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THE DEVELOPMENT OF LANGUAGE.

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THIS IS THE FIRST MAJOR SECTION OF A CHAPTER PREPARED FOR "THE MANUAL OF CHILD PSYCHOLOGY," P.H. MUSSEN, EDITOR, IN PREPARATION. IT IS AN INTRODUCTION TO TRANSFORMATIONAL GRAMMAR WRITTEN FOR PSYCHOLOGISTS AND PRESENTS SOME OF THE MAJOR IDEAS THAT HAVE BEEN DEVELOPED IN MODERN LINGUISTIC THEORY, ALONG WITH CERTAIN OF THEIR PSYCHOLOGICAL IMPLICATIONS. THE CHAPTER IS CONCERNED WITH TWO KINDS OF INTERACTIONS--(1) THE CONNECTION BETWEEN THE ACQUISITION OF LANGUAGE AND THE GROWTH OF INTELLECT, AND (2) THE CONNECTION BETWEEN BOTH OF THESE AND THE PROCESS OF MATURATION. THIS INTERACTION PROVIDES CONSIDERABLE INSIGHT INTO THE PROCESS WHEREBY A CHILD GROWS TO BECOME AN ADULT. WAYS OF THINKING ABOUT LANGUAGE (SAUSSURE'S "PAROLE" AND "LANGUE" AND CHOMSKY'S "PERFORMANCE" AND "COMPETENCE") ARE GENERALLY DEFINED AND FOLLOWED BY DISCUSSIONS OF FINITE-STATE GRAMMARS, RECURSIVENESS AND LINGUISTIC ABSTRACTION, AND PHRASE-STRUCTURE RULES. A REFERENCE LIST IS INCLUDED. THIS PAPER APPEARS IN "STUDIES IN LANGUAGE AND LANGUAGE BEHAVIOR, PROGRESS REPORT IV," PUBLISHED BY THE CENTER FOR RESEARCH ON LANGUAGE AND LANGUAGE BEHAVIOR, UNIVERSITY OF MICHIGAN, 220 EAST HURON STREET, ANN ARBOR, MICHIGAN 48108. (AMM)

The Development of Language

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This is the first major section of a chapter prepared for *The manual of child psychology*, P. H. Mussen (Ed.). It is an introduction to transformational grammar written for psychologists, and presents some of the major ideas that have been developed in modern linguistic theory, along with certain of their psychological implications.

Like the humors of the mind, the development of a child may conveniently be divided into four parts. One part is physical maturation; another is personality development, including the process of socialization; a third is intellectual development; and a fourth is language development. The division is artificial but useful, tolerated because of its advantages for orderly inquiry. However, it should not be allowed to obscure the fact that the four parts intertwine in complex ways to make up the process--absolutely unique in the animal kingdom--of human growth. Thus, it is clear that socialization depends on the acquisition of language. Yet, it is equally clear that language bears the marks of socialization, as the linguistic differences among social classes attest. The development of personality both acts on, and reacts to, the development of intellect, as evidenced by the cases where both fail, as in schizophrenia (Inhelder, in press). Indeed, although the interaction is rarely examined, the network of characteristics we call personality could not develop at all were it not for a child's capacity to represent his world in the particular way that forms the subject matter of cognitive psychology. Yet there are also differences in cognitive style, in the characteristic modes of thought that accompany particular types of personality (Kagan, et. al., 1963).

This chapter is concerned with two such interactions. One is the connection between the acquisition of language and the growth of intellect. The other is the connection between both of these and the process of maturation. The parts so intertwined may strike the reader as an arbitrary selection, and the proposed intertwining may at first seem bizarre. However, their selection is a rational one, and the interaction provides considerable insight into the process whereby a child grows to become an adult. But this is the substance of the chapter.

Preface

In order to understand the acquisition of language, it is essential first to understand something of what is acquired. We begin, therefore, with a linguistic introduction.

The second section follows directly from this. The phenomenon of language poses a challenge for psychologists. A grammar is a system of knowledge. It is everywhere complex and at many points abstract. Yet very young children acquire grammars and they do so in a surprisingly short period of time. For reasons to be discussed in this section, theories of learning based on S-R principles cannot account for this achievement. Explanations must follow other lines. One view is that the acquisition of language rests on definite cognitive capacities (the presence of which are reflected in language as linguistic universals). These capacities may be innate and may mature with time. The section concludes with a discussion of this alternative theory.

The third section, the largest of the chapter, begins the survey of language acquisition itself. It is organized under three major headings, one for each of the three main components of a grammar: phonology, syntax, and semantics. A description will be given of the methods typically used for studying the development of each component; then the emergence of the components themselves will be traced, insofar as this is known; and finally, there will be a discussion of the theoretical issues raised in the second section in the light of the empirical findings presented in the third. Wherever possible, mention will be made of children exposed to languages other than English, with the main contrast languages being Russian and Japanese.

The last section--actually a loose congeries of sections--takes up such topics as bilingualism, aphasia, language and thought, reading, and the language of culturally-deprived children, plus others.

<u>A caveat</u>. There has been no serious attempt to survey the literature on language acquisition in a comprehensive way. The chapter is organized on principles other than inclusion. For one thing, most of the references are recent, since 1954, when McCarthy's chapter on language development appeared in the second edition of *The manual of child psychology*. Her review should be consulted for the earlier work. For another thing, recent developments in linguistics pose issues for psychology that are crucial,

but, as yet, little appreciated, so examination of them takes priority over comprehensive citation. The criteria for including studies in this chapter, therefore, have been two: that they have not been covered by earlier editions of this *Manual*, and that they contribute in some way to the clarification, definition, or resolution of the theoretical questions raised by the process of linguistic development.

Linguistic Introduction

Take a sentence of a dozen words, and take twelve men and tell to each one word. Then stand the men in a row or jam them in a bunch, and let each think of his word as intently as he will; nowhere will there be a consciousness of the whole sentence (James, 1893, p. 199).

Thus did William James state one central linguistic problem. Consciousness of a whole sentence takes place in a single mind. It is something done with the separate words of a sentence, and this something could not be done under the conditions of James' proposed experiment. In this section, we review what is known of the process leading to the consciousness of sentences.

Propelled by the same revolution of thought that led to behaviorism in psychology, American linguists of the 1920's and 1930's were concerned to describe language in absolutely neutral terms. Descriptions were to reflect data. Linguistics was engaged in the discovery of the structure inherent in samples of speech. The aim was for completely objective, automatic, and rigorous procedures that would, when correctly applied, yield a correct portrayal of these structures. This would be the grammatical analysis, and it was not only to be correct, but also independent of extra-linguistic suppositions. Thus, Bloomfield (1933) wrote: "We have learned that we can pursue the study of language without reference to any psychological doctrine, and that to do so safeguards our results and makes them more significant to workers in related fields." Although one can question Bloomfield's actual independence from behaviorism, the general tenor of linguistic thought in the 1930's was that linguistics had no responsibilities in psychology. By the same token, psychology had little direct concern with linguistics. It is not surprising, therefore, that James' problem received little attention.

However, a different approach is possible, and, of late, has been under active development. In this alternative approach, linguistics aims to describe exactly what Bloomfield wanted to avoid--the specialized form of human knowledge that we bring to bear in the comprehension and production of sentences. Descriptions of knowledge have obvious import for psychology: whatever we know, we know by some psychological process. Under its new development, therefore, linguistics makes strong psychological assumptions, with the result that it occupies common ground with psychology. As we shall see, the direction of traffic through this common region has been almost entirely one way. Discoveries in linguistics pose the challenge; psychology is attempting to assimilate them. Perhaps, in the future, two-way traffic will become possible. If so, a full answer to James' problem will be at hand. We will understand the process that leads to a consciousness of a whole sentence. Until then, however, our discussion must be limited to describing the linguistic knowledge that is applied in this process, and it is to this better understood question that we now turn.

Linguists call the systematic characterizations of linguistic knowledge grammars. It is important to realize that these grammars are psychological theories. They strive to portray certain facts about the mind, i.e., they are supposed to be psychologically correct and they stand or fall accordingly (Katz, 1964). The psychological interest in such grammars is, therefore, straightforward. However, it is important--even crucial--to understand the limitations placed on this claim of psychological validity. A grammar relates to mental phenomena of a particular kind; it is not an all-purpose psychological theory. In particular, it is not a theory about behavior--the actual encoding and decoding of speech. This brings us to a fundamental distinction.

Competence and performance. A sharp distinction between competence and performance has been traditional in linguistics since Saussure's *Cours de linguistique générale* (1916), and was first drawn at least as early as the 18th century (Chomsky, 1966). One can think about language in either of two ways. There are, first of all, actual acts of speaking and hearing, taking place in time, subject to various distractions, limited by memory and by the general weakness of human flesh. These were called actes de parole by Saussure and performance by Chomsky (1957). Performance is linguistic behavior, either encoding or decoding speech. A theory of performance would clearly be a psychological theory, a fact that presumably needs no defense. At the present time, there are no theories of linguistic performance. Indeed, there is only the most fragmentary knowledge of the relevant parameters of such a theory, although the problem is one that now inspires considerable interest. A number of recent experimental studies can be regarded as bearing on it (e.g., Miller, 1962; Miller & Isard, 1963, 1964; Mehler, 1963; Slobin, 1966; McMahon, 1963; Gough, 1965; Savin and Perchonock, 1965).

The second aspect of language is the knowledge of syntax, meaning, and sound that makes performance possible. Saussure called such knowledge *langue*, and Chomsky has called it *competence*. A theory of competence is also a psychological theory, although of a type not usually considered by contemporary psychologists. Piaget, perhaps, comes closest in his aim to characterize the structure of logical thought. Because a grammar is concerned with knowledge, not behavior, factors (such as memory limitations, time restrictions, etc.) that are important to performance can be disregarded when thinking about competence. Competence is an idealization, an abstraction away from performance (Chomsky, 1965). Theories of performance and competence, therefore, deal with different topics. A grammar is not a recipe for producing sentences. That recipe is given by a theory of performance. Indeed, the problem for a theory of performance is to explain just how the information represented by grammar is realized in actual acts of speaking and hearing (Miller, 1962). The linguist's solution will not answer the psychologist's problem.

Perhaps the distinction between competence and performance, and the way in which they are related will become clearer if we consider an artificial example. In Table 1 are several strings of letters.[1] In each string there is an *a* or a *b* or both. Some of the strings have been circled. These we shall call "sentences" , by which is meant that they have a certain structure in common not shared by the other strings, the "non-sentences". Table 1

Insert Table 1 about here

is a skeletonized version of the set of all possible strings -- all possible combinations of the letters *a* and *b*--and thus is analogous to the output of that hypothetical set of one million monkeys set before one million dictionaries, who, in their random pointing, work out the plays of Shakespeare and next week's shopping list, along with every other combination of English words.

Our problem is to discover the structure that makes a string a "sentence" in Table 1. This can be done by the reader if he carefully examines the "sentences" and "non-sentences" listed in the table--the problem is not a difficult one. The reader can then test his discovery by judging the status of new examples. Try, for instance, aaaaabbbb, aaaaabbbbb, aaaab, bbbbaaaa, aaaabbbb. The second and the last of these are "sentences", the rest are not.

Knowledge of the principle that determines which strings are "sentences" and which are not is competence. It is not performance. Understanding the principle does not automatically lead to a correct judgment. It would not, e.g., in the case of a string that contained 10,000 a's followed by 10,001 b's. One must count the a's and b's and judge the result against the principle. Conversely, counting without knowledge of the principle will not tell one that aabb is a "sentence". Counting is performance, whereas knowledge of the principle that adjudicates the result of counting is competence. A grammar is concerned with the latter only. Some further theory is needed to explain how the principle is applied to the result of counting; this would be a theory of performance. There is, of course, competence in the counting, but that is a different domain (Klima, 1966).

The status of a grammar is the same as for any other scientific theory. It is an empirical hypothesis that deals with a mental phenomenon. Because it is an empirical hypothesis, a grammar is either true or false, and observations are made to discover its adequacy in this respect. Because it is a hypothesis about a mental phenomenon, the relevant observations have to do with knowledge of language. The possibility of describing a branch of human knowledge in an explicit way is surely one of the most exciting aspects of contemporary linguistics.

Let us now continue the example of Table 1 and consider several hypotheses that might account for the reader's understanding of the structures represented there.

Finite-state grammars. One method of representing structure, and, hence, competence, is to construct a state diagram. Such a diagram can be thought of as portraying a machine that can be in any of several states. The machine is so restricted that when it is in one state, it can move to other states only over specified legal routes. The resulting network of states and transitions will then embody a structure. Can such a machine, however construed, talk correctly? In particular, can it produce the "sentences" in Table 1? To make the machine talk at all, we must provide it with a means of recording its progress as it moves from state to state. We can do this by having the machine utter the name of the state it has just left. Since, in Table 1, the machine must produce strings of _a_'s and _b_'s, all the states will be labeled _a_ or _b_, and nothing else.

There is one further requirement to place on our machine. We want it to be superior to a mere list. One could, if patient enough, prepare a list of all the "sentences" made up from _a_ and _b_--writing down _ab_, _aabb_, _aaabbb_, etc. The difficulty with this list is that it would be endless, because there is no longest sequence of _a_'s and _b_'s. Thus, to be an advance over a list, our machine must be finite, although it may be large. It must have a finite number of states connected by a finite number of transitions, and yet be capable of producing an infinite number of correct sequences of _a_ and _b_. Such a machine, if successful, would provide the _grammar_ of the "sentences" in Table 1. Let us now try to construct a grammar along these lines.

The top diagram of Fig. 1 shows a machine of three states and three

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Insert Figure 1 about here
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transitions, which is able to produce the "sentence" _ab_.. It cannot, however, produce "sentences" longer than this. Running the machine twice yields a repetition, not a new "sentence", since we obtain _ab.ab_.. In order to produce the next longer "sentence" we must add two new states and three new transitions, as in the second diagram of Fig. 1. This new machine produces _aabb_. as well as _ab_.. However, it produces nothing else, and to enrich it we must add two more states and three more transitions, as in the third diagram. However, this machine is likewise restricted--its longest "sentence" is _aaabbb_.. In short, for each additional length of sentence, we must add further states and transitions. Since the list of "sentences" consistent with Table 1 is endless, the number of states and transitions we must add is endless also. The machine thus fails the last requirement stated above. It is not superior to a mere list which means that different kinds of grammars are needed.

Before considering these different grammars, however, it should be noted that the "sentences" in Table 1 and the grammars in Fig. 1 are not simply empty exercises. On the contrary, they are directly relevant to the concerns of this chapter. English has sentences of the kind listed in Table 1, and much psychological theorizing accounts for structures of the kind diagramed in Fig. 1. The fact that Fig. 1 cannot represent the "sentences" in Table 1, therefore, means that much psychological theorizing cannot account for significant portions of the structure of English. Let us take up the matter of structure first.

The "sentences" in Table 1 are built like an onion. The shortest is _ab_. The next longer "sentence" consists of another _ab_ sealed inside the first _ab_, and the next longer one yet results from surrounding _aabb_ with still another _ab_, and so on. If we use parentheses to indicate how the _a_'s and _b_'s are paired, a "sentence" of length six would be written as _(a(a(ab)b)b)_. Such structures are called _embeddings_, and, if not too long, are commonplace in English. (_The race (that the car (that the people sold) won) was held last summer_) stretches the bounds of credulity but it is a perfectly grammatical sentence (Miller, 1962).

Now let us take up psychological theory. The way to construct a finite-state device clearly is to link states by transitions. If the device is also to be a model of a learner, then it must be exposed to each transition link in the chain in such a manner that states will be connected by transitions that move in the correct directions. In the case of the first diagram in Fig. 1, the device must have been exposed first to an _a_, then to a _b_, and finally to a period. This requirement is inescapable. So long as the structure to be acquired can be presented in this steplike way, a finite-state device will faithfully reproduce it. All other structures, however, lie beyond its grasp.

This limitation--faithful reproduction of transitions but nothing else--is shared by every stimulus-response theory of learning, from the simple (Skinner's) to the complex (Osgood's). It is inherent in the basic S-R paradigm. Learning occurs when one presents an appropriate stimulus together with the correct response and stamps in a connection between the two through (depending on the theory) reinforcement, repetition, drive reduction, etc. All S-R theories are variations on this basic theme, and they all lead to the development of a finite-state device. This, therefore, is the relevance of Table 1. The "sentences" there could not be learned through _any_ process consistent with S-R theory. The reader who understands the principle of producing these "sentences" is himself a refutation of all consistent S-R models.

This critique might be answered by observing that there is no proof that our knowledge of the "sentences" in Table 1 is anything other than what the diagrams in Fig. 1 claim. The requirement of infinite productivity might be psychologically meaningless, and perhaps, a S-R analysis expresses the processes that actually take place.

There are, however, at least three things wrong with this defense. One is simply that it fails to explain how S-R theories are logically superior to the compilation of lists in the case of embedded materials. Even the most harassed housewife does not have a mind entirely awash with unstructured lists.

A second difficulty is that the diagrams in Fig. 1 cannot account for correct judgments about "sentences" never before encountered. If a novel "sentence" goes beyond the current degree of complication of a finite-state device, then it must be rejected as a "non-sentence", unless there is further training. This is the point of the test the reader was asked to take. If the reader had discovered the principle underlying the"sentences" in Table 1, he could correctly judge the sentencehood of novel strings without additional instruction. And if the reader could do this, then what he had learned could not be represented by a finite-state device.

The third difficulty is the opposite side of the coin. If we assume that a speaker's knowledge of English _can_ be represented by a finite-state device, then we are forced to make quite incredible claims about the learning ability of children. Take the following sentence: _The people who called and wanted to rent your house when you go away next year are from California_ (Miller and Chomsky, 1963). It contains a grammatical connection between the second word (_people_) and the seventeenth word (_are_): changing either one of these words to the corresponding singular form would produce an ungrammatical sentence. If the connection between _people_ and _are_ is carried by a finite-state device in our heads, then each of us must have learned a unique set of transitions spanning 15 grammatical categories. Making the conservative estimate that an average of four grammatical categories might occur at any point in the development of an English sentence, detecting the connection between people and are signifies that we have learned at least $4^{15} = 10^{9}$ different transitions. This is, however, a *reductio ad absurdum*. As Miller and Chomsky point out, "We cannot seriously propose that a child learns the values of 10^{9} parameters in a childhood lasting only 10^{8} seconds" (p.430). And even a highly efficient child, one who somehow could learn 10 transitions a second, would still miss the dependency when people and are are separated by 16 words or more.

These three difficulties add up to a single flaw. There is no way for a finite-state device to express the idea of recursion--the insertion of one component inside another component. However, recursion is a psychological fact. It is what the reader grasped in Table 1. It is behind the comprehension of sentences such as the race that the car that the people sold won was held last summer, as well as the people who called and wanted to rent your house when you go away next year are from California. What is needed, therefore, is a hypothesis about this mental ability. One is introduced in the next section.

Recursiveness and linguistic abstraction. Finite-state devices, in general, and S-R models, in particular, can copy only those structures that consist of states and transitions among them. These models will misrepresent anything that possesses some other structure. That was the difficulty with the representation of the "sentences" in Table 1 by means of the state diagrams in Fig. 1. If the reader understands the principle underlying these "sentences", he can tell that the part missing from aab is a second b to go with the first a. Similarly, he can tell that the sentence the car that the people sold was held last summer is peculiar because there is an incorrect verb for the noun-phrase, the car. In both cases, part of what is known about the structure of the sentence is that elements separated from each other actually belong together and not with the material that separates them. What they jointly belong to is an important fact about the sentence, and a correct linguistic representation must somehow portray it. It is on this hidden structural feature that a finite-state device founders.

Consider now the following two grammatical rules. Together, they will produce all and only the "sentences" consistent with Table 1.

$$X \longrightarrow aXb$$
$$X \longrightarrow ab$$

The arrow ($\longrightarrow$) means that the element on the left is rewritten as, or becomes, the elements on the right. By employing a further notational convention--that parentheses in a rule indicate optionality--the possibility of choosing or not choosing an element--the two rules above can be collapsed into one, as follows:

$$X \longrightarrow a(X)b$$

One may apply the expanded version of this rule (with the _X_) indefinitely. Each application lays down an _a_ and a _b_ with another _X_ in between. The new _X_ calls for application of the rule again, literally _ad infinitum_. This is recursion. The development of a "sentence" comes to an end when the option of not including _X_ is taken. Figure 2 shows the successive steps

Insert Figure 2 about here

taken in producing a "sentence" of length six, _aaabbb_.

The constituent in these "sentences" labeled _X_ is the part to which each _ab_ pair belongs, even though they are separated by other _ab_ pairs. The existence of _X_ is essential to the recursiveness of the rule, since its presence on the right is the only feature that requires another application of the rule.

However, note one important thing. The constituent _X_ is _abstract_. It never appears in the final form of a sentence, only in its derivation: _aXb_ is not a "sentence" in Table 1, just as the equivalent in English, _the people Sentence are from California,_ is not a sentence (c.f. pp. 34-37). Nonetheless, an abstract constituent is part of the structure of these sentences. It is such an abstraction that the reader gleaned from Table 1 and it is such an abstraction that he discovers in the sentence, _the people who called and wanted to rent your house when you go away next year are from California_. On this hypothesis, therefore, speakers can grasp aspects of sentence structure that are never included in the overt form of a sentence. We shall return to the question of linguistic abstractions repeatedly, since it poses a most challenging problem for psychologists. Somehow, linguistic abstractions are developed by children--just as the reader learned about _X_ in Table 1, children learn about structural features in English that are likewise never presented to them.

Phrase-structure rules. A grammar, we have said, represents linguistic knowledge. A grammatical rule, accordingly, represents a bit of linguistic knowledge. In the case of a rewriting rule such as X ⟶ a(X)b, the knowledge represented is that a(X)b is a species of the genus X. The rule itself is simply a means of expressing this idea.

Many aspects of language take such a form. The frog caught a mosquito, for example, is a sentence. The frog and the mosquito, in turn, are both noun phrases, and caught the mosquito is a verb phrase. Knowledge of these elementary facts can be naturally represented by means of rewriting rules; Table 2 shows how it is done for the frog caught the mosquito. Note that

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Insert Table 2 about here

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each of the examples given above, where one constituent is an instance of something else, is represented in the Table by a separate rule. The derivation makes the genus-species relation, as it applies to the sentence, explicit.

It is easy to show that the relations established by the rules in Table 2 correspond to facts that speakers of English know about the frog caught the mosquito. First of all, if a speaker is asked to divide the sentence into two major parts, the split will most likely be made between the frog and caught the mosquito, that is, between the NP and PredP of the first rule. If he is now asked to divide caught the mosquito into two parts, the line will come between caught and the mosquito, that is, between the V and NP of the second rule. It is very unlikely that a speaker would divide the frog caught the mosquito into the and frog caught the mosquito, or divide caught the mosquito into caught the and mosquito. Speakers honor the rules because the rules reflect information speakers have about the sentence. This correspondence can be revealed in a second way.

Suppose that we take the frog caught the mosquito and try to derive from it another sentence in the following manner (Miller, 1962). We try to find a single word that can replace a group of words in the original sentence without changing the grammatical structure. Our interest lies in seeing which groups of words can be so replaced. Replacements exist only for the constituents of the sentence--English has no words that belong to no constituents. A series of these derivations is shown in Table 3, and it can be seen that the replacements obtained in this manner

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Insert Table 3 about here

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correspond exactly to the derivation obtained through application of the rules in Table 2. We have here hard-core evidence for the validity of the rules in Table 2.

The structures portrayed in Tables 2 and 3 are a part of the phrase structure of English. Accordingly, the rules in Table 2 that produce this structure are called phrase-structure rules, and the diagram in the table is called a phrase marker. The function of the rules is to define which constituents of sentences are superordinate to which other constituents, to establish the order of constituents, to display the grammatical elements of the sentence (e.g., NP), and to define (in a way that will be explained later) the so-called basic grammatical relations--subject of a sentence, object of a verb, etc. The phrase marker is the structure produced through application of the rules. It can be presented as a diagram, as in Table 2, or by means of labeled brackets.

$$({}_{S}({}_{NP}({}_{Art}\text{the})({}_{N}\text{frog}))({}_{VP}({}_{V}\text{caught})({}_{NP}({}_{Art}\text{the})({}_{N}\text{mosquito}))))$$

includes exactly the same information as Table 2, and both represent the structure that speakers of English find in the frog caught the mosquito.

Note that grammatical rules represent linguistic structure. They describe tacit knowledge, not explicit knowledge. No one claims that the rules given in Table 2 are known to speakers of English as rules. If that were actually the case, linguistics could not exist--the field would be as pointless as would a "science" setting out to discover the rules of baseball. The distinction is perhaps obvious, but its importance justifies some elaboration.

One can imagine a continuum of interpretations of the rules in Table 2. At the weak end of the continuum phrase-structure rules might be regarded as summarizing regularities in behavior. In this case, S → NP PredP means that when English sentences occur, they consist of noun phrases followed by predicate phrases. There is no interest in representing linguistic knowledge under this interpretation, but, instead, in describing linguistic performance. The relevant observations are the frequency of sentences following the NP PredP format, of PredP's following the V NP format, and so forth, and there is no doubt that such observations would falsify the weak interpretation of Table 2. Sentences like the frog caught the mosquito are simply not common.

At the opposite extreme, the strong end of the continuum, the claim is that English speakers know the rules in Table 2 in much the form that the rules take when written. Clearly, this claim is false for the vast majority of English speakers.

The mid-point on this continuum of interpretations is the one intended for Table 2. English speakers do not know the rules in Table 2. But what they do know (it is claimed) is represented by these rules. Observations relevant to the intermediate interpretation have to do with a speaker's intuitions--for instance, that the mosquito is a grammatical constituent in English, whereas caught the is not. As we have already seen, such observations support this intermediate claim.

Phrase-structure rules, interpreted in the intermediate sense, are said to generate sentence structures. A term like "generate" tempts us to think that speakers actually plan sentences along the lines outlined in Table 2--they first decide to utter a sentence, then decide that the sentence will consist of a NP and a PredP in that order, then decide that PredP will consist of a V and a NP, and then, only at the end, decide what vocabulary to use. Such a scheme is one possible, though improbable, hypothesis about linguistic performance (Yngve, 1960, 1961; Johnson, in press). However, the theory of performance is not part of the grammatical analysis in Table 2. A grammar is quite neutral with respect to hypotheses about performance. The term generate is used by grammarians in a logical, not a mechanical, sense. As the linguist Lees once put it, a correct grammar generates all possible sentences of a language in the same way that a correct zoology generates all possible animals. Both capture the structural relations within their subject matter. The term generate will be used throughout the remainder of this chapter in its logical, non-mechanical, sense.

The linguistic observations made so far serve a fairly obvious purpose. Presumably, the parsing of the frog caught the mosquito given in Table 2 does not require elaborate defense. The facts are straightforward, and the principal merit in discussing them at all is that they acquaint the reader with some linguistic notation at a point where it is reasonably easy to see what the notation means. However, there are more profound, and psychologically more significant, insights entailed by three other linguistic concepts; and it is to these concepts that we now turn.

Transformations and the notions of deep and surface structure. In a general way, language can be described as the system whereby sound and meaning are related to each other. That sound and meaning are separate, and so need relating, is evident from paraphrase, where the same meaning is expressed in different patterns of sound (the man pursued the woman and the woman was pursued by the man), and from ambiguity, where the same pattern of sound has different meanings (outgoing tuna). Between sound and meaning stands syntax. The relation between sound and meaning is, therefore, understood to the degree that the syntax of a language is understood. In this section we shall examine what is known of this relation. After that, we shall take up the more obscure matters of what syntax relates, and consider, first, the semantic component, and, then, the phonological component of language.

Rationalist philosophers have argued since the 17th century that sentences have both an inner and an outer aspect--the first connected with thought and the second with sound (Chomsky, 1966). The kind of evidence that leads to this conclusion, and hence to the phenomenon of concern here, is given in Table 4 (after Miller & McNeill, in press). The three sentences on the left

Insert Table 4 about here

of Table 4 all have the same superficial form. They all start with a pronoun, they, followed by are, followed by a progressive form, followed by a plural noun. Despite the superficial identity, however, there are clear differences in structure among these three sentences. To understand the differences, we will eventually need the notions of a transformation rule and of deep and surface structure.

Sentence (a) differs from sentences (b) and (c) in several fairly obvious ways. One difference is that the two kinds of sentences accept pauses in different places. With sentence (a), one might say they - are buying - glasses, but probably not they - are - buying glasses. It is the opposite with sentences (b) and (c). One could say they - are - drinking companions or they - are - drinking glasses, but not they - are drinking - companions or they - are drinking - glasses, unless the reference was to cannibalism or suicide. A second difference is in the proper location of articles. We have they are buying the glasses but not they are the buying glasses. We have they are the drinking companions but not they are drinking the companions.

The location of pauses in a sentence is fixed by its phrase structure. Pauses tend to go around constituents, not inside them. The location of articles is likewise determined by phrase structure. They go before NPs only. We can thus summarize the differences between sentence (a) and sentences (b) and (c) by saying that they have different phrase structures. In particular, the progressive form in sentence (a) is associated with the verb <u>are</u>, whereas in sentences (b) and (c), it has moved over to the plural noun. The essential parts of the three phrase markers are as follows: (<u>they</u>) (<u>are buying</u>) (<u>glasses</u>), (<u>they</u>) (<u>are</u>) (<u>drinking glasses</u>), and (<u>they</u>) (<u>are</u>) (<u>drinking companions</u>).

Sentence (a) and sentences (b) and (c) are distinguished in their <u>surface structure</u>. The difference, as we have seen, has to do with the distribution of pauses and the location of articles. As we shall see later, surface structure is also intimately connected with stress and intonation. In general, the surface structure of a sentence has to do with phonology--with one of the two aspects of language that need to be related by syntax.

Let us now look more carefully at sentences (b) and (c). They accept pauses in the same way, they take articles at the same places, they are accordingly bracketed in the same way, and, indeed, they have the same surface structure. But it is clear that they are not structurally identical throughout. They differ in a way that is important to meaning, the other aspect of language that is to be related by syntax. That they differ in meaning can be seen in the paraphrases and non-paraphrases of the two sentences in Table 4. Sentence (b) means "they are glasses to use for drinking", and sentence (c) means "they are companions that drink." Exchanging the form of the paraphrase between (b) and (c) leads to a non-paraphrase. Sentence (b) does not mean "they are glasses that drink" any more than sentence (c) means "they are companions to use for drinking." Despite the identity of surface form, (b) and (c) differ importantly in underlying form. We shall say that they differ in <u>deep structure</u>, saving until later a more precise definition of what this means. First, however, let us note two implications that follow from the fact that (b) and (c) have the same surface structure but different deep structures.

One is that the <u>relation</u> between deep and surface structure must be different in the two sentences. The statement of this relation is assigned a special place in a grammar. It is done by rules of transformation, and it is these rules, together with the deep and surface structure of sentences, that embody the connection between sound and meaning in a language. The reader will have realized, of course, that in the statistical sense, sentences (b) and (c) are freakish. The vast majority of sentences that have different deep structures and different transformations also have different surface structures. Sentences (b) and (c) happen not to, but for this very reason, conveniently illustrate what is true of all sentences. Every sentence, however simple, has some kind of deep structure related to some kind of surface structure by means of certain transformations. The substance of grammar consists of making explicit these three terms.

The second implication of the difference in paraphrase between sentences (b) and (c) is that the deep and surface structures of sentences are not identical. This is evidently true of at least one of these sentences, (b) or (c). In fact, it is true of all sentences. Transformations provide enormous flexibility in developing surface structures from deep structures, and this advantage has been pressed in even the most elementary sentence types (an example with simple declaratives is given below). Thus, the deep structure of every sentence is abstract in the sense given above. The underlying structure, the part connected with meaning, is not present in the overt form of any sentence. The acquisition of linguistic abstractions is a universal phenomenon--it is a basic fact about the development of language and on its success rests the emergence of all adult grammar. It would be impossible to understand sentences (b) and (c) correctly if this were not so.

All these concepts--deep structure, surface structure, linguistic abstraction, and the way transformations tie them together--can best be seen in an example. The one we shall use is borrowed from Miller and McNeill (in press), and is based on Chomsky (1957). Consider the following sentences:

He walks (present singular)
They walk (present plural)
He walked (past singular)
They walked (past plural)

These four sentences mark two distinctions: number (singular and plural), and tense (present and past). Number is marked both in the form of the pronoun and in the inflection of the present-tense verb. Tense is marked in the inflection of the verb. Let us focus on the verbs, for it is here that a transformation becomes involved.

There are three verb suffixes-- *-s*, *-ø* (which means null, but is a suffix all the same), and *-ed*. They encode information of a certain type, viz., the form of the verbal auxiliary, so we might suppose that this information can be expressed by a re-writing rule of kind already discussed. If we label the genus part of the rule *C*, then we can use the following context-sensitive rule:

$$\underline{C} \rightarrow \begin{cases} \underline{\text{-s}} \text{ in the context } \underline{NP}_{sing} \\ \underline{\text{-ø}} \text{ in the context } NP_{pl} \\ \underline{\text{-ed}} \end{cases}$$

and summarize all four of the sentences above by a single schema, *NP + V-C.*

Let us now complicate the sentences slightly by incorporating an auxiliary verb, *be*, and see what happens to *C*.

He is walking

They are walking

He was walking

They were walking

The first thing to note is that using a form of *be* adds *-ing* to the following main verb. *C*, for its part, has moved forward. It is no longer attached to the main verb but to the auxiliary, and we have *be-s* (pronounced *is*), *be-ø* (pronounced *are*), and *be-ed* (pronounced *was* or *were*, number being marked on past-tense verbs in this case--a detail we can ignore). The schema for these sentences therefore is, *NP + be-C + V-ing*.

Next consider the effect of adding a different auxiliary verb, a form of *have*, to the original sentences. Doing so, we obtain:

He has walked

They have walked

He had walked

They had walked

The main verb again takes a suffix, this time, *-ed*, and *C* again moves forward to the auxiliary. It is the same, therefore, as when *be* is the auxiliary, except that different pronunciation rules are involved (*have-s* is *has*, *have-ø* is *have*, *have-ed* is *had*) and the main-verb suffix is *-ed*, instead of -ing. Indicating these changes, we obtain the schema, NP + have-C + V-ed, for the use of have as an auxiliary.

The two auxiliaries can be combined, of course, as in these sentences:

He has been walking

They have been walking

He had been walking

They had been walking

Both auxiliaries have the effects already demonstrated. Be adds the suffix -ing to the following verb and have adds a "past" suffix to be. (In this case, it is be-en, another difference in detail that we can ignore.) C also follows its pattern, for it is still attached to the first auxiliary verb. The schema therefore is NP + have-C + be-en + V-ing.

These sentences can be complicated still further by adding one of the modal auxiliaries. Modals are the words, will, can, may, shall, must. Let us add will:

He will have been walking

They will have been walking

He would have been walking

They would have been walking

C has moved forward again, attached now to the modal. Have still adds a "past" inflection to the following be, and be still adds -ing to the following main verb. The schema thus is NP + M-C + have + be-en + V-ing, where M stands for "modal".

It is evident from these examples that C always appears with the first member of an auxiliary construction, no matter how long this construction is. The location of C is a fact known to all speakers of English--he will had been walking obviously is not the way to indicate past tense in an auxiliary construction. Part of an English speaker's competence thus has C at the start of a verb phrase. Another part involves the contingency between have as an auxiliary and a following "past" inflection, as well as the contingency between be as an auxiliary and the following -ing. Let us try to represent these facts about competence by constructing a rule that meets the following two conditions: (1) the true order of elements is maintained, and (2) elements contingent on one another are placed together. Doing so will lead to a simple solution.

Meeting the first condition requires placing C first, then M, then have, and finally be. Since C appears in every sentence, our rule must make it obligatory. The remaining constituents, however, are optional, so we write them with parentheses. Let us call the whole construction "Auxiliary", abbreviate it "Aux", and put down the following rule:

Aux ⟶ C (M) (have) (be)

The following main verb (V) is omitted from this rule because it is introduced along with Aux by the PredP rule, which is now enlarged to read:

PredP ⟶ Aux V (NP)

The Aux rule is still incomplete, since it does not yet meet the second condition. The contingencies to be represented are that have goes with -en (or -ed), and be goes with -ing, so we write these elements together, and thereby produce the following:

Aux ⟶ C (M) (have-en) (be-ing)

after which there will always be a V.

We now have all but one of the rules necessary to generate the examples given above. The missing one, a transformation, will be provided shortly. However, in order to see the need for the transformation, and to appreciate the role it plays in representing the structure of these sentences, we should first see the result of producing sentences without it. The structural relations to be expressed by the transformation will be those not expressed by the rules already developed. If we have done our job well, the division between the two kinds of rules, the transformation and the phrase-structure rules, will correspond to a real division between two kinds of structural information within sentences.

Figure 3 contains a phrase marker generated by the phrase-structure rules presented in the preceding paragraphs. Note that the order of elements

Insert Figure 3 about here

at the bottom of the phrase marker is they + Past + will + have + en + be + ing + walk. This string and its associated structure is the deep structure of they would have been walking. The surface structure is a specific instance of the last schema given above--they + will-Past + have + be-en + walk-ing. The deep structure thus differs from the surface structure in the order of suffixes and verbs. Accordingly, it is abstract in the sense used here, since the deep-structure order never appears overtly. It is important to realize, nonetheless, that the deep structure in Fig. 3 reflects actual linguistic knowledge--the information summarized by C is always first in a predicate phrase, have and -en do always appear together, just as be and -ing do.

The deep structure must, therefore, be transformed in order to obtain the surface structure. The transformation is simple: wherever the sequence suffix-verb appears in the deep structure, change the order to verb-suffix (Chomsky, 1957). If the reader applies this transformation, he will find the surface structure of they would have been walking rolling out quite automatically.

There remains one important point. Note that the linguistic information expressed by the phrase-structure rules in generating they would have been walking is fundamentally different from the information expressed by the transformation rule. Which is to say that the distinction between the two is linguistically meaningful. The former rules define such matters as the genus-species relations within the sentence (e.g., they is an NP), establish the basic order of elements (e.g., C is first in the PredP), and indicate what the elements are (e.g., have-en is an element). Information of this kind is essential for obtaining the meaning of the sentence. The relations just mentioned, among others, are exactly what we understand of they would have been walking.

The transformation, in contrast, makes no contribution to meaning. It exists only because sound and meaning are not identical in English (or any language), and its sole purpose is to state the relation between them. The distinction between phrase-structure and transformation rules is thus fundamental to the analysis of language. Without it, the insight that sound and meaning are separate in language would be lost; and to suggest, as some have done (e.g., Braine, 1965), that transformations are methodologically unsound because they lead to arbitrary linguistic solutions, is to miss the entire point of transformational grammar.

The distinction between sound and meaning is a basic justification of transformational grammar, but the use of transformations in grammatical analysis is supported by other arguments as well. One is economy. If we dispense with transformations and try to generate sentences with phrase-structure rules alone, the result becomes unnecessarily complex. The sentences given above, for example, require eight different and independent phrase-structure rules, one for each combination of auxiliary verb and C, instead of the single phrase-structure rule required when a transformation is allowed. Without the transformation, we would need at least the following rules: $Aux_1 \rightarrow$ V-C, $Aux_2 \rightarrow$ be-C + V-ing, $Aux_3 \rightarrow$ have-C + V-ed, $Aux_4 \rightarrow$ have-C + be-en + V-ing, $Aux_5 \rightarrow$ M-C + V, $Aux_6 \rightarrow$ M-C + be + V-ing, $Aux_7 \rightarrow$ M-C + have + V-ed, and $Aux_8 \rightarrow$ M-C + have + be-en + V-ing. Note that these rules cannot be collapsed onto one another by means of the parentheses notation used before. The phrase-structure version of the auxiliary, therefore, not only overlooks valid linguistic generalizations--such as the fact that C always appears first in the auxiliary, or that there is an auxiliary, or that -ing depends on be and not on V--but it is simply cumbersome. Relative economy is always an argument in support of one theoretical interpretation over another, and using it in the present case inclines the balance toward a transformational grammar.

The argument of economy has special significance in the context of language acquisition. We prefer to think of children doing the simpler thing, whatever that might be. In the case of linguistic development, the simpler thing is to acquire a transformational grammar instead of a phrase-structure grammar. Accordingly, it is the former that we suppose is learned.

The suffix-transformation used in generating the English auxiliary verb is one rule within a vast and intricate network of transformations making up the language. Passive sentences, negation, questions of various kinds, conjunctions, the apposition of nouns and adjectives, and many others, all depend on transformations. The technical literature dealing with these rules is large and sophisticated; rather than summarizing it here, a task almost as unnecessary as it is hopeless, the interested reader is encouraged to turn to original sources. A volume edited by Fodor and Katz (1964) contains a number of significant papers. In addition, one should look at Chomsky (1957, 1963, 1964, 1965, 1966), Chomsky and Miller (1963), Chomsky and Halle (1966), Fillmore (1965), Katz (1966), Katz and Postal (1964), Miller and Chomsky (1963), and Postal (1964). A review of transformational grammar written for psychologists is contained in Miller and McNeill (in press).

There is one set of transformations of special significance, however, and this section will conclude with a discussion of them. Recall the artificial language presented in Table 1. Its "sentences" were built like an onion--such structures as (a(a(ab)b)b). The rule given to generate the "sentences" in Table 1 was X ——► a(X)b, in which there is an abstract recursive element, X. This much is phrase structure and it has an exact analogy in English (and all other languages).

In developing the deep structure of any sentence, it is possible to include the element S, thus calling for the insertion of another deep structure at that point. That sentence, in turn, may also have an S in it, calling for the insertion of yet another deep structure, and so forth. The result is the same onion-like structure presented in Table 1, and it has the same effect--making infinite productivity possible through recursion. Figure 4 shows a succession of such deep structures, each with another deep

Insert Figure 4 about here

structure embedded within it.

Figure 4 is the result of applying phrase-structure rules alone. It is, in other words, the deep structure of (the ostrich (that was terrified by the zebra (that the hunter shot))stuck its head in the sand), a sentence with two relative clauses. English employs several transformations to develop this surface structure from the deep structure in Fig. 4. In discussing them, we shall use terminology suggested by Lees (1960), and call the structure containing S the matrix and the S contained the constituent. Thus, D3 in Fig. 4 is the constituent of the matrix D2, and both are the constituent of the matrix D1. In Fig. 4, D3 is only a constituent, D1 is only a matrix, but D2 is both--a matrix for D3 and a constituent (containing D3) for D1.

These three components are complete structures unto themselves. If developed in isolation (ignoring the S in D1 and D2), each would result in a sentence. D1 is the deep structure of the ostrich stuck its head in the sand; D2 is the deep structure of a passive sentence, the ostrich was terrified by the zebra; and D3 is the deep structure of the hunter shot the zebra. It is obvious that more is required in combining these elementary structures than simply applying the transformations that each calls for alone--the auxiliary transformation in every case, and the passive transformation in D2. Doing only this much produces non-English: the ostrich the ostrich was terrified by the zebra the hunter shot the zebra stuck its head in the sand. To avoid a word salad like this, an embedding transformation must delete double occurrences of the same NP. Not every NP repeated in an English sentence need be deleted, of course. The ostrich stuck its head in the sand and the ostrich ate the worm is grammatical even though redundant and ambiguous. However, in the case of an embedded relative clause, deletion must occur, and the rule is that when the same NP is both a matrix subject and a constituent object the object-NP is moved to the front of its sentence structure and replaced by the word that. Let us call this operation the deletion transformation. In the case of Fig. 4, it produces the ostrich that the zebra that the hunter Past+shoot Past+terrify by+Passive Past+stuck its head in the sand. Applying the auxiliary transformation to this structure wherever called for (e.g, Past+shoot becomes shot), and the passive transformation to D2, the surface structure, of which Fig. 4 is the deep structure, rolls out.

Again, notice that a natural distinction exists between the information contained in the transformation and the information contained in the deep structure. As before, the latter has to do with meaning and the former with the relation between sound and meaning. When one understands a relative clause, he grasps the fact that there are two or more deep structures, one inserted in the other, with the deletions not performed. Obtaining the meaning of the ostrich that was terrified by the zebra that the hunter shot stuck its head in the sand depends on knowing that the first that means ostrich and the second zebra, which is to disregard both deletions in the semantic interpretation of the sentence.

There remains one point and we shall be done with this brief introduction to syntax. If transformations are correctly stated in a grammar, they apply automatically whenever the proper conditions exist in the deep structure. In other words, transformations are obligatory (Chomsky, 1965; Katz & Postal, 1964). The specification of the "proper" conditions is done by the structural index of a transformation and setting it down is an important part of writing a transformational rule. Should the structural index be wrong, a transformation will inevitably relate wrong deep and surface structures, even though the operations described in the transformation are themselves correct. To supplement the rules already mentioned, then, we must add that the auxiliary transformation applies to any occurrence of suffix + V, the passive transformation to any occurrence of NP, Aux V, ... NP_2 ... by + Passive (the subscripts indicating that the two NP's must be different and the dots indicating that other, unspecified, material can be inserted), and the relative-clause transformation to any case where the matrix-subject and the constituent-object are the same NP. The structural index is clearly part of grammatical knowledge. Applying the relative-clause transformation to two deep structures where the subject- and object-NP's are different results in a sentence that expresses the wrong meaning. If, for example, the deep structures of the ostrich stuck its head in the sand and the ostrich ate the worm are connected by the relative-clause transformation, meaning shifts and the result becomes something out of Alice in Wonderland--the ostrich stuck its head in the sand that ate the worm. Since violation of the structural index of a transformation leads to an inappropriate expression of meaning, it is evident that the structural index is a part of the relation between meaning and sound.

When we turn to the acquisition of grammar, we shall want to consider the acquisition of structural indices, as well as the acquisition of grammatical rules. We shall want to know, for example, if a child acquires a transformation (say, deletion) and a structural index separately, or if he acquires the transformation always in the context of a structural index. In the first case, a child would apply deletion in many places at once, but often inappropriately. In the second, a child would apply deletion always correctly, but at different times in different contexts. It is a question of whether or not a child learns what to do separately from learning where to do it.

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Footnote

[1]Table 1 and Fig. 1 are based on a series of lectures given by G. A. Miller at Harvard University in 1964. For a general discussion of some of the issues exemplified by Table 1 and Fig. 1, see Miller and Chomsky (1963).

Figure Captions

Fig. 1. Succession of finite-state devices for producing the "sentences" of Table 1.

Fig. 2. Production of <u>aaabbb</u> through application of the rule X ⟶ a(X)b three times. Illustrates recursion and the existence of abstract linguistic features.

Fig. 3. Underlying phrase marker (deep structure) of <u>they would have been walking</u>.

Fig. 4. Generalized phrase marker underlying <u>the ostrich that was terrified by the zebra that the hunter shot stuck its head in the sand</u>.

Table 1

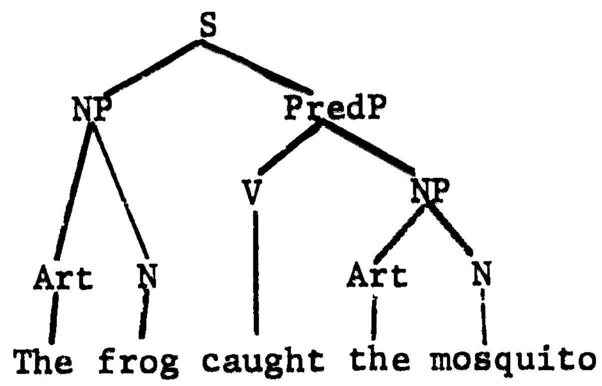
"Sentences" and "Non-Sentences" from a Language Made up of the Letters a and b. (Many Strings Have Been Omitted.) Circled Strings are "Sentences."

Length 1	a b
Length 2	aa [ab] bb
Length 3	aaa ⋮ aba ⋮ bbb
Length 4	aaaa ⋮ abaa [aabb] baba bbbb
Length 5	aaaaa ⋮ abbba ⋮ bbbab ⋮ bbbbb
Length 6	aaaaaa ⋮ aabbaa [aaabbb] bbbbbb
Length 7 and more	⋮

Table 2

Re-Writing Rules for Producing a Simple Declarative Sentence

1. S ⟶ NP PredP
2. PredP ⟶ V (NP)
3. NP ⟶ Art N



S = sentence. NP = noun phrase. PredP = predicate phrase. Art = article. N = noun. V = verb. Rule 2 covers both transitive and intransitive verbs, and for this reason has NP as an optional development. C.f. Chomsky (1965) for a more detailed treatment.

Table 3

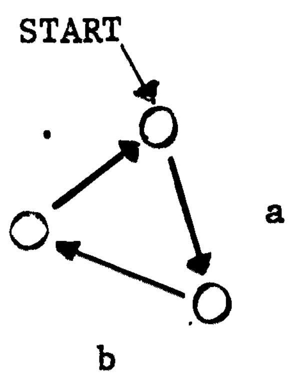
The Result of Replacing Groups of Words by Single Words in a Simple Declarative Sentence (Based on Miller, 1962)

<table>
<tr><td colspan="5">A sentence</td></tr>
<tr><td colspan="2">It</td><td colspan="3">acted</td></tr>
<tr><td>The</td><td>frog</td><td colspan="3">acted</td></tr>
<tr><td>The</td><td>frog</td><td>caught</td><td colspan="2">it</td></tr>
<tr><td>The</td><td>frog</td><td>caught</td><td>the</td><td>mosquito</td></tr>
</table>

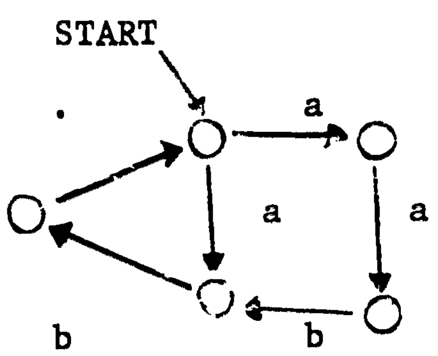
Table 4

	Sentences	Paraphrases	Non-paraphrases
a.	They are buying glasses		
b.	They are drinking glasses	They are glasses to use for drinking	They are glasses that drink
c.	They are drinking companions	They are companions that drink	They are companions to use for drinking

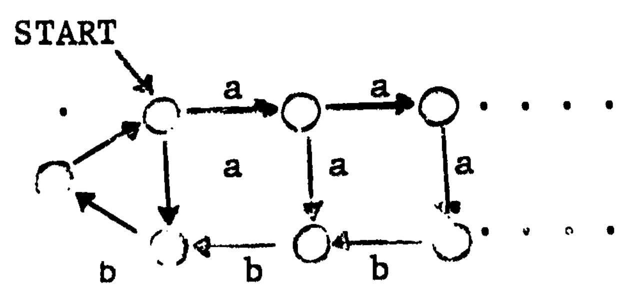
Machine — Sentences yielded



ab.

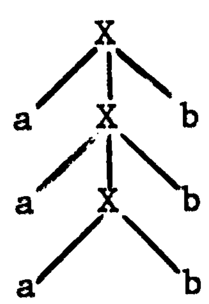


ab.
aabb.



ab.
aabb.
aaabbb.

Figure 1



	Structure	Sentence
Step 1		$(ab)_1$
Step 2		$(a(ab)_2b)_1$
Step 3		$(a(a(ab)_3b)_2b)_1$

Figure 2

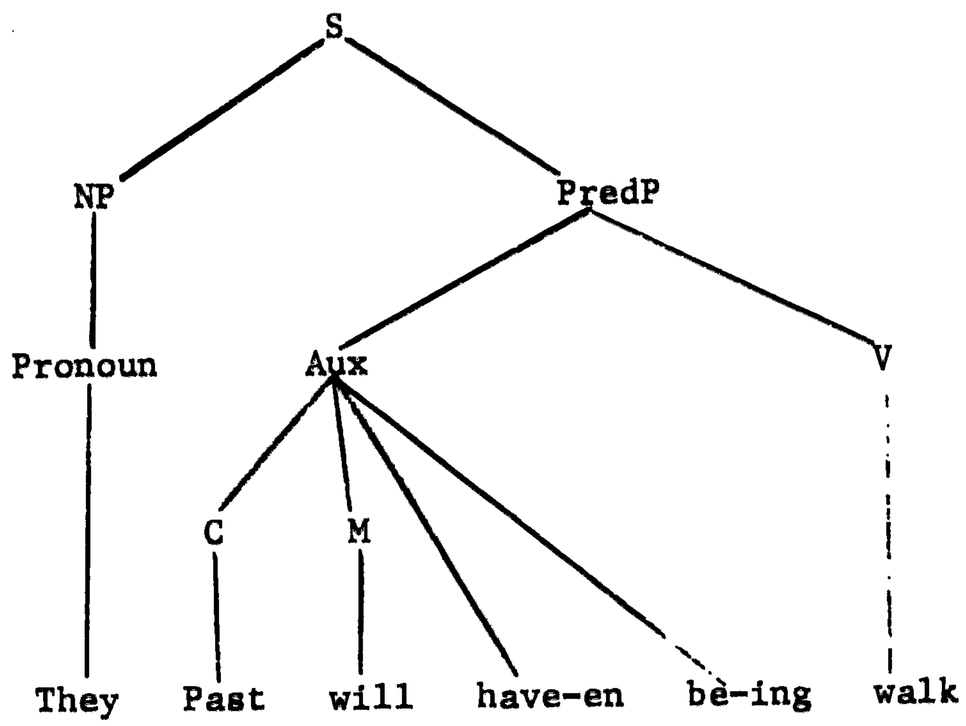


Figure 3

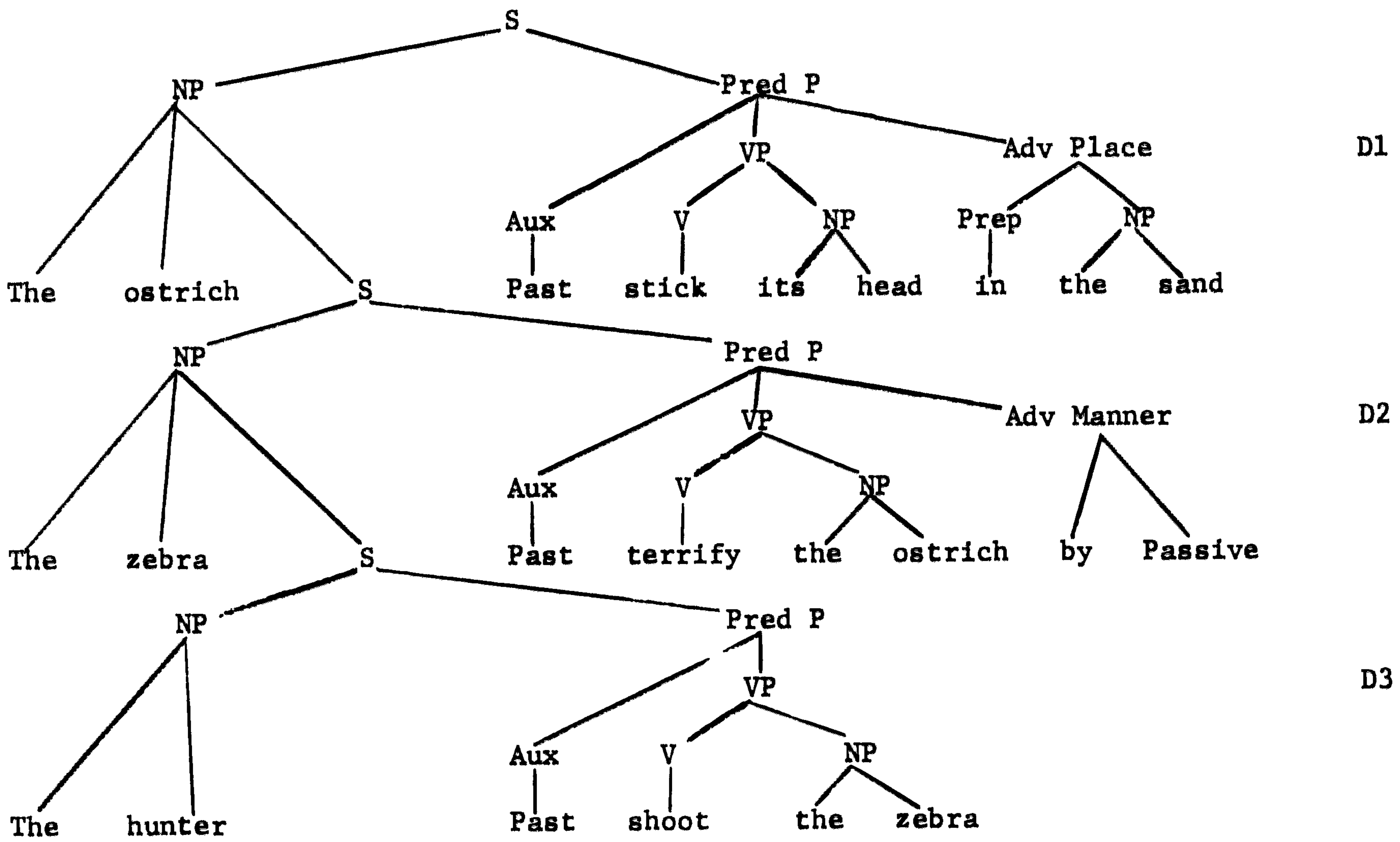

S
NP
Pred P
VP
Adv Place
D1
Aux
V
NP
Prep
NP
The
ostrich
S
Past
stick
its
head
in
the
sand
NP
Pred P
VP
Adv Manner
D2
Aux
V
NP
The
zebra
S
Past
terrify
the
ostrich
by
Passive
NP
Pred P
VP
D3
Aux
V
NP
The
hunter
Past
shoot
the
zebra

Figure 4