduction of word $n + 1$, given word n was correct. Measuring probe reaction times takes place after learning: the subject is presented with a single word (probe) from one of the sentences learned and he has to react as quickly as possible with a certain other word of the same sentence, for example, the following word, the preceding one, etc.

Several causes of the constituent boundary effect might be suggested without it being implied that the division of the sentence into constituents is maintained in the memory representation. One of them is a general grouping effect that also appears in the memorization of nonsense strings (cf. chapter 3); this is not a syntactic effect. That the subjects preferably have grouping coincide with syntactic constituents still needs to be explained. Here Kempen (1976; see also Levelt and Kempen, 1975) calls on 'syntactic retrieval plans' functioning during reproduction.

Suppose a subject has rote learned a list of sentences of the type

Quick horses won prizes. When he wants to reproduce one of these sentences, he first activates its semantic representation in long-term memory. The retrieval plan, then, might involve the following steps:

(1) look up information regarding the performer of the action;
(2) divide this information into one part describing the agent proper (N) and a second part containing a property of it (Adj);
(3) arrange these in the order Adj + N;
(4) look up information on the action performed;
(5) divide this into one part dealing with the action proper (V) and a second part for the object involved (N);
(6) arrange these in the order V + N.

An essential aspect of such retrieval plans is that larger syntactic units become available before their components. Kempen found direct evidence for this in a probe reaction time experiment where entire subject phrases were given as probes (e.g., *quick horses)* and the required reaction was the entire predicate phrase (e.g., *won prizes)* in one condition, or only the main verb *(won)* in the other. In the condition of whole predicates, the RTs (latencies until the beginning of the response) were almost 100 msec shorter than in the main verb condition. In the latter case, the subjects apparently used a retrieval plan which delivered 'too much' information, so that an extra processing step was required in order to cut the response down to the correct format.

However, this does not preclude the possibility that in the semantic memory representation of a sentence a division is present which corresponds to syntactic constituents. A study by Loosen (1972) showed that the strong constituent boundary effect, obtained by Levelt (1970) in the reproduction of sentences, which had been made difficult to understand by means of noise, maintained itself when the words were presented in random order. This is in agreement with the hypothesis that the constituent effect comes into being at retrieved time, as a result of reproduction factors. Experiments by Kempen (1976a) lend direct support to this position. Subjects learned a number of Dutch sentences which had been constructed according to a specific syntactic format, but had to partially reproduce them in a deviating syntactic format. For example, the content of *Those two Finns wrote texts* was partially reproduced as *Finns wrote* (with *Finns* serving as probe and *wrote* as response, or vice versa). Even though this transition is always relatively difficult if the subjects do not know which probe will be next (the constituent boundary effect of Kennedy and Wilkes), it became easy (in comparison with other transitions) in a partial reproduction task.

This did not hold, however, for the sequence *Finns-texts* during partial reproduction of the subordinate clause *because those two Finns 'texts wrote'* - the word-by-word translation of the Dutch equivalent. In this case, the constituent boundary effect does appear (the main constituent boundary is between *Finns* and *texts).* This, indeed, is what the theory of syntactic retrieval plans predicts. Since *Finns-texts* does not make up a syntactic construction - as opposed to *Finns-wrote* - there is no syntactic retrieval plan which retrieves from memory exactly this information: the name of the actor of an action, followed by the name of the object of that action (without anything else, e.g., the verb). Further experiments by Loosen (1972), too, show that the 'kernel assertion' of a sentence is remembered very well, whereas its syntactic format is readily forgotten. It is not before the reproduction stage that syntactic effects may come into existence.

3.5. Textual skills

In section 2.2 we gave a definition of the notion of presupposition and noted that presuppositions, precisely because they are not made explicit, play an important role in verbal communication. Grice (1967) speaks of a 'cooperative principle' in conversations, which comprises the following. At all times, the speaker supposes certain information to be available to the listener. This serves to the speaker as a basis for deciding what further information to add. This presupposed or 'given' information may have been supplied by the speaker himself during an earlier stage of the conversation. Thus, information which is new at a certain moment may be presupposed at a later stage. The listener, in turn, will also depart from this cooperative principle. If he wishes to understand a certain sentence occurring in a sample of continuous discourse he expects the presuppositions of the sentence to tally with the information available to him. He will then try to locate this information in his memory and add to it the assertion, that is, the new information. Clark and Haviland (1976) call this the 'given-new strategy'.

If the cooperative principle and the related listening strategy are indeed of general importance, then the comprehensibility of a text will depend on the extent to which this listening strategy can be successfully applied. Let us take the following example:

(a) The beer is warm.

Presupposition of this sentence is the presence of beer; assertion is that it is warm. Now, compare the next two texts:

(b) Mary gets some beer from the car. The beer is warm.
(c) Mary is fond of beer. The beer is warm.

In (b), the first sentence provides the information which is presupposed by the second one, namely, that there is beer. This does not hold for (c): Mary's fondness of beer does not guarantee its presence. If Clark's listening strategy is applied, text (b) must be easier to comprehend than text (c). Clark and Haviland (1974) did find a difference of approximately 140 msec in comprehension time for such pairs, in the expected direction.

Linguistic rules sometimes allow interchange of assertion and presupposition. Compare sentences (d) and (e):

(d) The dancer *who disregarded Sam* motioned to Jack.
(e) The dancer *who motioned to Jack* disregarded Sam.

In both cases, the relative clause contains the presupposition (in italics). This will typically be taken as the given information if the sentence appears in running text. Now, suppose the text begins as follows:

(f) *Michelle ignored Sam,* who was waiting at the bar. Turning her back, she began talking to a group of strangers. Sam was wild with jealousy.

If (f) preceeds (d), the information presupposed by (d) is easy to trace in (f): the italicized part of (f). This does not apply to the presupposition of (e). The sequence (f)-(d) will therefore be easier to comprehend than the sequence (f)-(e). Clark and Haviland (1976) indeed found a difference of more than 200 msec in comprehension time.

Due to various circumstances it sometimes happens that the presupposed information is, in fact, not present in the listener. He may have been intentionally misled by the speaker (see the experiments of Loftus and Zanni, 1973), or he may drop into the middle of a text (when turning on the radio, or, sometimes, when beginning to read a novel). It may be extremely difficult, then, not only to locate the presupposed information in memory, but to add new information as well. Bransford and Johnson (1973) demonstrated experimentally that, when the central theme is not brought out in the beginning of a passage, the comprehensibility of the text strongly decreases. See Ausubel (1960) and Dooling and Lachman (171) for similar results. The same principle was shown at work by Bransford and McCarrell (1974) in an experiment on sentence retention. They had their subjects memorize easy sentences (such as (g)) and hard ones (such as (h)).

(g) The office was cool because the windows were closed.
(h) The haystack was important because the cloth ripped.

When *the office* or *the haystack* were given as recall stimuli, sentence (g) was much easier to reproduce than sentence (h). When, in the learning as well as in the reproduction stage, the stimuli *air-conditioning* and *parachutist* were given the difference between (g) and (h) disappeared.

The view that locating the presupposed information is essential for the assimilation of new information, is less controversial than the problem of the format of the stored information. The latter issue brings us to the general problem of knowledge representations and, therefore, outside the scope of this chapter. As for the more specific issue of how text information is stored, models have been developed by text-grammarians (such as Van Dijk (1972) and Petöfi, see Petöfi and Rieser, 1973) as well as by psychologists (Dawes, 1966; Crothers, 1973). The latter models are special versions of conceptual networks. Formulated negatively, it appears from all experiments that the text as it is stored bears little similarity to the text as it is presented. According to Bransford and Franks (1971,1972) the text is coded in the form of an 'integrated semantic representation' of the objects, situations and events specified in the sentences. That is to say, the boundaries between the separate sentences disappear and the coded information often contains *more* than what is given in the text; in particular conclusions from it.

In one of their experiments, Bransford and Franks had their subjects study a series of sentences all dealing with one theme, for example, *the ants were in the kitchen, the jelly was on the table, the jelly was sweet, the ants ate the jelly.* These sentences were mixed up with sentences on other themes and joined together into longer sentences, for example, *the ants in the kitchen ate the sweet jelly.* In a recognition task, the subjects had to classify a number of sentences as 'old' or 'new'. Sentences were rated 'old' with greater certainty according as their meaning covered a greater part of the total theme, irrespective of whether or not they had actually been presented before. Barclay (1973) demonstrated that not only the actually presented sentences (e.g., *the lion is to the left of the bear, the giraffe is to the left of the lion)* were recognized as old, but also sentences which expressed logical inferences from the presented ones (e.g., *the giraffe is to the left of the bear).* Potts (1972) showed that such logical conclusions were sometimes 'remembered' better than the original information. This applied to sentences, embedded in continuous discourse, of the form *A is more intelligent than B* and *B is more intelligent than C.* Best scores received the question *"Is A more inteligent than C?'* Apparently, the information storage is such as to retain better the large difference between A and C.

In summary, text processing appears to continue the pattern we already found for syntactic processing: the literal information remains available for a short while only, probably no longer than a clause. During that period of time, the information is assimilated. This requires the presupposed knowledge to be located in memory, if not 'literally', then at least on the basis of rapid inference. Finally, the new information and, possibly, inferences from given and new information are added to the memory store.

3.6. Integrated models

Much research has been done on the integration of language behavior and general cognitive behavior. It is known as 'language and thought' (see, e.g., Carroll, 1964; Vigotsky, 1965) and 'language and perception' (see Berlin & Kay, 1969; Clark et al., 1973). However, it takes us out of the domain of strictly verbal input and output this chapter is confined to. We will only mention two types of integrated models which are so important to the psychology of language that their omission would be misleading.

Verification models

How do people verify whether a sentence is true or false with respect to a picture or another sentence? Independently of each other, Clark and Chase (1972) and Trabasso et al. (1971) have developed pertinent models which, in broad outlines, agree with each other. According to these models, verification proceeds in four stages: (1) representing the sentence, (2) representing the picture, (3) comparing the two representations, (4) generating the answer ('true' or 'false'). It is assumed that (1) and (2) produce propositional representations. If, for example, the picture shows an asterisk (A) with a plus (P) underneath, then the representation would be something like *A above P.* If the sentence is *The asterisk is below the plus,* the representation is *A below P.* The comparison process proceeds from left to right. Each time a mismatch occurs, the truth value, that initially is positive, is reversed. In the example, the only mismatch occurs at the pair *above/below* and, the end result being negative, the answer (stage 4) will be 'false'. The models predict reaction times for 'true' and 'false' answers and for affirmative and negative sentences. If one does not go too far away from the original experimental paradigm the predictions generally are confirmed. Besides, Clark (1969) made differential predictions for marked versus unmarked terms (see section 2.2 for definitions), specifically that marked terms require more reaction time. The effect of marking had already been demonstrated earlier for comparatives (Flores d'Arcais, 1970).

Winograd's artificial language user

Winograd (1972) wrote a computer program which had to engage in natural language (English) conversations with a robot, vis-a-vis a limited world of blocks and boxes which could be manipulated by the robot. Here follows a piece of conversation between experimenter (E) and robot (R).

E: Had you touched any pyramid before you put the green one on the little cube?
R: Yes, the green one.
E : When did you pick it up?
R: When I was stacking up the red cube, a large red block and a large green cube.
E: Why?
R: To get rid of it.
E: Why did you do that?
R: To clear off the red cube.
E: Why did you clear off that cube?

R: To put it on a large green cube.
E: Why did you do that?
R: Because you asked me to.

Winograd's program consists of subprograms for syntactic and semantic analysis, for conceptual inference, for planned performance of actions and, to a limited extent, for the generation of text (for a summary, see Levelt, 1974c). The development of such an integrated model has proved extraordinarily instructive since, again and again, gaps in linguistic and psycholinguistic theory were uncovered. Because, as a consequence, many ad hoc decisions had to be made, it is too early to evaluate such computer models in terms of their psychological plausibility, i.e., the extent to which they simulate pychological mechanisms. Nevertheless, the expectation is justified that model construction in the form of computer programs will give a strong impetus to psycholinguistic theory construction (cf. Kempen, 1976b).

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