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The author has developed a functional model for some aspects of language behavior which attempts to link a number of experimental findings within a relatively simple framework. In this paper the author sets out to "axiomatise some features of the model" (which had its origins in an attempt to account for a range of phenomena concerned with word recognition and production). The model is also compared to Chomsky's "idealized competence model" ("The Formal Nature of Language" in Lenneberg, 1967). The two systems are forced to be compatible in several areas. The author concludes that "Chomsky's grammar, as an axiomatization, appears to be superordinate to both psychological and linguistic theories and in one sense is a link between them." The analysis begun in this paper will be expanded further in "Models for Language Behavior," Allen and Unwin, 1969. (JD)

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CONSIDERATIONS OF GRAMMAR AND COMPUTATION IN LANGUAGE BEHAVIOR[1, 2]

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In earlier papers general considerations of the nature of word recognition and production led to suggestions, in functional terms, of a mechanism within which a wide range of behavior could be encompassed. In the present paper these suggestions are elaborated. Initially an attempt is made towards an axiomatic treatment of the previous formulation. Secondly, the possible nature of the processes involved in the understanding and production of sentences are considered using the simpler model as a basis and taking into account other experimental results and certain classes of linguistic fact. One conclusion of the inquiry is that in the limit it becomes impossible to distinguish between linguistic and psychological models for language and language behavior.

¶1. Over the past few years I have developed a functional model for some aspects of language behavior which has linked together a large number of experimental findings within a relatively simple framework. In this paper an attempt will be made to axiomatise some features of the model.[4] The following symbols will be used in a series of rules:

$\supset$	: when the left hand side of a rule is true or occurs, the right hand side is written or obeyed.
$\rightarrow$	: the variable changes its value and then returns to its original value with certain time characteristics.
(S)	: the operation S is numerical.
+ & >	: have their usual numerical meaning.
N, T^m & T^w	are numerical variables.
V, A, S, M, & W	are symbol types.
i	denotes a numerical unit, a logogen, with which are associated:
$[S_i]$, $[V_i]$, $[A_i]$ & $[P_i]$	: sets of semantic, visual, acoustic and phonological attributes,
M_i	: which can be regarded as identifying a morpheme,
W_i, R_i	: which are coded in phonological units.

For convenience of reference the rules of the system will be listed here. They will be explained and justified in the text in the sections indicated.

Rule 1(a):	$S^m_i \supset (N_i \to N_i + n^m)$	[¶3]
Rule 1(b):	$A^m_i \supset (N_i \to N_i + n^m)$	[¶3]
Rule 1(c):	$V^m_i \supset (N_i \to N_i + n^m)$	[¶3]
Rule 1(d):	$P^m_i \supset (N_i \to N_i + n^m)$	[¶6]
Rule 2:	$(N_i > T^w_i) \supset W_i$	[¶4]
Rule 3:	$W_i \supset R_i$	[¶5]
Rule 4:	$W_i \supset (T^w_i \to T^w_i - t)$	[¶8]
Rule 5:	$I_L \supset (T^w_j \to T^w_j - c)$ [for all j]	[¶9]
Rule 6:	$(N_i > T^m_i) \supset M_i$	[¶10]
Rule 7:	$M_i \supset [S_i]$	[¶10]
Rule 8:	$M_i \supset (T^m_i \to T^m_i + t)$	[¶14]

¶2. The model had its origins in an attempt to account for a range of phenomena concerned with word recognition and production, and its method of functioning will be discussed initially with this as the basis. The notion of "word" is developed further in ¶16.

The idealized situation to be explicated is that when a person, reader, or listener, has been given a certain amount of contextual information[5] and is required to further produce a single word response. This response may be required to match a further "immediate stimulus" in a "Recognition Situation" or may be called for in the absence of any stimuli in a "Generation Situation." Such situations are common in psychological experiments. This simple situation will be discussed first and later related to normal activities of listening, speaking, and reading.

Traditional psychology has related the data from the Recognition Situation to that from a Generation Situation by such statements as "the ease of perception of a stimulus word is determined by its probability of occurrence." However, it should be noted that the responses made in the two situations are identical in all but one respect, the subject always says (or writes) a word and may, in the Recognition Situation, claim he perceived it. The frequency with which the latter claim is made is a function (in a given context) of the clarity of the stimulus (S/N ratio, duration, or contrast); these are, however, the only variables in the situation. It seems reasonable then to assume that the underlying mechanism which determines the production of responses in a given context is identical whether or not a stimulus is present. The correlation between behavior in a Recognition Situation and in a Generation Situation is then solely a consequence of this common underlying mechanism.

When a group of subjects were asked to complete the sentence, "He asked the way to the ... " "station" was a high frequency response and "theatre" a low frequency response. With the sentence "That evening they went to the ..." the two words have the opposite relative frequencies. If another group of subjects is presented with one of these sentences and one of the words is then presented to him under reduced conditions, the likelihood of his response being correct is highly correlated with the probability of the word being given as a response to that context without any stimulus being present.[6]

Granted that we wish to say that the same mechanism is involved in the production of a response regardless of whether a stimulus is present, it is a small step to generalize to all forms of context. Furthermore, it agrees with our intuition to say that it is not the mere production of the response which is vital but what will be termed its "availability." Thus, if I write or say the word "TABLE," or ask someone to free associate to "CHAIR," or to complete the sentence "He put the plate on the ..." or to understand what is meant by "a piece of furniture with a flat top, usually wooden, commonly used for putting things on for the purpose of eating," or if one is shown a variety of objects, photographs, or drawings, the same response is available; it need not be made, however. The common source of the available response is termed a "logogen".

3. The logogen is thus defined as the (numerical) unit at which all information relevant to a single word response converges regardless of the source of the information and from which the response is made available. The relations between the Logogen System,[7] the information sources, and the response mechanism are depicted in Figure 1. The available response enters what is termed an Output Buffer.[8] If more than one response is available they are assumed to be ordered in the Output Buffer.[9] The channel labelled W_i is thus taken as allowing only the serial passage of information.[10]

Insert Figure 1 about here

Whether or not a particular response becomes available is dependent upon the amount of relevant sensory information (and the time available) and also, to a first approximation, independently, upon the amount of relevant contextual information.[11] The contextual information is depicted in Figure 1 as coming from "CONTEXT." Such information will hereafter be termed "semantic" without necessarily implying all or only what is meant by any other use of the term, inasmuch as any such use can be typified completely. With any logogen, i, are then associated sets of attributes

$[S_i]$, $[A_i]$ and $[V_i]$, described as Semantic, Acoustic, and Visual respectively. The occurrence in the logogen system of any one of these attributes results in an event occurring in the logogen _i_. This event is assumed to be a numerical event only and it is assumed that the event is identical regardless of the type of the attribute. The affected variable is called _N_ and we can thus write the rules:

Rule 1(a): $S_i^m \supset (N_i \rightarrow N_i + n^m)$,

Rule 1(b): $A_i^m \supset (N_i \rightarrow N_i + n^m)$,

Rule 1(c): $V_i^m \supset (N_i \rightarrow N_i + n^m)$.

Rule 1(a) says that the occurrence of a member $\underline{S_i^m}$ of the set $[S_i]$ results in the increase of a variable N_i by an amount $\underline{n}^m$. The value of _N_ then returns to its original level with time (see ¶7). It is of course possible (but arbitrary) to define the attributes in such a way that each one has an equivalent effect upon the value of _N_ (and so upon the likelihood of a particular response being available). It is, however, unlikely that such an attribute system would bear much resemblance to any formal semantic system, and it is intended that the present performance model should be capable of incorporating aspects of such a formal system. Thus, Katz proposes a set of semantic markers (distinct conceptual elements) for the word "knife" which includes such entries as [Physical object] and [Blade].[12] The latter would clearly affect the production of the response "knife" more than the former and so the values of _n_ would, in the present formulations differ for these two attributes. At some stage in the development of a formal semantic theory it should be possible to provide a principled prediction about the relative "n-values" of semantic markers.

¶4. Given sufficient information from sensory and contextual sources, a particular response is available. Such an event is described by:

Rule 2: $(N_i > T_i^W) \supset W_i$.

It is assumed that symbols such as $\underline{W_i}$, which represent available responses, are coded in a form related to a series of instructions for the articulation of the word. Since the available response can actually be made, this assumption seems unexceptionable. In fact it will be suggested that the code may be described as phonemic rather than phonetic (¶20).

Conrad (1964) has shown that when subjects are presented visually with a series of six letters, they make errors on immediate recall which are not visual in nature, but what he calls "acoustic." By this is meant that the error matrix correlates highly with the error matrix produced by subjects listening to letter names spoken in noise. Thus, a _C_ will be confused in memory with a _T_ and not with _O_ which more resembles it visually. Since the acoustic coding of the available words, they make errors (up to 25%) when asked immediately to identify the stimulus words from a set which includes the most common associates.[14]

¶6. The precise form of the sensory analysis system does not affect the operation of the central part of the proposed mechanism. There is, however, an implication that the form of the outputs from the Auditory Analysis System to the Logogen System (termed the Acoustic Code) does not contain symbols which could be given a phonetic realization. That is, such symbols could not enter the Output Buffer. This does not preclude the possibility of an objective one-to-one mapping of some features of the Auditory Code onto the Output Code; as symbols, however, they differ. Thus, I would not want to say that the Acoustic Code and the Output (or Response) Code were both "distinctive feature matrices" (Jakobson, Fant, & Halle, 1951; Jakobson & Halle, 1956). In fact the characterization of Distinctive Features has, in this respect, been ambiguous, since the features have been described in terms both of spectral analysis and articulation. It is not meant to imply that dual descriptions are badly motivated, merely that the form of the present performance model expressly distinguishes the Acoustic Code from the Output or Response Code, and does not demand bi-uniqueness between them. The acquisition of one is by no means dependent upon the acquisition of the other; deaf children can learn to speak; an anarthritic child can learn to understand speech (Lenneberg, 1964); the degree of speech understanding in mongoloid children is not correlated with the precision of a child's articulation[15] (Lenneberg, Nichols, & Rosenberger, 1964).

The work of Hubel and Wiesel (1963) has led to an increasing use of generative grammars in attempts to conceptualize pattern recognition with a notion of rewrite rules which combine elements at a particular level into more complex elements.[16] Thus, the processing involved in the recognition of a symbol may be represented by a tree structure. Clowes (1965) develops such a series of rules, termed Picture Grammars, for the recognition of digits. One of the final rules in his system may be written roughly as:

45 degree line + S. limb + N. or E. curve + E. limb = "Two."

Given the presence of the smaller elements, themselves derived from even smaller ones, the machine will then give an output of "2." In one sense the logogen may be regarded as the place where such a terminal rule is written. There is, however, one large difference; rules of the kind described are determinate and an output "2" will only appear if all four of the elements are present; the Logogen System, under certain context conditions, may only require three of them to be present, and in other conditions only two. Thus, an infinite number of alternative rewrite response would require an additional, and apparently unnecessary, series of rules, it is more economic to suppose the code in memory to be "articulatory." Such evidence as is available supports this view (Hintzman, 1965; 1967). The correlation between the two error matrices in Conrad's experiment would be accounted for by the high correlation between articulatory and acoustic descriptions.

¶5. For the moment the form of the symbols from which available responses of the type $\underline{W_i}$ are constituted will be termed the Output Code; this code will be modified on exit from the Output Buffer into a Response Code by rules which can be expressed in general as:

Rule 3: $W_i \supset R_i$.

The purpose of this rule will become apparent when linguistic units above the level of the word are discussed (¶20).

With the rules described to date there is no information in the available response as to the relative contributions of stimulus and context in its production. One justification for such a step is that when listening to a speech stream one is unaware that certain of the words would be unintelligible out of context (c.f., Lieberman, 1963). Similarly if a word is presented visually in a context at an exposure which would be insufficient for the word in isolation, a subject may make a different report about his percept; he may say, "I saw a word" instead of "I saw a flash." It is sufficient in the present model to state that if a sensory analyzer has produced more than a specific output, then a signal is sent to the Output Buffer. Such signals are termed $\underline{v}'$ and $\underline{a}'$ in Figure 1. The presence of one of these signals attached to a symbol $\underline{W_i}$ leads to a response, "I saw (heard) the word."[13]

It might be noted that the question as to whether an available response represents a stimulus is not one which would occur outside philosophical or psychological discussions. In this way Joan of Arc really did "hear" her voices; there was simply an erroneous production of an $\underline{a}'$ symbol. Such information would normally be of no concern to an individual, and could be of little utility, since we habitually are in a situation either of speaking or of listening (or reading). If we mishear a particular word in an utterance due, for example, to incorrect anticipation, we are normally aware of the error only if such a word does not make sense in the light of the following context. Such error detection would not be placed in the Output Buffer.

The suggestion that the logogen contains no information regarding which of Rules 1(a), (b), (c), had been applied gains some support from the observation that if subjects are asked to free associate silently to a list of 12 stimulus rules would be necessary in order to describe all the conditions under which a response may become available. A complete description of a picture grammar could, however, have the status of a competence model for the present performance model. The set of visual attributes $[V_i]$ would also be expected to include elements from other levels, for example, those elements which go to make N-curve, and the value n in Rule 1 would then be a function of the level of the element in the Picture Grammar. There will in addition have to be positional information relative to the beginning and end of a word, since an "initial ascender" attribute, say, will differ in its attribution from "final ascender." Such a problem will face any pattern recognition system.

The Auditory Analysis System is envisaged as operating in a similar way, and the temporal position of the attributes will have to be noted. The system is not committed to analyzing the word in phonetic or phonemic segments, nor is it committed to analyzing in strict temporal sequence, any more than the Visual Analyzer is committed to analyzing individual letters or analyzing from left to right. Errors in visual recognition most commonly have the length of the word correct (Morton, 1964c), and errors in auditory recognition of words commonly maintain the primary stress pattern of the stimulus (Savin, 1963). The problem of segmentation in utterances longer than a word is discussed briefly in ¶17.

¶6a. Although the notion that we recognize words by first recognizing letters or individual phonemes has been rejected,[17] the fact that we can recognize individual letters and that subjects will say, "I couldn't read the word but the first letter was 'P'" must be accounted for. Similarly we can recognize and repeat nonsense syllables written or spoken and repeat part of a half-heard word. In addition, such partial information can be utilized by the Logogen System since, if correct, such information will tend to increase the likelihood of a correct response being made on a subsequent presentation, and if incorrect will reduce the likelihood of a subsequent correct response. Similarly, in the absence of a stimulus, it is in principle possible that instructions "name a small Hebridean island" do not elicit a response, but the additional "with an initial S" would make available "Skye."

Since there are responses corresponding to letters there seems to be no reason for treating them differently from words. Thus, we will say that there are logogens corresponding to letters which make available the letter names. There will not, of course, be a set of semantic attributes relevant to such logogens; they will instead produce attribute symbols for the normal logogens.

The letter names re-enter the Logogen System via a feedback loop from the Output Buffer. This feedback route is necessary in the system for other reasons, notably the fact that given a string of words (such as a telephone number), we can "rehearse" them, "say them to ourselves," an indefinite number of times.[18] Since in rehearsal we have the words available as responses, the present system requires that the appropriate strings pass through the Output Buffer. Since the likelihood of correct recall is reduced if rehearsal is prevented, the Logogen System cannot of itself completely preserve the words in memory.[19] So, it would seem, a feedback loop is necessary. In addition then we will have to specify a set of phonological attributes $[P_i]$ to which the rule will apply:

Rule 1(d): $\supset P_i^m \supset (N_i \rightarrow N_i + n^m)$.

It is left open for the moment as to whether the set $[P_i]$ in this rule represents W_i or R_i; that is, whether or not Rule 3 is applied on exit from Output Buffer (see ¶20). Rule 1(d) does not affect our discussion concerning the relation between the Acoustic and Output Codes. Strings of P-attributes have a different origin and so a different point of entry into the Logogen System from strings of A-attributes.[20]

¶6b. If a letter can re-enter the Logogen System via the Output Buffer it will affect logogens differently depending on the overlap between the phonological description of the letter name and that of the words. Thus, if we asked a subject to provide a word beginning with P (visually presented) it would be expected that the response would be more likely to begin with /pi/ than when the subject was asked to "provide a word beginning with /pə/."

The clear recognition of a letter together with the other letters of a word has a different effect. If a subject is presented visually with txble in a tachistoscope, he is likely to respond with "table," and to claim he saw it. The effect of the x may at the most lead to comments like "there was a hair across the a" (Vernon, 1929). The careful reader, on the other hand, would not at this instant claim that txble could be seen as table, only that it was "table" with an x in place of the a. In general then we would want to say that the clear recognition of a letter, in other words the presence of a V-attribute from the top of a Picture Grammar tree, inhibits any logogen j not including such an attribute in the set $[V_j]$.[21] Thus, we do not claim to perceive "table." This inhibition is short lasting, however, and we are then able to decide what the word might have been. A similar analysis could be applied to partial acoustic information and to the recognition of nonsense syllables. It is suggested that the structure of the system (which might be visualized as a hyperspace with the attribute sets as dimensions) is such that a Logogen for new stimuli (possible with length restrictions) is set up in a single trial. The implications of such a suggestion will be discussed elsewhere.

¶7.[22] Since we can produce a single sound either by imitation, by seeing a printed symbol (such as /m/) or simply by deciding to produce such a sound, there must be some unit capable of generating the instructions for such a production. One possible modification of the system is that such units, termed Articulogens, are placed, as it were, at the exit from the Output Buffer and that they receive additional inputs directly from the Auditory Analysis System (i.e., by-passing the Output Buffer). It is possible that after they have operated (as the final stage in producing a sound) they become inactive for a period of about 1/5 sec.[23] We can now propose a way towards an explanation for the effects of Delayed Auditory Feedback and link such effects to results from experiments on dichotic listening.

It is commonplace that when subjects are performing one task they are less capable of receiving information from an unrelated source. Treisman, (1964a; 1964b) has shown that when one is repeating a passage which is played into one ear, one can retrieve very little information concerning a passage on the other ear. Roughly, the only available information concerns the pitch (and presumably intensity) of the voice and the language of the irrelevant passage--determined perhaps from vowel quality. She further suggests and provides evidence (1960) that the information on the rejected channel is "attenuated," and in general is not available to the system.[24] Whatever the nature of "attenuation" (there are several mechanical ways of producing its effects) it is assumed that its operation is not limited to a single stage.[25]

Now it would be inconvenient in the present system if we monitored our own voices, for the Logogen System would have no means of discriminating between internally generated signals and the auditory feedback. Such discrimination would be necessary because of the interval between a symbol W leaving the Logogen System and the auditory feedback of the production of the word.[26] We have to suggest then that such feedback is normally blocked (or attenuated) from the main body of the Logogen System, to prevent our own responses becoming available for a second time.[27] If this information is fed to the Articulogens they will go to a unit which is inactive, producing effectively a "null" signal if all is well. The only feedback from the acoustic loop then would be concerning pitch, volume, and vowel quality, information which is available from the rejected channel in Treisman's experiments.

If the acoustic feedback is obliterated by loud noise, three things happen. The pitch of the voice rises, the intensity of the voice rises, and the vowel quality changes.

If the acoustic feedback is delayed the same things happen but two additional features occur; vowels are lengthened and (in particular) stop consonants are repeated as if the subject is stuttering.

When the feedback is delayed, however, the symbols arising from certain sounds will arrive at the Articulogens at a time when they have ceased to be inactive. Hence, they will be interpreted as instructions for the articulatory mechanisms resulting in the observed behavior. This line of argument is extremely "strong" as it gives rise to precise predictions. For example, if the theory is correct, long vowels must be affected by delayed feedback more than short vowels.

These proposals also provide a means of describing the abnormality of stutterers, for it is known that delayed auditory feedback can produce temporary alleviation. This seems to indicate that some timing mechanism concerned with feedback is faulty. The only such mechanism in the present model is that controlling the inactive period of an Articulogen. We can then suggest that for certain of these units the inactive period is habitually delayed.[28] This suggestion is also experimentally testable.

¶8. The definition of "→" in (¶1) includes a statement that the changing variable returns to its original value with certain time characteristics. For $\underline{N}$ it is assumed that this delay time is short, otherwise the values of $\underline{N}$ could get out of control in continuous language tasks. It is not sufficient to have a rule restoring the value of $\underline{N_i}$ to zero whenever $\underline{W_i}$ appears, since logogens associated with words which are not available as responses, merely likely in a context or similar to a stimulus word, are continually being affected. Long-term effects may be observed, however, with words which have been available as responses. Thus, incorrect responses in a word recognition experiment are often words which have previously been given as responses (Morton, 1964c). To account for such phenomena there is a rule which has the effect of lowering the threshold of a logogen $\underline{i}$ whenever Rule 2 has been obeyed.

Rule 4: $W_i \supset (T_i^W \rightarrow T_i^W - t)$.

If $\underline{T_i^W}$ returns to its original value it does so with a long time constant. Repeated application of this rule with commonly occurring words will give rise to the word-frequency threshold effect. The short-term effects of word repetition are much greater than the long-term as may be shown by saying "hippotamus" to a respondent (or showing him a picture of one) and then asking for the name of an animal. The immediate experience of "hippotamus" far outweights the long-term experience of "cat" and "dog." The longer the question is delayed, however, the more likely "cat" and "dog" are to appear as responses. Thus, if the reader were now asked "Name an island," the response will be "Ceylon" or "Jamaica" rather than "Skye" which was written above.

¶9. Another feature of the variables $\underline{T^W}$ is that they appear to be controllable from outside the existing system. Thus, a subject may be required to report only what he sees, or thinks he sees. Under such instructions, with unfavorable stimulus conditions, the subject will often have no words available as responses. That is, the conditions for Rule 2 apply nowhere. If, on the other hand, the subject is always required to make a single word response, he can do so and will produce significantly more correct responses than under the more permissive instructions. Within the present system such a finding can be accounted for by a general rule wherein I_L is an instruction from outside the present system:

Rule 5: $I_L \supset (T_j^W \rightarrow T_j^W - c)$ (for all $\underline{j}$).

We can further assume that this rule can be applied repeatedly and that it takes time to apply. (There is no reason not to make such an assumption.) By relating our confidence in the correctness of a response to the number of times Rule 5 has been applied we can give an account of the relationship between confidence ratings of responses and the likelihood of the response being correct, and would predict the result that responses with lower confidence ratings would have longer latencies. A similar system can be assumed to exist in the detection of simple signals, such as pure tones in noise.

¶10. Up to now the rules provide only one exit from a logogen. Such a rule system is clearly inadequate. When subjects were required to read nonsense passages (statistical approximations to English) as quickly as they could, they made large numbers of errors which could only be characterized as grammatical (Morton, 1964b). Thus, personal pronouns were changed or inserted to agree in gender, person, and number with preceding nouns and pronouns, and verb inflections were changed to agree with preceding nouns or verbs. Such forms of error are distinct from errors which could be attributed to the existing rule system (such as repetition and transpositions of words). It seems, then, that even with passages with little structure, not being read with the aim of understanding or memory, the material undergoes some form of syntactic and semantic processing before words are available as responses. This is expressed initially by the rule:

Rule 6: $(N_i > T_i^m) \supset M_i$.

$\underline{M_i}$ is at present envisaged as a symbol string whose components have no significance other than permitting the operation of the following rule which essentially is a dictionary look-up rule.

Rule 7: $M_i \supset [S_i]$.

In Figure 1, which represents an acute simplification, $\underline{M_i}$ is sent from the Logogen System to the Context System where Rule 7 is applied. The set $[S_i]$ i then returned to the Logogen System (where Rule 1(a) will be applied) and will also be used in the more abstract systems. To produce the desired effect the value of T_i^m will normally have to be lower than the value of T_i^w. The sequence of events on the presentation of a stimulus word would thus be:

1. Context and stimulus cause Rule 1 to be applied.
2. Rule 6 applies when $(N_i > T_i^m)$.
3. $\underline{M_i}$ goes to the Dictionary where $[S_i]$ is produced by Rule 7.
4. $[S_i]$ returns to the Logogen System.
5. Rule 1(a) applies increasing values of $\underline{N_i}$ until $(N_i > T_i^w)$.
6. Rule 2 applies making the word available as a response.

It is not claimed that such is always the sequence of events when a subject is recognizing individual words. Once the context system is elaborated, it will, however, make it possible to explain the errors made in reading. Rules 6 and 7 do enable us to discuss certain kinds of context.

¶11. Suppose in a free association task the stimulus word was "cat". Following the application of Rules 6 and 7, the set $[S_{cat}]$ will affect values of $\underline{N_i}$ according to the n-value of the overlap of the sets $[S_i]$ and $[S_{cat}]$. Significant members of $[S_{cat}]$ might include: a. [mammal], b. [domestic], c. [quadruped], d. [furry], e. [allowed indoors], f. [affectionate-independent], g. [non-gregarious], h. [milk:drink relationship], i. [mouse:eat relationship]. The relationship or REL attributes are clearly special cases for the objects of the relationship, in this case "milk" and "mouse", and let us say the n-values are four in such cases compared with unity for all other attributes.[29] The value of N_{mouse} would be increased by seven since [S_{cat}] and [S_{mouse}] share attributes a, c and d, and the REL attribute adds four more. N_{dog} would increase by five (a, b, c, d, and e), and $N_{boa\text{-}constrictor}$ by six (b, e, f, g, h, i). In the latter case, h and i are simply shared attributes and do not define a relationship. If the values of T^w were all greater than seven, then the only way a response could emerge is by repeated applications of Rule 5, lowering T^w until Rule 2 applies, unless information enters the Logogen System by other means (as a result of higher level cognitive processes). If T^m is five or less for all three of the potential responses, then Rule 6 will apply in all cases, three M symbols being sent to the Dictionary, for there is no intuitive reason for making this exit from the Logogen System serial as there was for the exit to the Output Buffer. Rule 7 will then apply to all three M symbols and three semantic sets will be returned to the Logogen System. Which response is made would then depend upon the existing values of T^w and N in the three logogens. In principle it is possible that although "boa-constrictor" has been specified completely by its semantic attributes, the value of N_{boa} will still be less than T^w_{boa}. A situation such as this would characterize those words which were in our recognition vocabulary but not in our production vocabulary. It would also characterize the "tip-of-the tongue" phenomenon where someone knows what a word or name is, has positive information concerning it, but cannot produce it (Brown & McNeill, 1966).

To give an example of such an operation of the system, consider that one intends to say, "The night is stygian," that is, that a complete specification of this sentence in terms of syntax and semantics has been made at the level summarized to date as the Context System. It is possible that we would be able to describe the word "stygian" in all its detail, refer to its connotations and classical origins, but nevertheless be forced to say, "The night is gloomy." Rule 6 has been obeyed but the value of $T^w_{stygian}$ is too high to enable Rule 2 to operate. Since a word has to be produced to complete the sentence, Rule 5 would operate, lowering all values of T^w, and W_{gloomy} would follow from Rule 6 because of the overlap between [$S_{stygian}$] and [S_{gloomy}]. Since other W's could also be produced by such a procedure (for example, $M_{evening}$, because of the overlap between [S_{night}] and [$S_{evening}$]), some operation would have to follow comparing [S_{gloomy}] produced by Rule 7, with the derived semantic specification before the word would be produced.[30]

¶12. The distinction between T^m and T^w also provides us with an explanation for the phenomena of Perceptual Defense. This is the name given to the finding that under certain conditions when taboo or emotionally loaded words are briefly exposed, the subject makes no verbal response, and yet a physiological response may be detected. Although a number of the experiments in this area can be accounted for by merely supposing that the subject did not want to make the response in the experimental circumstances (in present terms the response would be available) it is unlikely that such an explanation will cover all the data (Brown, 1961; Minard, 1965). In the present system all we need say is that $\underline{T}^{w}$ is usually held relatively high for such words so that the production of the semantic set does not cause Rule 2 to be obeyed. One of the semantic attributes of such words would be related to its emotional nature and a simple rule operating on such a symbol would result in a physiological response. In addition, an experiment by Dixon (1958) showed that when subjects are forced to make a response to a subliminal taboo word, this response is very often a word given as a free association to the taboo word. Within the present system there is little difference between these two experimental conditions.

It will be noted that the phenomenon of "perceptual sensitization," whereby under certain conditions the visual duration thresholds for emotional words are lower than would be expected, presents no difficulties. All that need be specified is that some operation external to the system causes the attribute [emotional] to be sent to the Logogen System repeatedly. The nature of the operation is outside the scope of this model; all that we need to state is how it affects the postulated constraints.

¶13. The system also permits an economical description of certain dyslexic symptoms. Marshall and Newcombe (1966) describe one such patient who, asked to read storm, responded "thunder," reading thunder correctly. On another day the error was reversed. The subject was aware that the response was wrong and clearly knew what the stimulus word meant. Such a phenomenon is well known with object naming. To find it with word naming is somewhat more dramatic. In such a situation the value of T^{w}_{storm} must temporarily be effectively infinite, and the string W_{storm} cannot be released. Such a lability in rule specification is reminiscent of those explanations of schizophrenic speech which consider it not to be "random" but to follow from the strict application of semantic rules which are, however, continually changing.

Such an analysis has to account for the fact that, as Marshall and Newcombe point out, the errors which a dyslexic makes in reading do not completely match the responses given in a free association experiment. Notably the dyslexic's errors tend to be synonyms, and are never antonyms, which class of responses is the most common free association. All that is required, we suggest, is that in the free association task a single normally obligatory rule is relaxed. Such a rule should be related to the selection restriction rules in some semantic theories (Katz, 1964) which, for example, state that words containing the semantic marker [non-living] cannot be concatenated with predicate adjectives such as "tired" ("the fire is tired") whose subject nouns must contain the markers [living] and [animal].[31] The rule we require simply states that if a semantic attribute of the form [S-polar$^{K\pm}$] appears in the Logogen System, then all logogens whose set [S_i] contains an entry [S-polar$^{K\pm}$] with the opposite sign on _K_ are inhibited. Thus, the dyslexic will never produce an antonym. In a free-association experiment such distinctions are lifted and so we would expect antonyms to be given frequently as responses since there is complete overlap of the sets of semantic attributes of such pairs with the exception of the _polar_ attribute.

An exhaustive listing of types of polar markers is the province of a formal semantic theory. Some examples will illustrate the kinds of data to be accounted for. The word "coal", for example, will be defined by a series of markers including [black] and [burns]. Those two markers differ in the way that "This coal does not burn" differs from "This coal is white." "Non-burning coal" is a subclass of "coal" whereas "white coal," even if we know that the coal has been whitewashed by order of the camp commander to celebrate the visit of royalty, remains an anomaly, almost a metaphor; we still know it is black underneath. This distinction is perhaps related to the _Evaluation marker_ suggested by Katz. Thus, coal would have a marker termed not [Burns] but [Eval_{use}:(ease of burning)]. Not all examples are as clear cut, however; thus, "dark lamp", "hot snow", and "male woman" are unacceptable, whereas "dim lamp", "warm snow" and "masculine woman" may be used. Thus, with the context "Outside, on that white winter evening, came drifting down the soft flakes of hot _________," "snow" would not be a permitted or possible completion. Although for most people reading such a sentence slowly, "snow" would emerge as an available response, it being defined so clearly, it is eliminated instantly as one reads "hot" almost with a sense of shock. On the other hand, "She was a large, deep-voiced, muscular, strident woman," however, terrifying, would be permitted. Indeed, in spite of the fact that the adjectives would all be marked as extremely masculine in a masculine-feminine Semantic Differential Scale (Osgood, Suci, & Tannenbaum, 1957), the presence of "she" at the beginning of the sentence prevents one from completing it with "man."[32] Thus, since one would want to typify "male-female" as a polar marker, such a marker could not be used in a semantic description of the adjectives in the above sentence. Whatever the Semantic Differential Scale does, it does not provide us with a description of the set of semantic attributes in the sense used in this paper, nor, presumably, of semantic markers in the sense used in formal semantic theory.[33] The action of an opposing polar attribute is clearly related to the action of x in "txble" discussed in ¶6a.

¶14. The method of functioning of a logogen requires one further modification. At present, the recognition of a word requires:

1. Rule 6: $(N_i > T_i^m) \supset M_i$; sending M_i to the Context system.
2. Rule 7: $M_i \supset [S_i]$; returning the semantic description to the Logogen System.
3. Rule 2: $(N_i > T_i^w) \supset W_i$; making the word available as a response.

At Stage 3, however, there is nothing to prevent a further application of Rule 6 continuing the cycle indefinitely. Similarly the system could become unstable in producing alternately two "closely associated" words. Thus, we have to provide some method of damping the activity of the system. The simplest way of doing this is with the rule:

Rule 8: $M_i \supset (T_i \to T_i + t)$.

This rule, proposed for reasons of the dynamics of the system, turns out to have, a posteriori, predictive power, since the value of T_i^m would continue to rise if a word is repeated. Eventually, then, M_i would cease to be produced by Rule 6, and so the semantic description of the word would not be available to the higher cognitive processes.[34] Such, in fact, appears to be the case; the phenomenon being styled "Semantic Satiation."

¶15. The way in which the Logogen System has been described makes a lot of activity possible without there necessarily being any responses available. The values of N will be changed in any logogen sharing any semantic attributes with any word which is recognized or produced and, in spite of the damping rule (Rule 8) there is no reason why several successive applications of Rules 6 and 7 should not be made. Additional information will enter the system from the environment and as a consequence of autonomous activity of the higher cognitive processes. These factors could all result in changes in the values of N which were uncorrelated with the objective features of a psychological experiment. It is by no means unreasonable to assume that samples of these values of N might approximate a normal distribution. Such considerations give us a method of describing apparently probabilistic behavior without recourse to any concept of "random neural noise," and thus, although "chair" is the most common associate to "table," there is no reason to expect it always to be given. We can thus regard the logogens as having the properties of signal detection units and make quantitative predictions about their behavior. In addition, we can decide between a "passive" model of the present kind, where all processing is in parallel, and "active" models which involve the matching of an internally generated signal against the input, such as the analysis-by-synthesis model of Halle and Stevens (1962) and the Motor Theory of Speech Perception (Liberman, et al., 1962). The available evidence almost unequivocally supports the present model (Broadbent, 1967; Morton, 1967a). In addition, predictions made concerning the interaction of stimulus and context information in word recognition, the effects of varying the number of response alternatives and the effects of repeated presentation of a degraded stimulus are all upheld (Morton, 1967b).[35]

¶16. The output from a logogen has been termed simply a "word." Such a statement clearly requires clarification. Initially, I will attempt to define the linguistic unit which is related to a logogen in terms of the way the logogen itself has been defined. Firstly, a logogen is characterized not only by its acoustic attributes, but also by its visual attributes. Thus, we would say that "phrase" and "frays" affected different logogens, and so predict the result that whereas visual presentation of "phrase" facilitates subsequent recognition of phrase, it has no effect on the threshold of frays (Ross, et al., 1956). Secondly, since the set of semantic attributes also defines a logogen we would expect that homographs would also be separated at this level. Such a supposition is supported by an experiment by Marshall (1967), who obtained visual duration thresholds for words of widely ranging frequencies of occurrence, including words such as "chop" and "air" which had at least two very distinct semantic interpretations. Such ambiguous words turned out to have higher thresholds than would have been predicted from their frequencies of occurrence. The Thorndike-Lorge Word-Frequency tables do not list such words by their separate meanings and there are good reasons for supposing the Lorge Semantic Count to be unreliable (Marshall, 1967). Accordingly, Marshall asked other subjects to estimate the relative frequency of occurrence of the different meanings, obtaining a reasonable inter-subject consistency. The frequency of occurrence of the most frequently occurring of the alternative meanings gave a good prediction of the threshold. How large a difference in meaning is required for this to be true is uncertain. A mere verb-noun distinction need not be sufficient.

Further plausible refinements may be suggested which will be amenable to experimental verification. Firstly, for reasons of economy, it is suggested that all inflected forms of a word affect the same logogen. Thus, "walk", "walks", "walked", "walking", and possibly "walker", will all give rise to M_{walk}.[36] The bound morphemes -s, -ed, -ing would then be identified separately, and it would not seem rational to call such identifying units "logogens," for such morphemes are not normally produced as single responses. Similarly it is making no special assumption to state that the units identifying closed class morphemes differ from logogens. In addition such words have thresholds at variance with their frequency of occurrence. Let us suggest then that bound and closed class morphemes are specified somewhat differently on exit from the Logogen System. Specifically, suppose that symbols produced by the closed class and bound morpheme recognizers can be interpreted by a Surface Structure Analyzer. The Logogen System may be called a "Dictionary" for these and only these items, since symbols of the form $\underline{M_i}$ are merely look-up instructions. The Logogen System now produces an output which appears to be the minimum requirement for a surface structure analyzer of the type proposed by Thorne, Dewar, Whitfield and Bratley (1965). In addition to requiring no specification of the nature of open class morphemes, their algorithm assigns structural descriptions to the input predictively as opposed to synthesizing matching comparisons.

The first modification to be made to the flow diagram in Figure 1 then is the insertion of the preliminary surface structure analyzer between the Logogen System and the Semantic Dictionary (i.e., the location of Rule 7). Further modification of the Context System cannot at the moment be made in any detail. It is, however, possible to make some suggestions as to the form of such expansions and to show that the application of the foregoing is not limited to single word stimuli and responses.

¶17. In an earlier paper the notion of an "ideogen" was developed (Morton, 1964b).[37] It is simplest to conceptualize the Ideogen System as a multidimensional tree-like structure with levels roughly corresponding to successive levels of semantic abstraction. Nodes in the structure may be linked with other nodes on any level either via general cognitive processes (as a result of our past experiences and when producing a sentence) or via the surface and deep structure systems in the recognition and understanding of sentences. In the latter case the specification of the nodes and their relationships will have to be provisional and capable of alteration in the light of subsequent information. It is not known how the concepts of a counting variable and a threshold would be applicable to a system of this kind, but, on the hopeful principle that all processes are general ones, an attempt will be made (elsewhere) to so describe this system. For the moment such matters will be left vague (see ¶21).

Consider an incomplete sentence:

They went to see the new ________.

The way in which we complete this sentence cannot be a function of the sentences of precisely this form which we have encountered and produced in the past (Miller & Chomsky, 1963). If our experience of sentences affects our response at all, then clearly contexts of the form

Have you been to see the new _______?

I would travel miles to see the new ________?

Come to the exhibition of new ________!

and even more diverse and expanded forms would exert an influence. Equally, any actual experience of going to see new somethings would affect our behavior. These sentences and events have in common some basic "ideas"; such ideas require a metalanguage for description (i.e., a complete system of semantic attributes), but we can term them for the moment "travelling", "regarding", and "newness". According to the earlier paper, the simultaneous existence of these three ideas in a particular relationship (defined by the deep structure of the incomplete sentence) defined a point in the ideogen space. This point would be linked with other ideogens such as "building" and "art-form" in a way and to an extent determined by higher processes. Semantic attributes characterizing these ideogens would then be sent to the Logogen System and would operate on it in the way already described to make some response available.

In the earlier paper these links were described as "probabilistic" with some implication of a Markovian principle of operation. Such a notion is now expressly rejected. Ideogens are either linked or not. Links are labelled as Basic Grammatical Relationships: Subject-Predicate, Verb-Object, Noun-Modifier, etc. It would be convenient if the highest level of abstraction of an ideogen was that typified by the most general selection restriction rules (Katz, 1964) and "lexical insertion rules" (Chomsky, 1967). Symbols representing this level will be termed Semantic Primitives. An ideogen-level rule could then define potential links between ideogens as any existing at a higher level of abstraction.[38] Considerations of these kinds have the effect of restricting the Ideogen System to discrete operations and its structure must be relatable to formal linguistic constructs. There cannot then be a point in the ideogen space corresponding to the simultaneous occurrence of three distinct concepts. I propose instead that the Ideogen System maps bilaterally onto a General Cognitive System (GCS) in which non-linguistic information is available. The predictive sequence described in the preceding paragraph would reach its "highest" point in the GCS.

If the full sentence "They went to see the new house" was heard, the order of events envisaged would be:

1. The auditory analyzers produce a series of acoustic attributes, not necessarily in sequence (see ¶5).

2. The acoustic attributes affect the logogens, releasing M-symbols. Since the acoustic waveform will be incompletely segmented (and in some cases not at all), there will often be duplicate M's produced. It is tentatively suggested that the surface structure analyzer may be able to exclude the inappropriate ones.[39]

3. Assuming for the moment that the segmentation problem is solved, the surface structure analyzer will mark all open class morphemes with their form class and provide surface brackets.

4. At this stage other similar schemata perform a deep structure analysis on the string which will "assign relational notions over a phrase-structure component such as that given as output by the model in Thorne, et al." (Wales & Marshall, 1966, p. 55). I would like to suggest the possibility that the Dictionary intervenes, replacing all M_i by a labelled dummy in the symbol string and simultaneously releasing the equivalently labelled sets $[S_i]$ for return to the Logogen System and also for processing by the Ideogen System.[40] The reasons for inserting such a process are:

a. Since the surface structure analysis assigns form class entries to the occurrences of M they can be looked up, for noun-verb ambiguities will by then be resolved.

b. It would be useful to have feedback to the Logogen System from the preceding context as soon as possible.

c. The deep structure analyzer input is simplified; semantic information is not required and so the entries may as well be dummy (see ¶21).

d. The simultaneous processing of the semantic sets and of the full surface string permits an explanation of the result of Slobin (1966) who reported that children appear to have special difficulty with "reversible passives" in deciding whether or not a particular statement of a given picture is true or false. Reversible passives, for example, The boy was hit by the girl, caused more difficulty than sentences of the form The engine was repaired by the mechanic. If the semantic component were analyzed separately, then the engine-repaired-mechanic will be non-ambiguous[41] and can be evaluated without recourse to the deep structure analysis. The set boy-hit-girl on the other hand would be ambiguous and could be misinterpreted. Alternatively such ambiguous structures may require that the deep structure analysis is completed and the additional information deriving therefrom used to resolve the ambiguity. Thus, either the reversible passives would take longer to evaluate or they would produce 50% errors. Wales and Marshall (1966) propose an explanation whereby "The boy...hit...the girl is semantically well formed. (The implications of was and by are accordingly not explored.) The engine...repaired...the mechanic is semantically deviant and hence forces consideration of was and by in order to extract a non-deviant reading for the sentence node" (p. 71). They would then predict that the reversible passive would always be misinterpreted but would be reacted to more quickly than the non-reversible passive which would always be correct! In addition they imply that the Ideogen System derives ordered (i.e., relational) information from the surface structure whereas in the alternative explanation such information could only be derived from the deep structure, or from the underlying structure of the Ideogen System. We suggest then that the Ideogen System derives unordered semantic information from the surface structure (including, of course, noun, verb, adjective labels), and if the resulting set is unambiguous will not use deep structure information.[42] If the set is ambiguous, then relational information will have to be derived from the deep structure.

Since the set man-house-build-young is not in this sense ambiguous (there is only one way in which the set can be structured) whereas the set man-house-build-large is ambiguous, we would expect to find performance measures to distinguish between sentences of the form

The young man built the house

and

The large man built the house.

18. The sequence of events for the production of a sentence is much clearer. It would begin by the representation of an "idea" originating in the GCS mapped onto the Ideogen System. This representation would consist of a series of labelled ideogen outputs (of any degree of semantic specificity) together with their logical relationships. The deep structure system would have an input of these relationships together with labelled dummy entries.[43] From the relational information it would then compute the appropriate deep structure using the labelled dummies; the complex semantic sets could be entered then, or, in the interests of economy, such a procedure could follow application of the transformation rules. We would then have a string comprised of labelled brackets and semantic entries, the latter completely or only partially specified.[44] This string enters the Logogen System, where the semantic entries behave in the way already described, being replaced by phoneme strings, $\underline{W_i}$, which enter the Output Buffer. The brackets pass straight through the system and do not affect the logogens (which, of course, only accept semantic attributes from that input). Three rules would seem to suffice to preserve the order of brackets and entries in the passage through the Logogen System and into the Output Buffer, these rules being applied cyclically.

1. Admit all opening brackets unless one of the set [X] occurs.
2. Admit the next $\underline{W_i}$ from the Logogen System.
3. Admit all closing brackets.

The set [X] includes <u>be</u>, -<u>ed</u>, etc., to allow the correct passage of strings such as

$$[_S[_{NP}[_N \text{ John}]_N[_{NP}\ [_{VP} \text{ be + -ed } [_{ADJ}\text{sad}]_{ADJ}]_{VP}]_S.$$

One further restriction is required, that in the production of a sentence the semantic entries (i.e., groups of attributes) only enter the Logogen System one at a time. The next one must wait until an output has been acknowledged. This is necessary to prevent the phonemic descriptions of the morphemes emerging in the wrong order. Since the initial semantic specifications are not required to be exhaustive, and since the values of $\underline{T}^W$ for many of the logogens may be high, it may occasionally take some time (relatively speaking) for a particular word to emerge.

It should be noted that the method of selecting semantic entries to initiate a sentence is not the same as Skinner's (1957) suggestion that in the composition of a sentence, a set of "key responses" (nouns, verbs, adjectives) is first selected and that the sentence is constructed on the basis of these words. Chomsky has criticized this suggestion:

> "One might just as well argue that exactly the opposite is true. The study of hesitation pauses has shown that these tend to occur before the large categories--noun, verb, adjective .... Insofar as hesitation indicates ongoing composition (if it does at all), it would appear that the 'key responses' are chosen only after the grammatical frame" (1959, p. 54).

The present system allows (indeed requires) the selection of key responses before the grammatical frame, but granted that these responses are initially specified semantically and need not be specified completely, we can still have hesitations before the large categories (if indeed the measured hesitations do indicate ongoing composition).

There is nothing in the present model to prevent recursion or embedding. The ideogen space is conceived of as multidimensional and there are no inherent limitations on the number of ideogens which can be simultaneously active or on the extent of their relational interconnections. Indeed, a greater problem may turn out to be getting such a device to produce a simple sentence.

The production of a sentence was described above as a unitary, sequential operation. There seems to be no reason for restricting ourselves in this way, nor for ignoring the possibilities of feedback. To take a simple example, the utterance of the set stone-broke-window could be either active or passive without a change in meaning. How then can we describe the occasions on which these two forms appear? One possibility is that the first of the two nouns to be available as a response becomes the surface subject, and the decision to use the active or passive form is determined by feedback from the phonological system to the deep structure system from whence the appropriately transformed string proceeds for completion. As we have seen, one potent influence on the availability of a response is whether or not the response has recently been available. Thus we would say

I saw the window. The window was broken by the stone.

or

I saw the stone. The stone broke the window.

rather than

I saw the window. The stone broke the window.

or

I saw the stone. The window was broken by the stone.

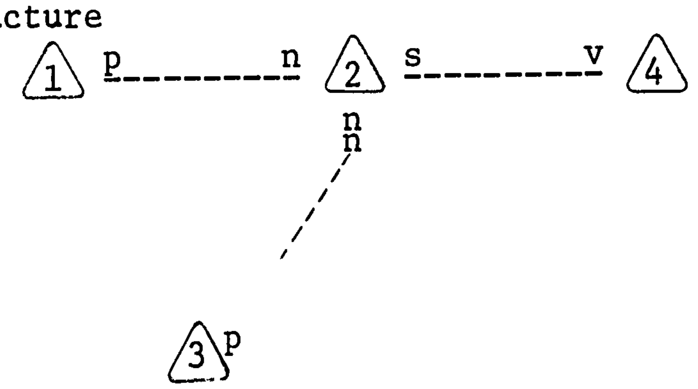
This form of inter-system feedback is not in fact necessary. If ideogens operate in a manner similar to the logogens, then we can propose that the order of processing within the deep structure system is determined by which labelled dummy (and its relational notation) is first "available"--in a sense analogous to the availability of responses. As such labelled dummies become available they enter a Deep Structure Buffer and will be processed in an order in part dependent upon availability and in part upon the relational marker. Thus following the question "Is he thin?" the order of availability of the ideogens might be <u>thin</u>--labelled $\triangle 1\ {}^{P}2$, <u>man</u>--labelled $\triangle 2\ {}^{N}1$, <u>man</u>--labelled $\triangle 2\ {}^{N}3$, <u>tall</u>--labelled $\triangle 3\ {}^{P}2$, where ^{N} and ^{P} stand for Noun and Predicate. $\triangle 1\ {}^{P}2$ could not be processed until $\triangle 2$ appeared, but $\triangle 1$ would be processed before $\triangle 3$ leading to the reply "The man was thin and tall." Such a system is prolific in predictions.

The above analysis accepts the transformational view that concatenated adjectives are derived from deep structure representations of the pair of sentences "The man is tall" and "The man is thin" from a linear sequence of a form equivalent to [(the man (the man is tall) is thin)]. In a performance model, the requirement of linearity at a level corresponding to deep structure can be abandoned, and an intuitively more plausible system substituted. This would have the dummy corresponding to <u>man</u> labelled $\triangle 2\ {}^{s}1 + {}^{s}3$. In fact it becomes easier to conceptualize operations in the deep structure store as being multidimensional, and we could represent the sentence under discussion as

$\triangle 1\ \underline{p}\text{----}\underline{n}\ \triangle 2\ \underline{n}\text{----}\underline{p}\ \triangle 3.$

Both the underlying sentences are represented in the above diagram in the form of the links marked n-----p. There is however only one symbol corresponding to "man," and consequently no need to introduce a deletion transformation in the derivation of the resulting sentence. (Though some other equivalent operation will be found to be necessary when the model is fully described. This operation would act at the time of deriving a linear string from the multidimensional structure.)

This form of representation also makes it easier to understand in what sense in a performance model the phrase "The tall man" could be derived from a deep structure representation of the sentence "The man is tall." If we have the structure



where s and v correspond (provisionally) to Subject and Verb and $\triangle 4$ represents "run," the resulting sentence will be "the tall thin man is running." The links corresponding to "the man is tall" ano "the man is thin" are intact in the structure corresponding to the more complex sentence.[45]

It is clear that considerations of these kinds lead to predictions of differences between different kinds of transformations which have been treated by some psycholinguists as being equivalent. (The fact that linguists treat them in some ways as equivalent is beside the point; there can be a formal similarity between processes with functional differences.) The knowledge that a sentence occurred in a passive transformation is clearly of no concern to any part of the system beyond the deep structure analysis system (except in the case where this information is required in order to disambiguate a reversible passive) because the primacy information (what Halliday would call the "theme") is preserved in the order in which the relevant morpheme symbols arrive at the semantic tree, and so in the order in which relevant information is passed onto the Conceptual System. The same is clearly not true of Negative and Question sentences; in these cases the form of the sentence is essential for a complete semantic interpretation, and the transformational information must be preserved and sent on to the Conceptual System. Thus we should not be surprised to discover behavioral differences corresponding to different transformations.

The form of the model is given in Figures 2 and 3.

Insert Figures 2 & 3 about here

¶19. There has just appeared an article by Chomsky (1967) in which an "idealized competence model" or "grammar" for language is characterized in some detail.[46] While, in Chomsky's words, "It would be tempting, but quite absurd, to regard (the particular model of competence) as a model of performance as well" (p. 435), there are certain points of correspondence between his grammar and the performance model developed above. These points cover the types of operation involved in production and perception of speech and their sequence of operation and the kinds of symbol string upon which these operations are performed.

The general structure of Chomsky's grammar is depicted in the diagram.

$$\begin{tikzcd} & & \text{Semantic Representation} \\ {} \arrow[r, "B"] & \text{Deep Structure} \arrow[ur, "S"] \arrow[dr, "T"'] & \\ & & \text{Surface structure} \arrow[r, "P"] & \text{Phonetic representation} \end{tikzcd}$$

B represents the base rules, and the mapping operations $\xrightarrow{S}$, $\xrightarrow{T}$, and $\xrightarrow{P}$ are carried out by the semantic, transformational, and phonological components of the grammar respectively.

The base system has two parts, the *categorical system* and the *lexicon*. The categorical system is a context-free phrase structure grammar which produces a terminal string made up of dummy symbols, $\triangle$, "grammatical elements" such as *be*, *of* and *past* and appropriate bracketing (representing the Phrase-marker or P-marker). At this stage a sample string might be

$$[_S[_{NP}[_N \triangle\ ]_N]_{NP}[_{AUX}past]_{AUX}[_{VP}be\ [_{ADJ} \triangle\ ]_{ADJ}]_{VP}]_S$$

The rules of the categorical system define basic grammatical relations such as Subject-Predicate and Verb-Object. The next stage is the insertion of *lexical entries*. These are sets of features--phonological (mainly *categorical distinctive features* which are binary in form) and semantic (a "dictionary definition"), together with syntactic features which operate to determine the places within a P-marker at which a particular lexical entry may replace a $\triangle$. The string may now look like

$$[_S[_{NP}[_N(John)]_N]_{NP}[_{AUX}past]\ _{AUX}[_{VP}be[_{ADJ}(sad)]_{ADJ}]_{VP}]_S$$

where (*X*) represents a lexical entry. This string is the Base P-marker, the deep structure which determines the semantic interpretation following application of the semantic component of the grammar ($\xrightarrow{S}$ in the diagram). The restrictions upon lexical insertion are sometimes narrow. Thus only a limited class of verbs can replace an occurrence of $\triangle$ dominated by V when this occurrence of V is followed in the VP by: [NP[of NP]]. Thus we can form "...persuade John of the fact" but not "...dream (see, annoy) John of the fact" (p. 425). In addition, though this point is not mentioned in the article being described, there will be restrictions upon lexical entries contingent upon the semantic features of those entries already inserted to prevent such sentences as "The stones live." Thus the grammar will have to specify an ordering of the replacements of the dummy symbols $\triangle$.[47] The complexity of the rules for lexical entry, operating as they do on the whole P-marker and not just on terminal, or other symbols, characterizes them as transformational rules. They are, however, distinct from the transformational component of the grammar which converts the base structure into the surface structure in the usual way. Bracketing is preserved in the surface structure as certain syntactic information is required for the phonological stage. In fact, the surface structure contains all information relevant to phonetic interpretation. In addition to the bracketing the surface consists of formatives and junctures. The formatives are matrices of binary categorical features (carried through from the lexical entries) including diacritic features which essentially indicate exceptions to rules. The junctures are of two types illustrated in:

What # disturb-ed # John # was # be-ing # dis-regard-ed # by # every-one

and are themselves a set of features. The rules of the phonological component convert this specification into a more detailed specification in terms of integers in which the value of each segment with respect to the phonetic features (for example, tongue height, degree of aspiration, etc.) is indicated. The phonological rules also change values, insert, delete, and rearrange segments to produce the complete phonetic representation.

¶20. The foregoing is of course only a sketch of Chomsky's competence model, but nevertheless describes all the essential types of string and operation. As he points out repeatedly, such a model must be sharply distinguished from a model of performance (production or perception) which, however, "will have to *incorporate* the theory of competence--the generative grammar of a language--as an essential part" (p. 436, my italics). There is no clear statement made as to how the grammar would recognize sentences ideally, and from the definition of a grammar: "A grammar generates a certain pair of sets (*s*, *I*), where *s* is a phonetic representation and *I* is its associated semantic interpretation" (p. 398), there is little indication that it is intended to, in a performance sense. One possibility is that starting from a phonetic description all the rules could be reversed to attain the semantic representation and the generative rules and lexical entries from which the phonetic description could have been derived.

Chomsky implicitly rejects such a viewpoint as far as a performance model of perception is concerned. In discussing one aspect of the phonological component he writes:

> "There is little doubt that such phenomena as stress contours in English are a perceptual reality .... There is however little reason to suppose that these contours represent a physical reality .... We might propose that the hearer uses selected properties of the physical signal to determine which sentence of the language was produced and to assign to it a deep and surface structure. With careful attention he will be able to 'hear' the stress contour assigned by the phonological component of his grammar, whether or not it corresponds to any physical property of the presented signal. Such an account of speech perception assumes, putting it loosely, that syntactic interpretation of an utterance may be a prerequisite to 'hearing' its phonetic representation" (pp. 413-414).

In addition he remarks that the phonological component "should provide whatever information is necessary to determine how the signal may be produced, and it should at the same time correspond to a refined level of perceptual representation" (p. 403).

Such notions appear to correspond to the view expressed above that "perception" can be defined within the system in terms of what have been called "available responses," together with some signal denoting that the sensory analyzers have been producing relevant information.

In ¶4, "perception" was defined as a response being available together with a signal indicating that one of the Sensory Analysis Systems had been active. This would locate the event at the entry to the Output Buffer. Most certainly it has to take place after application of the rules of the phonological component in Chomsky's grammar. Of the rules of the present model, Rule 3 ($W_i \supset R_i$) is the only one which could correspond. This rule is located at the exit from the Output Buffer.

Let us say then that the code of $\underline{W_i}$ is equivalent to a phonemic code, the categorical distinctive features and diacritic features of Chomsky's lexical entries. This will be the form of the symbol string in the Output Buffer; what has been called the Output Code. This string is then converted to a phonetic code (the Response Code) either inside or on exit from the Output Buffer by rules of the form of Rule 3 generalized to segments of any length.

This specification appears to be testable. Suppose, for example, a list of singular and plural nouns and verbs were presented visually for immediate recall or for reading at high speed. There will be errors made in the number of some of these words. If these errors result from ordering errors in the Output Buffer, then we would predict:

1. If the code is phonemic: equal confusion between /s/, /z/ and /əz/ types of plural and none between verb and noun endings.

2. If the code is phonetic: minimum confusion between /s/ and /əz/ types of plural and maximum confusion between similar noun and verb endings. Similar predictions would be made about the assignment of past to verb forms.

21. The present model and Chomsky's grammar are compatible with respect to the types of symbol string which are required and the types of operation required to convert one symbol string into another. The differences are differences which are to be expected from the nature and objectives of the two formulations. For purposes of comparison Chomsky's grammar will (illegitimately) be regarded as a model.

1. Chomsky: the lexical entries include:

a. phonological features

b. semantic features

c. syntactic features (lexical entry rules)

Morton: these features are separated:

a. phonological features represent the Output Code

b. semantic features define the nodes in the Ideogen System

c. syntactic features define the types of permitted relationship between the highest levels of the ideogen structure. Ideogens of this level may be termed Semantic Primitives.

2. Chomsky: as the first stage in the generation of a sentence, the categorical system, a part of the Base System, produces a bracketed string of dummy symbols and "grammatical elements" from phrase structure rules which define "basic grammatical relations." Selection of the rules is in part arbitrary (this being a characteristic of a grammar).

Morton: an idea to be expressed originates from the Cognitive System. This idea leads to the specification of ideogens and their relationships. The range of relationships is defined by the types of "basic grammatical relationship" and by which specific ideogens may be linked in which ways (expressing both "syntactic features" and "selection restriction markers"). These permitted relationships are specified by links between the dominating Semantic Primitives. Labelled dummies enter the Deep Structure Buffer, and the rules of the categorical system organize them into a bracketed string in a way partly determined by the order of entry of the dummies.

3. Chomsky: lexical entries replace the dummy symbols taking entry restrictions into account. This produces the base P-marker from which a complete semantic interpretation may be obtained by applying the semantic component of the grammar.

Morton: the string arising from the previous operation has been derived from the originating semantic interpretation and so there is no equivalent stage necessary.

4. Chomsky: the base P-marker is converted by the transformational component into a bracketed Surface Structure. Presumably, the Semantic Features are not present in the Surface Structure string. This string contains all information necessary for phonological interpretation.

Morton: the same rules operate on the string arising from Stage 2. It is not apparent at the moment whether or not the labelled dummy symbols have to be replaced by the semantic attributes which define the original ideogens before these rules operate. It would be an advantage to the machine if the rules could apply first, since the labelled dummies require fewer symbols for specification than the semantic attributes.

5. Chomsky: there is no operation corresponding to the following.

Morton: the bracketed string of semantic entries passes through the Logogen System and phonological (phonemic) entries replace the semantic entries. This string, in the Output Buffer, is identical to the surface structure in Chomsky's grammar.

6. Chomsky: the phonological component produces a phonetic representation.

Morton: the same rules apply on exit from the Output Buffer.

It can be seen that no strain is involved in adapting Chomsky's grammar to the present model. Whether or not the adaptation is justified will depend upon whether or not the basic grammatical relations and the restrictions of lexical entry can be expressed in an Ideogen System of the type described. Beyond this, the present model appears to be indifferent to the detail of the formal rules at any level or to the detail of any formal semantic theory.

The relationship between the model and Chomsky's grammar is not, of course, evidence of its virtue--psychological or linguistic. On the one hand some of Chomsky's notions have been adopted wholesale when the present writer had no original ideas; thus it might be better to say simply that there appears to be no contradiction between the two representations. On the other hand it is possible that a closer study of other linguistic theories may reveal relationships equally potent and may yield techniques which can be adapted into a model of this kind in order to explain features of language behavior not yet covered by generative grammars.

It must be remarked, however, that the nature of other linguistic theories remains obscure. There seems little doubt that this is a function of the purpose for which these linguistic theories were devised. Chomsky's grammar, as an axiomatization, appears to be superordinate to both psychological and linguistic theories and in one sense is a link between them. (See also the Appendix.)

Predictions from the Present Model

1. Predictions have already been made in ¶6b, ¶7, ¶17 and ¶20.

2. The word-frequency threshold effect should be independent of inflections on either the stimuli tested or the units contributing to the effect historically.

3. If compounds such as "police-station" have a double representation in the Logogen System, then experience of such words should affect the availability of the constituents. If not, then not.

4. Free associations should have a faster reaction time to a word generated by the subject himself than to words presented by an experimenter. This would follow since in the former case Rule 5 would have been applied to all the logogens in the first place. In the second case this rule would have to be applied after the stimulus word had been recognized. This prediction would require very careful experimentation.

5. Giving the subject the clue that a word begins with S, for example, should be less effective in a subsequent recognition task than saying that the word begins with /s/.

6. People who use hand sign alphabets should make different kinds of errors in short-term memory from people with spoken language, as their W code should be differently constituted.

7. A subject sh'd find it difficult to rem'ber which w'ds have been abbreviated.

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Footnotes

[1]This is a preliminary version of an article "Grammar and computation in language behavior." In particular the references are incomplete and ¶17 et seq. are subject to severe revision. I am grateful to John Marshall and Roger Wales for their comments on an earlier draft of the paper. The present version has benefited from discussion in a series of seminars I gave at the Center for Research on Language and Language Behavior where this version was written. I wish to state my appreciation of the efforts of the secretarial staff of CRLLB in preparing successive drafts in a very short time.

[2]The theorizing in this article goes far beyond that indicated by experimental evidence. The justification for this is two-fold. Firstly, many of the proposed features are amenable to experimental testing; predictions have been collected and placed at the end of the article; the astute reader should be able to add to the list. Secondly, even though some of the features (or indeed the whole model) might be falsified, or shown to be untestable, I would claim that any model with a hope of representing the activity of the brain has to be at least as complicated as the one proposed here. Models for limited samples of behavior seem to have come to the end of their utility, and simple models do not seem to have much chance of representing behavior outside the experimental situation upon which they were based. Consider, for example, the nature of the mechanism by which someone can say, as someone did, "I've used the word 'transformation' more often recently than the word 'dog' but I know that 'dog' occurs more frequently in the language." The present model is simple-- inded.

[3]A.P.R.U., Cambridge, England. Present address: Department of Psychology, Yale University (until June, 1968).

[4]The analysis in this paper will be extended further in "Models for language behavior," Allen and Unwin (1969). In particular, other models and types of model will be discussed more .horoughly, and problems of the acquisition of language and memory considered in relation to the model.

[5]The notion of "context" will be expanded gradually. Mention of the "Context System" is not meant to imply that types of contextual influence are not distinguished, mere' · that (provisionally) the influence of all kinds of non-sensory context on the Logogen System may be represented by the same kind of symbol. The Logogen System is not, however, the only place in the developed model where context exerts an influence.

[6]There are many other similar experimental results. In all of them it is assumed that the people in the two groups have common linguistic and other experience which leads to similar detail of construction of the underlying mechanisms. There are other experiments showing that differences in interest and attitude affect behavior but these reinforce rather than undermine the present argument. Note that the only sense in which "probability" is used in the paper is to describe distributions of responses; see also the discussion in ¶17.

[7]This system was termed a "Dictionary" in earlier papers. This term has been abandoned since it has unwanted connotations. Thus Wales and Marshall (1966) have incorrectly represented by ideas by assuming that the Logogen System was a "semantic store."

[8]This system has previously been called "Short-Term Memory." Since, however, there appears to be confusion in the psychological literature between Short- and Long-Term Memory as functional constructs and Short- and Long-Memory as a description of experimental conditions, the neutral, and more descriptive name Output Buffer is preferred. See A. D. Baddeley, "Short term effects in long term memory" (forthcoming) for an experimental demonstration of the confusion.

[9]This ordering is not meant to imply strictly serial processing. See ¶17 and ¶20.

[10]This notion proves invaluable in providing an explanation of kinds of interference between relevant and irrelevant sources of information in a variety of tasks. See J. Morton, "Categories of interference: mediation and conflict in card sorting" (forthcoming).

[11]The nature of the independence of sensory and contextual information is discussed qualitatively in a forthcoming paper (Morton, 1967b). It is not meant to imply that one can use the proportion of responses correct when a stimulus alone is present (P_s) and when context alone is present (P_c) to predict performance when both are present by the formula:

$$P_{sc} = P_s + P_c - P_s P_c.$$

Such is not the case.

[12]It is realized that markers are not words but assumed that the relative effects of markers bears some relationship to the relative effects of the words.

[13]The argument here is based on sufficiency; a supporting argument based on necessity would turn on the "perception" of elements not present in the sound wave (cf. Lieberman, 1965, and fn. 18 below).

[14]J. Morton (unpublished data); also fn. 10. Further experiments are in progress investigating similar situations.

[15]Such considerations are discussed in detail in Lenneberg (1967), Chapter 7. Presumably the anarthritic child experiences a sensation which would correspond to "perception" in addition to one corresponding to "understanding." In terms of the present model this requires an Output Code. It would however be irrational to expect the Output Code to contain symbols related to the articulation as is suggested for normal people. Hence we must say that "distinctive features," or whatever other code is used to characterize the Output Code, defined as they must be in terms of articulation (see also Chomsky, 1967, p. 403), cannot of themselves be biological universals. The biological universal must be the potential to create such a system (cf. Lenneberg, 1967, throughout).

[16]Note, however, Lenneberg (1967, pp. 216-217) argues strongly against too literal a use of such findings.

[17]The complete argument against supposing that we recognize individual phonemes in speech recognition would include considerations of the differences in the acoustic manifestations of stop consonants in different vowel environments, etc. (Liberman, 1957).

[18]There are of course limitations on the length of such a string. See Broadbent (1958) and Morton and Broadbent (1964) for further discussion of such feedback loops.

[19]It is not necessary that the subject perform some task which might "interfere" with the memory trace. M. Parlett (personal communication) has shown that if a subject is merely asked not to rehearse there is a memory loss.

[20]Since the recycling of available responses in this way constitutes a special situation, there must in addition be some device for preventing it when it is not desired.

[21]Technically we should say that the value of $\underline{T_i^w}$ has been raised infinitely since "inhibit" properly belongs to a different conceptual system.

[22]Reread fn. 2 before proceeding with this section.

[23]Cf. the operation of Rule 8, ¶14.

[24]Briefly, only those words are repeated from the rejected ear which are highly probable in the context of the preceding words on the accepted ear. Thus we would say that a severely reduced number of A-attributes come into the Logogen System from the rejected ear.

[25]In general I would want to say that all operations are universal. Thus types of transformational operation will be given at least two points of application in the system. (Lenneberg, 1967, argues cogently that they are common to all cognitive processes.)

[26]This interval is necessary for pre-programming the articulators; see Lenneberg (1967, pp. 98-107; cf. also Morton, 1964d).

[27]Counter-arguments based on statements like "Of course we hear our own voice" are invalid in the present system following the way in which "hearing" has been characterized (see ¶5 and ¶20). An observation which may be related to this point has recently emerged in experiments on immediate memory. If a subject is presented auditorily with a list of items to be recalled, the presence of a redundant and irrelevant item in the brief interval between presentation and recall has a particular effect on memory. If instead the subject is required to produce this redundant item in that interval, the pattern of errors in memory is qualitatively different in such a way as makes it unlikely that auditory feedback is the cause of the interference (Crowder, 1967; Morton, 1968).

[28]The variation found in the nature of the phonemes with which a particular stutterer has difficulties can be related to similar variability in other disorders (cf. ¶13).

[29]To the best of my knowledge the concept of a relationship attribute is new and the idea developed elsewhere. Clearly the range of types of such attribute would have to be limited in a meaningful way. One can suggest that they are limited to universal biological relationships--eating, drinking, comfort, enemies. The device does give us an additional means of accounting for free-association data in terms of "semantic competence." There is some discussion among linguists as to whether information of this kind should be included in a formal theory as semantic markers or whether it should be dealt with separately under a category of "knowledge of the world." Ultimately I think it will be necessary to say that while the first of these categories may be systematic and universal and the other unsystematic and ideosyncratic,

they nontheless exert their influence in a similar manner. That which is distinguishable in a competence model is not necessarily distinguishable in a performance model. The notion of "semantic attribute" used in this paper does not correspond to any one formal linguistic category. See Wales and Marshall (1966, pp. 58-68) for further discussion of this area.

[30]Such a comparison would have to go via the Output Buffer and the feedback loop, and an instruction would have to be included by which all other inputs to the Logogen System were blocked while the feedback loop was in operation. Further discussion is postponed.

[31]Note that the metaphor can be considered to gain its force not because it constitutes an exception to such rules, but because it involves their relaxation. Furthermore, the frequency of occurrence of metaphoric statements is irrelevant. However often "The fire is tired" or "The trees are happy" occur, their meaning is still determined in effect by reference to sentences such as "The man is tired (happy)." The fact that selection restriction rules may be called "Rules" does not mean that we are forced to regard them in the same way as any other "Rules."

[32]Examples such as these make nonsense of both linear theories of language behavior and associative theories of meaning. Thus when Howes and Osgood (1954) examine the combination of associative probabilities their reference to the implications of their results for views of underlying "linguistic processes" seems optimistic.

[33]It is trivial that a distinction between sex and gender will not solve the problem.

[34]The repetition of a word could be effected via the feedback loop from the Output Buffer to the Logogen System. If this were the case then we would expect $\underline{T_i^w}$ to <u>fall</u> following repeated application of Rule 4 and the availability of the response made more likely. Such a prediction accords with intuition but no experimental data are at present available.

[35]The papers by Broadbent (1967) and Morton (1967a; 1967b) use the Luce approximation to signal detection. See Green and Birdsall (1964) for a purer treatment of the effects of the number of alternatives.

[36]The original reason for suggesting such a condition was that subjects who were required to read passages of statistical approximations made uncorrected substitution errors such as "Rome" for "Roman" and "disappoint" for "disappointed" (Morton, 1964b).

[37]The term "Thought unit" was used in the earlier paper.

[38]Such a system has no resemblance to that of Osgood (1963); see also Wales and Marshall (1966, pp. 44-45).

[39]Further speculation at this stage is futile, since there are no data available which specify the kinds of ambiguity which must be accounted for at which level of analysis. Some potential "phonemic" ambiguities in the segmentation could be resolved in the Auditory Analysis System, others by the Surface Structure Analyzer. Before using a general explanatory principle of "feedback" from one system to another (as opposed to within a system), the potentials of individual systems must be set against data.

[40]The notion of dummy entries is extended from Chomsky's (1965, 1967) use.

[41]That is, the potential links between the appropriate ideogens, being constrained by the dominating ideogens, are unique. See ¶17.

[42]Note that this is not the same as Mowrer's (1960) suggestion that simple contiguity of words is sufficient explanation for the complex meaning conveyed by a sentence. The sentence Tom is a thief may, very loosely, be said to "condition the meaning" of thief to Tom. Such an attachment in the present model would be brought about by the deep-structure analysis of is. The sentence Tom ate twelve bananas would not have a similar effect since its structure is different and the lexical entry rules in dominating ideogens are also differently structured. See Wales and Marshall (1966, p. 69).

[43]The Ideogen System can be seen to have the function of transferring information between the higher cognitive processes on the one hand and the Deep Structure System and the Dictionary on the other. This idea is expanded slightly in ¶21.

[44]The notion of labelled brackets in a string is taken from Chomsky (1965; 1967).

[45]The method appropriate for distinguishing between the two kinds of linkage in the diagrammed structure is tentative as there appear to be certain similarities between verbs and adjectives. In particular the symmetry of the pair:

The falling leaves are brown
The brown leaves are falling

is persuasive in spite of counterexamples such as

The fallen leaves are brown
The brown leaves have fallen

Since I will wish to relate the kinds of permitted relationships between semantic primitives to what might be called "Cognitive Primitives" or "Cognitive Universals," and since "brown" and "falling" have a similar function cognitively--to discriminate between two types of the same token object--I want if possible to distinguish between verbs and adjectives other than by the type of linkage.

[46]Much of the material in this reference may be found in Chomsky's earlier works. The form of presentation, however, makes it particularly easy to relate to a model of the kind described in this paper.

[47]Chomsky deals with this point in "Aspects" (1965, p. 11 *et seq.*), where he argues that the choice of Verbs and Adjectives must be constrained by the free choice of certain features of Nouns. This is justified in terms of the kinds of rules he uses to deal with selection restriction and the simplicity criterion. However, it seems intuitively desirable to have the sentences

What may frighten the boy?
Who may be frightened by sincerity?
What may sincerity do to the boy?
Sincerity may do what to the boy?
Sincerity may frighten the boy.
The boy may be frightened by what?
Sincerity may frighten whom?
Whom may sincerity do what to?

etc., all derived from the same basic structure in the deep structure store in the present performance model. With the questions a symbol *Q* will have been sent to the deep structure store. At the point of entry of the sets of semantic attributes corresponding to the labelled dummies, one set will be (almost) null. The existence of the symbol *Q* results in the insertion of the *wh*-word, thus distinguishing the situation from the attempted production of "The night is stygian" described in ¶11. The features used by Chomsky in his selection rules may be seen to correspond to the structure of the Ideogen System (or semantic tree); the ordering and type of rule may correspond to the development of this system as the child learns to talk. In performance, then, we can still specify initially (i.e., have as the dominant idea) any element of the sentence without complication.

A Note on Types of Models

Normally only a two-way distinction is made in discussing types of models for language. The distinction between Competence and Performance models has been expressed in the following way. If we consider our ability to perform multiplication, the competence model for this ability would be represented by the set of multiplication tables. The performance model for multiplication reflects the limitations of our memory capacity. Thus we are unable to multiply two five-digit numbers together in our heads; with a pencil and paper, which have the function of increasing our memory capacity, we can approximate to the performance of the competence model.

This two-way distinction does not seem to represent adequately the relationship between a grammar such as Chomsky's and the way in which we actually speak. If we wish to complete the analogy with numbers, then perhaps Chomsky's grammar would be equivalent to a theory of Natural Numbers. There is no theory of Natural Numbers which includes statements such as "two X two = four."

Chomsky (1967, fn. 1) says "The term 'grammar' is often used ambiguously to refer both to the internalized system of rules and to the linguist's description of it." He also makes reference to his grammar as an "idealized competence model." I take such statements to imply the tripartite distinction which is implied by the analogy with the number system. Although we can distinguish clearly between the properties of a grammar and those of the other kinds of models, the distinction between competence and performance becomes rather arbitrary. In general we could say that the competence part of any model for language behavior is that part which bears a formal resemblance to the grammar; in Chomsky's terms it "incorporates" it. The Performance model is a machine for producing utterances using methods that need bear no formal resemblance whatsoever to the grammar and incorporating data irrelevant to the grammar.

Analogies between linguistic theory and general psychological theory seem to be equally confused. Thus, in the classical distinction between learning and performance in animal learning experiments, "learning" does not correspond to a grammar. A grammatical statement about maze-running might include a statement of what is learned (and could be performed) as "turn right at the cross." This remains an abstraction, part of a grammar, as far as the animal is concerned, until shown to be an accurate description of processes (cf. Lyons & Wales, 1966, throughout). Only then can it have a place in a model of learning or a model of performance. In this three-way classification the boundaries between the model types are blurred. Certainly it is no contradiction for a model to contain aspects which belong to all categories.

The following is an attempt to characterize the three types; in many respects it is unsuccessful. I abandon the terms "competence" and "performance" since their application does not seem to represent the distinctions which seem appropriate for this discussion, and will term the three levels Grammar, Category A and Category B.

A Grammar is evaluated by a number of factors among which are:

1. The sentence types produced by the model which are acceptable as "correct" English.

2. The sentence types produced which are not acceptable.

3. The sentence types not produced which should be.

4. Its simplicity; its formal elegance.

A Category A model has the following constraints:

1. It must "incorporate" a grammar; that is, the types of symbol string and the types of operation performed on them must be represented.

2. It must make qualitative predictions about actual behavior.

A Category B model must:

1. "Incorporate" a Category A model; that is, the order of operations in the Category A model must be reproduced. (This is not necessarily the same order as that of the grammar.)

2. Begin to make quantitative predictions.

3. Describe how language behavior can be produced outside the rules of the Category A model.

It is apparent that the model described in this paper is partly Category A and partly Category B and, inasmuch as sets of rules have been adopted in principle from Chomsky, partly grammar. Thus, features of the model cannot all be examined with the same criteria.

One possible way of distinguishing the Category A parts of a model from the Category B parts would be as follows. There are certain limitations to the present model as a Category B model in that it does not describe completely the potentials of the nervous system. For example, an experiment on memory may be such as to permit the subject to remember the total sound pattern, or to remember "word" by "word." Such results could not be used to criticize the present model any more than they could be used to criticize a grammar such as Chomsky's. In that respect the present model has aspects of Category A.

The distinctions made here may not correspond to the distinctions made by other people, psychologists, linguists, or grammarians, who may use the terms. This is obviously irrelevant. It is apparent that the definitions of the terms overlap and any system can contain aspects of all three of the categories which an attempt has been made to distinguish here. Such distinctions can be made for "linguistic" as well as "psychological" theories; at any rate from a psychologist's point of view.

Tentatively I would like to characterize various linguistic theories in the following way:

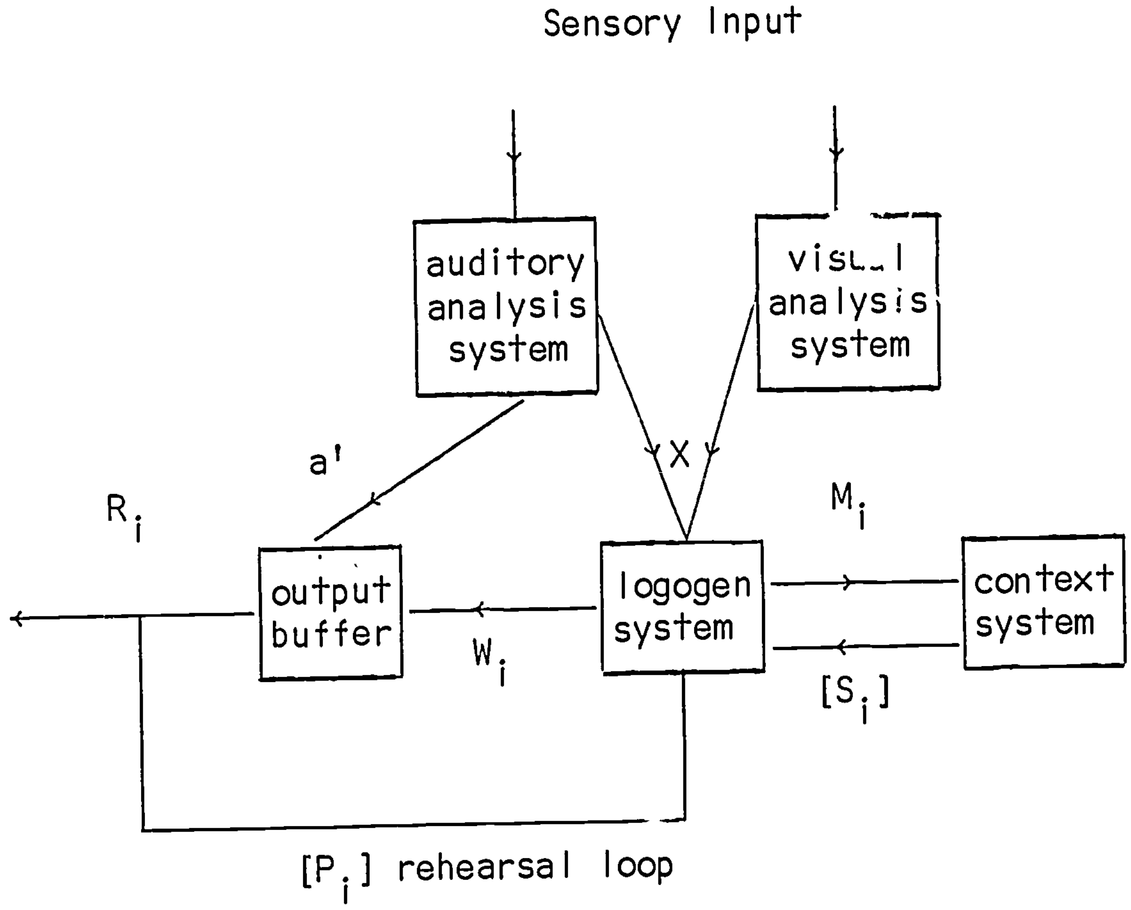
1. Chomsky, Katz, and Fodor; Fillmore; Lamb: Grammar
2. Tagmemics: half Grammar, half Category A
3. European linguistics: half Category A, half Category B
4. Halliday: A Category B model using terms and procedures which are usually restricted to grammars.

These suggestions are put forward purely for discussion. They do help, however, to see the relationship between the linguistic theories and point to the fact that, for example, Marshall and Wales' (Journal of Linguistics, 1966, 2, 181) criticism of Halliday's views is misdirected.

This discussion makes it apparent that whereas Chomsky's grammar is in no sense in competition with psychological models (whether or not they make any reference to him), aspects of other linguistic theories (again, purely from the point of view of a psychologist) do represent alternative models.

On the other hand, some linguists have recently argued in conversation that the ultimate aim of linguistics is to provide a complete description of How man converts sound into meaning and meaning into sound. If this is the case, and it is clear that there is no received opinion in linguistics on this point, then the goals of psychologist and linguist are identical and we must expect successive statements to converge. The relevance of criteria now takes on a temporary nature. At the moment it is irrelevant to exclude generative grammar on the grounds that we cannot produce or recognize infinitely embedded sentences as it is irrelevant to argue whether selection restriction rules operate on a base string or whether they describe the structure of a Semantic Tree. These two alternative statements must be viewed not in isolation but in the context of the systems of which they are part and the immediate aims and uses of these systems. The time may still not be here when we can meaningfully test linguistic theory with psychological experiments.

Simplified Model



X represents sensory attributes

Figure 1

For full explanation see text. ¶1 of the text gives the basic definitions and rules of operation.

The rules are conceived of as operating in the following locations: ("Location" should be interpreted not neurologically, merely functionally; that is, as imposing some ordering upon the operations.)

Rules 1 & 5:	Logogen System
Rules 2, 6, 4, & 8:	Individual logogens
Rule 3:	Exit of the Output Buffer
Rule 7:	Context System

The Recognition of a Sentence

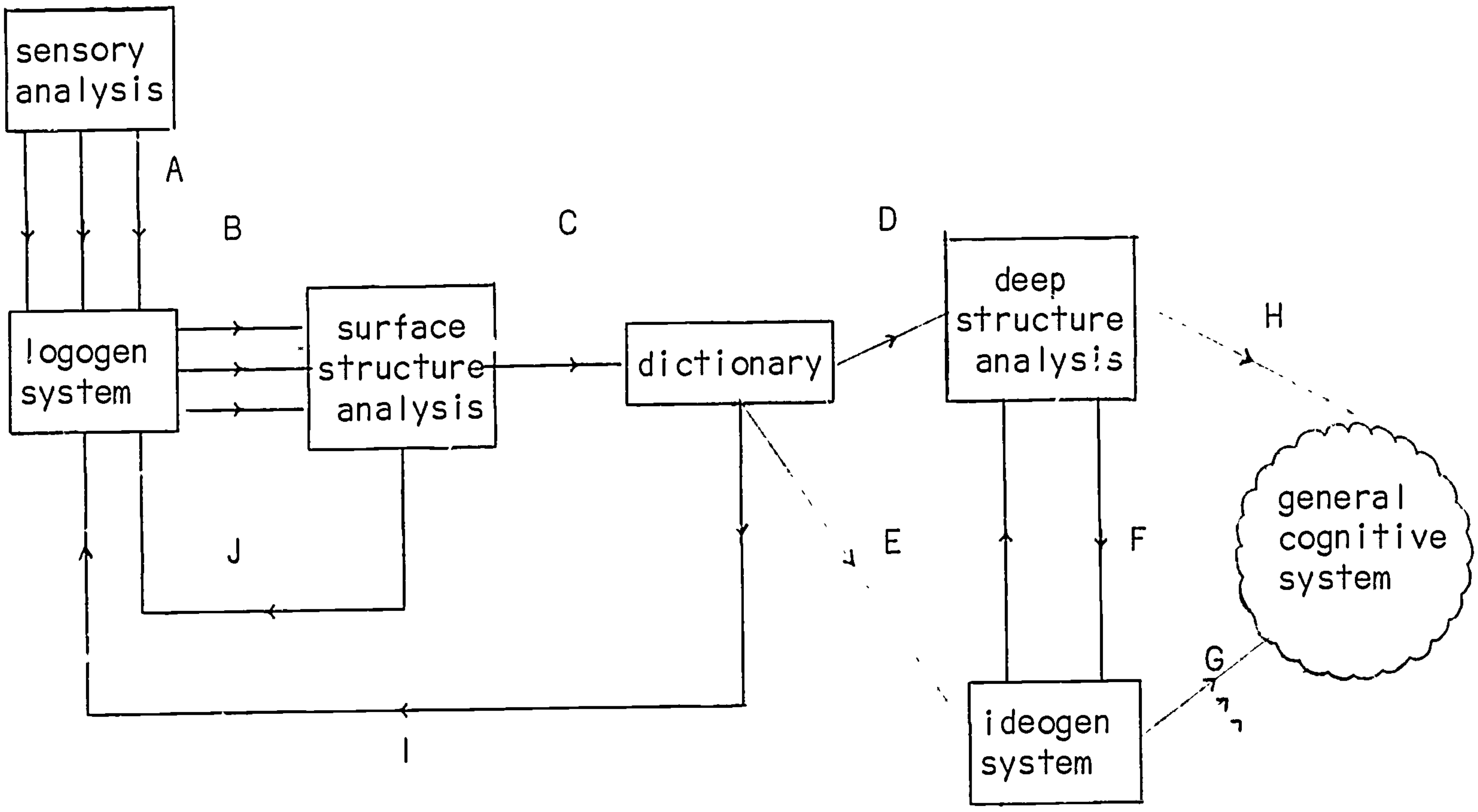


Figure 2

The natures of the strings at the successive stages are:

A - sensory attributes of the form V_i^m or A_i^m.

B - strings of open class morphemes by reference number, M_i, and closed class and bound morphemes specified for interpretation by the surface structure analyzer.

C - as B but bracketed and with form-class labels.

D - as C with M_i symbols replaced by labelled dummies 1.

E - semantic sets $[S_i]$ with labels corresponding to the dummies in D.

F - pairs of labelled dummies with their basic grammatical relationship such as 2 $\underline{v \quad\quad o}$ 5.

G - semantic sets with their basic grammatical relationships.

H - information such as "question."

I - feedback of sets $[S_i]$.

J - feedback of predicted surface types.

The Production of a Sentence

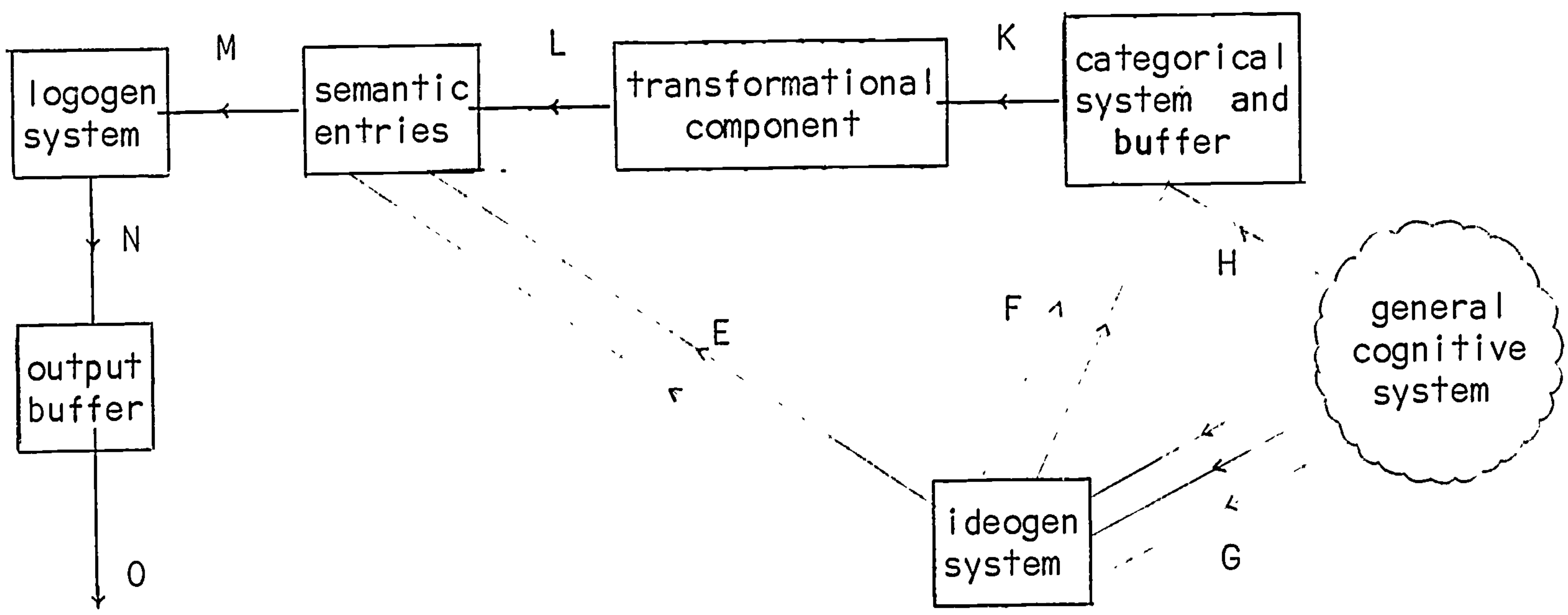


Figure 3

The natures of the strings at the successive stages are:

E, F, G, and H - as in Figure 2.

K - bracketed string with labelled dummies. (The need for this stage is questionable.)

L - as K but with surface structure ordering.

M - as L with dummies replaced by semantic sets of variable specificity.

N - bracketed string of phonemic descriptions.

O - phonetic description.