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Pandelis G. Halamandaris

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Bloomington, Indiana

August, 1968

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A STUDY OF THE SPEED OF UNDERSTANDING SENTENCES AS A FUNCTION OF SENTENCE STRUCTURE

SUMMARY

On the basis of the grammatical theory developed by Noam Chomsky, it is reasonable to presume that the different parts of a sentence may not all be understood with equal facility. One purpose of this study was to determine whether some of the grammatical relations within a sentence were understood more readily than others. Sentences of varying grammatical form were presented to Ss who were asked to verify them one at a time by comparing the content of each sentence with the content of a picture that was shown contiguously following the sentence. Speed of verification was taken as an index of understanding. The four independent variables, T-F, Aff-Neg, Act-Pass, S-V-O were combined in a 2 X 2 X 2 X 3 X Ss factorial design. The results showed that the subject-verb and verb-object relations were not significant at the .05 level of significance. Two two-way interactions were found to be significant, namely S-V-O X Aff-Neg and S-V-O X Act-Pass. The S-V-O variable was found to be significant in part, specifically, in the case of affirmative and passive sentences, but not in the case of negative and active sentences.

CHAPTER I

PROBLEM AND OBJECTIVES

Since the appearance of Chomsky's Syntactic Structures in 1957, the theory of Transformational Generative Grammar has become the focus of considerable attention in linguistics (Chomsky, 1957, 1961, 1962, 1965, 1966, 1967; Fodor and Katz, 1964; Katz, 1[illegible]5, Lees, 1957, 1960). Subsequently, a number of studies (e.g., Clifton, Kurcz, and Jenkins, 1965; Gough, 1965, 1966; McMahon, 1963; Mehler, 1963, 1964; Miller, 1962; Miller and McKean, 1964; Savin and Perchonock, 1965; Slobin, 1963, 1966) have appeared that make an attempt to use the grammatical theory set out in Syntactic Structures as a model for human language behavior in the laboratory situation.

Chomsky's main interest in the past decade has been to account for a speaker's intrinsic competence, which according to him is the central problem to which any significant linguistic theory must address itself. This intrinsic competence includes the ability of a mature speaker to produce a novel sentence of his language that other speakers of his language can understand.

Chomsky's manner of accounting for a speaker's competence is to construct an analytical system known as a transformational generative grammar.[1] Such a grammar

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[1]The significance of the terms transformational and generative will be clarified later.

consists of a set of rules whose application can, in principle, enumerate all the possible sentences in a language. The number of sentences in a language is, of course, indefinitely large, and clearly no speaker of a language could "store" an indefinitely large number of sentences. But on the basis of a comparatively limited experience with speech, each "normal" human being has developed a competence in his native language. Thus, a native speaker of a language has some "method" of understanding completely novel sentences. It is as if he possesses a set of rules which permits him to "evaluate the grammaticalness" of any novel sentence. For example, consider the following:

1. Every college in Australia should offer a course in how to prepare peanut butter

2. *the boy may frighten sincerity

3. *sincerity frighten may boy the

(Chomsky, 1965, p. 9; Thomas, 1965, p. 8)

These expressions may never before have been encountered by a given person. Nevertheless, the native speaker of the English language classifies each of these expressions

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*Indicates that a sentence is not grammatical. Saying that a sentence is not grammatical does not mean that the sentence is unintelligible or that no speaker of the English language would ever use it. Rather, what is meant is that this sentence deviates in some manner from full grammaticality. For, to be sure, many non-grammatical sentences can be interpreted with reference to an appropriate situation. It is necessary to distinguish between such sentences and sentences which do not need such interpretation.

as either being or not being an utterance in his language. He is said to do this on the basis of his understanding any utterance in his language. This understanding is said to imply that he has knowledge concerning the linguistic structure of any utterance. For example, item (1) could be understood although a speaker may never have heard it before, while the same speaker would likely say that items (2) and (3) are not English sentences. He might explicate his statement by saying that he has difficulty in trying to understand them, for these sentences deviate in one or more ways from the rules of English—e.g., either a semantic incongruity occurs or they violate a purely syntactic rule (Chomsky, 1965, pp. 75-77). This ability of a native speaker to distinguish between those "noises" which are well-formed sentences of a language, and those which are not, is said to derive from his competence. (Postal, 1964, p. 246)

The term "competence" is a theoretical term in the sense that it refers to hypothetical states of affairs with respect to the speaker-hearer. Competence is the knowledge of linguistic rules, categories, etc., that accounts for a native speaker's intuitions about his language. (McNeil, 1966, p. 77)

All that we can observe is a speaker's "performance," i.e., his expression of competence in speaking-hearing. However, competence is considered not to be directly

represented in any simple way in performance (cf., Chomsky, 1959). So, in attempting to use a formal grammatical theory as a model for human language behavior, Chomsky takes the view that we must make a clear distinction between "competence" and "performance," i.e., between a language user's knowledge of his language and the actual use he makes of that knowledge in concrete situations. According to Chomsky, competence must involve the knowledge of a finite system of rules that enables the native speaker of a language to understand and produce an indefinitely large number of sentences. (Chomsky, 1965, pp. 15-16)

So, Chomsky offered a solution to the basic problem in linguistics that the structural elements in language and the relationships between them are finite, and yet that they can account for an indefinitely large number of cases in a language, by proposing that a grammar should take the form of an exhaustive, compatible set of rules for generating sentences. Such a grammar will predict for any utterance in a language the linguistic structure that a native speaker will perceive in it (cf. Katz, 1964). Thus it may be said that if the grammar is perfectly explicit, then, given an ambiguous sentence such as,

4. They are eating apples.[2]

---

[2]Notice that this sentence is ambiguous, i.e., it

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the grammar can generate (i.e., enumerate) each of the two possible meanings of the sentence. Hence, such a grammar is called a generative grammar.

According to Chomsky a generative grammar deals with mental processes rather than observable ones. Further, a speaker's reports and viewpoints about his behavior and his competence may be in error. So it could be said that a generative grammar attempts to specify what the speaker actually knows, not what he may report about his knowledge. (Emphasis added.) (Chomsky, 1965, p. 8)

A generative grammar is a "system of rules that in some explicit and well-defined way assigns structural description to sentences." (Chomsky, 1965, p. 8) The postulated system of rules that enables the native speaker of a language to understand an indefinitely large number of sentences may be analyzed into three major components. (Chomsky, 1965, pp. 15-16) These components have been described by Katz (1966) as follows:

a. The Phonological component: a statement of the rules by which a speaker-hearer deals with the speech sound of his language

b. The Syntactic component: a statement of the rules by which a speaker-hearer organizes the sounds of his language into sentential structures. Since this set of structures is clearly infinite, it cannot, by definition, be

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could be interpreted as:
(1) The people are eating apples, or
(2) The apples are for eating.

represented by a list, but by a set of rules capable of indefinite reapplication.

c. The Semantic component: a statement of the rules by which a speaker-hearer interprets sentences as meaningful messages. (p. 111)

The Syntactic component of a linguistic description, in Katz's (1966) words,

> . . . is a set of rules that generates an infinite class of abstract formal structures, each of which describes the syntactic organization of a sentence. It is the source of the inputs to both the phonological and semantic components. The phonological component operates on such formal objects to determine their phonetic shape, while the semantic component operates on them to determine their meaning. Both the phonological and semantic components are, therefore, purely interpretive: they relate the abstract formal structures underlying sentences to a scheme for pronunciation, on the one hand, and to a representation of conceptualization, on the other hand. (p. 111)

These rules are recursive and may be endlessly reapplied to their own output to yield an unbounded set of formal objects, which formal objects are the sentences of the language under consideration. This enumeration excludes, of course, any string in the vocabulary of the language that is not a sentence in the language. (Katz, 1966, p. 123) The sort of rules that will appear in the syntactic component will be determined by the structure of the sentence that must be described. "Sentences of a natural language are concatentations of symbols in the vocabulary of the language." (Katz, 1966, pp. 120-123) For example, consider the sentence

5. the cat likes the mouse

and its syntactic description shown in Figure 1.

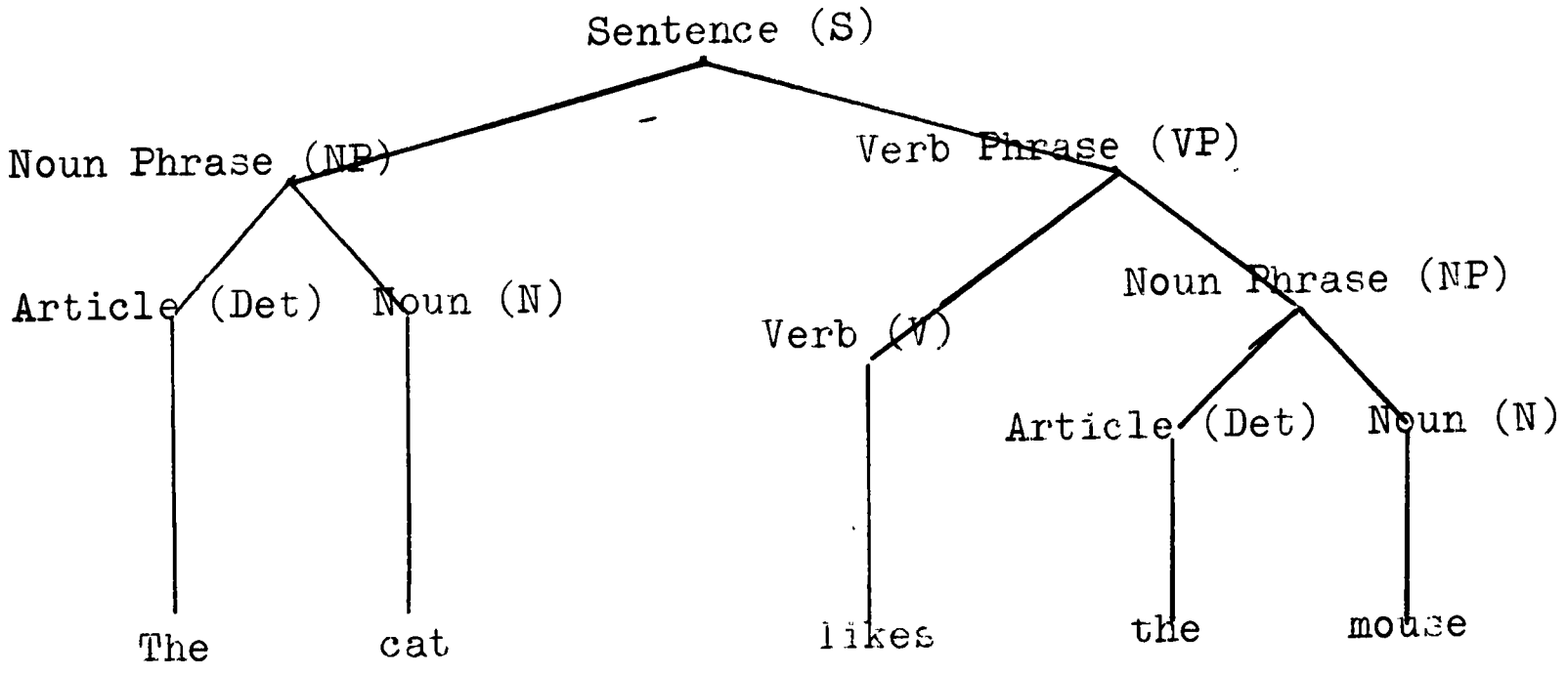

Figure 1. The arrangement shown is a final derived phrase marker. Such a figure provides the following:

a. The set of words of which the sentence the cat likes the mouse is composed
b. The order of words—e.g., that the article (determiner) the immediately precedes cat and mouse
c. The groups of words that form constituents of the sentence
d. The syntactic categories to which each of the words and constituents belongs—e.g., the cat is a noun phrase. (Katz, 1966, pp. 124-125)

The final derived phrase marker constituting this figure is said to provide the input to the phonological component of the sentence. The syntactic component specifies a "surface structure" for each sentence, which determines its phonetic representation.

In addition to specifying the surface structure, the syntactic component of a grammar specifies for each sentence a "deep structure," for which there is another type of phrase marker which describes the underlying structure of sentences and is thus an appropriate input to the semantic component. Such a marker is called an underlying phrase marker. (Katz, 1966, p. 131) The connection between the final derived phrase marker for a sentence such as the one in Figure 1 and the underlying phrase marker of that sentence is described by another type of syntactic rule called a transformational rule. These rules will be discussed later in this paper. It is a difference in the deep structure that distinguishes such sentences as

6. John is eager to please
and
7. John is easy to please

although at first glance both sentences appear to have the same structure, because their surface structures are similar. By reducing each sentence to its underlying structure we find that in sentence (6) the semantic interpretation is that John pleases somebody, while in sentence (7) the semantic interpretation is that somebody pleases John.

In distinguishing the "deep structure" of a sentence from its "surface structure" we say that deep structure is the underlying abstract structure that

determines the semantic interpretation and the surface structure relates the physical form of the actual utterance to its perceived or intended form. (Chomsky, 1966, p. 33)

The distinction between deep and surface structure (a distinction not made in structural linguistics) and the assumption that the surface structure is determined by the application of certain formal (syntactic) operations called "grammatical transformations" is the central idea of transformational grammar. The syntactic component is said to generate deep and surface structures for each sentence, and to include rules for interrelating them. (Chomsky, 1965, pp. 16-17)—hence the phrase Transformational Generative Grammar (henceforth, Transformational Grammar). Thus, the deep structure is considered to be more fundamental to language, and the analysis of deep structure is of primary importance. The nature of this analysis will now be described in simplified fashion.

The syntactic component, which specifies both deep structure and surface structure, consists of

1. A base subcomponent, a system of rules which generates an underlying phrase marker, and
2. A transformational subcomponent, as shown in Figure 2, a set of rules which converts underlying phrase markers into their final derived phrase markers.

The base subcomponent in turn consists of

i. a categorial subcomponent, and
ii. a lexi on

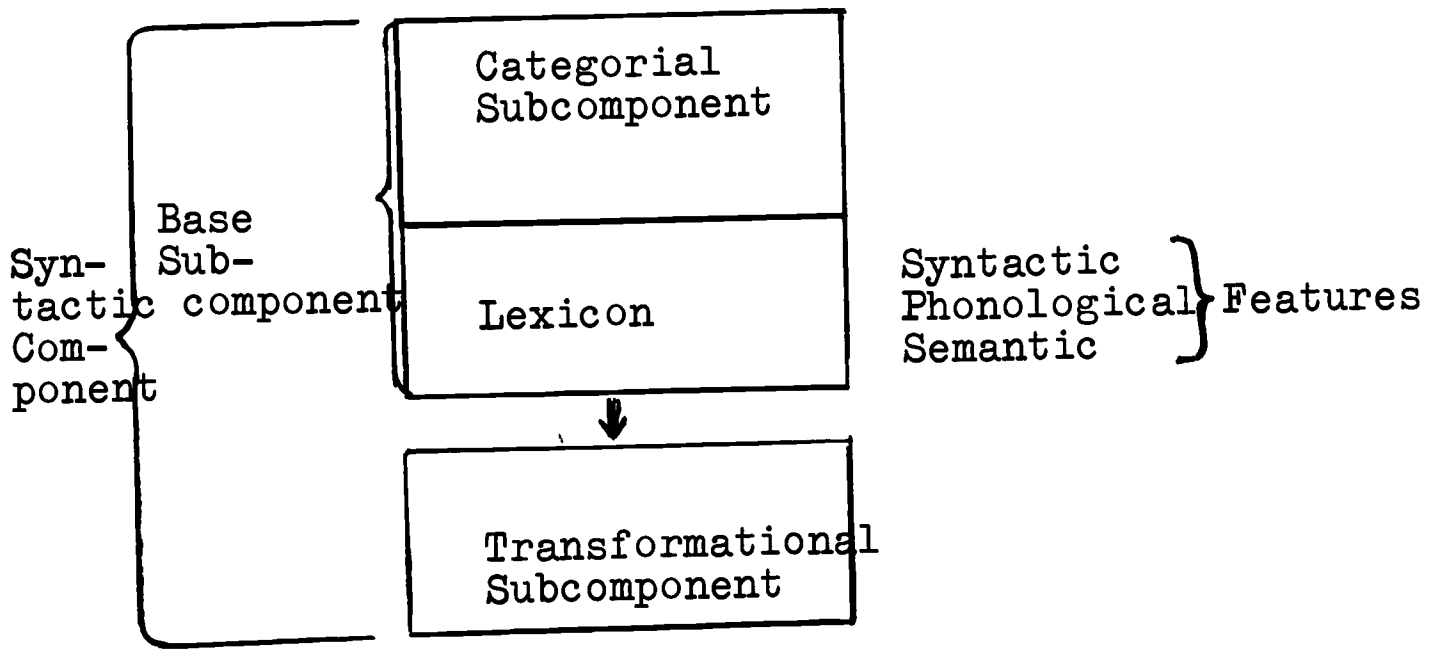

Figure 2. A Schematic Representation of the Syntactic Component

The categorial subcomponent of the base is made up of a complex set of rules (rewriting rules) of the following types:

i. branching rules such as S→NP^Predicate-Phrase, where S is read "a given sentence," the arrow symbol is read "is rewritten" or "may be replaced by," NP is read "Noun Phrase," and the Symbol is read "concatenated with" or "strung together."

ii. subcategorization rules such as [+ Count] → [± Animate], i.e., if a noun has been subcategorized as countable ([+ Count]), then this noun must of necessity be further

specified as to whether it has the feature "Animate" [+ Animate] or the feature "non-Animate" [- Animate].

Now consider the following example taken from Aspects of the Theory of Syntax (Chomsky, 1965, p. 85):

8. Sincerity may frighten the boy

The branching rules of the grammar for the above sentence are the following:

S →NP ⌢ Aux ⌢ VP, i.e., Sentence is rewritten as Noun Phrase concatenated with Auxiliary (ultimately, the word "may") concatenated with Verb Phrase.

VP →V ⌢ NP, i.e., Verb Phrase is rewritten as Verb (V) concatenated with Noun Phrase.

NP →Det ⌢ N, i.e., Noun Phrase ("the boy") is rewritten as Article (Det—i.e., Determiner) concatenated with Noun.

NP →N, i.e., Noun Phrase ("Sincerity") is rewritten as Noun.

Det→the, i.e., Article is rewritten as the (definite article)

Aux→M, i.e., Auxiliary is rewritten as Modal.[3]

The subcategorization rules are as follows:

i. N→[+ N, ± Common), i.e., a Noun takes the syntactic feature [+ N] and can be either Common [+ Common] or Proper [- Common].

ii. [+ Common]→[± Count], i.e., if this is a common N then it can take either

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[3]The modals include such auxiliaries as shall, will, can, may, and so on.

the feature of countability [+ Count] or the feature of non-Countability [- Count].

iii. [+ Count]→[± Animate], i.e., if this N is a countable N then it takes one of the features [± Animate] (as explained under subcategorization rules).

iv. [- Common]→[± Animate], i.e., if this N is Proper then it takes one of the features [± Animate].

v. [+ Animate]→[± Human], i.e., if this N is Animate then it takes either the feature Human [+ Human] or the feature non-human [- Human].

vi. [- Count]→[± Abstract], i.e., if this N is not countable [- Count] then it takes either the feature Abstract [+ Abstract] or non-Abstract [- Abstract]

Now, all of the above rules generate the structural description of the preterminal string, as exemplified in Figure 3.

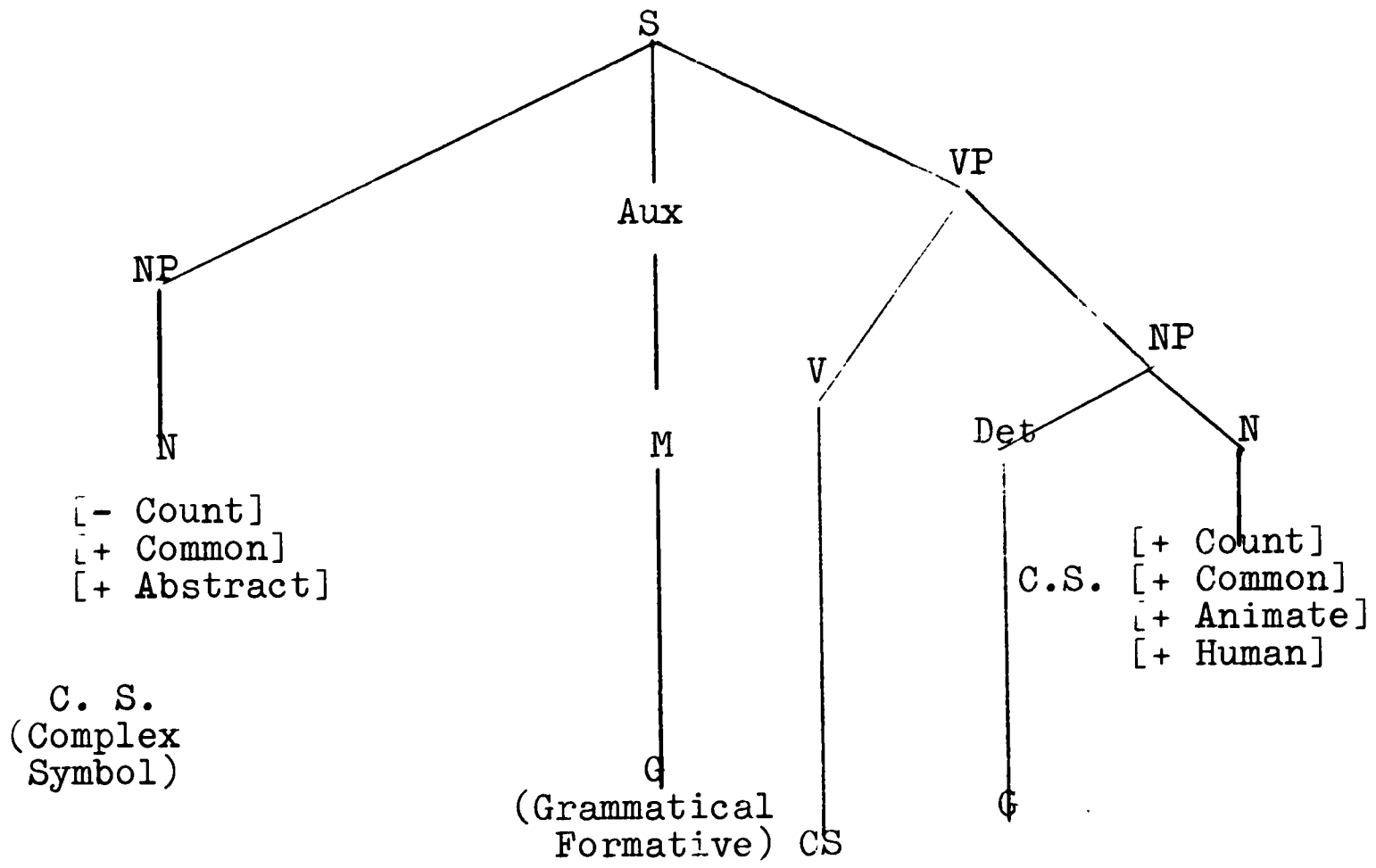

Figure 3. The Structural Description of the Preterminal String for (8) according to the Branching and Subcategorization Rules

Thus, we can say that a preterminal string such as that in Figure 3 includes (i) Complex Symbols (CS), which consist of specified syntactic features, and (ii) Grammatical Formatives (G), which consist of minimal syntactically functioning units such as Perfect, Possessive, etc. However, the preterminal string does not, by definition, have any lexical formatives such as boy and the. The lexical formatives are to be substituted into the CS "frame" of the preterminal string according to lexical

rules.

The G are determined once the lexical formatives have been substituted into the CS "frame" of the preterminal string.

The preterminal string in this diagram "dictates" the features that each lexical entry should have in order that it correspond with a part of the preterminal string. Thus, the categorial subcomponent generates one or more diagrams like that in Figure 3, with more than one diagram being necessary where a sentence may be construed in more than one way.

Now that we have described the branching rules and the subcategorization rules of the categorial subcomponent, we shall now describe the lexicon. The lexicon is an unordered set of entries specifying certain features. For example, we can say that in view of the fact that the features listed below are some of the features of the noun "man," a non-exhaustive listing in the lexicon of this noun is as follows:

[+ N
+ common
+ concrete
+ animate
+ human]

The lexicon is made up of lexical items having (a) phonological features, (b) semantic features, and (c) syntactic features. Thus a lexical item such as bee can be partially represented in the lexicon by the phonological

feature set [Consonantal$_1$, Voiced$_1$, non-Continuant$_1$, . . . Vocalic$_2$, non-Grave$_2$, . . .] indicating through the subscript that the first "segment" of bee, i.e., b, is consonantal, voiced, and a non-continuant, . . . , and that its second "segment" is vocalic, non-grave, ... (Chomsky, 1967, p. 70)

The semantic features, the second set of features listed above which form a part of the lexicon, are of the type [± Artifact].

The syntactic features, the third set, can be subdivided into inherent features such as,

[Det_] →[± Count],	i.e., if there is a preceding article, the noun that follows is either countable [+ Count] or uncountable [- Count].
[+ Count]→[± Animate],	i.e., if the noun is countable, then the noun is either Animate [+ Animate] or non-Animate [- Animate],

and contextual features such as,

[+ V, + _____NP] ("transitivity")

Contextual features, unlike other syntactic features, always specify some aspect of the phrase-marker to which the lexical item having the feature corresponds. For example, in the present case "transitivity" specifies that in the phrase-marker the verb precedes the NP of the VP, as in Figure 1.

Having considered the contextual features—according to Chomsky (1965) "we then have a general rule of subcategorization to the effect that a Verb is positively specified with respect to the contextual feature associated with the context in which it occurs." (p. 93) Thus it could be said that strict subcategorization rules impose a categorization on the symbol V in terms of features of the context in which V occurs, i.e., such rules state the frame in terms of category symbols (NP, Adj, etc.). Thus a symbol such as V is analyzed in terms of its categorial context. An illustration of this type of rules is the following:

$$V \rightarrow CS / \_\_\_ \begin{Bmatrix} NP \\ Adj \\ Prepositional\text{-}Phrase \\ etc. \end{Bmatrix}$$

i.e., Verb is subcategorized as CS preceding NP such as the book in Bring the book; or preceding Adj. such as sad in Grow sad; or preceding a Prepositional-Phrase, such as on a new course of action in Decide on a new course of action.

The selectional rules, for (8) such as,

$$[+\ V] \rightarrow CS / \begin{Bmatrix} [+\ Abstract] & Aux\ \text{----} \\ -\!-\ Det & [+\ Animate] \end{Bmatrix}$$

assign features of the Subject such as [+ Abstract] and features of the Object such as [+ Animate] to the Verb. (Chomsky, 1965)[4] These rules state the frame in terms of

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[4]This rule has been simplified for the purpose of exposition.

syntactic features. A symbol is analyzed in terms of syntactic features of the frames in which it appears. Thus a selectional rule of a lexical item restricts the lexical features of other items with which the given item enters into grammatical relations. These features sub-classify each verb in terms of certain syntactic features of the preceding noun functioning as subject-of the sentence and/or the following noun functioning as object-of the VP. The latter are usually what are called selectional restrictions or "restrictions of co-occurrence." The selectional restrictions or selectional rules define a selectional relation between two positions in a sentence, such as the position the of the verb and that of the immediately preceding or immediately following noun. Such selectional relations imply grammatical relations.

It is necessary at this point to introduce certain relations that pertain to sentences and their elements. We shall adopt the following definitions used by Chomsky: (1965, p. 71) (i) Subject-of: [NP, S]; (ii) Predicate-of: [VP, S]; (iii) Object-of: [NP, VP]; (iv) Main-Verb-of: [V, VP].[5] Considering Figure 1, according to Chomsky

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[5] (i) The relation of a Noun Phrase to a Sentence when NP is immediately dominated by S.
(ii) The relation of a Verb Phrase to a Sentence when VP is immediately dominated by S.
(iii) The relation of a Noun Phrase to a Verb Phrase when NP is immediately dominated by VP.
(iv) The relation of a Verb to a Verb Phrase when V is immediately dominated by VP.

we can say that the cat bears the relation [NP, S] to the cat likes the mouse. The mouse bears the relation [NP, VP] to likes the mouse. And likes bears the relation [V, VP] to likes the boy. Other relations, such as Subject-Verb, can be defined derivatively in terms of the relations defined above.

Thus, the selectional rules of the type discussed above determine the type of verb that a sentence will take, given a subject and an object implying grammatical relations such as Subject-Verb and Verb-Object. According to Chomsky (1965, p. 119) the lexical categories V and N are "strictly" subcategorized. However, the lexical categories V and Adjectives are "selectionally" subcategorized in terms of syntactic features of preceding and following N's. This property of the V and the Adjective, to "select" certain features of the NP functioning as Subject-of and Object-of the sentence in the deep structure is fundamental to the grammar in order to determine the lexical categories.

It will be recalled that sentence (8) was used above to illustrate the application of the branching and subcategorization rules of the categorial subcomponent. This same sentence will now be used to illustrate the application of the definitions of the lexicon entry. The lexicon entries for (8) are the following:

(sincerity, [+ N, -Count, + Abstract])

(boy, [+ N, + Count, + Common, + Animate, + Human, . . .])

(may, [+ M])

As can be seen in this example the G, i.e., the grammatical formatives (cf. Figure 3), are not among the lexical entries, for these units can be predicted. The verb "frighten" is compatible with the selectional rules which are imposed by the noun. A statement of the sub-categorization of the verb is as follows:

(frighten, [+ V, + ____NP, + [+ Abstract] Aux___Det [+ Animate],
+ Object-deletion, . . .])

The statement may be interpreted as follows: "frighten" is a verb and occurs before NP, i.e., this verb must be transitive. This verb must take an Abstract NP as subject and in addition it should have an Animate object. The object can be deleted in cases such as Sincerity may frighten. It is selectionally subcategorized in terms of the preceding and following noun.

Now if the features which make up the lexicon are not distinct[6] from those features of the position of the preterminal string such as in Figure 3 then the lexical items can be inserted thus specifying the deep structure of a sentence, which in turn is mapped by the transformational rules into a superficial or surface structure.

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[6]By distinct is meant that, e.g., if the features in the lexicon are [+ Animate + Count + Human] and the features in the preterminal string are [+ Animate + Count], we can conclude that the features of the lexicon and those of the preterminal string are not distinct. But if one feature in the lexicon is + and the same feature in the preterminal string is -, then we can conclude that these features are distinct.

In recapitulating, we can say that grammatical rules are used to generate a string of sets of features and formatives, i.e., lexical formatives such as the, boy, etc., and grammatical formatives such as Perfect, Possessive, etc. In exemplifying the above we can say that a "word" is taken from the lexicon and is inserted in the preterminal string of the corresponding CS which is composed of features which somehow determine the "syntacticity" of the "word" to be inserted. For example, if the "word" taken from the lexicon is a verb, i.e., the features are those of a verb, then the features of the position of the preterminal string should not be distinct from those of the verb. In that instance we can say that we use only the syntactic features and not the semantic. The semantic features will provide the meaning of the sentence and not the generation of the sentence. For practical purposes both features will be considered necessary for generating grammatical sentences.

Some of the features which will be included in the preterminal string will have features which will indicate the necessary transformations which are needed in order to produce the terminal string containing these words. Consider for example the following: The idiosyncratic features of the verb buy, i.e., it begins with a Voiced non-Continuant, that it is a Transitive Verb, that it has irregular inflections, that it involves transfer of

ownership, etc., must all be represented by features of the lexical entry. (Chomsky, 1967, p. 71)

To complete our illustration of (8), the preterminal string of Figure 3 is compared with the lexical entries of that sentence, and through the lexical rules the lexical entries are "accepted" or "rejected" for the preterminal string of Figure 3, and thus Figure 4 is derived.

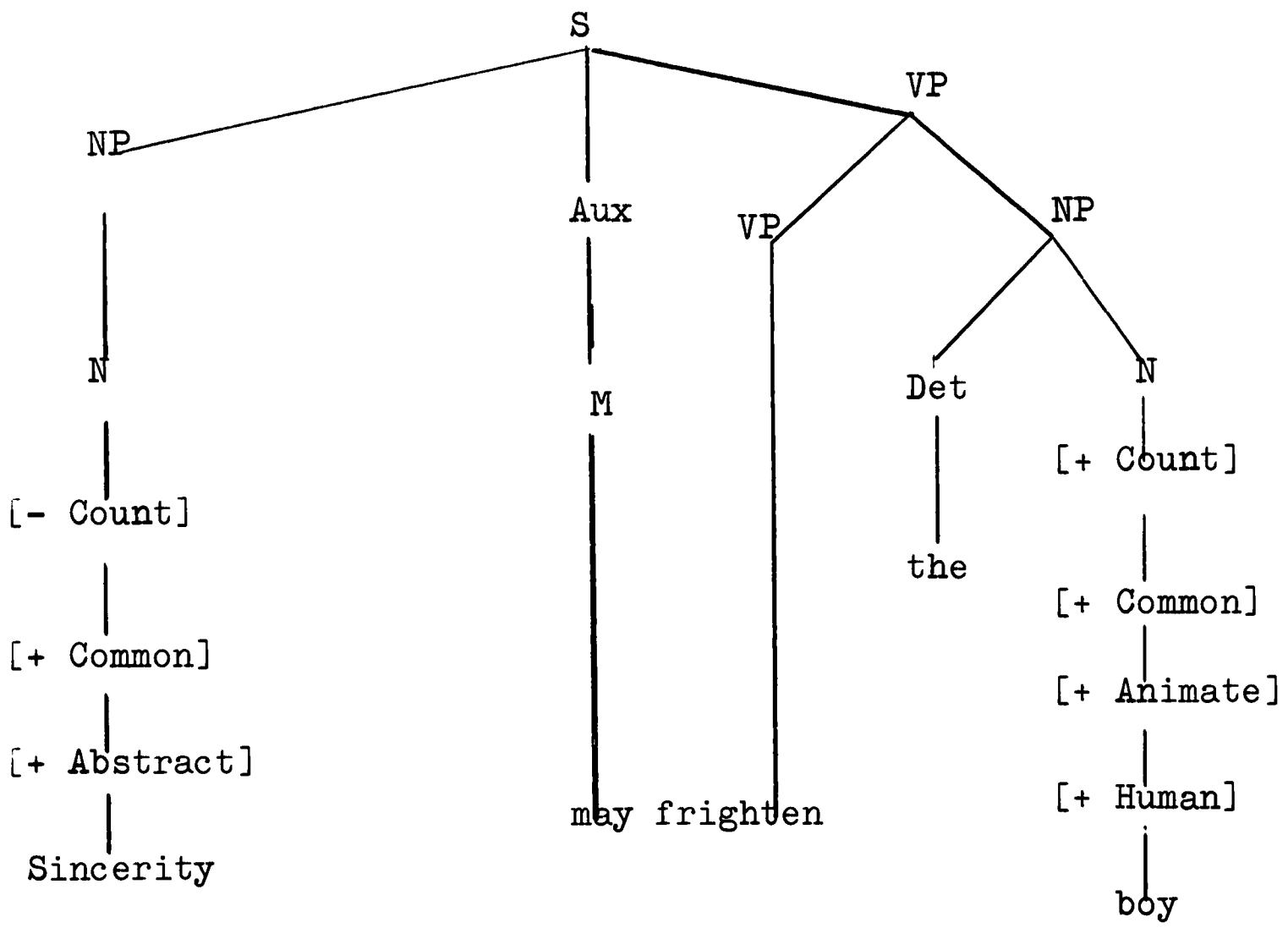

Figure 4. Phrase Marker for (8) before Any Transformations Have Been Applied

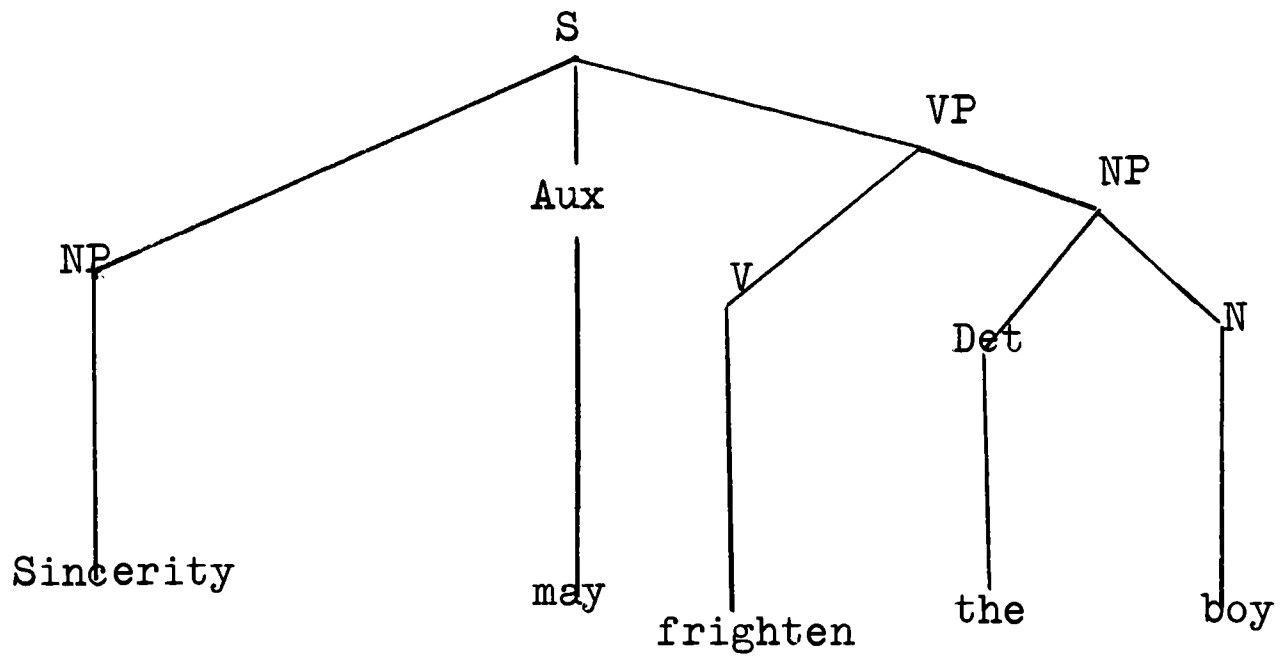

Figure 5. The Final Derived Phrase Marker for (8)

Thus the "basis" of a sentence which is the sequence of the aforementioned string on Figure 4 is "mapped into" the sentence Sincerity may frighten the boy, by a transformational rule. This is, therefore, an explanation, in part, of how a reader or listener can understand a sentence in which the grammatical relations have been "obscured" in the surface structure (Thomas, 1965, p. 19).

It may be said that the full syntactic description of a sentence consists of its final derived phrase marker and its underlying phrase marker; in the case of ambiguous sentences, there may be more than one underlying phrase marker. The transformational rules automatically assign to a sentence a final derived phrase marker (ultimately, a surface structure). (Chomsky, 1965, p. 128) So we can say that the transformational rules of a grammar operate on deep structure to transform underlying phrase

markers by permitting, deleting, and adding elements to yield other structures.

Thus we can say, given a base phrase-marker, that a N carries its features over by selectional rules to other lexical categories, in this case to the verb.

CHAPTER II

RELATED RESEARCH

Chomsky demonstrated that grammars, and in particular their syntactic components, can be treated formally as systems of generative rules (cf. Chomsky, 1963; Katz and Postal, 1964; Miller and Chomsky, 1963; Klima, 1964). This important development in linguistics had far-reaching effects in psycholinguistics. Within this theoretical framework, many studies have been conducted concerning such diverse phenomena as the "storage capacity" of memory, the effects of syntactic complexity on understanding, and the occurrence of natural units in language.

Miller (1962) was the first person to derive and text empirically some implications of Chomsky's linguistic formulation. Miller carried out a number of experiments designed to test the prediction he derived that the time required to perform a grammatical (specifically, a transformational)[1] operation was a positive function of its complexity. The subject's (S's) task was to match the sentence of one column with their grammatically-altered counterparts in a second column. For example, a sentence

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[1]For convenience of exposition, Miller and others have expanded the usage of the term transformation beyond its use as referring to formal linguistic rules relating deep and surface structures that are intended to describe unconscious mental processes. It is said that when, for example, a person identifies a passive sentence as having the same meaning as a certain active sentence, he has "performed a transformation."

in Column 1 might have been Jean helped the old lady (Simple, Affirmative, Active, Declarative—SAAD), while its passive counterpart in Column 2 was The old lady was helped by Jean. The sentences in Column 2 differed from those in Column 1 by one or two transformational operations, and the order of sentences within each of the columns was random. Before beginning the task, Ss were instructed which operations were involved in a particular pair of columns, e.g., a pair of columns might consist of active sentences in Column 1, and passive sentences in Column 2. In another pair of columns, affirmative sentences might be in Column 1 and negative sentences in Column 2, etc. Baseline search time was determined by having Ss locate in Column 2 the untransformed versions of sentences of Column 1. For example, in order for the Experimenter (E) to determine the baseline time he could have presented to the S the following two columns:

Column 1	Column 2
( ) The boy hit the girl.	1. The cat ate the bird.
( ) The dog bit the man.	2. The boy kicked the ball.
( ) The cat ate the bird.	3. The boy hit the girl.
( ) The boy kicked the ball.	4. The dog bit the man.
etc.	etc.

Although the example given may leave the impression that in some instance S would have been able to choose the correct sentence in Column 2 by reading only a portion of

a sentence in Column 1, this was not true in the actual experiment. The time taken to match the sentences in Column 2 with the identical sentences in Column 1 was considered the baseline search time for the task involved in the following two columns involving the Passive Transformation:

Column 1a	Column 2a
( ) The boy hit the girl.	1. The bird was eaten by the cat.
( ) The dog bit the man.	2. The ball was kicked by the boy.
( ) The cat ate the bird.	3. The girl was hit by the boy.
( ) The boy kicked the ball.	4. The man was bitten by the dog.
etc.	etc.

Thus, if we subtract the time taken to match the sentences in columns 1 and 2 from the time taken to match the sentences in columns 1a and 2a, presumably we have the time that was necessary for S to perform implicitly the passive transformation of the sentences in Column 2a.

Miller predicted that sentences which involved two transformations would take a longer time to be matched. For instance, if an Active Negative sentence (N), such as, The boy did not hit the girl, were given in Column 2 and the Passive Affirmative (P) of the above were required to be matched in Column 1, it was assumed that S would "undo" the work of the negative transformation and then

apply the passive transformation. While if the N were given and S were required to match it with its Passive Negative (PN) transform, it was assumed that S would apply the passive transformation but, of course, would not be required to "undo" the negative. On this view, it would be predicted that the result of the experiment would be that the difficulty of matching SAAD with N or P and the difficulty of matching PN with N or P would be comparable. Also, the difficulty of matching SAAD with PN and the difficulty of matching N with P would be comparable. However, the latter two cases of matching would be more difficult than the former two cases. It was found that the average speed of matching varied significantly as a function of the nature of the transformation. The changes that were accompanied by the most rapid matching were those from SAAD to N and from P to PN. Considerably slower were those from SAAD to PN, and from N to P. The times required for matching in these and other instances were as follows:

SAAD	matched to N	1.1 sec. more than the baseline search time
P	matched to PN	1.2 sec. more than the baseline search time
SAAD	matched to P	1.5 sec. more than the baseline search time
PN	matched to N	1.8 sec. more than the baseline search time
SAAD	matched to N	2.7 sec. more than the baseline search time

The evidence indicated additivity of the transformation times, that is, the time to carry out both the P and N transformations was of the same order of magnitude as the sum of the times required to carry out the P transformation and the N transformation separately.

Miller and McKean (1964) carried out a second experiment to test the same predictions made in the earlier experiment. Sentences were presented tachistoscopically. S was instructed that upon the presentation of a sentence, he was to perform covertly a specific transformation. When S had performed the transformation, he was to press a button. This response resulted in the presentation of a search list (comparable to Column 2 of the previous study) and also in the stopping of a timer which had started upon the presentation of the sentence.

Thus, with this technique the search time was separated from the presumed processing time. The searching task was employed only to provide a check on the accuracy of performance. The resu ts here were comparable to those with the pencil and paper method. The presumed speed of transformation varied significantly as a function of the nature of the transformation. The presumed transformation times were as follows:

SAAD	matched to N	.39 sec.
P	matched to PN	.40 sec.
SAAD	matched to P	.74 sec.
PN	matched to N	.99 sec.
SAAD	matched to PN	1.14 sec.
N	matched to P	1.8 sec.

As in the earlier experiment, there was evidence of additivity of the transformation times. The time required for the SAAD to N transformation added to the time required for the SAAD to P transformation approximately equalled the time required for the SAAD to PN transformation.

It may be pointed out that whereas one transformation was said to be involved both in SAAD to N and SAAD to P, the time required for the SAAD to P transformation was almost twice the time required for the SAAD to N transformation. In connection with the description below of experiments by Mehler certain theoretical developments will be described that attempt to account for this discrepancy.

Mehler (1963) found a close relationship between transformational complexity and recall of sentences. He had Ss learn a list of sentences of various grammatical types and scored their performance in terms of the syntactic errors which were made in recall. Mehler used eight lists of eight sentences each. Each list contained one of

the eight syntactic types, and each sentence on a given list was derived from semantically disparate (i.e., non-synonymous) SAADs. S was presented orally with the eight sentences making up a given list, one at a time. After he had heard all of the sentences of the list, S attempted to recall them. Then, the sentences were presented again and S was again tested for recall, and so on, for five presentations. Ten Ss were used for each of the eight lists. He found that SAAD sentences were always easiest to recall, followed in difficulty by N, P, and PN, in that order. The N, P, PN order conforms to the results of both the Miller and the Miller and McKean studies and is consistent with the number of transformations involved in each case.

However, the results were not in keeping with certain new theoretical developments. Some of these developments will be implied in the next few paragraphs although description of them will be deferred until the end of the present chapter. Letting the symbol < mean "was easier than," according to the new theoretical developments, the results should have been SAAD<P<N<PN rather than the obtained SAAD<N<P<PN. The new theoretical developments assume that the degree of difficulty between SAAD and P should be minimal in view of the fact that the meanings of the two sentences are the same, i.e., although the surface structure of a passive sentence is different from

that of an active sentence, both sentences have the same deep structure.

When S made syntactic errors in recall, twice as many of them were simplifications (remembering sentences in forms closer to the Kernel) than complications (remembering sentences in forms further from the Kernel). This result suggested that Ss "recode" sentences in kernel form, and, when instructed to recall the original sentence presented ". . . they supplement their memory of the kernel with a footnote [marker] about the syntactic structure." (Miller, 1962, p. 760) That is, the sentence is assumed to be represented in memory, not in its surface form, but in some form minimally necessary to specify semantic content and with a set of transformational instructions for deriving the final syntactic form. The minimal grammatical information required for semantic interpretation seems to be represented by the deep structure of a sentence. According to Mehler, since the SAAD forms have the minimal number (zero) of syntactic "footnotes," they should be the most easily and accurately remembered.

Wason (1961) investigated aspects of negativity in a sentence. Ss were required to determine whether a statement about a number was true or false and to produce a number that would change the sentence such as to make it either true or false. Even at the end of practice it was found that negative statements such as, Seven

is not an even number required a longer time for evaluation of their truth value and a longer time to change such as to make them true, than did their corresponding affirmatives such as, Seven is an odd number.

In a study by Clifton, Kurcz and Jenkins (1964) a distance metric was used to compare the generalization decrements obtained between various grammatical constructions. Each S was instructed that he was going to see a list of sentences and that he should press a key immediately after he silently read each sentence. The S was also instructed to try to remember the sentences on the list so that he could recognize them later. The list was composed of 48 SAAD, P, N, and PN sentences in equal numbers. Immediately after the presentation of the fourth list, S was instructed that he was going to see a longer list containing the sentences he had seen on the training list as well as some others. He was instructed to press the key only whenever he thought he recognized a sentence that he had seen earlier. The list was composed of 48 new sentences that were transformed versions of the original sentences. It was predicted in keeping with the new theoretical developments that the order, in terms of increasing latency, of transformation would be P, N, PN. The mean latencies of responses in the case of each of the kinds of transformations presented in the longer list were as follows:

1.	N - PN	.51 sec.
2.	SAAD - P	.71 sec.
3.	P - PN	.98 sec.
4.	P - N	1.46 sec.
5.	SAAD - N	1.59 sec.
6.	SAAD - PN	1.76 sec.

The results showed that the distance between sentences related by the passive transformation was less than the distance between sentences related by the negative transformation. The distance between sentences related by the negative transformation (Nos. 3 and 5 above) was not consistently less than the distance between sentences related by the combination of passive and negative transformations (Nos. 4 and 6). This result did not support the predictions made by the author nor the results of Miller (1962) and Miller and McKean (1964). In each of these two latter studies, described earlier, Ss made the negative transformation consistently in a shorter time than the passive-negative transformation.

Gough (1965, 1966) and McMahon (1963) attempted to apply transformational theory to situations in which semantic and pragmatic variables were at play. Gough and McMahon each asked his Ss to determine the truth value of sentences of the four grammatical types listed above, i.e., SAAD, P, N, and PN.

In Gough's first study (1965) E read to S a sentence such as, The boy kicked the girl, and immediately afterwards presented him with a picture. S had to decide whether the sentence was true or false on the basis of the content of the picture. S indicated his decision by pressing the appropriate one of two buttons. The time measured was from the time the picture was presented until S pressed one of the two buttons. The procedural difference between Gough's first study and his second study (1966) was that in the second study he allowed a period of time to elapse between the reading of the sentence and the presentation of the picture. Gough found an additive effect like that found by Miller (1962) and Miller and McKean (1964)—i.e., the time taken to confirm P sentences added to the time taken to confirm N sentences equalled approximately the time taken to confirm PN sentences. Active sentences were confirmed faster than passive ones, and affirmative sentences faster than negative ones. The interaction between these variables was not significant. Gough's findings indicated, however, that the true-false variable interacts with the affirmative-negative variable, which was interpreted as being due to the rôle of semantic factors. This interpretation was based on the fact that the difference between affirmative and negative sentences that were false was larger than the difference between affirmative

and negative sentences that were true.

McMahon required S to indicate whether a presented sentence was true or false by depressing one of two keys, each of which stopped a timer that was activated when the sentence was presented. His sentences were of the type: 5 precedes 13. McMahon found that Ss made more errors on negative sentences than on passive negative sentences.

The order of increasing mean latency was as follows (from easiest to most difficult):

SAAD

small difference with respect to latency

P

large difference with respect to latency

N

small difference with respect to latency

PN

In veiw of the fact that the present results confirm those of Gough (1965, 1966), it seems plausible that semantic variables as well as syntactic variables affect the understanding of sentences. It is of interest that the two small differences between sentence types in McMahon's study occurred when the types were synonymous—i.e., SAAD and P, and N and PN. McMahon's data also lent support to the idea of a two step process (additivity) in understanding passive negative sentences. He was able to predict quite accurately the response time to passive negative sentences by adding the difference between the response times to SAAD and P, to the difference between the response times to SAAD and N.

SAAD sentences were responded to most quickly and PN most slowly. The semantic variable of affirmation-negation seemed to be more important than the variable of transformational complexity in this case. These findings are congruent with the findings of Wason's experiment, described earlier, with regard to the difficulty of processing information phrased in the negative.

Savin and Perchonock (1965), operating within the revised formalization of linguistic theory, attempted to answer the question, "Do grammatical transformations really 'take up space' in memory?" by using an ingenious "overflow" method. An assumption made in this study was that the greater the complexity of a sentence, as indexed by the number of rules required for its generation, the greater will be the demands it makes on storage. Savin and Perchonock sought to confirm this prediction by requiring Ss to recall both a sentence and a set of unrelated words. In particular, Ss were presented with a sentence followed by a string of eight words, e.g., "Has the boy been hit by the ball? . . . tree, cat, truck, mouth, lamp, rain, short, blue." The S tried first to recall the sentence, then to recall as many of the words as he could. The number of words successfully recalled was the measure of storage requirements for a particular sentence type (always assuming that the sentence was correctly recalled, of course). The more words recalled,

the less the storage requirements for the sentence.

Their findings suggest that those sentences with one transformational operation interfered less with recall of word strings (required less storage) than those with two operations. The SAAD sentence was the least interfering of all. A striking finding of Savin and Perchonock was that a particular transformational operation apparently took the same storage space, whatever other transformations it was associated with, e.g., the question transformation was equally difficult when the SAAD sentence that was transformed to an interrogative sentence was P, PN, etc.

However, the Savin and Perchonock study was repeated by Bates (1968), with the result that Savin and Perchonock's findings were not confirmed. Consequently, it is a moot question as to whether their results were reliable.

Studies by Miller (1962) and Miller and McKean (1964) and all other studies which were conducted prior to 1964, at which time the new theoretical developments in Transformational Grammar mentioned above occurred, were based upon a common set of assumptions which was dictated by linguistic theory.[2] The original theory

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[2]If a grammar is thought of as a scientific theory about the generative competence of speakers of a particular language then, according to Chomsky, "linguistic theory" is assumed to be the metatheory of grammar.

postulated that a single deep structure underlies the simple active affirmative declarative, the negative, the passive, the passive negative, etc., versions of a particular sentence, each being derived from this single deep structure through the application of various transformations. In the case of the SAAD, only obligatory transformations applied; in the others, one or more optional transformations. For example, the same deep structure was presumed to underlie the derived sentences, The boy did not hit the girl, and The girl was hit by the boy, each being derived from this underlying base structure by the optional application of the negative and passive transformations, respectively. The revised theory (Katz and Postal, 1964) postulated that the deep structures underlying the simple active affirmative declarative, the negative, the passive, the passive negative, etc., versions of a sentence are distinct in that each contains markers which "trigger" the application of the (now obligatory) negative, passive, passive negative, etc., transformations.

It will be recalled that such dependent variables as response latency were found to vary as a function of such differences between sentences as that between The boy did not hit the girl and The girl was not hit by the boy. Within the framework of the original theory, it was said that the "speed of understanding" the second

of these sentences was lower because there were more transformations relating the deep structure to it than in the case of the first sentence.

Mehler (1963), whose study was described earlier in this section, obtained results that did not wholly confirm such expectations. Based on the theory of Transformational Grammar, S's recall could typically be described as involving a base form plus a transformational "footnote."

Apart from these findings linguists felt the need for a revised theory in order to eliminate the necessity for the ad hoc restrictions which were imposed in order to prevent the passivization of middle verbs[3] such as weigh, fit, suit, etc. For example, of the two sentences, He weighed ten pounds and He weighed the girl (Wales and Marshall, 1966, pp. 48-49), only the latter may take the passive form, i.e., we can have, The girl was weighed and this sentence can take manner adverbials, but we cannot have the passive form of He weighed ten pounds. In order to get around the ad hoc restrictions, the theory is now formulated in such a way that the passive is regarded as a possible realization of a manner adverbial —any verb that can take an adverb of manner can be

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[3]According to Thomas (1965, p. 122) middle verbs are those transitive verbs which cannot form a passive and also cannot be followed by manner adverbials.

passivized.[4] Thus passives are now generated in the deep structure by labelling "by passive" as adverb of manner and thus the passive transformation is made obligatory in the underlying base structure. An example of the deep structure in such a case is illustrated in Figure 6. An example of the surface structure is illustrated in Figure 7.

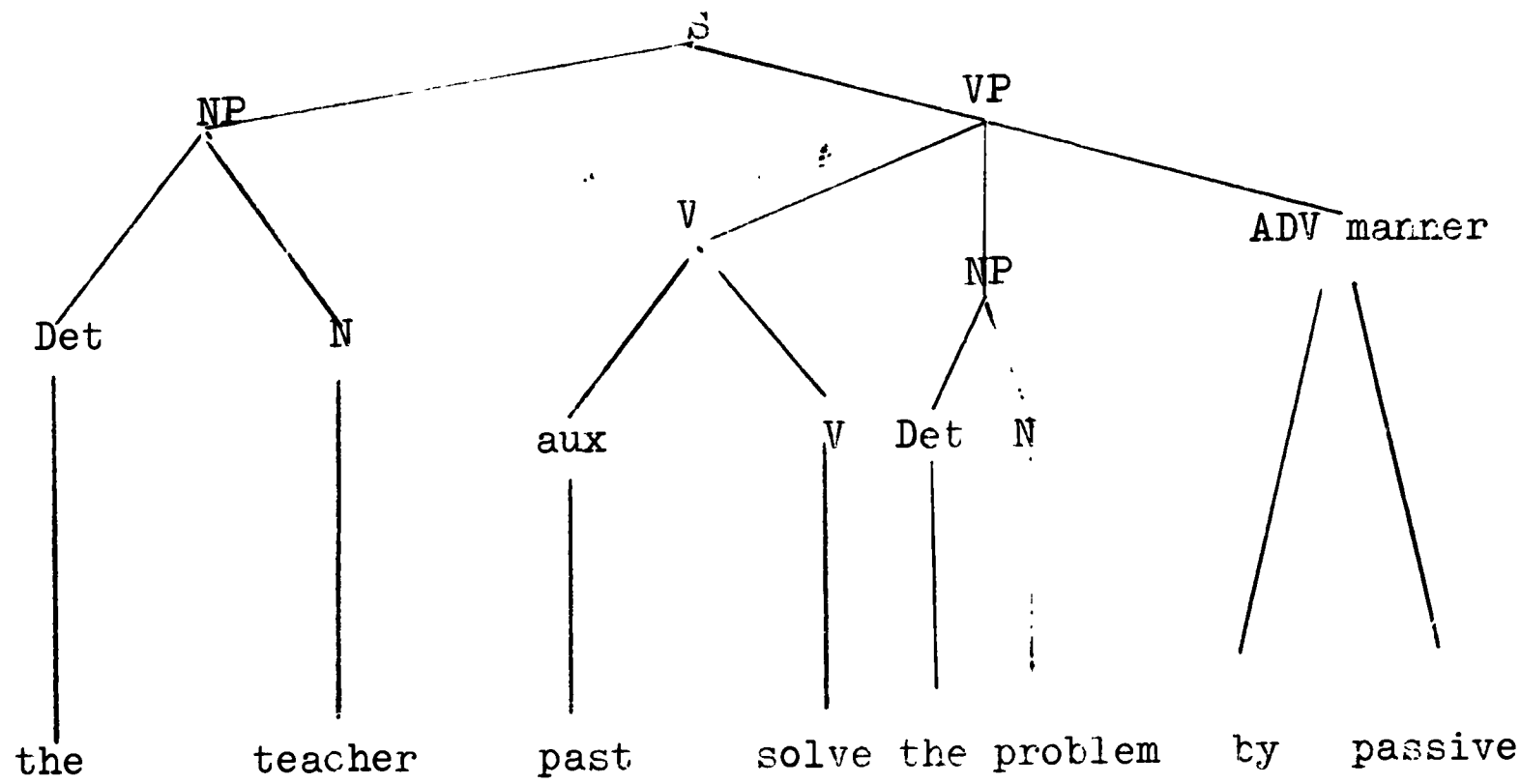

Figure 6. Deep Structure underlying the Sentence, The problem was solved by the teacher.

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[4]The manner adverbials referred to are specifically those which can be paraphrased as "in a 'Adj' manner, (or way)," e.g., "carefully"—in a careful manner, "enthusiastically"—in an enthusiastic manner.

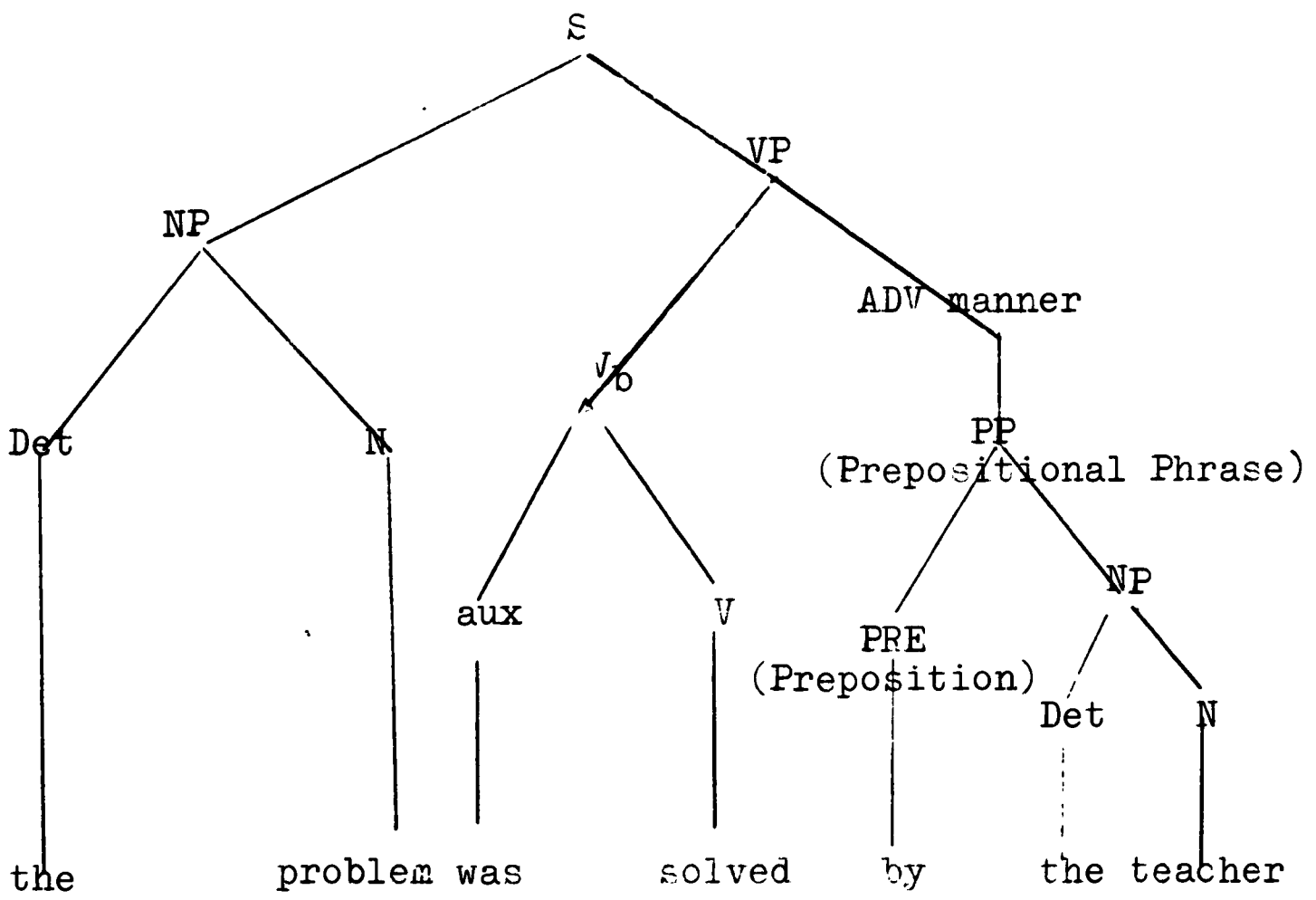

Figure 7. Surface Structure of the Sentence The problem was solved by the teacher.

However, as Wales and Marshall (1966, p. 50) have pointed out, the results of studies that confirmed predictions from the original theory are consonant with the revised theory.

Empirical Implications. As discussed earlier, the transformational theory describes the relation between the deep and surface structures, as illustrated in Figures 6 and 7, respectively, by means of transformation rules. Psycholinguists have treated these relations as constituting a psychological theory of language. To say this is to say in effect that what the linguist refers to as a transformation is assumed for theoretical purposes to correspond

to implicit behavior on the part of speakers of a language that is lawfully related to overt language behavior. Thus one comes to speak of transformations not just as a set of linguistic rules but as implicit behavior on the part of speakers that is reflected in their overt language behavior. Such psycholinguistic implications as that the more complicated a grammatical transformation is, the longer it will take people to perform it, were tested by certain of the studies described above, and the results supported the prediction based on the original theory, that simple transformations (e.g., SAAD to N and P to PN) would require less time than complicated transformations (e.g., SAAD to PN, and N to P). Thus, the use of Transformational theory as a psychological theory has met with some success.

Chomsky (1965, pp. 113-120) has shown that the grammar must specify co-occurrence restrictions in such a way that the subject and object nouns are selected independently and that the main verb is selected in terms of the features of both the subject and object nouns. On the other hand, selection of the subject and object in terms of the verb leads to irrelevant subcategorizations of nouns and complicates the statement of the rules specifying the co-occurrence restrictions. It is of interest to determine whether such an asymmetry in selectional restrictions can be found experimentally.

The primary purpose of the present study is to determine whether certain other analytic differences described in transformational theory are paralleled by certain behavioral differences. Specifically, the primary purpose is to determine whether the different parts of sentences that stand in the subject-verb or verb-object relation to each other are understood with differing speed.

The secondary purpose of the present study is to test the generality of the results of previous studies.

It seems plausible that corresponding to the asymmetrical relations between verbs and nouns there might exist an inequality with respect to the speed of one's understanding of these different parts of a sentence.

We might determine speed of understanding by first showing a person a picture representing some state of affairs and then reading to him a sentence whose truth, relative to the picture, he is to ascertain. We could determine his speed of understanding various aspects of the sentence by having sentences falsify the picture in various ways on different occasions. A major difficulty with this procedure is that the parts of a sentence occur sequentially, and thus one would expect quicker understanding of earlier parts of the sentence. However, by first reading the entire sentence and then showing the picture, this source of bias can be eliminated.

The experimental questions that bear on the primary purpose of the present study are as follows:

1. When a subject is presented a sentence orally and is immediately afterwards presented a picture which may either confirm or falsify the sentence, does his reaction time in ascertaining the truth value of the picture vary as a function of whether the picture falsified the sentence with respect to (a) the subject-of, (b) the main-verb-of, or (c) the object-of the sentence?

2. Does the above relation vary as a function of the nature of the transformation—i.e., is there an interaction between kind of change introduced by the picture and this transformational variable? The experimental question that bears on the secondary purpose of the present study is as follows:

3. Does a subject's reaction time vary as a function of the nature of the transformation?

CHAPTER III

METHOD

Subjects

Twenty-six Ss participated in the experiment. All were undergraduate students of Indiana University.

Materials

The sentences which were verified were 16 in number. They consisted of four SAAD sentences plus the Negative (N), Passive (P), and Passive Negative (PN) transforms of these. The four declarative sentences which were used corresponded to the first four of the eight "events" described in the next paragraph. The four sentences were as follows: The boy hit the girl, The boy kicked the girl, The girl hit the boy, and The girl kicked the boy.

The "events" of the experiment were presented pictorially. Each time an event was presented, it either confirmed or falsified one of the 16 sentences. The events were the possible combinations of a boy or a girl hitting or kicking a boy or a girl. There were eight such events, as follows: A boy hitting a girl; a boy kicking a girl; a girl hitting a boy; a girl kicking a boy; a boy hitting a boy; a boy kicking a boy; a girl hitting a girl; and a girl kicking a girl. An ink drawing of each event and of its mirror image was prepared,

yielding 16 pictures.

Both the sentences and the pictures that were used in the present study were exactly the same as those used by Gough (1965, 1966), although the procedure was different in important respects.

The 16 sentences which were to be verified were paired with each of the 16 pictorial stimuli. However, as Gough (1965) has pointed out, the results of such pairings would be that an affirmative sentence (active or passive) would be confirmed by one event (two pictures) and falsified by three events (six pictures), while the reverse would be true for a negative sentence. To preclude this asymmetry, in the case of each affirmative sentence the same confirmation event occurred three times instead of once. Similarly, in the case of each negative sentence the same falsification event occurred three times instead of once. Hence, both affirmative and hegative sentences were confirmed and falisified the same number of times. For example, in the Appendix, in which are presented four of the sentences that were read, together with some examples of their associated pictures, it will be noticed that pictures No. 2 and No. 3 that were presented following the sentence, The boy hit the girl, were identical with picture No. 1.

Procedure and Apparatus

In brief, the situation for this experiment involved a task in which S compared two successively presented stimuli and indicated whether the second stimulus was "true" or "false" with reference to the first stimulus. S did this by pressing one of two decision buttons, a "true" button or a "false" button. For example, S would hear the sentence The boy hit the girl and then see a picture of a boy hitting a girl. The correct response by S would be to press the "true" button. When the sentence The boy hit the girl was followed by a picture of a boy hitting a boy, for example, the correct response would be to press the "false" button.

The sequence of events in every trial was as follows: (a) the onset of the first stimulus (S_1) (e.g., the tape recorded sentence The boy hit the girl), (b) the termination of S_1 and simultaneously the onset of the second stimulus (S_2) (e.g., a picture of a boy hitting a girl) as well as the starting of a clock); and (c) the button-pressing response, resulting in the clock's stopping. S's decision time, i.e., his latency from S_2 onset to response, was measured to the nearest .01 second.

On each occasion that a picture falsified the just-preceding sentence, the picture was falsified in one of three ways. One way was that the picture was such that its content corresponded semantically to a change in

the noun of specifically that noun phrase [NP] which was the subject-of the sentence. In this case it is said that the picture falsified the sentence with respect to the subject-of the sentence. A second way was that the picture's content corresponded semantically to a change in the main-verb-of the verb-phrase-of (VP of) the sentence. In this case it is said that the picture falsified the sentence with respect to the main-verb-of the verb-phrase-of the sentence. A third change was that the picture's content corresponded semantically to a change in the noun of specifically that NP which was the object-of the VP. In this case it is said that the picture falsified the sentence with respect to the object-of the VP. This yielded for one sentence, e.g., The boy hit the girl, plus its N, P, and PN transforms, 24 pairings of sentences with events. These 24 pairings together with the additional 24 pairings resulting from the use of the mirror images of the events resulted in 24 X 2 = 48 pairings for each of the four simple, declarative sentences together with its transforms. So for all four sentences together with their transforms there were 48 X 4 = 192 sentence-picture items to be presented to each S.

The plan of the experiment resulted in a 2 X 2 X 2 X 3 X Ss factorial design, i.e., True-False X Affirmative-Negative X Active-Passive X Subject-Verb-Object X Ss.

The 192 sentence-picture pairs were presented in the same random order to each subject.

Ss viewed slides projected on a rear-projection screen fixed at eye level in a wall of the experimental room. The subjects were seated at a 30 inch table. They viewed the screen from a distance of approximately 2.5 feet. Two microswitch response buttons were mounted on the table eight inches apart. The right button was to indicate "true," the left, "false." As indicated earlier, Ss were required to press one of the two buttons for each sentence-picture pair in order to indicate whether the picture was true or false with reference to the sentence.

The cubicle in which the experiment took place was dimly lit by a shaded overhead lamp and was ventilated by an electric fan which also functioned to mask extraneous noise coming from outside the experimental environment. All projection, controlling, and recording equipment was located in a room immediately adjacent to the experimental cubicle in which the viewer was located. The experimenter (E) monitored S's performance from the adjacent room via the recording equipment.

Each S participated during a single session, one S at a time. A series of nine practice sentences preceded the 192 trials of the experiment proper. Each S was seated before the screen, and then E read the following instructions:

I am going to show you several pictures on this screen (E points to screen), one slide at a time. Each slide will contain a boy and a girl, or two boys, or two girls, in each case hitting or kicking each other.

Just before I show each slide, you will be read a sentence that has been tape recorded—e.g., the sentence may be The boy hit the girl, or it may be The girl was not kicked by the boy.

After you have heard each sentence and the slide that follows that sentence appears on the screen, I want you to find out as quickly as you can whether the slide is true or false with reference to the sentence you just heard. Whenever the slide is true with reference to the sentence, press the right button (E points to the button). Whenever the slide is false with reference to the sentence, press the left button (E points to the button).

It is important that you press the appropriate button, i.e., the right button for true slides and the left button for false slides (E shows the buttons) each time. But also it is important that you press the button as quickly as you can each time. Do you have any questions? (If questions occurred, E re-read appropriate parts of the instructions.)

Remember that you press the right button for each correct slide and the left button for each incorrect slide. It is important that you press the button as quickly as you can.

So that you can get a feel for what is involved, I am going to give you some practice before you do the actual experiment. Each slide of this presentation is an actual slide of the experiment. You may respond to these practice slides as if it is the actual experiment. After the practice session, I'll ask if you have any questions.

S was then presented nine practice items. After the nine practice items, any questions that S asked were answered by E's re-reading the appropriate parts of the instructions.

During the test series, E paid careful attention to S's performance, noting in particular whether S behaved

in accordance with the instructions. Before the experimental run, E checked directly with the S regarding his understanding of the task. Following the test series of practice items, the experimental run was introduced as follows:

"Are you ready?" Approximately 10 seconds after S indicated that he was ready, the first sentence of the experiment was presented.

The slides were projected on a 6" X 4.5" opaque screen with a Kodak Carousel projector. The presented image of the slide was four inches high.

Sequencing of slide projection was controlled automatically by a Roberts stereo tape recorder connected to the projector via a Kodak Slide Tape Synchronizer. One track of the magnetic tape carried electronically-timed beeps which triggered the shutter mechanism of the projector; the other track carried the sentences for the experiment. Ss were to be given a maximum time period of five seconds to make a response. However, all Ss responded in a shorter time than this on all trials.

The electronic pulse produced by the Kodak synchronizer, which converted the beep to an electronic signal, triggered both the projector and an electronic clock. A delay was built into both systems (projector and clock), because completion of the circuit to the bulb and not the advance of the projector controlled the

image on the screen. Approximately at the time the bulb reached full illumination the clock was triggered. A train of pulses from the clock were counted electronically, and the total number of pulses recorded on punch paper tape. S's response both stopped the clock and turned off the projector bulb. Three trays of slides were used. The first tray included 78 slides (nine slides for the practice session and 69 for the actual experiment), the second included 79 slides, and the third 44 slides. At the end of each tray a break of three minutes was given to each S.

CHAPTER IV

RESULTS

It will be recalled that the primary purpose of the present study was to determine the relative speed of Ss' understanding (a) the subject-of, (b) the main-verb-of, and (c) the object-of a given sentence. Understanding was defined as the determination of the truth-value of a sentence that was read to S in relation to a picture state of affairs that was presented to S immediately afterwards. Speed of understanding was defined as the time between the onset of the presentation of the picture and S's pressing one of two buttons to indicate either that the picture did or that it did not confirm the sentence.

The secondary purpose of the experiment was to test the generality of the results of previous studies that showed an effect on speed of understanding of certain other variables characterizing sentences.

The results that bear on the primary purpose of the study will be presented first. The mean verification time in seconds for each of the three kinds of discrepancies between the semantic content of the sentences and pictures, i.e., discrepancies with respect to the subject, the verb, and the object of the sentences were as follows:

S: 1.33

V: 1.41

O: 1.35

To test the statistical significance of the differences among these means, an analysis of variance was performed. For convenience, each verification time was multiplied by 100. The critical region that was adopted to define the significance of experimental effects in this and all other analyses corresponded to the .05 level of significance. This analysis also included certain other independent variables that will be discussed later. The results of the analysis are shown in Table 1. As shown in this table, the "Subject-Verb-Object" (S-V-O) variable was not significant. Thus, on the basis of the main effect of this variable, we can conclude that there was no evidence that the asymmetry characterizing both the subject-verb relation and the verb-object relation in transformation theory was paralleled by experimental outcomes. However, Table 1 also shows that the S-V-O variable interacted significantly both with the Aff-Neg variable and with the Act-Pass variable.

TABLE 1. ANALYSIS OF VARIANCE OF VERIFICATION TIME AS A FUNCTION OF THE AFFIRMATIVE-NEGATIVE, ACTIVE-PASSIVE, AND SUBJECT-VERB-OBJECT VARIABLES

Source	DF	MS	F
Affirmative-Negative (Aff-Neg)	1	948425.65	51.7745*
Active-Passive (Act-Pass)	1	121541.55	5.7411*
Subject-Verb-Object (S-V-O)	2	102156.16	3.0673
Subjects (Ss)	25	382349.27	
Aff-Neg X Active-Pass	1	21900.62	3.6146
Aff-Neg X S-V-O	2	113098.42	5.8968*
Act-Pass X S-V-O	2	34697.08	3.6394*
Aff-Neg X Ss	25	18318.3739	
Act-Pass X Ss	25	21170.11	
S-V-O X Ss	50	33303.98	
Aff-Neg X Act-Pass X S-V-O	2	10389.70	1.3426
Aff-Neg X Act-Pass X Ss	25	6058.78	
Aff-Neg X S-V-O X Ss	50	19179.30	
Act-Pass X S-V-O X Ss	50	9533.56	
Aff-Neg X Act-Pass X S-V-O X Ss	50	7738.0251	

Table 2 presents the array of mean verification times that corresponds to the various combinations of the variable S-V-O and Aff-Neg.

TABLE 2. MEAN VERIFICATION TIME AS A FUNCTION OF THE AFFIRMATIVE-NEGATIVE AND SUBJECT-VERB-OBJECT VARIABLES

	AFF	NEG
S	1.27	1.39
V	1.38	1.44
O	1.24	1.46

As can be seen from this table, the interaction was a complex one. In the case of affirmative sentences the Verb took longer to be verified than did the Subject or the Object of the sentence; while in the case of negative sentences the Verb took longer to be verified than did the Subject, but the Object took longer to verify than did the Verb. In order to determine for affirmative and negative sentences separately whether there were significant differences as a function of the S-V-O variable, the Duncan multiple range test was applied to the means in Table 2. The results of this test showed that for affirmative sentences the mean verification time where the locus of the discrepancy was the subject and where the locus was the object, the differences were significant from that of the verb. However, for negative sentences none of the differences was significant. So the implication of these results is that the asymmetry is paralleled by experimental findings in the case of affirmative sentences but not in the case of negative sentences.

Table 3 presents the array of mean verification times that corresponds to the various combinations of the variables S-V-O and Act-Pass.

TABLE 3. MEAN VERIFICATION TIME AS A FUNCTION OF THE ACTIVE-PASSIVE AND SUBJECT-VERB-OBJECT VARIABLES

	ACT	PASS
S	1.32	1.34
V	1.36	1.46
O	1.34	1.37

As can be seen from this table, the Verb took longer to be verified both in active and passive sentences. In order to determine for active and passive sentences separately whether there were significant differences as a function of the S-V-O variable, the Duncan multiple range test was applied to the means in Table 3. The results of this test showed that for passive sentences the mean verification time where the discrepancy between sentences and pictures was with respect to the verb significantly greater than the mean verification time where the locus of the discrepancy was the subject and where the locus was the object. However, for active sentences none of the differences was significant. So the implication of these results is that the asymmetry is paralleled by experimental findings in the case of

affirmative sentences but not in the case of negative sentences.

The results that bear on the secondary purpose of the study will now be presented. It will be recalled from the Related Research section that Miller (1962), Gough (1965, 1966), and others investigated the effect on understanding of one or more of the variables True-False, Active-Passive, and Affirmative-Negative. Generally, it was found that true sentences were understood more readily than false one, that active sentences were understood more readily than passive ones, and that affirmative sentences were understood more readily than negative ones. In the present study the mean verification time for each of these types of sentences was as follows:

True:	1.32
False:	1.36
Act:	1.27
Pass:	1.40
Aff:	1.26
Neg:	1.42

To test the statistical significance of the differences between these pairs of means, an analysis of variance was performed. Again, for convenience, each verification was multiplied by 100. The results of the analysis are shown in Table 4. Thus the present results confirm the results of prior studies with respect to these variables.

TABLE 4. ANALYSIS OF VARIANCE OF VERIFICATION TIME AS A FUNCTION OF THE TRUE-FALSE, ACTIVE-PASSIVE, AFFIRMATIVE-NEGATIVE VARIABLES

Source	DF	MS	F
True-False (T-F)	1	479808.17	7.8872*
Active-Passive (Act-Pass)	1	5142704.01	64.167*
Affirmative-Negative (Aff-Neg)	1	8389745.55	101.799*
Subjects (Ss)	1	1918054.43	
T-F X Act-Pass	25	513023.55	8.846*
T-F X Aff-Neg	1	421020.01	2.2728
Act-Pass X Aff-Neg	1	774212.01	16.827*
T-F X Ss	25	48984.25	
Act-Pass X Ss	25	80145.05	
Aff-Neg X Ss	25	82414.27	
T-F X Act-Pass X Aff-Neg	1	1476060.01	27.333*
T-F X Act-Pass X Ss	25	34686.67	
T-F X Aff-Neg X Ss	25	185240.8993	
Act.=ass X Aff-Neg X Ss	25	46009.8591	
T-F X Act-Pass X Aff-Neg X Ss	25	53140.0991	

Table 5 presents the array of mean verification times that corresponds to the various combinations of the variables T-F and Act-Pass.

TABLE 5. MEAN VERIFICATION TIME AS A FUNCTION OF THE TRUE-FALSE AND ACTIVE-PASSIVE VARIABLES

	T	F
ACT	1.23	1.31
PASS	1.40	1.40

As can be seen from this table active true sentences were verified faster than active false sentences. However, passive true sentences and passive false sentences were verified equally fast. This result is at variance with the results obtained by Gough (1965), who did not find an interaction between these variables.

Table 6 presents the array of mean verification times that corresponds to the various combinations of the variables Act-Pass and Aff-Neg.

TABLE 6. MEAN VERIFICATION TIME AS A FUNCTION OF THE ACTIVE-PASSIVE AND AFFIRMATIVE-NEGATIVE VARIABLES

	ACT	PASS
AFF	1.16	1.34
NEG	1.43	1.46

As can be seen from this table, whereas active affirmative sentences were verified considerably faster

than passive affirmative sentences, active negative sentences were verified only slightly faster than passive negative sentences. This result, like those in Table 5, is at variance with the results obtained by Gough (1965), who in this case also did not find interaction between these variables.

Table 7 presents the array of mean verification times that corresponds to the various combinations of the variables T-F, Act-Pass, and Aff-Neg.

TABLE 7. MEAN VERIFICATION TIME AS A FUNCTION OF THE TRUE-FALSE, ACTIVE-PASSIVE, AND AFFIRMATIVE-NEGATIVE VARIABLES

	T		F	
	ACT	PASS	ACT	PASS
AFF	1.07	1.36	1.27	1.33
NEG.	1.40	1.45	1.37	1.48

The results presented in this table can, of course, be described in three separate ways. That is, the manner in which each of the two-way interactions varies from one value to the other of the third variable can be described separately. Let us consider as an example of these three possible interpretations the variation of the T-F, Aff-Neg interaction as we go from active sentences to

passive sentences. For active sentences, true affirmative sentences were verified faster than false affirmative sentences, while false negative sentences were verified faster than true negative sentences. On the other hand, for passive sentences, false affirmative sentences were verified faster than true affirmative sentences, while true negative sentences were verified faster than false negative sentences.

CHAPTER V

DISCUSSION

The fact that only for some types of sentences did the Verb take longer to be verified than the Subject or the Object of sentences makes it clear that meaningful parallels between transformational theory and empirical findings must involve aspects of the theory other than subject-verb and verb-object relations. Specifically, the syntactic and semantic characteristics of sentences that lead us to describe sentences as affirmative, negative, active, passive, etc., must be taken into consideration. We shall now examine the extent to which such characteristics may be meaningfully described as relevant to the verification of different parts of a sentence.

The question arises as to whether subject-verb and verb-object relations are affected by whether a sentence is affirmative or negative. In transformational theory such a difference between sentences is assumed to be paralleled in deep structure by whether the underlying structure has or does not have a negative marker. The subject-verb and verb-object relations remain the same in the two instances. Therefore, it would appear that no theoretical analysis based on transformational theory as it now stands can be made such as to accommodate the experimentally-obtained interaction between the S-V-O and Aff-Neg variables.

Although not reported in the Results section, additional results that are of incidental interest will now be reported and discussed. It was found that the verification times of the subject and the object of active sentences did not differ significantly from the verification times of the subject and the object of passive sentences. This result was in accordance with current transformational theory.

According to Chomsky (1965) a passive sentence such as The boy was hit by the girl has a "grammatical" subject, i.e., the subject with respect to the surface structure (boy) and a "logical" subject, i.e., the subject with respect to the deep structure (girl). Briefly we can say that the actor of the sentence The girl hit the boy and of The boy was hit by the girl is the same, i.e., both sentences have the same deep structure although their surface structure is different. In the present study the verification time for the subject and the object of the sentence in the passive was that of the "logical" subject and "logical" object. Thus, the non-significant difference between the subject in active sentences, as well as between the object in active sentences, and that in passive sentences is consistent with current theory.

Gough's (1965) failure to find an interaction between Aff-Neg and Act-Pass was not confirmed in the present study. Since such an interaction was found in

the present study, the hypothesis that the effects of these variables are additive, i.e., that the understanding of NP (negative passive) sentences requires successive application of the passive and negative transformations was not confirmed. This finding conforms with the revised transformational theory, i.e., with the view that deep structure of a sentence is not a unitary K where optional transformations are applied, but rather consists of a number of separate underlying structures with only obligatory transformations.

Of course, the present study and Gough's study differed procedurally in certain respects. For example, it will be recalled that in the present study on each trial the content of the picture and the content of the sentence differed in only one respect. In Gough's study a sentence was allowed to differ from the picture which followed it in several respects. Conceivably the discrepancy between the two studies may have occurred because of such a procedural difference. If this is so, this discrepancy is reminiscent of the discrepancies within the present study discussed earlier, namely, the fact that in the case of affirmative and passive sentences the verb took longer to confirm than the subject and object, whereas in the case of negative and active sentences the verb did not take longer to confirm than the subject and object. As in the case of that intra-study discrepancy

we may say of the inter-study discrepancy that it would appear that no theoretical analysis based upon the transformational theory can be made such as to accommodate this discrepancy.

As for the three-way interaction between T-F, Act-Pass, and Aff-Neg, this finding, like the finding of the two-way interaction between Aff-Neg and Act-Pass, was at variance with Gough's (1965) results. Again, this discrepancy may be attributed tentatively to procedural differences between Gough's study and the present one. Also, once more we may say that there are no formal distinctions made in transformational theory that are paralleled by the complexities of the experimental results. Concerning this and other failures to find such parallels in the present study, it may be profitable to supplement transformational theory with the psychological theory in order to permit a systematic description of empirical findings. However, such an attempt is beyond the scope of the present study.

Finally, it should be pointed out that two methodological problems arose in connection with the present study. One of these problems was resolved prior to the beginning of the present study. It had to do with possible effects on the relative verification time of the subject and the object of the fact that the difference between the subject-verb and verb-object relations was

reflected in the pictures. That is, the object was always the recipient of the action and the subject was always the initiator of the action. Consequently, any difference between the verification times for the subject and the object could be due to this pictorial difference. Therefore, in the preliminary study S's speed of identifying a given person in the pictures was investigated as a function of whether that person was the actor or the recipient of the action. Results suggested that speed of identification was not affected by this variable.

The second problem is still to be resolved. An implicit assumption that must be true in order that one may say that the results are acceptable is that the visual discriminability of those aspects of the pictures that corresponded to the subject and object of the sentence was not different from the visual discriminability of that aspect of the pictures that corresponded to the verb of the sentence. It is clear that if, for example, S finds it quite difficult to discriminate whether the actor of a picture is hitting or kicking, his verification time will be correspondingly long. The determination of whether such a difference in discriminability exists should be quite easy. Ss could be read the two words boy and girl and then required to indicate by pressing one of two buttons whether a succeeding picture confirmed the words. Similarly, they could be read the word hit

or the word kick and required to indicate by pressing one of two buttons whether a succeeding picture confirmed the word. If the verification times in these two instances were the same, the assumption of equal discriminability would be supported.

CHAPTER VI

SUMMARY

On the basis of the grammatical theory developed by Noam Chomsky, it is reasonable to presume that the different parts of a sentence may not all be understood with equal facility, i.e., with equal speed. One purpose of this study was to determine whether some of the grammatical relations within a sentence were understood more readily than others. Such information supplements other psycholinguistic studies (e.g., Gough, 1965, 1966; Miller, 1962; Miller and McKean, 1964; Slobin, 1963, 1966).

Sentences of varying grammatical form were presented to Ss who were asked to verify them one at a time by comparing the content of each sentence with the content of a picture that was shown contiguously following the sentence. Speed of verification was taken as an index of speed of understanding. On a given occasion, the sentence was either active or passive, affirmative or negative, and confirmed or falsified by a picture. Further, on those occasions when the sentence was falsified it was falsified either with respect to the subject-of the sentence, the main-verb-of the sentence, or the object-of the sentence. Each subject responded on all of the 192 occasions that were arranged. The four independent variables were combined in a 2 X 2 X 2 X 3 X Ss factorial design.

The results showed that the subject-verb and verb-object relations were not significant at the .05 level of significance. Two two-way interactions were found to be significant, namely S-V-O X Aff-Neg, and S-V-O X Act-Pass. The S-V-O variable was found to be significant in part, specifically, in the case of affirmative and passive sentences, but not in the case of negative and active sentences. From the present results it would appear that no theoretical analysis based on transformational theory as it now stands can be made such as to accommodate the experimentally-obtained interactions.

The results in general supported those obtained by Miller (1962), Gough (1965, 1966), and others. Active sentences were verified faster than passive, and affirmative sentences were verified faster than negative, in keeping with current trends of the theory.

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APPENDIX

APPENDIX

Below are shown one of the four simple, declarative sentences together with its negative (N), passive (P), and passive-negative (PN) and also the pictures to be used for verification of the sentences. Some examples of the actual pictures are given. In remaining cases a notation indicates the nature of the picture to be used. For example, BHG indicates a picture of a boy hitting a girl, while BKG indicates a boy kicking a girl.

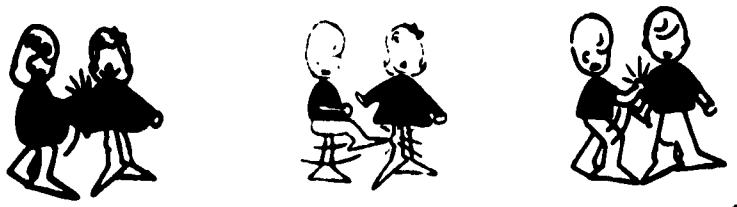
THE BOY HIT THE GIRL

1. True

picture 1 picture 2 picture 3

2. False

picture 4 picture 5 picture 6



picture 7 picture 8 picture 9

3. True
Mirror

BHG BHG BHG

picture 10 picture 11 picture 12

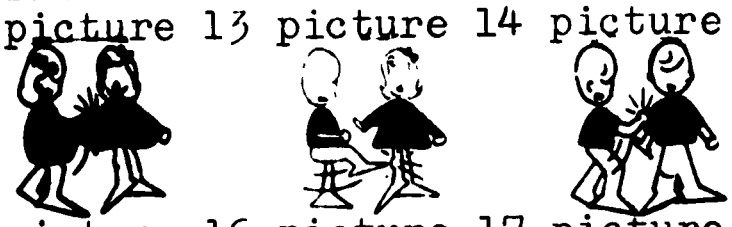
4. False
Mirror

GHG BKG BHB

(N) THE BOY DID NOT HIT THE GIRL

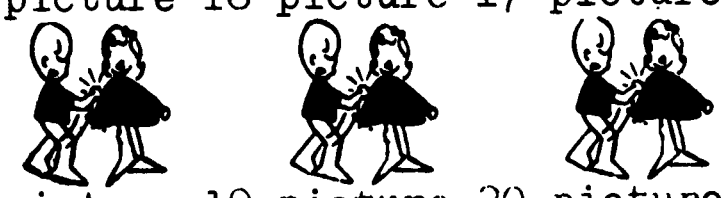
1. True

picture 13 picture 14 picture 15



2. False

picture 16 picture 17 picture 18



3. True
Mirror

picture 19 picture 20 picture 21

4. False
Mirror

picture 22 picture 23 picture 24

(P) THE GIRL WAS HIT BY THE BOY

1. True

picture 25 picture 26 picture 27

GH by B GH by B GH by B

2. False

picture 28 picture 29 picture 30

GH by G GK by B BH by B

3. True
Mirror

picture 31 picture 32 picture 33

GH by B GH by B GH by B

4. False
Mirror

picture 34 picture 35 picture 36

GH by G GK by B BH by B

(PN) THE GIRL WAS NOT HIT BY THE BOY

		picture 37	picture 38	picture 39
1.	True	GH by G	GK by B	BH by B
		picture 40	picture 41	picture 42
2.	False	GH by B	GH by B	GH by B
		picture 43	picture 44	picture 45
3.	True Mirror	GH by G	GK by B	BH by B
		picture 46	picture 47	picture 48
4.	False Mirror	GH by B	GH by B	GH by B