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ABSTRACT

Differences between formal constraints on a generative grammar and concepts of efficiency in transforming sentences provide different expectations regarding performance measures if the grammar is taken as a psychologically real model. To contrast these views, subjects were given sentences varying in voice, mood, and modality and asked to transform them to various syntactic patterns. Their response latencies were not clearly related to either grammatical or performance model expectations. Error frequencies, however, were related only to the performance model which assumed that subjects transform stimulus sentences directly into response patterns without using a kernel form as an intermediate, linking step. The use of formal grammatical models as if they reflected psychological processes is seen as being of questionable value. (Author)

GRAMMATICAL SIMPLICITY OR PERFORMATIVE EFFICIENCY?

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INTRODUCTION

For more than ten years now the psycholinguistics literature has reflected an active interest in attempts to relate the recent formal grammars of the transformational, generative type to either the psychological status of a user's knowledge of his language, or to the processes which lead to language production. Early attempts began with a strong "direct correspondence" hypothesis suggesting that the various transformational steps in the grammar which related one syntactic pattern to another had direct counterparts in the way users process their language (Miller, 1962; Miller & McKean, 1964).

In terms of linguistic theory, it was claimed that syntactic patterns in English could be "simply" related by postulating a base or kernel sentence form to which various transformation rules might be systematically applied in order to derive (i.e., describe) the various syntactic possibilities. If an active, declarative, affirmative sentence is taken as the null case, i.e., that actual realization of a kernel which requires no major transformations in order to be produced, then the grammar can incorporate transformation rules to passivize, negate, or interrogate the kernel form.

This simplifies a grammar in the formal sense that only one rather than eight syntactic patterns needs to be independently developed in the base. While this is considered to be a strong justification for the system in formal linguistic terms, it is, as Miller (1962, p. 758) noted at the outset:

> ... by no means obvious a priori that the most economical and efficient formal description of the linguistic data will necessarily describe the psychological processes involved when we actually utter or understand a sentence.

The tone of this remark is useful in drawing attention to the fact that there can be fundamental differences between the purposes of psychologists and linguists when they are ostensibly looking at the same phenomenon, but it should also be noted that in it, Miller obscures the important distinction between language process and language product.

Subsequent work followed suit. It seemed to take the grammatical model as a given and the model itself grew from a formal device for capturing the regularities observed in language output to a model of the process which leads to that production. It was suggested, for instance, that sentences are stored in memory in the kernel form plus separate storage of syntactic markers (Mehler, 1963); that sentences occupy space in memory storage as a function of their transformational complexity (Savin & Perchonock, 1965); that complex sentences must be transformed to their kernel forms before they can be understood (Gough, 1965); that a generative grammar indicates how a hearer would understand a sentence (Miller & Chomsky, 1963); etc.

Further research has toned down some of this early exuberance and it is to be hoped that grammatical models - a <u>sine qua non</u> for psycholinguistic research - will be placed in their proper perspective. This will require a recognition that, while the usual concept of a grammar is that it describes what is acceptable in language output, it does no more than to describe those patterns. The problems resulting from the process/product confusion have been recognized in many other areas of psychology and have been pointed out explicitly for this area by Broadbent (1970) but, nevertheless, transformational generative grammars continue to be used as a basis for studies of language processing.

Certainly speakers and hearers require an agreement regarding the semantic import of a set of syntactic patterns (in other words, they must possess functionally equivalent grammars), but once they have agreed upon or learned a system, communication is possible whether the system is elegant or not. Presumably the system that is realized in any particular language will be shaped by the users of that language so as to become, in some sense, efficient and effective, but simplification for use is not necessarily related to simplification of notational schemes for describing instances of that use.

Dinneen (1967, p. 106) has pointed out a basic distinction in grammars which results from differences in the purposes for which various grammars might be written. While most non-linguists relate the concept of grammar to a set of prescriptive rules required in order to speak, read, or write a language, formal linguists view grammars as devices which permit them to speak efficiently <u>about</u> a language. Thus a transformational generative grammar bears little resemblance to the notion of "rules to be learned" in order to speak a particular language. A third, quite different reason for writing a grammar might be to represent what it is that a speaker knows when it is said that he knows a language and how that knowledge is represented in the mind of the speaker. Claims along these latter lines have been made for transformational generative grammars (Chomsky, 1965, p. 4; Pylysnyn, 1972) even though their original development was not for this purpose and the basis on which they were developed is totally inadequate for such claims (Derwing, 1973, Chap. 8).

There are any number of theoretical and practical problems associated with attempts to use formal linguistic models as psychological models to be tested (Watt, 1970). A basic implication of early generative models - that syntax could be usefully described independently of its semantic implications - is immediately at variance with the psychological fact that linguistic stimuli are reacted to primarily in terms of their meaning (lexically and syntactically conveyed) and only secondarily - if at all - in terms of their syntactic form. When subjects are forced to attend to syntactic patterns rather than lexical content, it has been demonstrated that they still respond more as a function of the semantic significance of the patterns than in terms of properties of the patterns as such (Baker, Prideaux, & Derwing, 1973).

Actually, even the early Miller studies (which looked at only six out of 64 possible pairings of syntactic patterns) did not support the original version of a transformational grammar but, rather, were related more to a simple performative notion. Both the initial Miller (1962) study and the Miller & McKean (1964) follow-up suggested, e.g., that to move from a simple negative to a negative-passive required only one transformation. However, in order to perform in strict accordance with the grammar, a subject would first have to detransform the negative to obtain the base or kernel form and then apply the negative and passive transformations to it in order to develop his response. Miller's formulation of the subject's task was a much simpler performative model in which it was assumed that a subject made only those alterations necessary in order to change the stimulus into the response. This position was confirmed by his results; a strictly grammatical model would not have been confirmed.

The present study was undertaken to contrast a more precise version of a transformational grammatical model of syntactic relatedness (treating it as if it were a process model) with a simple, direct performance model for sentence manipulation, and to assess these against data covering all 64 possible combinations of stimulus and response pattern pairings rather than the restricted set considered by Miller. The grammatical model was interpreted here to suggest that the user, in order to pass from one sentence form to another, must reduce a given stimulus sentence to a kernel form and then transform it into a required response pattern. The performance model was established to suggest that the most efficient approach would simply be to transform the stimulus into the response directly. Several alternative models between these two extremes were also examined. Two measures of performance which have appeared often in investigations of this area, response latencies and error scores, were both used to examine the predictive value of each model.

PROCEDURE

Eight sets of stimuli were constructed by selecting systematically overlapping sets of 64 sentences from a list of 128 based on 16 lexically different subject-verb-object strings realized in each of the eight possible combinations of voice (active or passive), mood (declarative or interrogative), and modality (affirmative or negative). Each set contained four instances of each content in different syntactic patterns, and each pattern occurred eight times. Each stimulus pattern was paired with the eight possible response patterns to cover the 64 possible stimulus/response pairs. The sets were randomized for presentation with the constraint that no content or stimulus or response pattern could immediately succeed itself in the list.

A display panel was constructed consisting of three columns of two windows each labelled for voice, mood, and modality. A control console permitted the experimenter to pre-set three two-position switches so that, at the start of response timing, the panel would indicate which of the eight syntactic patterns would be required in the response.

The subjects, 32 male and 32 female undergraduate volunteers, were tested individually, 16 of each sex by a male and 16 by a female experimenter.[1] Eight subjects, four male and four female, were run with each of the eight sentence sets. Each test session was tape-recorded in its entirety to permit computer measurement of response latencies and to permit later analysis of errors, intonational patterns, etc. The tape was started following the general instructions, a few sample trials, and the resolving of any questions the subject had.

For each trial the subject was handed a card containing a stimulus sentence. He read this aloud and, just as he finished, the experimenter depressed a button which simultaneously generated an inaudible start signal on the tape and illuminated the display panel showing the required response pattern. The subject retained the card during the formulation and production of his response so as to avoid extraneous problems due to memory limitations.

The general instructions and practice trials served to emphasize that response times could be obtained only from responses which were syntactically correct and given promptly; to accomplish this, subjects were encouraged to fully formulate a response before beginning to give it. As soon as the subject began his response, the experimenter depressed a button which generated an inaudible stop signal but, if the response contained any syntactic error or noticeable pauses, suggesting additional processing by the subject, that trial was rejected and repeated later on in the session. Response latencies, then, were measured (for correct responses only) from the illumination of the display panel to the <u>beginning</u> of a subject's response.

The response latency analyses were thus based on 4,096 correct response trials, 64 from each of the 64 subjects. In addition to these, 1,261 trials containing syntactic errors were tabulated for analysis. These errors, of course, were due primarily to the pressure on the subject to respond as quickly as possible.

RESULTS

The two basic models, the grammatical model (S>K>P) and the performance model (S>P), were constructed in terms of both the number of transformations (T's) and the number of elementary operations (EO's) which must be carried out in order to change the stimulus form to a given response form either through the kernel or directly. Counts in terms of EO's differ from those based on T's primarily in terms of giving more weight to the passive transformation. Passivization requires five EO's while negation and interrogation require only two each. Each T is simply counted as a unit in the first version, as shown in Table 1; the EO count appears in Table 2, and would more closely represent the "number of things to be done" by the subject if he operated at a less global level than that of transformations. These are formally equivalent to Chomsky's (1965, p. 144) elementary transformations.

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Insert Tables 1 and 2 about here

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Following the grammatical notion that T's are applied to the base form, early work in this area viewed passivization, negation, and interrogation as adding something to the sentence, thereby making it more complex. These happen to be, for English, the overtly "marked" aspects of voice, mood, and modality being considered in these studies. However, in other languages, both forms are overtly or differently marked. As Baker et al. (1973, p. 203) have pointed out:

> ... an English sentence is not either passive or not passive. It is either passive or active, i.e., it must have one or the other voice. Similarly, a sentence must have a mood - most commonly either declarative or interrogative - and a modality, either affirmative or negative. This suggests that, rather than choosing to add a passive transformation or not, the speaker must opt for one or the other positive aspect of voice, and similarly for mood and modality. The choices, of course, are dictated by the speaker's intention to communicate a specific meaning which takes a particular syntactic form in a given language.

Thus it is clearer to view these factors as two-state variables and to represent the stimulus and response patterns as they appear heading the rows and columns of Tables 1 to 3. Such a characterization provides more explicit information on the relatedness of sentence types and it does not, a priori, make one form appear necessarily any more complex than any other. A concept of complexity, from the point of view of the subject, is better established by the data rather than imposed on it.

The 64 response latencies (RL's) were expressed as stanines for each subject in order to normalize their distribution and to eliminate overall differences among subjects since only relative differences between syntactic patterns were of interest here. Mean stanine scores were computed for each stimulus/response pair for the 64 subjects, and the total number of errors committed in handling each pair was tabulated. These are reported in Table 3 as means and as sums respectively.

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Insert Table 3 about here

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In addition to considering the two extreme models - the grammatical and the simple performative one - three others were considered. If the "markedness" aspect of the task were to affect performance, i.e., if adding or deleting markers were the basic task, then it ought to be easier to delete what is present than to think of what must be added to effect a particular change. An add/delete model was constructed by somewhat arbitrarily weighting deletions as 2, 1, and 1 steps for voice, mood, and modality; and additions as 4, 2, and 2 steps. This was developed for both the S>K>R and the S>P paradigms. The final model considered the possibility that a subject might realize that the syntactic form of the stimulus was not really required in the performance of his task, and he might have been able to ignore it completely. If he merely extracted the basic information concerning agent, verb, and object and then expressed these in the required response form, he would be operating in a basic K>R model. However, allowance was made for two steps in order to permit the subject to detect and reverse the positions of agent and object in passive stimuli.

Each of these various "strategy" matrices was correlated with the response latency and the error data as shown in Table 4. In general, the RL data appear to correlate better with a grammatical (S>K>R) model, but the relationship to a performance model (S>R) is also significant. The strongest relationship for the RL data, r = .57 for T's in the S>K>R form, only suggests about 32% common variance - which is not too impressive for a general model in any case.

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Insert Table 4 about here

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Among the models themselves, any S>R pattern would correlate at zero with any S>K>R pattern so the various correlations, within T's or EO's, can be looked upon as independent predictors. The various S>R matrices (and the S>K>R forms), however, are highly correlated (about .99) so that differences among those forms would be difficult to discern. The K→R model correlates strongly with the S→K→R patterns, but near zero with the S→R patterns.

Since both S→K→R and S→R models appeared to be somewhat related to the RL data, either different strategies were being employed for different parts of the problem or significant variation in strategy from subject to subject was being indicated. In an attempt to determine subsets of subjects who might show more consistent strategies, the data were subjected to a hierarchical clustering analysis (Veldman, 1967, p. 308). This indicated five relatively distinct groups with 19, 15, 14, 8, and 8 members respectively. Correlation of each group's results with the models indicated that the first and third groups were best represented by a performance model (r = .60 and .38), while the second and fourth reflected the grammatical pattern (r = .44 and .53). The fifth group showed no significant pattern.

The specific nature of the differences between these groups, though potentially interesting, will not be pursued here. It is hoped that the detailed, subject by subject analyses currently in progress will fully develop these, especially in terms of the kinds of errors committed and how these relate to stimulus and response patterns as well as response times. For the moment it is sufficient to observe that, obviously, no general claims can be made for any of the models examined with respect to the RL data. Further general analysis would be pointless.

Response latencies, of course, have often been criticized and judged to be a poor dependent variable because time can be consumed by so many factors extraneous to the processing to which the scores are being related. A serious effort was made in this study to limit the timing as much as possible to the period in which sentence manipulation was taking place, but full control is clearly impossible. Whatever has been measured was obtained with a relatively high degree of reliability in the sense that the correlation between the mean profiles (64 elements) of two randomly selected halves of 32 subjects each was .809 so that it is not a matter of non-systematic or random variation. It simply appears that time is being given to something other than sentence manipulation as reflected in the models, and different sets of subjects are adding to these basic times in different ways. Precisely what is going on in terms of response latencies is simply not clear at this time.

An obviously less ambiguous dependent variable ought to be the frequency with which errors were committed in changing from one sentence form to another. The models tested basically reflect, in one scheme or another, the number of things to be done in order to accomplish the changes. Clearly, the more things there are to do, the more opportunity for error exists, so error frequency should indicate model adequacy - assuming an appropriate one has been supplied for testing. The reliability of this measure, obtained in the same way as was done for the RL data, was .799, almost identical with the other measure.

Table 4 shows a strong correlation of .81 (66% common variance) between frequency of errors and the S>R (performance) model expressed in terms of elementary operations. Here it seems quite clear that only the performance model is predictive. The error data were submitted to a cluster analysis as was done for the RL data, but here the results indicated only one major group of 51 subjects, a small second group of 9, and 4 others not fitted into either one of these. It seemed reasonable to view the results as reflecting a general or common pattern and to conclude that the performance model would account for the error data.

Several immediate implications follow from this. Firstly, the performance model suggests that the specific syntactic pattern of the stimulus or the response is not the critical variable. (Note that the rows and columns of the S>R pattern in Table 2 all have equal means of 4.5 EO's.) What is critical is mainly the "distance" or number of steps required to change from any given stimulus to any given response. Secondly, there is no indication at all that the subject detransforms to a base form and then builds a response; he simply makes the number of changes called for to change from S to R. Thirdly, the somewhat better prediction in terms of EO's rather than T's would suggest that it is appropriate to view passivization as more than a unitary change from the point of view of the user.

Since syntactic patterns as such do not appear to be critical, it then becomes reasonable to reorganize the data in terms of the types of grammatical changes required, regardless of response pattern, and to examine these across all of the stimulus patterns. The results of such a reorganization are shown in Table 5, and they prove quite inter-

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Insert Table 5 about here

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esting. The data were subjected to an analysis of variance using the 64 subjects as replicates and dealing with the four factors represented in Table 5: the voice, mood, and modality of the stimuli (two levels for each factor), and the types of changes (eight levels).[2]

The results showed a significant difference due to the voice of the stimulus, indicating that passives (742 errors) are, in general, more difficult to deal with than actives (519 errors). This difference would not be predicted by the simple performance model, but this is the only major aspect of the stimulus pattern as such which appears to affect the data. Mood and modality do not. Errors considered as a function of changes show a rather simple, well-ordered pattern. Repetition of the stimulus sentence, the "no change" case, led to no more than an occassional error in responding. Simple mood and modality changes were equally difficult, but voice change was twice as difficult as either of these. The mood + modality change is roughly equal to the sum of these two performed singly. Similarly, voice + mood and voice + modality are equivalent to the sums of their single changes. An additive model does not quite hold for the voice + mood + modality total - a result of about 320 would be expected - but the simplicity of the pattern clearly suggests a rather mechanistic approach to the task quite in keeping with the implications of what has been called here, the performance model.

DISCUSSION

There is no particular need to belabor some of the more obvious criticisms of experiments such as this. It is quite evident, for example, that the subject is not engaged in natural language processing in the sense of discourse, that sentences without a context are, to a great extent, effectively meaningless, etc. These points are clearly recognized just as it is clearly recognized that no current grammatical theory extends beyond the isolated sentence. The motivation for this study was to try to make it clear that the transformational generative grammatical models of formal linguistics have little direct applicability for describing how subjects manipulate sentences. Some linguists, for quite different reasons, would strongly concur with this view.

Many of the earlier psychological studies, however, strongly suggested that the grammatical model characterized the manner in which the subject has organized his knowledge about his language so that, by logical inference, it should govern how he would manipulate linguistic material. No one has overtly claimed that subjects detransform and then retransform sentences as implied here by the S>K>R models, but this position must be recognized as logically connected to studies which claim to have found evidence supporting a generative grammar as a model. Such theories do not provide for any formal mechanism which would permit the subject to move from a given stimulus form to a given response form without recovering the base or kernel form as a necessary intermediate step. If the psychologists cited earlier were not supporting the whole of the theory, then they should have made it clear just what it was they were supporting.

The formal linguist, of course, need not be concerned about the "failure" of his model to predict performance as long as no claims are made about the possible psychological reality of his inventions. Similarly, the psychologist should have very little interest in purely descriptive grammars motivated by non-psychological considerations. However, as soon as a linguistic theory graduates from being simply a theory about the structure of a language (Chomsky, 1957, p. 49) to being a theory of the structure of the knowledge of the user of that language (Chomsky, 1965, p. 4), then adequate psychological justification is required for the acceptance of that linguistic theory. It is no longer sufficient to defend such theories only on purely formal, intrinsic grounds, as is currently the case in linguistics.

Psychologists must become fully aware of the fact that the so-called processes implied by generative grammars are only formal, descriptive devices used to provide economies in notation and representation of the underlying regularities linguists have discovered in language output. As such, the grammar provides a device for assessing the grammaticalness of a given utterance (a test could be made to determine if the grammar would "generate" or incorporate such a string) but there is nothing in this matching process which implies that grammar and user produce the string by the same means.

As far as can be determined, the primary reason which some linguists (e.g., Chomsky, 1965, pp. 18-27; Postal, 1966; Bever, 1970) have given for claiming that their grammars are psychologically real in any sense is that the relations which they have built into the grammar stem from their "intuitions" about their language. Unfortunately, the intuitions of various linguists do not often coincide and the acrimony of the ensuing debates does not instill a sense of confidence in the stability of any given formulation. Spencer (1973) has shown that non-linguists are more consistent in their judgments about language data than linguists are, and he concludes that "...linguists' intuitions should not be uncritically accepted as a secure data base for the derivation of a theory of natural language of the speech community (p. 97)."

Some linguists insist that their theories are, in fact, responsible to empirical, extrinsic criteria, but their use of such terms would appear strange to the non-linguist. Prideaux (1971) has shown that what have been offered as empirical tests are actually only additional formal principles which are not empirical at all. He concluded (p. 345) that:

> ...the effort to make grammars responsible to something external to the formalism of the grammar - a necessary aim if our grammars are ever to be considered as representations of any kind of psychological reality - has, to this point, failed.

When psychologists have attempted, through their methods, to test what they construe as the logical implications of current grammatical theory, if it is taken as a given, the results are, for the most part, equivocal or negative (Watt, 1970).

A review of the quickly growing series of studies which have examined how subjects manipulate language stimuli classified as a function of grammatical properties supports, as this study does, Bever's (1970, p. 342) contention that subjects do, in fact, manipulate linguistically defined structures, but their behavior does not mirror or directly simulate the grammatical processes that relate those structures within a grammar.

The real import of this is the implication that the majority of elements or structures included in a grammar are important as a basis for stimulus and response description or classification of linguistic material, but the so-called processes implied by generative grammars do not govern or describe how users relate those structures. This is so simply because the grammatical processes are processes only by the weakest of analogies; they are merely formal expressions of relatedness imposed upon actually different structures simply because the grammarian chooses to see them that way. No such processes as such have ever been observed in themselves or in their effects.

Many a useful technical term has had its usefulness destroyed when its definition has been permitted to become so broad, so inclusive that it fails to convey any precise information. If the concept of a grammar is not to share this fate, then it should be limited to its essential function within the study of language and psychology. Language is, in fact, systematic and the nature of that system, for any given language, is discoverable and describable if adequate samples of that language are analyzed. The possible descriptions are, by definition, grammars of that language.

If a grammar is to be something more than a mere catalogue of all of the structures observed to occur in the linguistic output with sufficient frequency to justify their inclusion in a grammar, then some attempt at a systematic taxonomy of forms should lead to statements of relationships among structures which will better reflect the systematicity of the language. It was primarily for this reason that the concept of transformation was proposed, and it is precisely these kinds of relations which are called into question here as an adequate basis for representing how users relate the elements of their language. What kind of relationships should be considered? What is the system of language which should achieve expression through them?

In the late 1950's, linguistics was captured by a strong desire to reduce all of language to a meaning-free, formal syntax where the relationships among postulated structures were adjudged to be true or, at least, correct if they were the simplest or most elegant in formal notation. In the 1960's even the strongest proponents of syntax had to recognize the sterility of an approach which was so reductionistic. Some appreciation of the need for semantic constraints appeared, but a somewhat strained attempt to preserve at least the primacy of syntax and the elegant formal systems in which it had been expressed led to an attempted distinction between deep and surface structure (Katz & Postal, 1964; Chomsky, 1965). The 1970's have already shown an effective rejection of the primacy of syntax which is rapidly being pushed into its proper subsidiary role as a vehicle for semantics (e.g., Chafe, 1970; Fillmore, 1968; Lakoff, 1970).

What has been demonstrated in this relatively brief span of time in formal linguistics is a rapid shift from grammars for the sake of formal description of the underlying vehicle of a language to grammars for the sake of characterizing the structures people use in trying to communicate information. Clearly the latter system, and the kinds of relations it envisages, is going to be much more complex and irregular than the former, but just as clearly it will be much more to the point for psychologists and for psycholinguistics. As Allport (1961, p. 11) observed some time ago in a different context, "It is the duty of science to illuminate what _is_, not merely what is convenient, or what is traditional."

It is now abundantly clear that linguists must examine a great deal of experimental data gathered by psychological techniques and that psychologists must obtain information from linguists so that observations will be gathered with respect to relevant structures. In other words, there is a need for a psycholinguistics which is not a hybrid, but which is a truly integrated, single discipline. The apparent autonomy of linguistics has been rightfully eroded over the past ten years because language without consideration of language users is a sterile pursuit. However, as the true dimensions of psycholinguistics begin to emerge, the need for sophisticated linguistic analysis becomes greater and greater in order to provide appropriate parameters for that discipline.

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FOOTNOTES

1. The authors are indebted to Karel Sauby and John Gray for their careful gathering of the data for this study.

2. The analysis also included an assessment of the eight different sentence sets to which the different groups of subjects were assigned as well as the effects of the sex of the experimenter and of the subjects. None of these produced effects which would influence the other factors under discussion in this report.

TABLE 1

NUMBER OF TRANSFORMATIONS LINKING STIMULUS AND RESPONSE PATTERNS FOR A GRAMMATICAL AND A PERFORMANCE MODEL

Model	Stimulus Pattern*	Response Pattern* ADF	ADN	AIF	AIN	PDF	PDN	PIF	PIN
Gram.	ADF	0	1	1	2	1	2	2	3
(S→K→R)	ADN	1	2	2	3	2	3	3	4
	AIF	1	2	2	3	2	3	3	4
	AIN	2	3	3	4	3	4	4	5
	PDF	1	2	2	3	2	3	3	4
	PDN	2	3	3	4	3	4	4	5
	PIF	2	3	3	4	3	4	4	5
	PIN	3	4	4	5	4	5	5	6
Perf.	ADF	0	1	1	2	1	2	2	3
(S→R)	ADN	1	0	2	1	2	1	3	2
	AIF	1	2	0	1	2	3	1	2
	AIN	2	1	1	0	3	2	2	1
	PDF	1	2	2	3	0	1	1	2
	PDN	2	1	3	2	1	0	2	1
	PIF	2	3	1	2	1	2	0	1
	PIN	3	2	2	1	2	1	1	0

*A = active D = declarative F = affirmative
P = passive I = interrogative N = negative

TABLE 2

NUMBER OF ELEMENTARY OPERATIONS LINKING STIMULUS AND RESPONSE PATTERNS FOR A GRAMMATICAL AND A PERFORMANCE MODEL

Model	Stimulus Pattern*	Response Pattern*							
		ADF	ADN	AIF	AIN	PDF	PDN	PIF	PIN
Gram.	ADF	0	2	2	4	5	7	7	9
(S→K→R)	ADN	2	4	4	6	7	9	9	11
	AIF	2	4	4	6	7	9	9	11
	AIN	4	6	6	8	9	11	11	13
	PDF	5	7	7	9	10	12	12	14
	PDN	7	9	9	11	12	14	14	16
	PIF	7	9	9	11	12	14	14	16
	PIN	9	11	11	13	14	16	16	18
Perf.	ADF	0	2	2	4	5	7	7	9
(S→R)	ADN	2	0	4	2	7	5	9	7
	AIF	2	4	0	2	7	9	5	7
	AIN	4	2	2	0	9	7	7	5
	PDF	5	7	7	9	0	2	2	4
	PDN	7	5	9	7	2	0	4	2
	PIF	7	9	5	7	2	4	0	2
	PIN	9	7	7	5	4	2	2	0

*A = active D = declarative F = affirmative
P = passive I = interrogative N = negative

TABLE 3

MEAN STANINES FOR RESPONSE LATENCIES AND FREQUENCIES OF ERRORS FOR 64 SUBJECTS

Score	Stimulus Pattern*	Response Pattern* ADF	ADN	AIF	AIN	PDF	PDN	PIF	PIN
RL	ADF	3.6	3.4	4.3	4.2	4.4	5.0	4.4	4.8
	ADN	3.8	4.2	4.9	5.1	5.2	4.8	5.3	5.1
	AIF	3.7	4.9	5.4	5.2	4.8	5.1	5.4	4.9
	AIN	3.9	5.1	5.0	5.4	5.3	6.1	5.5	5.7
	PDF	4.2	5.0	5.2	5.6	4.6	4.6	4.6	4.6
	PDN	5.4	5.2	6.0	6.0	5.0	5.0	5.5	5.0
	PIF	4.2	5.5	5.4	5.7	5.1	5.5	5.5	4.5
	PIN	4.2	5.2	6.5	5.8	5.8	5.9	5.1	4.1
	Mean	4.1	4.8	5.3	5.4	5.0	5.3	5.2	4.8
Errors	ADF	1	3	14	10	12	26	16	32
	ADN	3	5	29	7	22	10	38	18
	AIF	4	10	4	13	25	24	15	32
	AIN	7	8	19	4	22	35	31	20
	PDF	27	28	40	32	4	9	12	15
	PDN	26	22	52	48	12	7	34	14
	PIF	25	46	22	45	10	22	3	10
	PIN	26	29	35	30	28	15	9	5
	Sums	119	151	215	189	135	148	158	146

*A = active D = declarative F = affirmative
P = passive I = interrogative N = negative

TABLE 4

CORRELATIONS BETWEEN MODELS AND RESPONSE DATA

Models		Mean RL Stanines	Frequency of Errors
Transformations:	S→R	0.26*	0.74**
	S→K→R	0.57**	0.19
	K→R	0.34**	0.11
Elem. Operations:	S→R	0.34**	0.81**
	S→K→R	0.49**	0.18
Add/Delete:	S→R	0.24	0.63**
	S→K→R	0.45**	0.12

*r (p = .05) = .250 **r (p = .01) = .325

TABLE 5

ERROR FREQUENCIES AS A FUNCTION OF THE TYPE OF CHANGE REQUIRED

Stimulus Pattern	Type of Change Required for Response								
	None	Mod.	Mood	Voice	Mod.+ Mood	Voice +Mod.	Voice +Mood	Voice +Mood +Mod.	Tot.
ADF	1	3	14	12	10	26	16	32	114
ADN	5	3	7	10	29	22	18	38	132
AIF	4	13	4	15	10	32	25	24	127
AIN	4	19	8	20	7	31	35	22	146
PDF	4	9	12	27	15	28	40	32	167
PDN	7	12	14	22	34	26	48	52	215
PIF	3	10	10	22	22	45	25	46	183
PIN	5	9	15	30	28	35	29	26	177
Sums	33	78	84	158	155	245	236	272	1261