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OF LINGUISTIC VIOLATIONS.

The Ohio State University, Ph.D., 1975
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SIMULTANEOUS MONOTIC MASKING AS A FUNCTION
OF LINGUISTIC VIOLATIONS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Gail Donna Chermak, B.A., M.A.

★ ★ ★ ★ ★ ★

The Ohio State University
1975

Reading Committee:

Dr. John W. Black
Dr. William Melnick
Dr. John Ferraro
Dr. Wallace Fotheringham

Approved by:

Adviser
Department of Communication

VITA

September 30, 1950	Born - Brooklyn, New York
1971	Research Assistant, College of Dentistry, University of Kentucky, Lexington, Kentucky
1971	"Lingual Pressure Patterns" Paper presented to American Dental Association Student Research Program, Chicago, Ill.
1972	B.A. in Speech Communication, The State University of New York at Buffalo, New York
1972	Phi Beta Kappa
1972-1975	Fellow, The Ohio State University, Columbus, Ohio
1973	Thesis - "The Intelligibility of Monosyllabic Words Masked By Linguistic Strings".
1973	M.A., The Ohio State University, Columbus, Ohio
1973-1974	Graduate Teaching Associate, The Ohio State University, Columbus, Ohio
1973-1975	Member of the Academic Affairs Committee of the Speech and Hearing Science Section of the Department of Communication

PUBLICATIONS

"The Intelligibility of Monosyllabic Words Masked by Linguistic Strings",
Ohio Journal of Speech and Hearing, 9 (1974), 133.

FIELDS OF STUDY

Major Field: Speech and Hearing Science
Minor Field: Psychology

Vita Continued

Studies in Audiology - Professors Paul Hiswander and Ernest Nilo

**Studies in Speech and Hearing Science - Professors John W. Black,
William Helnick,
John Ferraro, and
Yukio Takefuta**

Studies in Learning Theory - Professor Delos Wickens

Studies in Neuropsychology - Professor Donald Meyer

TABLE OF CONTENTS

	Page
Vita	ii
List of Tables	vi
List of Figures	vii
 Chapter	
I INTRODUCTION	1
Rationale	1
Purpose	5
Context of the Study	6
The Hypotheses	11
Summary	11
Definition of Terms	13
Organization of the Report	16
 II REVIEW OF THE LITERATURE	17
Masking of Speech	21
Tones	21
Noise	23
Voices	25
 Linguistic Structure, Statistics, and Speech	
Perception	30
Learning and Memory	38
Echoic Memory	41
Short-Term Memory	46
Attention	49
Single-Channel Theories	51
Broadbent's Filter-Theory	51
Filter-Amplitude Theory of Attention	55
Attention as Response Suppression	55
Attention as Auditory Synthesis	56
Multi-Channel Theory	58
Central or Peripheral Locus	59
Set and Expectancy	60
Linguistic Feature Detectors	61
Summary	64

Chapter	Page
III PROCEDURES AND INSTRUMENTATION	66
The Masker Material	66
Recording Instrumentation and Procedure	67
Calibration of the Stimuli and Masker Materials	70
Subjects, Procedures, and Instructions	73
Treatment of the Data	75
The Hypotheses	75
Statistical Treatment of the Data	76
Summary of Procedures and Instrumentation	76
IV RESULTS AND DISCUSSION	78
Masking Efficiency as a Function of Linguistic Violations	78
Relations Among Performance Under Six Conditions of Linguistic Masking	83
Discussion of Results	85
Information Theory	85
Figure-Ground Perception and Closure	88
Linguistic Analysis	90
Attention	93
Learning	98
Memory	99
Linguistic Feature Detectors	102
Interaction Effects and Summary	103
V SUMMARY AND CONCLUSIONS	107
Conclusions	109
Areas for Further Research	111
Consequences for Speech Perception	111
APPENDIXES	
A Masking Material Constructed by Miller and Isard	113
B Results of Follow-up Experiment	122
REFERENCES	126

LIST OF TABLES

Table	Page
1. Mean Duration, Standard Deviation, and Mean Pause Time for Class A (Grammatical Strings), Class B (Semantically Anomalous Strings), and Class C (Ungrammatical Strings). Computed Set-by-Set	69
2. Summary of analysis of variance. Six treatment conditions were forward grammatical, backward grammatical, forward semantically anomalous, backward semantically anomalous, forward ungrammatical, and backward ungrammatical strings. The dependent variable was the mean articulation score computed in percentage points. II, 36.	79
3. Mean articulation scores in percentages and standard deviations for 6 conditions of linguistic masking. II, items/condition, 25; II, listeners, 36.	
4. t-values for 15 pairs of related measures. N, 36; df, 35.	82
5. Pearson product-moment correlation coefficients for 6 conditions of linguistic masking. The dependent variable was percent correct of 25 monosyllabic words. N, 36.	84
6. Interpretations of applicability of theories and models to the experimental results	110

LIST OF FIGURES

FIGURE	PAGE
1. Long time average spectrum of speech. (Denes and Pinson, 1963, p. 116).	4
2. The articulation score as a function of the percent of time the speech was on. The level of the speech was held constant at 95 dG and the speech wave was interrupted at a rate of nine times per second. (Miller, 1947, p. 120).	26
3. The articulation score as a function of the intensity of different numbers of masking voices. The level of the desired speech was held constant at 95 dB.(Miller, 1947, p. 119).	28
4. Schematic diagram of Broadbent's filter theory of attention	52
5. Perceptual filtering and/or response suppression in attention.(Greenwald, 1972, p. 59).	57
6. Schematic diagram of experimental equipment	72

SIMULTANEOUS MONOTIC MASKING AS A FUNCTION OF LINGUISTIC VIOLATIONS

CHAPTER I

INTRODUCTION

As used in the study of audition, masking denotes the process by which the detectability of one sound is impaired by the presence of another sound. The sound that was audible and is now less audible is called the masked sound or the maskee, while the sound that renders this masked sound less audible is called the masking sound or masker.

The utilization of masking facilitates: (1) the study of the operation of the auditory system (Green, 1967), (2) the investigation of signal detection and the strategies of subjects (Pollack, 1964), and (3) the procurement of diagnostic information (Hood, 1960). In the context of the present investigation, interest was focused on this latter consequence of masking, specifically on the ability of a masker to reduce the intelligibility of speech. Masking may be deliberate, as seen in a controlled experiment, or it may be incidental as is aircraft noise for the resident of a household. The report under discussion involves the intentional, controlled presentation of a masker.

Rationale

White noise, a noise for which the spectrum density is substantially independent of frequency over a specified frequency range, and an audible

sinusoid of pressure fluctuations at one discrete frequency have been the most popular masking stimuli in experimental studies; however, white noise alone has been the more prevalent of these maskers in clinical settings. More specifically, wide-band white noise has been the predominant masking stimulus in speech audiometry; and therefore a tool for audiological evaluations. The assessment of word recognition provides important clinical insights as well as opportunities to discover general principles governing both perceptual discrimination and verbal behavior.

Due to the interfering nature of noise, information processing or discriminial processing is less efficient in a noisy channel than in a noiseless channel. Noise supposedly deteriorates the processing of information in every aspect as it increases error and equivocation, and thus reduces communicative efficiency (Hsia, 1968).

The masking of speech is of interest in that: 1) masking improves the validity and reliability of clinical audiometric measures by isolating the ear under test, and 2) a practical problem encountered in real life circumstances is the need to understand a speaker against a background of irrelevant noise. However, wide-band white noise is not the sort of masker usually encountered. Much everyday conversation coexists with meaningful background "babble", which is usually discontinuous, although often approaching zero, dynamic, and similar in spectral composition to a low-frequency noise. Clearly, white noise is unlike "everyday" background noise.

In addition to the non-representative nature of white noise, experimentation has determined that the optimal masking noise is uninterrupted and has a spectrum similar to the "long-interval speech

spectrum" which is being masked. Optimal, in this context, refers to the most efficient masker in terms of masking effectiveness per units of energy. A typical "long-interval speech spectrum" is shown in Figure 1.

Speech is a relatively low-frequency signal, with most of the power carried by frequencies below 1 KHz. The nature of speech itself implies that communication is most seriously disrupted by sounds of which energy is concentrated in the frequencies below 1 KHz.

Therefore, white noise is an atypical masker since environmental noise is non-continuous (rhythmically or arrhythmically interrupted), dynamic (displaying diverse and rapid changes), and is also non-optimal as reported by Miller (1947). Nonetheless, white noise is utilized in most clinical situations. As a result of the non-representative, non-optimal character of white noise, linguistic strings, spoken by one voice, were employed as maskers in the present study, the subjects' task being to identify recorded monosyllabic words. One may view "everyday babble" as being comprised of several voices, producing strings of words. Since the content and the acoustic spectrum of this "babble" will vary in keeping with the linguistic rules employed, systematic violation of the rules should conceivably provide information concerning the essence of the interactions and their consequences for masking efficiency.

Although the "long-interval spectrum" of a single voice is nearly optimal for masking speech, the spectrum at any one moment does not include all of the necessary frequencies, due to variations in the level of one voice and the relatively long intervals during which no masking sound is present. Thus as Miller (1947) concluded, several voices

Figure 1. Long time average spectrum of speech.
(Denes and Pinson, 1963, p. 116).

would produce a continuous masking signal. However, the use of sentences spoken by one voice as a masker is not unprecedented as seen, for example, by the work of Speaks et al. (1967) in which the Synthetic Sentence Identification (SSI) sentences and a competing speech message were delivered to the same ear, the slope and performance level of the performance-intensity (PI function) of the masker being investigated.

Miller (1951) suggested that the crucial factor for intelligibility seems to be the masking spectrum rather than the linguistic or semantic content of the "babble", and Dirks and Dower (1970) seemed to confirm this statement. However, their experiment dealt with two extreme conditions. Forward speech obeys the laws of syntax, semantics, and phonology, while backward speech violates the same. That is, these investigators observed the effects of a masker which conformed to the rules of the language as opposed to a masker which did not. It is the suggestion of this investigator that the systematic violation of one or two of these systems of rules, as opposed to the simultaneous violation of all three parameters, can better resolve the question of the significance of content. Chermak (1973) showed differential masking efficiency using a condition, the construction of which is located between two dichotomous extremes on a sentential-non sentential continuum.

Purpose

The reason for conducting the present investigation was to examine the use of linguistic strings as maskers and the differences among them.

This was undertaken based upon the evidence that white noise is a non-optimal and a non-representative masker, and as such, linguistic strings, as maskers, were examined. The precedent for utilizing the human voice as a masker can be seen in Wolf (1971), Miller (1947) and others.

The maskers were the test material used by Miller and Isard (1963), 150 sentences arranged into 6 classes, based upon the type of linguistic violation. The masker material is more completely described in Chapter III, and the stimuli as they were used by Miller and Isard are found in Appendix A.

The research under discussion involved: 1) expanding the conditions employed by Chermak (1973), 2) subjecting the data to a more rigorous statistical analysis than done previously, and 3) interpreting the results in a broader context than was done previously.

Although only semantic, syntactic, and phonologic rules were manipulated in this study, another class of rules which apply to language usage is pragmatics, the relations between symbols and the user of the symbols. One may infer several cursory statements regarding pragmatics and its effects upon linguistic masking through the incorporation of expectancy, set, and other psychological aspects of the listener, for pragmatics involves non-linguistic information about the context in which a sentence is uttered, about factors governing the degree of belief the listener would assign to the sentence, etc.

Context of the Study

While not directly manipulated in this study, certain adjunct areas

bear upon the multi-dimensional perceptual and sensory processes occurring when a listener performs the identification task presented here. That more than one process can take place simultaneously within the nervous system is supported by a theory of Hebb (1949), in which he proposed that different stimuli activate physically different elements in the brain, and more than one element might be active simultaneously.

One such area concerns that which some have designated "perceptual masking" (Carhart et al., 1969), or excess masking due to perceptual or semantic interferences. As stated above, one long-time voice is a near optimal masker, but not quite so due to variations and pauses. However, it may be that the linguistic nature of the masker increases masking efficiency beyond that which is attributable to intensity, acoustic spectrum, and temporal continuity.

There seems to be in the listener some factor which discards part of the presented information, but which is not sensory masking, and these processes of selection are not completely random, for the probability of adequate selection is changed by properties of the competing sounds and the state of the listener. (Broadbent, 1956, p. 533).

The area of generative grammar has recently been of concern not only for its role in the production and description of language, but also for its part in the perception of language. The basic inquiry has centered around whether this system of rules is merely a convenient way to summarize linguistic data, or also has some relevance for the

psychological processes involved. (Miller, 1962). One major hypothesis is that the sequence of rules used in the grammatical derivation of a sentence, corresponds step-by-step to the sequence of events that occur when a person processes the sentence (Hayes, 1970). A series of experiments has given initial support to the existence of a perceptual strategy of isolating lexical sequences that correspond directly to underlying sentence structures (Fodor and Bever, 1965; Garrett, Bever, and Fodor, 1966; Bever, Fodor, and Garrett, 1966).

In addition to the evidence supporting the active use of phrase structure to impose perceptual structure on the actual acoustic stimulus, linguistic parameters have been shown to have important consequences for: 1) recall of verbal material (Miller and Selfridge, 1950; Sypher, 1971; Mehler, 1965; Savin and Perchonock, 1965), 2) sentence recognition (Sachs, 1967), 3) intelligibility of sentences (Miller and Isard, 1963), 4) sentence storage (Weisberg, 1971), and 5) sentence comprehension (Foss and Lynch 1969; Wang, 1970), etc. In fact, Chomsky has proposed that violation of linguistic rules affects the acceptability of the resulting sentence and that the amount of loss of acceptability is a function of the generality and priority of the rule violated. Miller (1956) proposed that any characteristic of the stimulus which imposes organization on the stimulus or affords subjects a potential grouping (chunking) of items in the stimulus, should facilitate learning, and linguistic parameters appear to retain such a characteristic. Savin and Perchonock (1965) supported Miller's contention with the evidence that sentences are easier to remember than words are in random order.

The realm of attention was also very relevant to the present work. That is, there are two potential reasons why it is difficult to listen to one message in the presence of another. One voice masks the other, and they both compete for attention. Cherry (1953) demonstrated that if the two speech samples have the same semantic content and are spoken by the same talker, a listener cannot separate one message from the other. That this is not masking was shown by Cherry (1953) in that, if the two speech samples are different in context, one message can, with effort, and repeated playback, be identified and spoken back. Broadbent (1956) showed that failure of attention causes decrement of performance in sequential messages where masking is not involved. It is quite apparent that competing messages both mask and divide attention, and the decrement in performance must be attributed to both.

As attention seems to be an appropriate dimension of the processes involved with sensory masking, Dallett (1964) introduced the concept of the relation of memory to masking and intelligibility. Thus, a listener may not remember hard-to-hear messages as well as clear and distinct ones, (conversely one may not hear hard-to-remember messages as clearly as one hears simple ones). Perhaps errors in intelligibility are to be attributed to either a subject's failure to remember accurately or to errors resulting from masking, as well as to errors following a decrement in attention. Dallett's work indicates that the decrease in intelligibility that results from masking is accompanied by an added decrement in short-term memory. This notion is enhanced by studies which support short-term memory as acoustic or speech-motor, based upon the initial discovery by Conrad (1962) that patterns of errors in short-

term memory resemble those in the perception of speech.

Questions concerning linguistic structure and memory have received much attention (Bransford, 1971). Miller (1962) pointed out that normal speech unreels too rapidly for hearers to make successive low-level phonemic, phonetic, syntactic, and semantic decisions for each unit. He suggested that probably the decisions about the early items in a sentence are delayed until enough has been heard to support a higher-level decision, and he chose the phrase as the most likely decision unit for heard speech, which corresponds to the concept of chunking as a unit of immediate memory recoding.

As well as short-term memory or immediate memory, which must exist in order to understand a sentence, since one must remember a good deal about the beginning when one has reached the end, another medium exists. Theories of perception and memory usually assume the existence of a sensory information system that retains primitive physical storage features of a stimulus presentation even after the stimulus is terminated (Heisser, 1966). The concept of a brief sensory storage (echoic storage or precategorical acoustic storage) has played a central role in recent discourse on the disposition of human information processing (Darwin et al., 1972), and as such was germane to the present work. The proposition is that sensory data are initially represented in a literal, labile form for a brief duration during the course of conversation, and then converted into a relatively more persistent categorized form. Forward masking, the presentation of the maskee after the termination of the masker, which preceded it, can be accounted for by assuming that an auditory image outlasts the masking stimulus presentation.

The information in the masking stimulus is perserved in some form after termination of the stimulus, and this information can affect later decisions, for instance, word identification.

The Hypotheses

The following hypotheses were tested:

Hypothesis I. There is no difference in the mean articulation scores of monosyllabic words masked by: 1) forward and backward-reproduced grammatical strings; 2) forward and backward-reproduced semantically anomalous strings; and 3) forward and backward-reproduced ungrammatical strings.

Hypothesis II. There is no relationship between the subjects' mean articulation scores under any two of the six foregoing conditions.

Summary

Interest in matters of the time domain or duration prompted that the verbal material employed for the measurement of speech intelligibility should consist of sentences of sufficient duration to permit systematic alteration of temporal characteristics of the speech. Assurance of validity and reliability of audiometric measures as well as increased knowledge of auditory processing in speech perception will materialize only through the use of representative laboratory conditions, including representative masking stimuli, which for the investigation under discussion, is also similar to the optimal conditions.

Speech perception involves at least two primary interdependent operations: reception and linguistic construction. Thus, the perception

of speech involves a process of reception of stimuli and the classification of incoming stimulus patterns in accordance with categories established by previous learning.

Linguistic strings, which served as maskers in this study, are representative, near "optimal", and enable manipulations which could help explain the function of linguistics, apart from acoustics, for masking and indeed, for speech perception, of which masking is a component. This is highlighted by considering that distortion and masking cause subjects to rely more on linguistic knowledge than upon the acoustic information.

The ultimate problem in speech perception is to determine how a listener neurally decodes the acoustic speech signal (Abbs, 1971). Current research supports the proposition that the auditory system operates as a feature detector and decodes human speech through its innate ability to detect and respond to various distinguishing parameters of the acoustic sound stream. Peters (1967) believed these features relate to the articulatory properties of the vocal tract. Pisoni and Lazarus (1974) recognized the possibility of specialized complex higher-order linguistic feature detectors. Geschwind (1970) has claimed that these detectors are part of the central speech processing mechanism which functions to analyze not only phonetic information, but also semantic and syntactic information.

The influence of linguistic rules upon attention and memory have begun to be isolated. Furthermore, memory and attention bear upon perception, as seen by the work of Massaro (1970) in which he viewed perceptual processing as the analysis of the sensory input in which

features are detected that correspond to encoded features in memory and when a sufficient number of features are found in the sensory input that correspond to the features of the item in memory, recognition of that item occurs, and also by Massaro and Kahn (1973), in which it was argued that echoic memory involves not only central processing but is also affected by distraction.

The present investigation was conducted to examine the role of linguistic parameters upon masking efficiency. Memory and attention were viewed by this investigator as simultaneous features of the complex process of word identification against the background of a competing speech message. Thus, this report considered factors other than the noisiness of speech which may cause it to mask, such as distraction, memory, and linguistic knowledge. Applications and consequences for speech perception in general will be discussed.

Definition of Terms

For the purpose of this report, the following definitions are applicable.

Processes

Analysis-by-Synthesis as viewed by Stevens and Halle (1967), is a means to the perception of speech by which one perceives an event only after one has synthesized or reconstructed the event internally.

Attention is the selective aspect of perception and response.

Cognition is the flow of information in the organism.

Constituent Analysis relates to the linguistic rules applicable to the segmentation of speech at the level of the surface structure.

Detection represents that situation in which one asks what is the weakest stimulus to which a listener can respond the majority of the time.

Discrimination represents that situation in which one asks what is the smallest stimulus difference between two stimuli that can be perceived the majority of the time.

Echoic Memory is the brief persistence of a stimulus after its termination in an unencoded form.

Identification represents the situation in which the stimuli must be detectable and discriminable, and in addition the listener provides a specific and unique response to each different stimulus.

Information Processing involves the decision making strategies in the human organism, the result of the present features of the stimulus and prior experience.

Masking denotes the process by which the detectability of one sound is impaired by the presence of another sound.

Perceptual Processes (Psychological Processes) encompass all subject strategies and events which relate to decision and response making.

Phrase Structure relates to the linguistic rules applicable to the segmentation of speech at the level of the deep structure.

Recognition as contrasted with detection, involves the subject's ability to make some judgment regarding the stimulus other than simply the presence or absence of such a stimulus.

Secondary Maskers are contributors to overall masking efficiency but are not directly related to intensity, frequency or spectrum, or duration.

Short-Term Memory (Active Memory, Immediate Memory) is the trace of a stimulus after it has been presented only once.

Linguistics

Contextual Constraint is the degree of determination that preceding words exert upon the choice of subsequent words in English sentences.

Deep Structure represents the underlying "logical" relations which the words bear to each other in a sentence.

Linguistics is that branch of science which contains all empirical investigations concerning language.

Linguistic Strinos are strings of words which vary in degree and nature of syntactic, semantic, and/or phonological violation.

Phonology is a component of language which converts surface structure into the sound patterns of spoken utterances.

Rule Systems as applied to language, relate to the language universals, prelinguistic in character, which shape human language.

Semantics is an explanation of the speaker's ability to produce and understand new sentences beyond the point to which grammar is such an explanation.

Surface Structure describes the hierarchical structural associations among adjacent words and clauses in a sentence.

Syntax is a device that specifies the infinite set of well-formed sentences and assigns to each of these one or more structural descriptions.

Others

Accumulation Effect as observed in studies of short-term memory, refers to an increase in recall for items as a result of repetition.

Information is the amount of uncertainty or unexpectedness.

Long-Interval Speech Spectrum is the spectrum of continuous speech averaged over time.

Monotic involves the presentation of some stimulus material to one ear only.

Shadowing is the repetition of one of two dichotic messages.

Simultaneous suggests the presentation of at least two events concurrently in time.

Organization of the Report

The report is divided into five chapters. Chapter I includes the introduction, rationale and purpose of the study, the hypotheses to be tested, the context of the research, and definitions of terms used. Chapter II contains a review of related literature. Chapter III is a description of the experiment, including the masker material, speakers, listeners, data recording, and processing and instrumentation. In Chapter IV, there is a presentation and discussion of the results of the experiment. The final chapter consists of the summary and conclusions of the research.

CHAPTER II

REVIEW OF THE LITERATURE

Knowledge of the susceptibility of the ear to interference has practical value. Present knowledge is largely a carry-over from the development of powered communication systems, specifically the telephone. Many different experimental conditions have been investigated, for example, masking of pure tones by another pure tone, white noise, narrow-band noise, etc; and masking of speech by white noise, narrow-band noise, bursts of white noise, etc. The degree to which speech is masked has been shown to depend upon three characteristics of the masking signal: 1) intensity relative to the intensity of the speech (maskee), 2) acoustic spectrum, and 3) temporal continuity (Miller, 1947).

To discuss even the simplest problems in speech production and speech perception, it is helpful to try to distinguish the significant aspects of speech from the nonsignificant. This distinction is not simple in terms of the physical parameters of the speech signal. Therefore, one turns to extra-physical aspects of communication, for example, language. Here, a sentence is not the linear sum of the words that comprise it, nor is the meaning of an utterance the sum of the meanings of the words that constitute it. Similarly, while the organs involved in the production and the reception of sound, and the central

nervous system, as well as the inherent nature of sound waves, greatly determine the process of speech perception--and indeed masking--one must recognize the consequence of other factors, more abstract ones.

Shannon and Weaver (1949) demonstrated that the users of language possess an extensive knowledge of the statistics of their language, and they have developed the application of information theory and probability to communication. Black (1961) concluded that there are matters other than phonetic intelligibility involved in speech recognition. Ladefoged and Broadbent (1950) showed that listeners may hear two physically identical sounds as different if they occur in different acoustic contexts, and Miller and Isard (1963) showed that the grammatical structure and "meaningfulness" of a sentence affect the perception of individual words in the message.

In a classical view of speech perception, for example that of Helmholtz, attention was focused on frequency or spectrum as being of prime importance for the recognition of sound. While the distribution of acoustic energy with frequency is important in the identification of speech sounds, work in recent years has shown that recognition is a very complex matter (Fry, 1964). Cole and Scott (1974) emphasized the value of invariant cues and envelope cues of speech waves as well as the transitional cues for speech perception. As there are multiple physical cues, there are also multiple statistical cues involved in speech perception and multiple processes occurring somewhat simultaneously within the listener and affecting cognition. Lieberman (1963)

suggested that the perception of speech is aided by such extra-acoustic events as grammatical structure and semantic content. Similarly Fry(1964) saw that in making any single recognition, the listener has at his disposal a number of different cues and may use all or some cues as the occasion demands. Masking, an unwanted aspect of communication--and one aid to the study of audition--is also complex and comprised of variables other than intensity, frequency, and duration.

Apparently not all acoustical features of speech are significant for vocal communication and not all significant features of speech have an acoustic representation, for perception of speech involves grouping and interpreting various elements, and cannot be simply predicted from studies of one's ability to discriminate among arbitrary acoustic stimuli. The non-human quality of synthetic speech, and the multiplicity and redundancy of acoustic cues, serves to illustrate this discrepancy. In a similar vein, masking will remain somewhat misunderstood until the other elements contributing to it are isolated. Some of these may be "linguistic".

In addition to the study of masking as it may be related to linguistics, there may be interactions between masking and memory, between masking and attention, and between these and linguistics. Dallett (1964) began the investigation into memory and intelligibility. Neisser (1966) noted that since the auditory input is extended over time, memory must preserve it long enough for the process of speech perception to operate. Cherry (1953) and Broadbent (1952) emphasized that competing messages both mask and divide attention. Broadbent (1957)

concluded that selection depends upon characteristics of the input itself and on information in a more permanent store. Glucksberg and Cover (1970) found that "nonattended stimuli" were stored (remembered) briefly, possibly in echoic form, but not held in permanent storage.

For the purposes of this report these more "abstract" factors that may affect the efficiency of masking, such as language, attention, and memory will be designated secondary maskers. Therefore, a secondary masker is viewed as a contributor to an overall reduction of speech perception; however it is not directly related to intensity, frequency or acoustic spectrum, or duration. These latter parameters are components of a primary masker. The segmentation of this term, and the justification for it will be tested in Chapters III and IV.

Speech is composed of periodic and aperiodic sounds. Some of the sounds in speech have tonal quality (vowels), some have noisy characteristics (unvoiced plosives and fricatives), and some sounds have both. Some sounds of speech are more intense than others. Most of the energy of speech is in the low frequencies. (The energy is in the band 50 Hz - 10 KHz, but the greatest amount is in the 100 - 600 Hz band as seen in Figure 1).

Miller classified the sounds which might interfere with speech into at least three categories: 1) tones, 2) noises, and 3) voices. These categories will be used in the following discussion of masking. The review of the research is organized under the following topics: 1) research involving the masking of speech by tones, noises, and voices, 2) research on the influence of linguistic structure and statistics to masking and speech perception, 3) research involving

learning and memory, 4) research on echoic memory, 5) research involving short-term memory, 6) research on attention, selective listening, and expectancy and set, and 7) research involving linguistic feature detectors.

The primary purpose of this chapter is to provide background information relevant to the research discussed in this report. A secondary objective of this chapter is to assemble and organize material which relates to secondary maskers. At this point it would seem appropriate to caution the reader to view the material presented as composed of fact accepted by the scientific community, and speculation. It will be the task of the reader to recognize the limits of one realm and the beginnings of the other.

Masking of Speech

Tones

Stevens, Miller, and Truscott (1946) stated that low frequency tones disrupt the speech signal more than high frequency tones, since most of the energy in the speech signal is carried by the frequencies below 1 KHz.

They found that for weak intensities the maximal masking is produced by sine waves of 500 Hz, whereas at high intensities the greatest amount of masking occurs at or near 300 Hz.

This effect is presumably due to the rapid spread of masking into the higher frequencies as the

intensity of the masking tone is increased. This upward spread is aided by distortion in the ear which produces aural harmonics at high sound levels, and also by the characteristics of the response of the individual auditory nerve fibers. (Miller, 1947, p. 106).

The effect of masking speech with pure tones concurs with that which was observed about the effect of masking one pure tone with another: 1) masking is greatest at or above the frequency of the masking tone; 2) masking tends to be greater for tones of neighboring frequencies than for tones widely separated along the scale; 3) low frequency tones effectively mask high frequency tones whereas high frequency tones are much less effective in masking low frequency tones; and (4) the rate at which masking increases as the masking tone is raised in intensity depends upon the frequencies of the tones (Hegel and Lane, 1924).

The masking of speech by complex tones has been studied and the research indicates two important generalizations: 1) low frequencies are more effective than high frequencies, and 2) the greater the harmonic content of the tone the better its spectrum blankets the frequency range of speech (Miller, 1947).

The effectiveness of masking speech with complex tones is basically the same as with the use of a pure tone; however, since the complex tone is composed of a fundamental frequency and its harmonics, it masks the entire range of speech frequencies at lower intensities than do pure tones. At high frequencies, pure and complex tones are equally ineffective for masking speech (Miller, 1947).

Noise

White noise, an extreme example of aperiodicity, has a uniform power spectrum, i.e. all frequencies are represented in such a noise at equal average energies. However, as used, an attenuation of 6dB/octave often characterizes it. Hawkins and Stevens (1950) studied the effect of white noise on the perception of speech. They concluded:

The speech thresholds (like the pure tone thresholds) are relatively little affected by the lowest levels of masking noise. At higher noise levels the thresholds for speech are raised by approximately 10 dB for each increment of 10 dB in noise level.
(Hawkins and Stevens, 1950, p. 12)

Thus, the relationship between masking and the intensity of noise is linear. Miller and Licklider (1950) described this relationship between speech and noise in terms of the ratio of the average speech power to the average noise power, signal-to-noise ratio (S/N). Pollack (1949) added that the effect produced by noise on the loudness or threshold of speech is a function of S/N ratio, rather than the level of speech or noise alone.

Research on the effects of white noise upon the perception of speech has shown that the high and low frequencies of white noise are less effective because the ear is less sensitive to these frequencies; and the masking noise must be at least 20-30 dB above the threshold before appreciable masking occurs (Miller, 1947).

Narrow-band noise is produced by filtering white noise selectively, and may be defined as a cluster of frequencies encompassed in a restricted range. The frequency around which the cluster is grouped and the width of the frequency range are matters of choice.

The results obtained from masking of speech by noise are similar to the masking of speech by pure tones. Sounds of low frequency will, if sufficiently intense, mask the entire range of frequencies involved in speech, but high-frequency noise will not mask the low frequencies of speech. At low levels, the high-frequency bands are more effective than the low-frequency bands due to the distribution of energy in speech (i.e. the high-frequency speech sounds (consonants such as /s,ʃ/ etc.) and consonants as a group are crucial to intelligibility). As the intensity of the high-frequency band noise is raised, the high frequency sounds of speech are masked, but this does not spread to the high-energy low frequencies. However, as the intensity of a low frequency band of noise is raised it masks the high-energy low frequencies; as the intensity is increased further, the masking effects cover the entire frequency range of speech, and complete masking is obtained. Thus, experimentation has indicated that the optimal masking noise has a spectrum similar to the "long-interval" speech spectrum which is being masked. Although 135Hz-400Hz and 350Hz-700Hz are good maskers, neither of these narrow bands is as effective as a wide band of 20Hz-4KHz. In addition to the masking of speech with steady-state (continuous) white noise, one may also study the effects of the masking of speech utilizing interrupted (non-continuous) white noise.

Pollack (1954) and Calero et al., (1962) studied the effect of masking speech with interrupted white noise. These investigators indicate that the masking effectiveness of an interrupted noise may be less than that of an uninterrupted noise (presented at the same

intensity level). Miller and Licklider (1950) found that when the noise is interrupted more than 200 interruptions per second (ips) it is "continuous". The effectiveness of masking of interrupted noise decreases as the interval between bursts increases within the range of 10 ips to 200 ips. The "ear" (listener) is adept in patching together interrupted fragments of speech. The ear is able to integrate and interpret those portions of the speech available when the masking sound is not present. Miller states:

With the speech on only one-half of the time, 80 percent of the words were still correctly heard. It was not until 80 percent of the speech wave was missing that none of the words could be understood. When the noise is present less than 50 percent of the time, practically no masking is produced... Noise present 80 percent of the time is considerably less effective than uninterrupted noise. (Miller, 1947, p. 122).

← This result is shown in Figure 2.

Berry and Merbonne (1971) compared the masking functions of speech modulated white noise, generated by multiplying white noise by the amplitude envelope of the speech signal to be masked, and white noise. They concluded that subjects recognized the speech-like character of the modulated noise. Because of the difficulty encountered in "processing" this strange speech-like signal, the perceptual system may have become "overloaded", resulting in reduced performance for relatively simple speech sounds.

Voices

As stated previously, a single voice is a relatively poor masking signal, apparently because, although the long-interval spectrum of a

Figure 2. The articulation score as a function of the per cent of time the speech was on. The level of the speech was held constant at 95 dB and the speech wave was interrupted at a rate of nine times per second.
(Miller, 1947, p. 120).

single voice is nearly optimal for masking speech, the spectrum at any moment does not include all of the necessary frequencies. The variations in the level of a single voice are great, and there are relatively long intervals during which no masking signal is present. With several voices (as seen in Figure 3) a "continuous" masking signal is produced.

The content of the competitive speech may be of importance. Tramell and Speaks (1970) found that the listener performed more successfully (higher sentence identification or less efficient masking) when the competing message was played in a backward mode (pauses between words and the long term frequency characteristics of the competing forward speech were preserved, while the semantic content of the message was largely eliminated). However, Dirks and Bower (1969) found listener performance to be the same with forward and backward competitive speech. Chermak (1973), comparing forward speech, semantically anomolous speech, and ungrammatical speech, found listener performance to be depressed (efficient masking) when semantically anomolous speech was the masker. Both Tramell and Speak's, and Chermak's results support the importance of linguistic significance, while Dirks and Bower point to the nonsignificance of linguistic rules. At this time the evidence is not conclusive.

Berry and Herbonne (1971) indicated that the amplitude envelope of speech is an adequate cue to cause differential processing of speech modulated white noise as compared with white noise. This study depicted one consequence of the dynamic pressure variations over time occurring during speech.

Carhart et al. (1969) observing what they referred to as

Figure 3. The articulation score as a function of the intensity of different numbers of masking voices. The level of the desired speech was held constant at 95 dB. (Miller, 1947, p. 119).

"perceptual masking" due to semantic influences, suggested differences between competing speech messages and noise or pure tones as maskers. Likewise, Egan, Carterette, and Thwing (1954) suggested differences between the masking of speech by noise, where in both cases listeners must "filter out" the uninformative noise components from the complex acoustic stimuli. A speech signal can be considered as a series of events, suitably chosen, having certain conditional probabilities. These probabilities have high values relative to those of a random noise. When speech is masked by noise, the joint probabilities between events in the speech series and events in the noise series are low; on the other hand, when the interference is another speech message, not only are the joint probabilities high within the interfering events, they are also high between the events of the signal and the interference. Thus, an interfering speech message not only masks the speech signal, but becomes confused with it.

A wide variety of sounds has been examined in terms of the extent to which they interfere with speech. This interference has been measured using articulation testing methods (speech discrimination). For all maskers, the important dimensions of the stimulus are the intensity, the spectrum, and the temporal pattern of the sound; however, many researchers attribute additional properties to linguistic parameters; the degree and direction of such influences are only conjectured. Certain general statements concerning masking deserve reiteration: masking depends primarily on the S/I ratio over the range of frequencies involved in speech; interruptions in the masker decreases its effectiveness, and narrow-band noise is the most critical masking source, but no

narrow band is more effective than a wide band of 20 Hz - 4 KHz; although a single voice is a relatively poor masking signal, several voices would produce a continuous masking signal; and content of the competitive speech may influence masking efficiency.

Linguistic Structure, Statistics,
and Speech Perception

Measuring the effect of familiarity, frequency, and length, etc. of the masker, is a new field; but these same variables have been examined in relation to the test materials of the articulation test. For example, Mefford, Houck, and Sadler (1970) found both structural properties and association patterns of the stimuli to affect perception. Therefore, familiarity, frequency of occurrence, word length, and context are of concern in building a test.

Hirsh, Reynolds, and Joseph (1954) investigated the intelligibility of different speech materials and found that words are more intelligible than nonsense syllables under a variety of experimental conditions. Furthermore, the intelligibility of meaningful words is a direct function of word length. Miller, Heise, and Lichten (1951) found words more difficult to recognize alone than when in context as a result of: 1) the decrease in vocabulary size due to the reduction in the number of alternative words provided by the sentence, 2) the sentence context enables one to organize the flow of sound into decision units larger than individual words perhaps into constituents, and 3) sentence structure allows for acoustic "referencing", for the physical surround

establishes a frame of reference for the decoding operation. Egan (1948) obtained 80 percent intelligibility for sentences as opposed to 50 percent intelligibility for words measured under the same conditions. Again, context allows for limitation on the range of alternatives from which responses may be selected. Miller and Isard (1963) stated that linguistic rules serve to limit the number of alternatives from which responses may be selected. The word-frequency effect, investigated by Savin (1963), follows from these two observations: 1) different subjects give the same incorrect responses, and 2) these responses are usually more common (in frequent use) in ordinary usage than the stimuli which they are given. Pollack et al. (1959), had previously shown that for known message sets the prime factor determining intelligibility is the phonemic interconfusability among the words, while for unknown message sets the prime factor determining intelligibility of a word is its frequency of occurrence relative to the frequencies of the words with which it might be confused. Miller and Isard (1963) postulated that the intelligibility of strings of English words depends at least in part upon their conformity to linguistic rules known to the listener.

Thus, one's responses are based upon fragmentary perception combined with one's knowledge of the language. Responses tend to be meaningful whether correct or incorrect. In addition, responses tend to be of relatively high frequency of occurrence in the language, and other factors such as familiarity, context, and length influence the subject's response. Solomon and Postman (1952) noted further, that it is important to account for the complex personality factors of each

subject which reduce or enhance the operation of physical parameters. Carlton (1953) found that relationships between word value and an individual's personal value influenced word intelligibility. The implications of previous research has suggested that underlying linguistic constructs affect the test materials, and as Miller and Isard (1963) have stated, "in order to understand a spoken sentence it is necessary to process the received acoustic signal according to the linguistic rules of the language." (Miller and Isard, 1963, p. 217). Thus, perception is more accurate when this processing can be performed in its habitual fashion. The impact may be that these influences upon test materials also have significant ramifications for the masker.

As stated previously a major hypothesis of one model of speech perception, is that the sequence of rules used in the grammatical derivation of a sentence, that is, the derivational history of the sentence, corresponds step-by-step to the sequence that a person follows when he processes the sentence. This is the correspondence hypothesis (Hayes, 1970). A linguistic masker may engage some of these same perceptual processes in the listener.

Garrett, Bever, and Fodor (1966) suggested that since grammar formalizes the inherent structure of a natural language, it may be supposed that a grammar provides an explanation of the linguistic capabilities of a speaker insofar as these capacities are attributable to his abilities to manipulate linguistic structures. Neisser (1966) proposed that if analysis-by-synthesis (a means to the perception of speech by which one perceives an event only after one has synthesised or reconstructed the event internally), is a chief mechanism of speech

perception, then study of syntax is an integral part of cognitive psychology. Thus, the generative rules of grammar that describe the language of the speaker, provide a vehicle of understanding for the listener. One would seem to speak and listen grammatically. Miller and Chomsky (1963) supported the Halle-Stevens proposal as the chief mechanism of speech perception (analysis-by-synthesis), i.e. that we deal with sentences we hear by reformulating them ourselves; that we grasp their structure with the same apparatus that structures our utterances.

Fodor and Bever (1965) stated that grammar provides a means for an analysis of the structure which underlies the acoustic pattern exhibited by a phonetic description. It does so, in part, by providing a constituent analysis for each sentence. That is, in speech perception the continuous speech input is segmented according to the constituent structure of the sentence. This constituent analysis is a representation of the more abstract segments of which a sentence is composed.

The technique developed by Ladefoged and Broadbent (1960) involving subjects' reports of click location, revealed a difference in the size of errors made by sentential and non-sentential strings. Using this same technique, which is based upon the gestalt assumption that a perceptual unit tends to preserve its integrity by resisting interruption, Fodor and Bever (1965) revealed the presence of phrase boundaries in the perception of sentences. They concluded, that their findings appear to demonstrate that the major syntactic break plays an

important role in determining the subjective location of noises perceived during speech, thus supporting the hypothesis that the unit of speech perception corresponds to the constituent.

The results of Fodor and Bever's (1965) study might be questioned, the suspicion being, that the major syntactic break is signalled by some acoustic means, such as pause or intonational cues in the pronunciation of the sentence. In additional research, however, Garrett, Bever, and Fodor (1966) demonstrated that there are no clear acoustic cues which mark the breaks between constituent phrases.

Abrams and Bever (1969) demonstrated Fodor and Bever's view with a task that minimized the possible influence of memory strategies and response bias, and concluded that attentional systems tapped by their reaction time measures are distinct from the behavioral processes which produce the systematic errors in click placement.

These findings are reflected in other studies of speech perception such as Liberman et al. (1967). It seems that the listener assigns a perceptual structure to speech sounds on the basis of that listener's knowledge of the rules of language. The perceiver is an active interpreter of the acoustic speech signals which he receives.

However, the issue of the unit of speech perception corresponding to the constituent is not completely resolved, for several areas remain unclear, for example, the level at which the constituent analysis occurs. The controversy centers around whether active segmentation by the listener is accomplished by constituent analysis at the level of the surface structure or by phrase structure analysis at the level of the deep structure. Syntax would be utilized in constituent analysis

and semantics would be utilized when applying phrase structure rules; however semantics may be involved to some extent in constituent analysis, and syntax may be involved to some extent in the application of phrase structure analysis.

Blumenthal (1967) and Rohrman (1968) asserted that listeners actively organize speech into segments defined in terms of underlying "logical" sentential relations, while Chapin et al. (1972) concluded that the segmentation process is guided by an overall strategy of attempting to close off constituents at the highest possible level (which corresponds to the major surface constituent structure). One can find support for both views, for instance Sachs (1967) supported Blumenthal's and Rohrman's contention. She found that changes in the surface structure of a sentence were not noticed by subjects when they tried to recall whether a given sentence was one which they had heard earlier, and therefore, subjects stored sentences on the basis of the deep structure, and forgot the surface structure. A study by Johnson (1966) supports the latter opinion, for he found that errors occurring when subjects attempted to learn sentences, indicated that subjects learned sentences, not as wholes, but as groups of words which were then put together to form the entire sentence, and that these groups of words corresponded to the smallest constituents in the surface structure. Jarvella (1971) reasoned that

since a listener cannot predict when an utterance will become too long to process as a single chunk, it is reasonable that the listener should segment the speech into natural linguistic units, such as sentences and clauses, and interpret them before his limited memory span is exceeded. Moreover,

the initial syntactic segmentation of a constituent from a sentence may be quite rapidly followed by its semantic interpretation.
(Jarvella, 1971, p. 409).

Larsen (1971), employing a click displacement technique similar to Fodor and Bever, tested the hypothesis that noise heard during speech should tend to be located perceptually between words rather than within words, for the units of constituent perception are the constituents of the constituents and so on until the level of individual words. His results indicate no resistance of psychological units to interruptions, for more responses occurred within words than between, although the direction of displacement was predicted using the Fodor and Bever notion. Larsen concluded that syntactic structures seem to influence the process of locating clicks, but the nature of the influence is unsure.

Reber and Anderson (1970) contended that linguistic operations such as those proposed by Fodor and Bever and non-linguistic operations (memory and attention) interact. Thus, they suggested that relocation errors are due primarily to attentional priorities based upon Titchener's (1909) law of prior entry. They referred to their hypothesis as attentional vs. the linguistic hypothesis previously proposed.

Bever, Lackner, and Stoltz (1969) incorporated Chomsky and Miller's (1965) theory that perceptual units in speech are defined as sequences with high transitional probability bounded by points of low transitional probability. They claimed that listeners actively use knowledge of both syntactic structure and of transitional probability during speech

perception; however transitional probability alone does not provide a general account for the behavioral segmentation of speech.

Although several hypotheses (attentional and transitional probability hypotheses) have been advanced as alternate means to explain that which Fodor and Bever proposed is the result of the linguistic-correlation hypothesis, there seems to be little doubt that linguistic rules and generative grammar play a role in the process of speech perception. It is reasonable to speculate that the consequences of these linguistic rules and statistics for speech perception affect auditory masking, not only in terms of the maskee but also in terms of the masker. Although a listener is typically instructed to ignore the masker in such situations, somewhat "unconscious" processing of the masker might follow the course implied by the results of the above mentioned research. Whether the role of linguistic structure and statistics is of major consequence, or one of several interacting factors, remains unknown at this time.

In summary, it has been proposed that: 1) both structural properties and association patterns of the stimuli (frequency of occurrence, word length, etc.) affect perception; 2) a major hypothesis of one model of speech perception is that the sequence of rules used in the grammatical derivational history of a sentence corresponds step-by-step to the sequence that a person follows when he processes the sentence, possibly incorporating constituent analysis and phrase-structure rules; and 3) linguistic operations and non-linguistic operations (memory and attention) may interact in the perception of speech.

Learning and Memory

Linguistic structure and statistics appear to affect speech perception and thus these variables must be considered in terms of their effect upon masking, a deterrent to perception. However, these factors have been also shown to affect learning and memory, processes which may be involved in the identification of a word against a background of irrelevant information, and thus facilitate the perception of speech.

Marks and Miller (1964) have shown that the presence of either syntactic or semantic structure in word strings facilitates the learning of such strings, by providing psychologically effective constraints on the number of alternative messages that a listener expects to hear. Thus, they found intelligibility to be greatest for grammatical sentences, lower for semantically anomalous sentences, and lowest for ungrammatical sentences. Danks (1969) found syntactic and semantic deviations to lengthen processing time because of additional steps involved in providing syntactic or semantic description, and meaningfulness had the larger effect since failure to provide an acceptable semantic description may require supplementary syntactic reprocessing before an acceptable semantic description is discovered. Wang (1970) asserted that it is not comprehension which facilitates performance in this learning task, but rather the fact that there are two types of linguistic structures to provide the listener with independent bases on which to organize the content of the string in memory. Epstein (1961) contended that subjects may distribute their attention

unevenly and unsystematically among the items when confronted with unorganized material, thereby increasing time spent in learning, and/or organized material may be easier to encode or may already possess this type of classification. Johnson (1965) concluded that when subjects are presented the task of learning grammatically structured material, it may be that part of the learning has already occurred. Miller and McKean (1964) found additional time spent in semantics rather than syntactic operations, and concluded that syntactic operations in normal usage are automatic and involuntary; therefore any deliberate and explicit control that a person can exercise over these linguistic operations is principally and perhaps exclusively at the semantic level.

Gough (1965) determined that the speed of understanding a sentence varied with the number and nature of transformations separating it from its kernel. Miller and Isard (1963) concluded that if a sentence is understandable (conforms to all linguistic rules), it will also be relatively easy to hear. Foss and Lynch (1969) proposed that sentence comprehension can be conceptualized as a set of decisions made by the listener as he hears a sentence, and concluded that decision difficulty at one "level" of linguistic processing interacts with the decision making processes concerned with other levels. Deese (1969) pointed out that interpretation (a linguistic concept) arises when there is understanding (a psychological concept), which further depends upon an analysis of both the surface structure and the deep structure (the grammatical components of sentences as well as some semantic analysis).

Slamecka (1969) incorporating the sentences used by Miller and

Isard to study intelligibility, conceded that retention is inversely related to linguistic violation. Weisberg (1971) using intrasentence word association (ISWA) as an index of the organization of a sentence in memory, supported the theory of sentence storage based upon the deep structure, rather than the surface structure; however Forster (1966) has reported that strings of nonsense words were learned faster when grammatical structure was given the string. Mehler (1965) cited the well observed phenomenon that a person can often "rephrase" in his own words the general sense of a message, and concluded that it would seem to indicate that semantic components of a meaningful sentence are generally easier to recall than are its specific grammatical details. He proposed that subjects analyze sentences into a "semantic component" plus "syntactic corrections", and thus most errors in recall are due to syntactical confusions. Savin and Perchonock (1965) pointed out, that if the capacity of memory is constant, it follows that each word of a sentence cannot be remembered as a separate chunk, for if it were then sentences would be just as difficult to remember as the same words in random order, and this is not the case. They further suggested that increasing syntactic complexity produces an increasing strain on short-term memory due to increased information processing, which follows from Mehler's (1963) model of storage of sentences consisting of the kernel plus tags identifying grammatical transformations. Dobrow (1970) supported the notion that sentences are remembered and recalled in terms of the semantic representation of the indicated words and concepts. Fillenbaum (1966) demonstrated that "not closed" was

mistakenly recalled as "open" more often than as the syntactically related "closed". O'Connell et al. (1968) investigated grammatical structure and prosody (intonation) and found that both facilitate recall, thereby confirming the powerful organizing effects of constituent structure. Olive and Nakatani (1974) concluded that the lack of prosody causes all words to seem equally important; thus the burden of assessing the relative importance of the individual words is on the listener.

Results from recent investigations concerning linguistics and learning and recall of verbal material provide conflicting findings; however as Savin and Perchonock (1965) indicated, the necessity for some avenue to structure sentences undoubtedly exists, and most of the reports support the deep structure of sentences as relevant to sentence organization on the psychological level. Thus, the use of linguistic strings as maskers may involve some of the perceptual analysis in other language related experimental tasks.

Researchers involved in learning and memory have determined that:

- 1) the presence of either syntactic or semantic structure facilitates learning;
- 2) retention is inversely related to linguistic violation;
- and 3) syntactic and semantic structure contribute to the successful storage of sentences.

Echoic Memory

The "persistence" of auditory impressions makes them briefly available for processing even after the stimulus has been terminated.

The notion of auditory persistence was expounded by Miller (1948), in connection with the perception of short bursts of noise. Neisser (1966) designated this stage of cognition echoic memory, and stated that the existence of such a store is suggested by observation that sound is an intrinsically temporal event, requiring that information occurring early in the time course of a stimulus be stored temporarily, awaiting integration with later information to permit perception of the whole unit. Stern, noting that "unitary perception" applies only to phenomena lasting under 0.8 sec., referred to this period of time as the "conscious present" (Bekesy, 1960). Echoic memory has been described as a kind of transient memory, representing a preliminary and brief storage in some medium which is subject to very rapid decay. Estimates of time constants range from 250 msec. to 5 sec. depending upon the nature of the stimulus and the paradigm in which they were presented (Springer, 1973). The existence of such a stage of cognition follows from observations of common everyday experiences.

New modes of organization could hardly be learned if inappropriate ones destroyed the basis for learning, for the foreigner who is told "No, not zeal, seal!" could not benefit from this advice unless an echoic memory preserved the initial /z/ for comparison with the subsequent /s/. Moreover, the suprasegmental phonemes seem to depend on a relatively long echoic memory. If the difference between the rising inflection of 'you can come?' and the level of 'You can come!' is to be detected, the acoustic basis of 'you' and 'can' must still be available when 'come' appears. (Neisser, 1966, p. 201).

In addition to empirical demonstration, direct experimental evidence has established the existence of echoic memory. Deutsch (1951) in a preliminary report discovered after-effects which would indicate

that there is something analogous to visual figural after-effects in hearing. In an experiment conducted by Eriksen and Johnson (1964), subjects' attention to the reading of a novel precluded any encoding of the sounding of a beep; therefore they inferred that recall in this procedure must have been based on echoic memory alone. Similar findings were described by Peterson and Kroener (1964). They showed that the ability to recover a nonattended auditory stimulus shows a negatively accelerated decay function in time. Fraisse (1963) reasoned that one must have echoic memory for the perception of rhythm; therefore he carried out extensive studies of the structure of rhythm and reported that "intertap intervals" greater than 2 sec. apart seem to lose their rhythm, thus one estimate of the time constant of echoic memory.

Further work has elucidated some of the features of echoic memory. Crowder and Morton (1969) labelled echoic memory--precategorical acoustic storage (PAS). They maintained that prior to categorization information is held briefly in a form appropriate to the input mode. The assertion was made that information in PAS could be processed and coded to the level of feature analysis; however they defined categorization to a level at which there becomes the potential for a direct linguistic response. Thus, it is raw information that is held in PAS since it has not yet made contact with the listener's overlearned linguistic repertoire. They depicted PAS as the most primitive level of perception and stated that information in PAS is lost due to 1) displacement by subsequent auditory events, and/or 2) decay with the passage of time.

Massaro (1970, 1971, 1972, 1973) conducted many investigations relating to this same area which he classified as preperceptual auditory images. Like Neisser (1966), Massaro (1971) reasoned that since the processing of information usually requires the analysis of a temporal continuum of sensory features, some sensory storage of the early impressions during the later inputs is necessary for perception of the message. He made two assumptions: 1) the auditory image persists beyond the stimulus presentation and preserves its sequential information, and 2) recognition entails a readout of the information in the preperceptual auditory image. This readout takes time and is referred to as the temporal course of perceptual processing.

Massaro maintained that the detection masking paradigm is not appropriate for studying the temporal course of auditory identification or recognition; therefore a recognition masking task was devised to determine the properties of the auditory information storage system and to quantify the temporal course of processing of auditory information. He determined: 1) pitch identification of a short test tone can be interfered with by a retroactive masking tone (the pitch identification improved as the silent interval between test and masking tone increased up to about 250 msec); 2) a short masking tone is as effective as long masking tone (therefore the masker precludes perceptual processing, not merely interferes with it); 3) frequency similarity of masker to test tone is not critical for preclusion; and 4) presenting the masking tone contralateral to the test tone presentation does not decrease backward masking in the recognition paradigm (therefore the preperceptual

auditory image is located centrally rather than at the peripheral level).

The auditory after-image has been likened to the visual after-image, which has received much attention (Sperling, 1960). Macworth (1963) discussed incoming visual stimuli as being stored in two different ways: 1) a preliminary, very brief storage, followed by 2) a selective process leading to a somewhat more durable storage.

That this brief storage is not the classical, more durable, short-term storage or active verbal memory (Neisser, 1966) was indicated by Turvey (1967) who demonstrated the absence of an accumulation effect with repetition for echoic memory. Such an effect is seen in short-term memory. Turvey reasoned that the lack of encoding in the preperceptual information store deleted any accumulative effect. Broadbent (1963) further differentiated these two systems based upon the lack of decay due to interference in echoic memory as seen in short-term memory. Neisser (1966) differentiated echoic memory from short-term memory through the differential effect of the rate of presentation upon the two media. The greater the rate of presentation, the poorer the recall for encoded material, but the better the recall for uncoded material, since echoic memory fades with time. Helton (1963) and Howbray (1964) referred to the "Preperceptual sensory stores" and the "Postperceptual memory".

If one accepts the existence of echoic memory, one may propose that such a store would indeed affect all auditory input. One might further speculate that all auditory input would be treated in the same fashion in such storage as follows from the work of Crowder and

Morton (1969) in which they refer to echoic memory as "precategorical."

Short-Term Memory

Neisser (1966) conceived of a mechanism which takes information out of echoic storage and puts it into short-term memory (STM) or active verbal memory. This conversion of information, or the recoding: 1) protects information against the passage of time, and 2) takes a certain amount of time to occur.

McGeoch and McDonald (1921) examined the methods of encoding over short intervals of time. They found that the degree of forgetting was related to the degree of associative similarity between the interpolated learning and the original learning. However, since the discovery by Conrad (1962) that patterns of errors in STM resemble those in the perception of speech, there has been considerable interest in the source of these "acoustic" confusions, and a number of experiments have shown that information stored in STM is still very much auditory information (Conrad, 1959, 1962, 1964).

Conrad (1964) found that subjects, upon seeing a consonant, seemed to encode the consonant in keeping with its acoustical dimensions. Wickelgren (1965) concluded that partial forgetting of an item is possible, producing intrusion errors that share the unforgotten property common to both the original item and the intrusion item. The work of Conrad and Hull (1964) suggested that differences in memory span for digits, letters, and words, are due to the greater possibility of confusions in a larger vocabulary. Conrad, Freeman, and Hull (1965)

comparing acoustic factors vs. language factors in STM, concluded that for short term storage of consonant sequences, encoding of presented material depends much more upon what the individual letters sound like than upon the frequency with which they have been previously met in the course of using language.

The acoustic coding model of STM proposed by Conrad and Wicklegren is not accepted by all, and in fact the alternate association model had been proposed by McGeoch and McDonald (1921) long before the acoustic model of STM was proposed. Wickens and Eckler (1968), using a release from proactive inhibition paradigm, concluded that the important variable is the conceptual class in which the material is encoded rather than its acoustic characteristics. Levy (1971) supported the view that STM is not an "acoustic store" containing purely acoustic traces, but rather STM is a flexible system in which information is encoded in several forms. Klein (1970), incorporating a recognition task, found that subjects use acoustic and semantic features to represent words in memory. Forrester and King (1971) found the degree of semantic relatedness among list items to be an effective variable in influencing free recall, while acoustic relatedness had no effect upon the amount of words recalled. Heisey and Duncan (1971) proposed syntactical encoding in STM after they demonstrated release from proactive inhibition when syntax was changed. Marshall et al., (1969) suggested that the finding that bilingual subjects can recall a word equally well when, its other language translation is substituted for some of its repetitions, despite the fact that the item and its

translation may be visually and phonetically different, supports the associative model of STM coding, that a concept or meaning is stored in STM not a word in a particular language.

While the significance of STM for speech perception is presently accepted, the morphology of this memory is controversial. Phonemes, allophones, and distinctive features are rather abstract concepts. Even restricting oneself to events occurring within the nervous system, one cannot say that a phoneme, allophone, or feature is merely a sequence of auditory (sensory) events, because it is also a sequence of speech-motor commands and also the kinesthetic feedback from speech at other phases of the verbal communication process. Certainly there is a growing school of linguists and psycho-linguists that believe it is necessary to postulate abstract levels of processing language material. These abstract verbal systems are very likely not purely sensory or motor modalities, though they undoubtedly receive input from sensory systems and can provide output to motor systems.

What existing data do not answer is the question of whether the verbal trace in STM is in: 1) an auditory (sensory) modality, 2) an articulatory (motor or kinesthetic-sensory) modality, or 3) an abstract verbal modality. A decisive study has yet to be undertaken, and the results of such a study would greatly influence future work in speech recognition, learning, etc. Many theories attempt to dichotomize memory in terms of differential semantic and acoustic encoding; however studies have confirmed the influence of both semantics and acoustics on STM. Although a listener is not overtly attempting to "remember" the masker,

syntax, semantics, and phonology might in fact aid in that "remembering" and thus possibly result in increased masking effectiveness, while the absence of these linguistic parameters might inhibit "remembering", and thus decrease the masker's effectiveness.

Attention

Neisser (1966) defined attention as an allotment of analyzing mechanisms to a limited region of the field. This selection is based on a combination of an analysis of the pertinence of the possible inputs and the actual inputs that have arrived. Broadbent (1958) defined attention as the selective aspect of perception and response, in which different perceptual "analyzers" each provide a set of mutually exclusive descriptions for a stimulus. Norman (1968) proposed that selection is determined by contextual, grammatical, and meaningful cues as well as by the physical form of the inputs.

One may view attention, the selective operation of the human perceptual system, as a consequence of the limited capacity of the system. Attention enables an observer to extract more information from a selected stimulus configuration (Picton et al. 1971).

The phenomenon of selective attention has been investigated by many researchers. Deutsch and Deutsch (1963) posed three questions pertaining to the process: 1) How are different streams of information kept distinct by the nervous system?, 2) How is a resulting babble thereby avoided?, and 3) Why is only one of the messages dealt with at any one time?. The following discussion encompasses four theories which

purport to answer these queries.

Studies in the area of selective listening and attention have employed a somewhat standard design constructed to understand why even though either message becomes understandable if the listener is instructed to ignore the other, the two messages together cannot both be understood even though the necessary information is available to the ear. The task concerns the possibility of answering or shadowing (repeating that which one hears), one of two messages which start at the same point in time, but one of which is irrelevant (Broadbent, 1952A).

Broadbent (1952) considered the possibility that the results from the foregoing experiments were contaminated by masking, however he concluded that

the process of selecting part of the presented sounds for analysis and response is not infallible and may lead to errors distinguishable from those due to masking. (Broadbent, 1952, p. 431)

The difficulties in changing the voice to be selected does not occur when one voice is always to be selected, and so cannot be due to simple masking, and therefore irrelevant information increases errors presumably because it is not discarded. Irrelevant messages produce this type of effect because they are not discarded, even when they are not strictly simultaneous. Poulton (1953) found that separate speakers reduced mishearings which were correlated with the degree of interference, by helping subjects distinguish the noise from the two sources, and reduced omissions by giving a clear indication of which speaker to be monitored. Cherry (1953) has shown that if two speech samples have the

same semantic content (e.g. a series of cliches strung together) and are spoken by the same talker, a listener cannot separate one message from the other. That this is not masking as such was shown by Cherry in that if the two speech samples are different in context, one message can, with effort and with repeated playback, be differentiated out and spoken back.

Single-Channel Theories

Broadbent's Filter-Theory

Broadbent proposed the filter theory of attention, in which he suggested that these filters can be "tuned" by the observer to any of a large number of "channels". The filter only passes information from the channel to which it is tuned, and possible channels might be the sense organs, voice quality, etc. However, response to several channels is possible when the rate of information flow is low and only information passed can affect the subject's response or be long remembered. Howbray (1964) concluded that only when a stimulus has been processed by some unknown part of the nervous system can it be validly considered to form a part of memory. Figure 4 is a flow chart for Broadbent's filter theory of attention.

Thus, the filter theory of selective attention, assumes that when several messages reach the senses, they are initially processed in parallel, but must at some eventual stage converge on a perceptual or decision channel of limited capacity. To reduce the load in the perceptual system, a selective filter blocks irrelevant messages before they reach the bottleneck.

Figure 4. Schematic diagram of Broadbent's filter theory of attention.

However, there are experimental findings which are contrary to the model proposed by Broadbent, in which irrelevant messages are rejected before their words and meanings are identified. For example, Moray (1959) employing the shadowing of one of two dichotic messages technique, found certain patterns which are important to the subject are selectively transmitted even when the block is in operation, i.e. the person's name. In addition, he found that although subjects were ignorant of the content of a message simultaneously presented to the other ear, they could state whether it was speech or noise, a man's or a woman's voice, etc., thereby indicating that the block is central to some pattern analyzing mechanism. Cherry (1953) found that the rejected signal has certain statistical properties recognized, although the detailed aspects are unnoticed. Important words and certain features were allowed through the selective filters, despite the fact that they came from the rejected ear.

Treisman (1960), incorporated the findings of Moray and Taylor (1958) that the higher the transition probabilities between the words the more likely they were heard and repeated correctly. She found that subjects did hear words from irrelevant messages if these were highly probable in the context of the message they were repeating. Even the proponent of the filter theory, Broadbent (1962) acknowledged that when a listener knows to within a small number of alternatives what each message will be, the filter will pass both messages; however, when one or both messages are drawn from a large number of possibilities, only one message gets through.

Thus, Treisman demonstrated that not only important words, but highly probable words would be allowed through the selective filter. Cherry (1953) demonstrated that when a 2-6 sec. delay between the same signal to both ears exists, listeners do detect it. Treisman reasoned that the above results indicate that comparisons between the messages must be made at a central level, and requires the identification of words and meanings rather than the simple analysis of the sounds, since subjects noticed the identity of the messages even when they were in different voices or different languages (Treisman, 1964).

If names, probable words, and identical meanings in the rejected message can force themselves on the subject's attention, he must be listening to it in some sense (Neisser, 1966). Moray (1959), Peters (1954), and Deutsch and Deutsch (1963) found it necessary to assume that all inputs are analyzed rather completely, with filtering or selection taking place subsequent to the analysis as opposed to the filter theory in which analysis occurs subsequent to selection, and at a low processing level. Gillespie (1970) defended the position that all nonattended stimuli reach a level where they have the potential to be assigned the meaning associated with words. Peters (1954) concluded that a message will reach the same perceptual and discriminatory mechanism whether attention is paid to it or not and such information is then grouped or segregated by this mechanism. However, one must still face the fact that so little of the rejected message does make an impression. Treisman (1960) has developed a filter-amplitude theory in which she attempts to account for the data so far accumulated.

Instead of a filter which eliminates signals, she proposed a filter which attenuates signals, and these weakened signals can still be picked up by specially tuned cognitive systems.

Filter-Amplitude Theory of Attention

Two experiments may be cited which support Treisman's contentions rather well. Oswald, Taylor, and Treisman (1960) played to subjects, while they were asleep, a recorded sequence of names. Before going to sleep the subjects had been instructed to close one fist whenever they heard their own name and also for one other specified name. Both relevant names produced far more sleeping fist-clenchings than the irrelevant names, and the subject's own name produced most of all. Howarth and Ellis (1961) found that, using spoken names in a noisy background as the stimuli in a recognition experiment, subjects could recognize their own name 77 percent of the time at a S/H ratio at which other names were heard only 50 percent of the time. They arrived at two conclusions: 1) sleep attenuates or weakens the strength of external stimuli, and 2) more familiar stimuli, for example one's own name, are attenuated less. Treisman's argument is that inattention to one ear in a shadowing experiment simply weakens the signal among them. She adds that only the information content of the message is attenuated--not its loudness.

Attention as Response Suppression

Both Broadbent (1953) and Treisman (1964) proposed theories of selective attention achieved through selective perception. Broadbent proposed a filter which operated at an early stage of perception and which functioned to prevent further perceptual analysis at verbal levels

for any messages other than those marked by the physical features of the primary message. Treisman (1964) modified Broadbent's (1958) conception of the filter, declaring that the filter did not totally prevent verbal analysis of rejected messages but, rather, attenuated the rejected message's signal properties to the point that only important stimuli could receive full verbal analysis.

An alternate conception of the selection process was proposed by Deutsch and Deutsch (1963) and was more recently restated by Norman (1968). In this alternate conception, it is assumed that all rejected messages are analyzed to the point of verbal recognition. Selective attention is assumed to be achieved by limitation of postperceptual processes such as holding message content in short-term memory storage or selection of an overt response.

Greenwald (1972) concluded that the nervous system may: 1) limit perceptual analysis of verbal distractor sequences that are either random or predictable, and 2) suppress verbal responses that tend to be elicited by predictable distractors. Thus, both modes may be operative in selective attention (see Figure 5).

Attention as Auditory Synthesis

Neisser (1966) offered a model of attention conceived of as auditory synthesis. Thus he saw two hypothetical stages in the perception of speech: 1) the preliminary identification of words and other cognitive units carried out by a passive filter system, and 2) the active process of analysis-by-synthesis in which listeners produce "inner-speech" (at some level of abstraction) to match the input.

Figure 5. Perceptual filtering and/or response suppression in attention.
(Greenwald, 1972, p. 59).

He viewed this latter constructive process itself as the mechanism of auditory attention. Thus, to "follow" one conversation in preference to others is to synthesize a series of linguistic units which match it successfully.

Multi-Channel Theory

Allport et al. (1972) suggested that while the single channel hypothesis of attention, which has received numerous affirmations (Broadbent, 1958; Deutsch and Deutsch, 1963; Neisser, 1966; Moray, 1967; 1969), may be applicable in situations which call for simultaneous attention to two closely similar or even identical tasks (Moray, 1969), a multi-channel hypothesis of attention may be more descriptive when tasks to be performed are highly dissimilar. This more appropriate model would be that of a number of independent, special purpose computers (processors and stores) operating in parallel. In general, any complex task will depend on the operation of a number of independent, specialized processors, many of which may be common to other tasks. To the extent to which the same processors are involved in any two particular tasks, truly simultaneous performance of these two tasks will be impossible. On the other hand, the same tasks paired respectively with another task requiring none of the same processors, can in principle be performed in parallel with the latter without mutual interference. While the brain may, in certain circumstances, exhibit "single-channel" operation, as when one is presented two similar tasks, the role of multi-channel operation cannot be disregarded.

Central or Peripheral Locus

Presently, none of the models of selective listening has been overwhelmingly accepted; however the question of central or peripheral locus for this process has been fairly well established. Picton, Hillyard, and Galambos (1971) recorded the click-evoked electrical responses of the human cochlear nerve from the external auditory meatus concurrently with the cortical evoked potentials from the scalp. Results indicated that paying attention to the clicks during a discrimination task resulted in a highly significant enhancement of the cortical response but no change in the cochlear nerve response. Hence, no evidence was obtained for the operation of a peripheral filtering or gating mechanism during attention in man. Broadbent (1957) argued that some central factors are involved when two messages are presented to the ears at the same time. Poulton, Webster, and Thompson (1953) found that the similarity of relevant and irrelevant material produced decreased efficiency in selective listening, indicating central participation. Cherry (1953) showed that listeners can separate out two messages, but not if it is a stream of cliches, therefore indicating that the listener is making use of the transition probabilities between words and phonemes, a factor which is clearly not sensory.

Other investigators have sought to determine the site of the "filter" incorporated in the theories of Broadbent and Treisman. While it is fairly well established that the filter is centrally located, how "central" its location is, is not known. Wilding and Underwood (1968) indicated that the selective filter was between the

analysis of physical characteristics and the analysis of semantic content. However, other reports (Moray, 1959; Peters, 1954) indicated a post-semantic analysis filter.

If one considers Neisser's (1966) definition of attention as the allotment of analyzing mechanisms to a limited region of the field, One may begin to see the many ramifications affecting the masking situation. That is, although a listener is instructed to ignore, or "pay no attention" to the masker, the allotment of analyzing mechanisms may not follow these instructions, especially when one is attempting to ignore very sensible, intact sentences, or on the other end of the continuum, humorous, distracting, non-phonological "gibberish."

Set and Expectancy

An area which is very closely related to attention is set or expectancy. Bruce (1958) considered the set to occur prior to an act of perception, at which time the percipient is in a state of preparedness to receive a particular class of stimulation, and to operate on that stimulation in certain predefined ways. Hall (1958) concluded that what a person sees is a function of what he expects to see. Miller, Heise, and Lichten (1951) studied the effect of syntactical contextual constraint and established verbal habits, upon word identification. Black (1952) offered set or expectancy to explain their results, which indicated that familiar words possess a characteristic of being more accurately identified. Bruce (1958) studied the effect of structural contextual constraint upon intelligibility and found

that when inappropriately prefaced, sentences are likely to be misinterpreted to a considerable extent.

As Carnap (1942) noted, when one observes an application of language, one observes an organism producing a sound or gesture as an expression to refer by it to something, e.g. an object. If, in an investigation explicit reference is made to the speaker, or to the user of a language, then one must assign it to the field of pragmatics, and as Morris (1946) concluded, pragmatics presupposes both syntax and semantics. Pragmatical study involves the relations between the expressions of a language and its users, relations such as acceptance, belief, or social features of language.

Although pragmatics, the interaction of a language user with the language was not directly controlled in the present investigation, information regarding this aspect of language can be inferred from such notions as expectancy and set which in turn may be elucidated through the present results, for one type of linguistic masker may have been more expected, acceptable, and/or believable and therefore easier to disregard.

Linguistic Feature Detectors

There are many reasons for believing that the sounds of speech belong to the structure of language and are highly interconnected with other parts of the language hierarchy. If this is so, one would expect these interconnections to be evident in the neural foundations of language. Stevens (1971) suggested that the auditory mechanism must be endowed with "property detectors", each of which responds to an acoustic attribute corresponding to a feature of language. The characteristic

of a property detector is that it yields a response when the acoustic signal has an appropriate attribute, but there is a sharp reduction in response when the signal does not possess this attribute.

The attribute to which a property detector responds is not necessarily the absolute value of a simple physical entity such as the frequency of a spectral peak or the amplitude of some component of the signal. Rather, the attribute will generally correspond to a more complex pattern of events in time and frequency, such as a set of spectral peaks with the proper relative frequencies, a rising or falling spectral peak, etc. Cooper (1974) proposed that acoustic pattern detection rather than invariant cue detection may be the mode of operation of feature detectors.

There is some evidence for the existence of such property detectors from psychoacoustic experiments and from data on electrophysiological responses measured in the auditory system. For example, evidence from electrophysiological experiments show that there are units in the auditory cortex and in the inferior colliculus that respond to tones that are rising in frequency and other units that respond to falling tones (Whitfield and Evans, 1965; Nelson, Erulkar, and Bryan, 1956). Warren et al., (1967) found that the perception of non-speech acoustic codes appear to be less proficient than comparable speech communication. Eimas et al. (1973), utilizing a selective adaptation procedure in which the sensitivity of a feature detector is lowered, found a linguistic feature detector which mediates the perception of voicing contrasts through the dimension of voice onset time. (Voice onset time (VOT) is the time between the consonant release burst and laryngeal pulsing).

An utterance consists of a sequence of units or segments, each of which is characterized by a bundle of these attributes or features. When a speech signal is received by a listener, the implication is that several property detectors are activated, corresponding to the features comprising each segment, and the outputs of these property detectors provide a decoded version of the signal that is subjected to further processing at higher levels.

When a phonetic segment is generated in the context of a word or in a larger linguistic unit, the individual distinctive features are not necessarily actualized in the clear, unadulterated form implied by the above discussion. Certain acoustic attributes may be distorted or even missing from the acoustic signal. The listener most certainly will be required to resort to higher level information, such as constraints imposed by the phonological rules of the language, the lexicon, and syntactic and semantic rules, in order to decode the signal.

Thus, the distinctive features provide a framework that underlies the production and the perception of speech. They specify a set of ideal targets or goals which may not always be achieved during normal speech. The modifications of the features presumably occur as a consequence of the dynamic properties of the speech-generating mechanism. The basic acoustic feature is obscured, and only some secondary characteristics which identify the feature remain, and which depend upon the particular context in which the feature appears.

It may be expected that these secondary characteristics are not decoded by a listener through transformation by some property-detecting mechanism,

but are interpreted by some process that requires the listener to learn the modifications that the speech mechanism imposes on the ideal acoustic attributes. One possible mechanism that has been suggested is an analysis-by-synthesis scheme. (Stevens, 1971, p. 232)

Summary

In summarizing the information presented in Chapter II, research has indicated: 1) low frequency tones and bands of noise are more effective and efficient maskers than high frequency tones or bands of noise; 2) a wide band of 20 Hz - 4 KHz is more effective than any single narrow band; 3) the masking effectiveness of an interrupted noise may be less than a continuous noise; 4) two broad areas are involved in the perceptual categorization of visual and auditory stimuli, one based on the physical characteristics of the sound and the other based on the association patterns elicited by the stimuli; 5) grammar provides a means for an analysis of the structure which underlies the acoustic pattern exhibited by a phonetic description; 6) a listener assigns a perceptual structure to speech sounds on the basis of one's knowledge of the language; 7) syntactic and semantic structure facilitate learning and recall; 8) auditory impressions persist after the termination of the stimulus; 9) both echoic memory and STM are relevant to speech perception; and 10) attention seems to involve filtering and perhaps response suppression at some central level.

Thus, while many aspects of signal and masker have been studied,

the effect of varying degrees of linguistic constraint upon the effectiveness of a masking signal has yet to be investigated. This experiment was designed to permit such a study, and to interpret results in a context of the complex simultaneous cognitive processes occurring, such as attention, memory, pragmatical and linguistic related perceptual decisions, which have been designated secondary maskers.

CHAPTER III

PROCEDURES AND INSTRUMENTATION

The significance of the effect of linguistic parameters upon masking efficiency was measured using articulation scores. With these scores as an index, comparisons were made among the grammatical, semantically anomalous, ungrammatical, and backward-reproduced strings.

The Masker Material

Miller and Isard (1963) constructed "linguistic strings" which they used as test material for an articulation (discrimination) test. The strings were referred to as sentences, and employed three different base-structures: noun-phrase, verb, noun-phrase; modifier, noun, verb modifier, noun; and noun, verb, noun, prepositional phrase. Examples of these sentences are: A witness signed the official legal document (a grammatical sentence); A witness appraised the shocking company dragon (a semantically anomalous sentence); and A legal glittering the exposed picnic knight (an ungrammatical sentence). The vocabulary was the same for grammatical, semantically anomalous, and ungrammatical sentences. Semantically anomalous sentences were constructed systematically from grammatical sentences. Each grammatical sentence contained five content words which were nouns, adjectives, verbs, or adverbs. Prepositions and articles were not included in this count. The semantically

anomalous sentences were constructed by taking the first word of the first sentence, the second word of the second sentence, the third word of the third sentence, the fourth word of the fourth sentence, and the fifth word of the fifth sentence and combining them into a new sentence that violated the standard semantic rules of English. Ungrammatical strings were created by performing the operation described for the formation of semantically anomalous sentences backward. The fifth word of the first sentence, the fourth word of the second sentence, and so forth, were combined to form a sentence which violated both semantic and syntactic rules. In this manner, five sets of sentences (each set consisting of 10 grammatical, 10 semantically anomalous, and 10 ungrammatical strings) were constructed. The original five sets of sentences may be found in Appendix A. The construction and development of the backward strings will be discussed in the following section.

Recording Instrumentation and Procedure

The Miller-Isard sentences (1963) were recorded by a male speaker of General American English on 175-1/2-600 tape using a Magnecord 1022 recorder which was being operated at a speed of 7 1/2 inches per second, and then spliced and arranged so that all 50 of the grammatical strings were abutting. This process was repeated for the semantically anomalous and the ungrammatical strings; this was done in order to reduce the pause time between strings and thereby provide a more continuous masker. Pause time, as used here, refers to the time during which speech activity is reduced below some predetermined value within and between sentences.

For the purposes of the present study, the 50 abutting grammatical strings were re-recorded in a backward mode on 175-1/2-600 tape using a Magnecord 1022 recorder which was being operated at a speed of 7 1/2 inches per second. This was accomplished by running the original tape through the recorder and then placing this reel in a playback position. Thus, the tail end of the tape was recorded first. The same procedure was utilized for the semantically anomalous strings and the ungrammatical strings, thereby resulting in three distinct classes of backward strings: backward grammatical strings, backward semantically anomalous strings, and backward ungrammatical strings.

The original 150 strings were analyzed using the Bruel and Kjaer Graphic Level Recorder (see Table 1). Reasoning that the backward conditions would give data essentially identical to their respective "forward parent" condition, backward strings were not analyzed in this manner. It became apparent that mean duration varied from one forward condition to another. This may have been due to longer pauses within strings. Accordingly, pause time within strings was measured. — Pause time was defined as a drop of 10 dB from the average major deflection for a period of 100 msec. These values were obtained by measuring the duration of pause time using the readout from the level recorder within each string in millimeters and converting to milliseconds. The mean pause time for each class of strings was then computed. Since mean pause time was relatively constant from one forward condition to another, (Class A and B and B and C varied by

TABLE 1

Mean Duration, Standard Deviation, and Mean Pause Time for Class A (Grammatical Strings), Class B (Semantically Anomalous Strings), and Class C (Ungrammatical Strings), Computed Set-by-Set.

CLASS A	Set					Grand $\bar{X}$
	1	2	3	4	5	
$\bar{X}$ Duration (msec.)	2.738	2.680	2.749	2.804	2.441	2.682
δ (msec.)	.249	.316	.154	.366	.290	
$\bar{X}$ Absolute Pause Time (msec.)	.053	.061	.067	.047	.032	.052
δ (msec.)	.021	.021	.018	.032	.023	
CLASS B						
$\bar{X}$ Duration (msec.)	2.659	2.657	2.826	2.907	2.502	2.710
δ (msec.)	.338	.252	.213	.405	.294	
$\bar{X}$ Absolute Pause Time (msec.)	.047	.057	.051	.041	.032	.047
δ (msec.)	.016	.018	.017	.023	.019	
CLASS C						
$\bar{X}$ Duration (msec.)	2.930	2.962	3.035	3.090	2.907	2.994
δ (msec.)	.424	.191	.227	.394	.338	
$\bar{X}$ Absolute Pause Time (msec.)	.050	.071	.064	.041	.042	.053
δ (msec.)	.030	.019	.014	.026	.023	

only .005 and .006 msec, respectively, as indicated in Table 1). Increased duration appeared to be due to increased syllable duration. However, to check upon the acoustic equivalence of all the linguistic maskers, the non-phonological masking condition was manifested by three backward conditions, not simply backward speech or, as labelled in this report, backward grammatical strings. The assumption was that if indeed the three forward conditions were equivalent, the three mean measures of masking efficiency obtained under the three backward (non-phonological) conditions would not be significantly different across conditions, since the backward conditions retained the overall time and frequency pattern of the parent forward condition. Thus, the three backward maskers served a dual function: 1) they provided non-phonological maskers, violating grammatical, semantical, and phonological rules (as applied by native speakers of English); and 2) they served as an internal check upon the acoustic equivalence of the forward maskers.

Six "half" lists of the C.I.D. W-22 Series (List 3A, parts 1 and 2; List 3B, parts 1 and 2; List 4A, parts 1 and 2) were recorded on 175-1/2-1200 tape from an original disc using an Ampex 440 recorder which was being operated at a speed of 7 1/2 inches per second. They functioned in the capacity of the stimuli.

Calibration of the Stimulus and Masker Materials

The stored linguistic strings and the monosyllabic words were calibrated in the same manner. After setting up and connecting the

experimental equipment in the manner suitable to the present study (see Figure 6), the linguistic strings and the monosyllabic words were played back on one of two Magnecord 1022 recorders. The volume controls were positioned at a point which allowed for both comfortable monitoring and deflection of the needle on the VU meter within non-distorted limits. These settings were held constant throughout the experiment. The maximum peak per linguistic string and per monosyllabic word was determined. (The use of peak values in the calibration of speech material has been demonstrated by Powers and Speaks, 1973). This was accomplished by reading the peaks from an RMS voltmeter. The statistical mean maximum peak for each type of material was computed, which was -1.6 dB and -2.7 dB for the linguistic strings and monosyllabic words respectively. In order to equalize the two types of materials, 1.1 dB of attenuation was introduced into the Daven Company Attenuation Network with an input from the recorder playing the linguistic strings. Upon isolating a string and a word representative of these values, each was played back and the sound pressure level was measured with a Bruel and Kjaer Sound Level Meter, Type 2204, and its associated Bruel and Kjaer Artificial Ear, Type 4152. Both the word and the linguistic string measured 80 dB SPL. Attenuation of 10 dB was then introduced into one attenuator, thereby reducing the sound pressure level of the words to 70 dB. Attenuation of 18 dB into the other attenuator reduced the sound pressure level of the strings to 62 dB. Thus, a speech-competition ratio of +8 dB was employed in the present study, the monosyllabic words being delivered

- A. Magnecord 1022 Recorder (monosyllabic words).
- B. Magnecord 1022 Recorder (masking strings).
- C. and D. Daven Company Attenuation Network, Type H693.
- E. Telephonic TDH-39 Headphone with an MX-41/AR Cushion (*Dummy cushion fills other headphone).
- F. Hewlett Packard RMS Voltmeter, Model 400D.

Figure 6. Schematic diagram of experimental equipment.

at 70 dB SPL and the masking strings at a level of 62 dB SPL. (A +8 dB speech-competition ratio was chosen following a pilot run.) The playback volume was kept constant throughout the experiment. Each experimental session was preceded by a check using a RMS Voltmeter to insure that no change had taken place.

Upon inspection of the data this investigator considered modification of the calibration procedures; therefore a followup experiment utilizing 18 subjects was conducted in the same manner of the original experiment with the exception of the calibration of the masker materials. Instead of a mass mean for all 300 strings, a mean for each class of strings was determined, which was then utilized in individually calibrating every class to produce the desired output of 62 dB SPL using the attenuation network. During the experimental sessions, each condition entailed an individual attenuator setting, as opposed to one attenuator setting for all conditions utilized in the original experiment.

Subjects, Procedures and Instructions

Thirty-six college age subjects participated in this experiment. All had normal hearing and were native speakers of English. No one was familiar with the Miller and Isard sentences.

Subjects were presented with six lists of monosyllabic words, twenty-five words in each list. Half-lists were incorporated as opposed to full-lists because of the limited duration of the masking strings. Support for use of half-lists is indicated by Elpern (1961) and Resnick (1962). These words were presented at 70 dB SPL in the

subject's right ear using the Magnecord 1022 recorder and the TDH-39 headphones with an MX-41/AR cushion and a dummy cushion in the left headphone. Simultaneously, the competing speech (masker) divided into six classes was presented to the same ear, with a speech competition ratio of +8 dB.

The subject's right ear was chosen to receive the input as investigators have consistently demonstrated that right ear scores are higher than left ear scores when normal listeners hear dichotic speech signals. This has been taken to support the primacy of the crossed auditory pathways and the executive function of the left hemisphere for speech and language (Lowe, 1970; Papcum et al., 1974; Inglis, 1965; Kimura, 1961; Wood et al., 1971). The dominant hemisphere may possess a linguistic device, contributory to the perception of speech (Studdert-Kennedy and Shankweiler, 1970).

Thus, six conditions were examined, each subject serving under all conditions, consisting of twenty-five words with the grammatical strings as the competitor; twenty-five words with the semantically anomalous strings as the competitor; twenty-five words with the ungrammatical strings as the competitor; twenty-five words with the backward grammatical strings as the competitor; twenty-five words with the backward semantically anomalous strings as the competitor; and twenty-five words with the backward ungrammatical strings as the competitor (masker). To control for learning effect, counter-balancing among masking conditions and randomization among monosyllabic word lists were incorporated. Six of the thirty-six subjects were presented with

Task A first (grammatical sentences); six, with Task B first (semantically anomalous sentences); six, with Task C first (ungrammatical sentences); six, with Task D first (backward grammatical sentences); six, with Task E first (backward semantically anomalous sentences); and six, with Task F (backward ungrammatical sentences) as the first task, such that the following order evolved: ABCDEF, BCDEFA, CDEFAB, etc.

Listeners were instructed as follows:

You will hear one-syllable words, each one always preceded by the phrase, "you will say", in your right ear. Simultaneously you will hear strings of words, also in your right ear. You are to ignore the strings of words and concentrate on the one-syllable words, writing what you think the word was in the space provided on your response form. Guess if you are not sure.

Write-down responses were requested to avoid scoring bias on the experimenter's part (Nelson and Chaiklin, 1970).

Treatment of the Data

Articulation scores of thirty-six subjects for six experimental conditions were computed in percentages and served as measures. After determining these values, it was possible to analyze statistically the data and to test the hypotheses which are stated in the next section.

The Hypotheses

Repeating from Chapter I, there were two hypotheses tested.

Hypothesis 1. There is no difference in the mean articulation

scores of monosyllabic words masked by: 1) forward and backward-reproduced grammatical strings; 2) forward and backward-reproduced semantically anomalous strings; and 3) forward and backward-reproduced ungrammatical strings.

Hypothesis II. There is no relationship between the subjects' mean articulation scores under any two of the six foregoing conditions.

Statistical Treatment of the Data

A treatment-by-subjects analysis of variance was used to test the first hypothesis (Lindquist, 1953). The measure used in this analysis was the mean articulation score for monosyllabic words for each of the subjects for each masking condition. The treatment-by-subjects analysis of variance was used to test for a difference between the mean articulation scores obtained by all subjects for all six listening conditions. (Lindquist, 1953, p. 156). t-tests for differences between individual pairs of treatment means were used to determine which of the mean scores were significantly different.

Pearson's product-moment correlation was used to test the second hypothesis. The same measures utilized in the previously mentioned tests were incorporated. A test of the significance of the coefficient of correlation was used to determine which of the correlation coefficients were significant (Wiseman, 1966, p. 7).

Summary of Procedures and Instrumentation

One hundred fifty linguistic strings were arranged to yield six

classes of maskers, each representing a different type and degree of linguistic violation. One class was labelled the grammatical strings and consisted of sentences which obeyed the laws of syntax, semantics, and phonology; one class was labelled the semantically anomalous strings and consisted of strings of words which obeyed the laws of syntax and phonology, but violated the laws of semantics; one class was labelled the ungrammatical strings and consisted of strings of words which violated the laws of syntax and semantics, but obeyed the laws of phonology; and three classes of strings were labelled backward grammatical, backward semantically anomalous, and backward ungrammatical strings, all of which violated the laws of syntax, semantics, and phonology.

Thirty-six normal hearing, college age, native speakers of English, served as subjects for six conditions. Both monosyllabic words and linguistic maskers were fed to the subject's right ear simultaneously, and subjects were asked to write the word they heard, ignoring the strings of words. A follow-up experiment employing eighteen normal hearing, college age, native speakers of English serving as subjects was conducted. The follow-up experiment replicated the original experiment except for a modification in calibration procedures.

Analyses of variance, t-tests, Pearson product-moment correlations, and tests of the significance of the coefficients of correlation, were incorporated to test the hypotheses. The results of these tests are included in the following chapter.

CHAPTER IV

RESULTS AND DISCUSSION

Two experimental hypotheses were tested statistically as described in Chapter III of this report. The results of the statistical tests are in the present chapter along with a discussion of these results.

Masking Efficiency as a Function of Linguistic Violations

Mean articulation scores under each condition are in Table 3. Subjects correctly identified more words when the masker was the forward grammatical strings, the backward grammatical strings, the backward semantically anomalous strings or the backward ungrammatical strings than when the masker was the semantically anomalous strings, or the ungrammatical strings. A treatment-by-subjects analysis of variance was used to test the first hypothesis: there is no difference in the mean articulation scores for monosyllabic words masked by: 1) forward and backward-reproduced grammatical strings; 2) forward and backward-reproduced semantically anomalous strings; and 3) forward and backward-reproduced ungrammatical strings. A summary of this analysis is included in Table 2. A significant difference among mean articulation scores was found; thus, the null hypothesis was rejected.

TABLE 2

Summary of analysis of variance. Six treatment conditions were forward grammatical, backward grammatical, forward semantically anomalous, backward semantically anomalous, forward ungrammatical, and backward ungrammatical strings. The dependent variable was the mean articulation score computed in percentage points. N,36.

Source	SS	df	MS	F
Subjects	77,391.4	35		
Treatments	76,971.8	5	15,394.3	4.16*
Error	648,113.0	175	3,703.5	
Total	802,476.2	215		

*Significant beyond the .05 level of confidence.

TABLE 3

Mean articulation scores in percentages and standard deviations for 6 conditions of linguistic masking. N, items/condition, 25; N, listeners, 36.

Condition	Grammatical	Backward Grammatical	Semantically Anomalous	Backward Semantically Anomalous	Ungrammatical	Backward Ungrammatical
Mean ($\bar{X}$)	61.1	66.6	52.4	62.8	53.6	62.2
Standard Deviation (δ)	9.1	13.7	13.3	10.9	12.7	9.3

Fifteen t-tests were computed to determine which differences were statistically significant. Table 4 includes t-values for fifteen paired samples. (Due to the tendency of this statistic to produce type I errors (calling something significant when it's not), when utilized in multiple comparisons, one must be aware of a possible overstatement of differences.) Thus, 1) the mean articulation scores obtained with semantically anomalous strings and ungrammatical strings functioning as maskers were not significantly different from each other, 2) the mean articulation scores obtained with semantically anomalous strings and ungrammatical strings functioning as maskers were significantly different from scores obtained under all other conditions, and 3) the mean articulation scores obtained with grammatical strings, backward grammatical strings, backward semantically anomalous strings, and backward ungrammatical strings functioning as maskers were not significantly different from each other. The latter statement offers support to the assumption, based upon mean pause-time data, that the classes of linguistic strings were acoustically equivalent. However, the question of equivalence might still be suspect since shorter syllables provide for the opportunity for both forward and backward masking in addition to simultaneous masking. As used here forward masking refers to the masking of material which follows the presentation of the masker in time, and backward masking refers to the masking of material which precedes the onset of the masker.

The follow-up experiment, conducted to insure that the differences in mean peak values among the six classes of strings did not influence the data obtained, produced results which were similar to those of the original experiment. Tables of mean values, analysis of variance, and t-tests can be found in Appendix B.

TABLE 4

t-values for 15 pairs of related measures. N, 36; df, 35.

Condition	Grammatical	Semantically Anomalous	Ungrammatical	Backward Grammatical	Backward Semantically Anomalous	Backward Ungrammatical
G	--	3.97*	3.45*	2.01	.81	.49
SA	3.97*	--	.44	4.19*	4.30*	4.43*
UG	3.45*	.44	--	5.18*	4.26*	4.14*
BG	2.04	4.19*	5.18*	--	1.48	1.48
BSA	.81	4.30*	4.26*	1.48	--	.27
BUG	.49	4.43*	4.14*	1.48	.27	--

* Significant beyond the .05 level of confidence.

Relations Among Performance Under Six
Conditions of Linguistic Masking

The second hypothesis: there is no relationship among subjects' performance under one condition of linguistic masking and subjects' performance under any other condition of linguistic masking, was tested with Pearson's product-moment correlation. These coefficients are included in Table 5. Subjects' performance for eight of the fifteen correlations were significantly related, although the extent of that relationship was small, as were the percentages of variance in common which never exceeded 16%. While the null hypothesis was rejected, the magnitudes of the coefficients of correlation warrant further investigation in this area. The correlation coefficients of the semantically anomalous strings and the ungrammatical strings were similar in that they shared significant correlations with three other conditions, the grammatical strings, the backward semantically anomalous strings, and the backward ungrammatical strings. These correlations: 1) provide additional support for the non-significant difference found between these two conditions in the analysis of variance and subsequent t-tests; and 2) imply that these strings acted in a similar fashion as maskers. The significant correlation between the grammatical strings and the semantically anomalous and ungrammatical strings implies that similar factors might be operating and influencing these strings when they function as maskers. The same may be said for: 1) the backward grammatical strings and the ungrammatical strings;

TABLE 5

Pearson product-moment correlation coefficients for 6 conditions of linguistic masking. The dependent variable was percent correct of 25 monosyllabic words. N, 36.

Condition	Grammatical	Backward Grammatical	Semantically Anomalous	Backward Semantically Anomalous	Ungrammatical	Backward Ungrammatical
G	--	.06	.37*	.24	.31*	-.05
BG		--	-.11	.24	.35*	-.11
SA			--	.30 *	.31*	.36*
BSA				--	.40*	.21
UG					--	.38*
BUG						--

*Significant beyond the .05 level of confidence.

2) the semantically anomalous strings and the grammatical, backward semantically anomalous, ungrammatical, and backward ungrammatical strings; 3) the backward semantically anomalous strings and the semantically anomalous and ungrammatical strings; 4) the ungrammatical strings and the grammatical, backward grammatical, semantically anomalous, backward semantically anomalous, and backward ungrammatical strings; and 5) the backward ungrammatical strings and the semantically anomalous and ungrammatical strings.

Discussion of Results

The discussion of the results will be organized in the following manner: 1) information theory as a model to be utilized in discussing the results; 2) figure-ground perception and closure as models to be utilized in discussing the results; 3) discussion of linguistic analysis; 4) discussion of attention; 5) discussion of learning; 6) discussion of memory; 7) discussion of linguistic feature detectors; and 8) discussion of interaction effects.

Information Theory

Shannon (1948) applied information theory to the process of communication. Pollack (1953) utilized an approach to verbal learning based upon a theory of information. Studies such as these introduced the use of information theory as a method for human-communication research. Miller and Nicely (1955) and Singh and Black (1966) incorporated information theory along with distinctive feature theory. Black (1954) studied the information of sounds in context, and thus

applied information theory to the code of communication as well as to the judgments of listeners. As used in studies of speech, information, organization, and predictability are seen "to room together in this theoretical house" (Miller, 1953, p. 3). The amount of information contained in a message is measured in terms of how much this message reduces the number of possible outcomes. Information refers to the amount of uncertainty, unpredictability, or unexpectedness. The knowledge of the rules by which language is constructed enables a listener to predict, to some extent, words in a sentence or phrase on the basis of preceding words. The rules of language contribute to redundancy, and the amount of information per word is reduced by redundancy. Thus, semantics, syntactic and phonological rules increase or decrease the probability of a given word occurring in a given context.

If the linguistic maskers utilized in the present experiment are considered as message sources which have the potential to convey information, then, in terms of probabilities, "one feels intuitively that grammatical strings are more probable (conforming to linguistic rules) and so convey less information, than semantically anomalous strings, which in turn are more probable (and less informative) than ungrammatical strings" (Miller and Isard, 1963, p. 224), which in turn are more probable than the backward or non-phonological strings. Thus, a more probable masker will convey less information, and perhaps require less processing in terms of attention, memory, etc. This could be utilized to explain the present results in that grammatical

strings conveying little information are relatively easy to process compared to the semantically anomalous strings in which successive pairs of words are often quite unusual and improbable. Thus, the masker is "ignored" more efficiently for the grammatical strings than for the semantically anomalous strings, and greater (higher) articulation scores are seen under the former condition. The ungrammatical strings are more improbable than either the grammatical strings or the semantically anomalous strings due to the violation of both the semantic and syntactic rules of language. As such these strings provide more information. However, the additional information contained in the ungrammatical strings relative to the information contained in the semantically anomalous strings did not appear to cause increased attention, etc. or in other words did not appear to increase the efficiency of the masker any more than the semantically anomalous strings which were more efficient maskers than the grammatical strings. It is not clear at this time why this should be so; however it may be the result of interactions discussed later in this chapter. The backward strings, while in violation of all three rule systems of language and therefore possessing the greatest amount of information, did not cause poorer performance as measured by the articulation score. Perhaps due to the total improbability inherent in these strings, they lose their information value and thus are classified as "meaningless" material, and as such do not gain attention, relocate in short term stores, etc.

Egan, Carterette, and Thwing (1954) considered a speech signal as made up of a series of events, suitably chosen, having certain

conditional probabilities among them. These probabilities have relatively high values as compared with the conditional probabilities of the corresponding events of a random noise. Thus, when a speech masker interferes with a speech signal, it not only masks the signal but also becomes confused with it. Therefore, in the present experiment, the semantically anomalous strings and the ungrammatical strings functioned more efficiently as maskers possibly due to the improbabilities within each class, resulting in increased interference and confusion. The grammatical strings were not subject to this improbability within class and as such were not as efficient maskers. The backward strings were possibly not "recognized" or "handled" as speech material, i.e. the extreme improbability within the class resulted in "pseudo-linguistic" processing of the masker, or in other words, treatment of the masker as random noise, and thus creating less interference due to confusion.

Figure-Ground Perception and Closure

The general constancy of most of our perceptions implies the existence of an underlying organizational pattern. The first of these is the phenomenon of figure-ground (The phenomenon of figure-ground may be one aspect of this organization). This may be defined as the perceptual process by which a particular object or object quality is seen to stand out against a background constituted by the remaining objects or object qualities. Goldstein (1948) suggested the term "dedifferentiation" to include a breakdown in one's ability to distinguish between the foreground and the background of a particular

sensory configuration. Figure-ground enables an individual to attend to a particular sound source against a background of other environmental noises and to shift one's attention from one sound source to another. Figure-ground aids in explaining that which has come to be known as the "cocktail-party effect", or the ability of an individual to attend to and understand one conversation while disregarding the other tumultuous chatter which often characterizes such parties. Another factor of importance in perceptual organization is closure. This term refers to the tendency of individuals to perceive an incomplete figure as being complete. Among other things, it accounts for the ability of a person with marked hearing loss to correctly perceive sounds that are inaudible to him. Closure is obviously dependent upon prior experience with the whole figure.

As a model to be incorporated in discussing the present results, one could speculate as to the different figure-ground relationships inherent in the six experimental conditions. Thus, the backward conditions presented the listener with the situation in which the figure (monosyllabic word) was sufficiently different from the ground for the subjects to perform relatively well (see Table 3). If one examines the mean articulation scores among the forward masking conditions one sees that the semantically anomalous strings and the ungrammatical strings, while different from the general set or pool the monosyllabic words may have been drawn from, present the listener with confusion in the ground, and thus performance is depressed.

Grammatical strings functioning as maskers do not present this confusion, and thus, while they are not markedly different from the pool or set from which the monosyllabic words were drawn, they do enable the listener to perform more successfully. An objective of the chapter is to discuss specific perceptual processes which may be responsible for the figure-ground phenomenon such as attention, memory, linguistic analysis, etc.

The need to provide closure, even to an event which one is presumably ignoring, could aid in accounting for the different mean articulation scores obtained under different conditions of linguistic masking. That is, although the strings are grammatical in the semantically anomalous condition, they do not meet "semantic closure", for they are "meaningless". The ungrammatical strings fail to meet either "semantical or grammatical closure". Thus, both conditions are likely to affect perceptual processing in some respect (e.g. attention, linguistic analysis, etc.) and thus depress articulation scores under these conditions. The grammatical strings pose no closure problem and the backward strings are perhaps too remote from the listener's notion of a string or sentence to call into play the phenomenon of closure. Therefore, articulation scores under these conditions would be elevated relative to the semantically anomalous and the ungrammatical conditions.

Linguistic analysis

The results are consistent with the results of previous studies (Trammell and Speaks, 1970; Chermak, 1973; Berry and Nerbonne, 1971; and

Carhart et al., 1969). These investigations point to the significant influence of linguistics above and beyond its acoustic influence when a masker is linguistic in nature.

Miller and Isard (1963) stated that in order to understand a spoken sentence it is necessary to process the received acoustic signal according to the linguistic rules of the language. If one assumes that a linguistic masker, although presumably (ostensibly) ignored, is processed similarly, and if, as Fodor and Bever (1965) concluded, this processing involves constituent analysis, the results of the present investigation seem highly plausible. That is, the grammatical strings which conform to the rule systems of language are easily and perhaps more quickly analyzed, "understood" and perhaps disregarded thereafter, enabling the subject to perform the identification task relatively well. Such strings provide for constituent analysis and also the application of phrase structure rules at the level of the deep structure. Semantically anomalous strings do possess grammatical structure, but the confusion due to its semantic improbabilities highlighted by the notion that a word does not stand for a thing but rather for a concept, complicates the process of constituent analysis, possibly prevents the use of phrase structure rules, and as such serves as a more disruptive masker. Ungrammatical strings, lacking syntactical structure do not permit constituent analysis, and probably impede the application of phrase structure rules because of the semantic improbabilities and confusion. Therefore, constituent analysis cannot be applied, does not aid the subject, and

may in fact increase the difficulty of the listening task. While the backward strings lack syntactical structure, they also lack semantical and phonological structure. This complete violation of the rule systems may enable the subject to process these strings as "pseudo" non-linguistic material and thus reduce the complexity of the task. Thus, the violation of semantical rules impedes the process of constituent analysis and possibly prevents the application of phrase-structure rules, while the violation of grammatical rules preempts the process of constituent analysis. However, once the semantic rules are violated, the detriment does not seem to increase due to the further violation of the grammatical rules as evidenced by the similarity between mean percentages for the semantically anomalous and the ungrammatical conditions (see Table 3). Perhaps the semantic confusion not only impedes the process of constituent analysis but prevents it as the lack of syntax in the ungrammatical strings does. Another explanation for the similar mean articulation scores between the semantically anomalous and the ungrammatical strings rests in the influence of factors other than linguistic analysis-factors which will be discussed later. A third explanation for the similarity of performance when semantical rules are violated and when semantical and grammatical rules are both violated may be considered in view of the disagreement as to the level at which constituent analysis occurs. While some have relegated constituent analysis to the level of syntax (Fodor and Bever, 1965; Bever and Fodor, 1966; Chapin et al., 1972) others have relegated it to the level of the deep structure or

semantics (Blumenthal, 1967; Rohrman, 1968; Sachs, 1967). Johnson (1965) suggested that language substructures may themselves be substructured, and perhaps this substructuring is at the level of the deep structure. Thus, if constituent analysis is dependent upon semantical as well as syntactical rule systems, then the violation of one or both might equally disrupt the process. The application of phrase structure rules, primarily determined by the semantics of a sentence, is impeded or possibly prevented in both cases. The similarity in mean values obtained under the forward grammatical and the three backward conditions implies that although the backward strings may have been processed as "pseudo" non-linguistic material, some recognition of its linguistic essence must have been realized for the performance under these conditions was not worse or significantly different from the forward grammatical condition as would be expected of white noise as compared to a forward grammatical masker (Berry and Nerbonne, 1971).

Thus, the consideration that linguistic constituents determine the perceptual processing units imposed by the listener on heard sentential material may be invoked to explain the present results. Several variations of this notion have been advanced.

Attention

Although subjects were instructed to "ignore" the masking material in the present experiment, this investigator cannot be certain that subjects did "ignore" the maskers. One of the most

puzzling questions about the perceptual selection process is the extent to which the listener can control its parameters (Larkin and Greenberg, 1970). If subjects can control this process to any degree then one must investigate listening strategies. If, for instance, subjects alternately attended to the stimuli and masker materials, and switched when they were signaled (by the carrier phrase "you will say") to the stimulus, then one must consider shifting attention and processing time in any discussion of the results. If one assumes that they cannot exert control in this selective aspect of perception, then one may interpret the present results with more assurance. At least one study (Robinson, 1970) showed the limits of "objective" selective attention are exceeded when delayed auditory feedback is the nonattended message.

The results can be viewed as supportive of a theory of attention as proposed by Norman (1968), Deutsch and Deutsch (1963), and Greenwald (1972). That is, if the grammatical strings were easily recognized due to their linguistic conformity, and the backward strings were easily disregarded due to their complete linguistic violation, both would require extensive verbal analysis prior to the suppression or filtering. Neither Broadbent's or Treisman's model provides for the necessary verbal analysis. On the other hand both the semantically anomalous strings and the ungrammatical strings were inherently confusing and in violation of one or two rule systems--semantics and syntax. This may have caused increased perceptual or verbal analysis to eventually reach the point of inattention, or perhaps this confusion

and violation prevented complete inattention. The latter speculation is supported by the notion that selection depends upon characteristics of the input itself and upon information in a more permanent store (Broadbent, 1957). Thus, if this "more permanent store" did not contain information concerning semantic anomalies or grammatical deviations this could account for a less effective selection process. Norman (1968) also offers support for this latter contention in that he viewed pertinence as based upon the expectations of future inputs and clearly semantically anomalous strings and ungrammatical strings are not to be expected. In view of Greenwald's (1972) contention that limited perceptual analysis and/or response suppression tend to be elicited by either random or predictable sequences, one may infer that the grammatical strings (functioning as predictable sequences) and the backward strings (functioning as random sequences) elicited these processes and thus provided less distraction to the subjects than the semantically anomalous or ungrammatical strings did, and thus higher mean articulation scores were found under the former conditions. The results do not seem supportive of a multi-channel theory of attention as discussed by Allport et al. (1972), for such a theory might predict poorest performance under the grammatical condition and progressively better performance as the violation of linguistic rules increased. The more dissimilar the speech and the competing message are, the greater the opportunity for parallel processing of the stimuli and masker, and the better the resulting articulation scores. Clearly this is not the trend seen in the mean values (Table 3).

As previously stated, whether or not subjects did "ignore" the masker material as instructed and whether subjects can exert control in some manner over the situation is not known with any certainty. If one assumes that subjects may have switched attention between the competing messages during the task, another explanation of the results follows. That is, as Mewhort et al. (1971) concluded, switching attention requires processing capacity, and the greater the encoding difficulty the greater is the amount of time necessary to switch or the lesser is the amount of switching actually accomplished. Thus, when the semantically anomalous strings and the ungrammatical strings functioned as maskers, the greater was the encoding difficulty at some level; therefore it required more time to switch thereby depressing articulation scores under these conditions. It may be that the backward strings were not more difficult to encode, but in fact easier to encode in terms of their "pseudo" non-linguistic nature, and thus less time was required to switch attention and thus articulation scores under these conditions were not depressed. Grammatical strings, posing little encoding difficulty, likewise did not depress articulation scores. One may also view this as Treisman (1971) did in that it takes time to reset the parameters for perceptual processing when attention is alternated.

Hockey (1970) offered another explanation for the present results in that selectivity of attention increases concomitantly with arousal and noise increases arousal. Thus, the backward strings being more

"noise-like" ("pseudo" non-linguistic) increased the capacity of the listener to selectively attend to the speech stimulus and ignore the masker. Better articulation scores under these conditions of masking can be explained in this way. However, this line of thought would predict that articulation scores under the semantically anomalous and ungrammatical conditions would be progressively better than those scores observed when the grammatical strings functioned as the masker and this was not evident from mean values (Table 3).

Familiarity of the masker in relation to attention provides for another explanation of the results under consideration. Kagan's discrepancy principle (1970) stated that stimuli that vary moderately from a scheme receive longer periods of attention than do stimuli that either are familiar or are so different that they appear to have no relationship to the scheme. Brown et al. (1969) found that stimuli of a certain degree of novelty--not too familiar and not too strange--command the greatest attention. Although both of these studies involved children, their significance for the interpretation of the present results cannot be overlooked. Thus, the semantically anomalous strings and the ungrammatical strings possess a certain degree of novelty, "semi-familiar", and as such engage the attentional mechanism more than the grammatical (very familiar and backward string (totally unfamiliar) do; therefore, causing poorer performance under the former conditions.

In terms of expectancy and set, both within the realm of pragmatics,

it is clear that the semantically anomalous strings and the ungrammatical strings presented the listener with an unexpected situation, which may affect the shifting of sets, which would add to both the amount of perceptual processing and the time spent in perceptual processing. In addition, these two conditions may have been less acceptable or believable; therefore they were more difficult to disregard. Grammatical strings would meet the expectancy of the listeners, and perhaps be more acceptable to them. The backward strings, being beyond the limits imposed by native speakers of English, upon English, would be outside the realm of interference. Such reasoning would predict the pattern of results seen in Table 3.

Learning

Information obtained through experiments in learning may be very useful in understanding the present results. An assumption which is preliminary to the following discussion is that the masking material is processed in some fashion after it leaves the peripheral auditory system. Without speculation as to what that processing might involve, one may inquire as to the applicability of knowledge concerning the process during learning to the processes executed during masking.

Harks and Miller (1964) found that the presence of either semantic or syntactic constraint facilitates the learning of linguistic strings. Danks (1965) found that syntactic and semantic violations lengthen processing time with meaningfulness exerting the larger effect. Johnson (1965) proposed that part of the learning has already been completed when subjects are presented grammatical material. These

studies help to explain the present results in that semantical, and grammatical and semantical violations, as seen in the semantically anomalous and the ungrammatical conditions respectively resulted in depressed articulation scores. One could speculate that these maskers required increased processing time and/or an increased amount to process, while the grammatical strings provided for more efficient processing. The ease of performance under the backward conditions would not be predicted using this rationale, and attentional mechanisms or interactions to be considered later might better explain results under those conditions.

Memory

The notion of auditory persistence or echoic memory would lead one to predict that whatever effect it exerted during one condition, would be exerted equally during all other conditions provided the S/N ratios and temporal and spectral characteristics were highly similar among conditions. That this would be so was supported by Massaro (1971) and Crowder and Morton (1969) in which echoic memory was shown to be pre-categorical in nature. However, Crowder and Morton (1969) asserted that information in the PAS could be processed and coded to the level of feature analysis. Thus, backward strings would probably receive some differential treatment relative to the forward strings due to the loss of feature permanence in the backward mode (Black, 1973). That these backward conditions were affected in a similar fashion, and that they were affected significantly differently than most forward conditions can be seen in Table 3 and Table 2 respectively. Further

support for the contention of similar effect among these backward conditions can be seen in Table 6. Thus, the backward conditions showed significant correlations with almost the identical conditions.

Although the PAS or echoic memory would affect all of the conditions (except the backward conditions) in the same fashion, short-term memory, which Neisser (1966) contended would be the subsequent storage mechanism, quite probably exerts a differential effect across conditions. While the controversy over the morphology of this store is unsettled, three possibilities prevail: short-term memory is 1) an auditory modality; 2) an articulatory modality; and 3) an abstract verbal modality. If one supports the notion of STM as functioning based upon abstract verbal units, then the present results meet yet another explanation.

As Slamecka (1969) concluded, retention is inversely related to linguistic violation. Weisberg (1971) supported the theory of sentence storage based upon the deep structure, however Forster (1966) reported that strings of nonsense words were learned faster when grammatical structure was given the string. Mehler (1965) concluded that semantic components of a meaningful sentence are generally easier to recall than are its specific grammatical details. Taken together, these conclusions support the need for some type of linguistic organization in memory. In terms of the present results, the grammatical strings would probably be "remembered" less well than the semantically anomalous strings due to the inability of listeners to remember the

syntactical details of a sentence. However, the semantically anomalous strings and the ungrammatical strings might be "remembered" better or simply cause increased processing or processing time because the semantics, which is subject to easier retention, is disruptive in both cases. The backward strings may not be "remembered" or considered in STM due to their lack of any abstract linguistic content; therefore performance under these conditions would be better (as well as performance under the condition of the grammatical strings) than performance when the semantically anomalous or ungrammatical strings functioned in the capacity of maskers.

If one accepts the articulatory modality as representative of the morphology of the STM trace, then one could conjecture that the backward string, not being typical of the articulatory habits of speakers of English, would be remembered less well than the forward conditions, and thus performance under these conditions would be improved relative to the performance under the forward conditions. However, this reasoning would not aid in explaining the differences among the forward conditions. One could apply the above rationale substituting the auditory modality for the articulatory modality, as the backward strings were not typical of the auditory sound patterns listeners experience, in spite of reports that some of the distinctive features heard in forward speech retain their identity when played in a backward mode (Black, 1973).

Linguistic Feature Detectors

Abbs (1971) considered the ultimate problem in the study of the perception of speech to be the determination of how a listener neurally decoded the acoustic speech signal. Many researchers have supported the proposition that the auditory system operates as a feature detector (Stevens, 1971; Peters, 1967; Pisoni and Lazarus, 1974; Geschwind, 1970). While some investigators consider these features to relate to the articulatory properties of the vocal tract (Peters, 1967), others recognize the possibility of specialized complex higher-order linguistic feature detectors (Pisoni and Lazarus, 1974; Geschwind, 1970). Thus, these detectors may function to analyze not only phonetic information, but also semantic and syntactic information.

If one accepts these postulates, the results of the present study warrant discussion in another light. The grammatical strings might be subject to "efficient" analysis as a result of their adherence to syntactical, semantical, and phonological rules, while the semantically anomalous and the ungrammatical strings might cause delayed analysis or prolonged analysis due to their inherent semantical and syntactical violations, respectively. This type of analysis could occupy the central nervous system in some fashion so as to disrupt or in some way cause less efficient processing of the monosyllabic words with which the listener is concerned. The backward strings on the other hand, violating syntactical, semantical, and phonological rules, may be quite readily detected and classified as

"noise" or "pseudo-linguistic strings" and readily disregarded, thus resulting in better performance under these conditions as seen in Table 3.

Interaction Effects and Summary

Although parsimonious theories and explanations are goals of scientific endeavors, such parsimony can sometimes be regarded as "the progenitor of confusion". Such would be the case in the present discussion if this investigator simply treated each explanation of the results as functioning independently of all of the other explanations considered in this report. Certainly, the human organism is subject to simultaneous multi-sensory stimulation and the operation of the organism is dependent to some extent upon past experience and learning. The behavior observed at any one point in time on any one task is affected by many facets of the individual's system and that individual's environment. As has been pointed out in the consideration of any one explanation, the logical conclusions do not always agree with the data, and some reasons (lines of reasoning) do not obviously apply to all classes of linguistic maskers. Therefore, it would be useful to consider all speculation and concepts leading to that speculation, together.

This researcher does not propose to outline the effects of the joint functioning of all of the theories proposed; indeed this is not known to any great extent by anyone. However, some insight into the total processing might be achieved through consideration of such interactions. At any rate, such considerations also provide for a

summary of this chapter.

To commence this discussion the assumption may be made, in view of Heisser's (1966) contention concerning attention, that no high-order processing of any signal is accomplished without an allotment of analyzing mechanisms to a limited region of the field. This allotment will be considered as selective attention. Thus, one must attend to a message or task prior to the emission of any behavior, in the present situation, prior to word identification. The inherent capacity of some classes of linguistic maskers (the semantically anomalous and the ungrammatical strings) to demand greater attention, either in processing time and/or in quantity of processing will at the onset influence differential means among these conditions and the other four conditions examined.

Secondly, although this investigator is not presupposing any serial ordering of events or mechanisms as many or all of these processes may occur simultaneously, linguistic analysis may again favor the ease of processing and eventual disregard of some conditions of linguistic masking over the others. That is, the grammatical strings, possessing both syntactical and semantical constraints, may be analyzed more efficiently in terms of constituent analysis and phrase structure rules than the semantically anomalous strings and the ungrammatical strings which lack semantics, and syntax and semantics respectively.

Thirdly, if one considers memory in its role in speech perception

as viewed by Miller (1962), another differential develops among the classes of strings. Thus, the semantically anomalous strings and the ungrammatical strings both possessing semantic confusions may result in disruptive effects in memory if one accepts the notion of STM as semantic or associational, and thus cause increased negative interference with the task at hand.

Fourthly, one must consider the effects of the hypothetical linguistic feature detectors. If these are operative, then the semantic and syntactical confusions and aberrations present in the semantically anomalous and ungrammatical strings, may increase the burden upon these detectors, and result in increased processing time or quantity of processing necessary and again result in negative disruptive effects in terms of the identification task required of the subjects.

Perhaps all of these facets of the identification of the monosyllabic word against a background of a competing message eventually come to influence attention, making attention the crucial factor in the task. Certainly this possibility exists and might look something like the following. The increase in attention allotted to the masker may be a direct result of set-backs in linguistic analysis, memory, and feature detection processes. Such would be the case when the semantically anomalous and ungrammatical strings served as maskers.

The term "secondary masker" as introduced in Chapter II of this report was suggested as the result of inductive reasoning. That is,

attention, memory, linguistic analysis, and feature detection, seem to influence the masking efficiency of linguistic strings beyond that which is attributable to their acoustic "noisiness", which was judged to be relatively equivalent for all classes of the linguistic materials.

CHAPTER V

SUMMARY AND CONCLUSIONS

The primary goal of the present investigation was to determine whether grammatical, semantical, and phonological constraints affect masking efficiency. The rationale for the study centered around the non-representative nature of white noise and its non-optimal characteristics as determined by Miller (1947). In addition, the conclusions by Miller (1951) and Dirks and Bower (1970) that content and linguistic rules respectively, do not influence masking, warranted a further and more detailed examination.

Thirty-six college age, normal hearing, native speakers of English served as subjects. The experimental task involved the identification of monosyllabic words chosen from the C.I.D. W- 22 series against a competing message. The competing speech was the linguistic strings originally constructed by Miller and Isard (1963). Each subject participated in six listening conditions with: 1) forward grammatical strings as the masker; 2) backward grammatical strings as the masker; 3) forward semantically anomalous strings as the masker; 4) backward semantically anomalous strings as the masker; 5) forward ungrammatical strings as the masker; and 6) backward ungrammatical strings as the masker. Both monosyllabic words and linguistic masker were presented simultaneously to the subject's right ear.

Subjects were instructed to ignore the maskers and write down the monosyllabic words heard. They were further instructed to guess if they were not sure. Articulation scores computed in percentages served as measures.

A treatment-by-subjects analysis of variance and subsequent t-tests indicated that: 1) performance under the forward semantically anomalous strings and under the forward ungrammatical strings functioning as maskers was depressed relative to the other conditions; 2) performance under the forward semantically anomalous strings and under the forward ungrammatical strings were not significantly different from each other; 3) performance under the forward semantically anomalous strings and under the forward ungrammatical strings were significantly different from all other conditions; and 4) performance under the forward grammatical strings, backward grammatical strings, backward semantically anomalous strings, and backward ungrammatical strings was not significantly different from each other.

Subsequent correlational analysis indicated several significant correlations between subjects' performance under one condition of linguistic masking and under another condition of linguistic masking. It was found that the forward semantically anomalous strings and the forward ungrammatical strings formed significant correlations with the same conditions, thus providing additional support for the non-significant difference between these two conditions indicated by the t-test for related measures.

These results could be expected based upon theories of attention,

linguistic analysis and statistics, memory, and linguistic feature detection. Information theory and concepts of figure-ground and closure provide models with which to structure the results. Table 6 summarizes these interpretations. As indicated in Chapter IV, the pivotal concept may very well be attention, for any perceptual strategy will eventually rest upon the allotment of attentional mechanisms to the task.

Conclusions

Results of this study support the importance of the effect of linguistic parameters upon masking efficiency and indicate that of the six maskers studied, the forward semantically anomalous strings and the forward ungrammatical strings are the most effective, based upon the percentage correct responses to monosyllabic words.

The importance of such findings could have effects in terms of clinical audiometrics, where the present predominant masker is white noise. Thus the use of running speech as the competitive signal

might be a more valid masker and as a result of this study might take the form of forward semantically anomalous strings or forward ungrammatical strings.

The present study offers support for: 1) the single channel model of attention as proposed by Norman (1968), Greenwald (1972), and Deutsch and Deutsch (1963) in which response suppression and/or perceptual filtering occur subsequent to verbal analysis; 2) the models of short-term memory which incorporate abstract linguistic

TABLE 6

Interpretations of applicability of theories and
models to the experimental results

	Cram.	Sem. Anom.	Ungram.	Back. Gram.	Back. Sem. Anom.	Back Ungram.
Information						
Theory	+	+	+	-	-	-
Figure Ground	+	+	+	+	+	+
Closure	+	+	+	-	-	-
Linguistic						
Analysis	+	+	+	-	-	-
Attention	+	+	+	-	-	-
Memory	+	+	+	-	-	-
Learning	+	+	+	-	-	-
Linguistic						
Feature Det.	+	+	+	-	-	-

parameters as the morphology of the short-term trace; and 3) the utilization of linguistic analysis (constituent analysis and phrase structure rules) in speech perception, learning, and recall.

Areas for Further Research

Areas for further research include studies using populations other than normal adults, such as children, centrally impaired subjects, presbycusis subjects, etc. Such investigations could provide information concerning auditory perceptual development and pathological consequences. Before specific linguistic constructions could be incorporated in audiological diagnostics, the present study must be replicated using various speech competition ratios. In addition, a comparison between the linguistic maskers incorporated in the present study and white noise modulated in a speech-like wave form would aid in the final determination of the advantage of linguistic strings over white noise as maskers; specifically the advantage of the forward semantically anomalous strings and the forward ungrammatical strings over white noise.

Consequences for Speech Perception

As auditory masking is a component of auditory perception, results of the present report may provide insight into the general nature of speech perception. Specifically, the present results imply that any acoustic theory of speech perception such as that proposed by Fant (1967)

must be expanded to provide for the influence of semantic content,, probabilities, etc. Thus, a strict acoustic theory of speech perception would probably fail to account for the supra-acoustical aspects of speech signals and their perception. In the same vein, a motor theory of speech perception as proposed by Liberman (1957) would also meet these same limitations. Even a neurosensory feature detector theory of speech perception as proposed by Abbs and Sussman (1971) fails in accounting for these extra-acoustic aspects of perception. Again, parsimony is a goal, but not one to be attained at the expense of an adequate theory which would describe, explain, and predict events given sufficient preliminary data.

APPENDIX A

Masking Material Constructed By Miller and Isard

SET 1Grammatical:

1. A witness signed the official legal document.
2. A jeweler appraised the glittering diamond earrings.
3. A magazine exposed the shocking political corruption.
4. A storm prevented the annual company picnic.
5. A knight slew the ferocious fire-breathing dragon.
6. Sloppy fielding loses baseball games.
7. Romantic poetry describes eternal love.
8. Spilled ink leaves ugly spots.
9. Total chaos follows nuclear attacks.
10. Instant coffee saves wasted minutes.

Anomalous:

1. A witness appraised the shocking company dragon.
2. A jeweler exposed the annual fire-breathing document.
3. A magazine prevented the ferocious legal earrings.
4. A storm slew the official diamond corruption.
5. A knight signed the costly political picnic.
6. Sloppy poetry leaves nuclear minutes.
7. Romantic ink follows wasted games.
8. Spilled chaos saves baseball love.
9. Total coffee loses eternal spots.
10. Instant fielding describes ugly attacks.

Ungrammatical Strings:

1. A legal glittering the exposed picnic knight.
2. A diamond shocking the prevented dragon witness.
3. A political annual the slew document jeweler.
4. A company ferocious the signed earrings magazine.
5. A fire-breathing official the appraised corruption storm.
6. Loses poetry spots total wasted.
7. Describes ink attacks instant baseball.
8. Leaves chaos minutes sloppy eternal.
9. Follows coffee games romantic ugly.
10. Saves fielding love spilled nuclear.

SET 2Grammatical:

1. Colorless cellophane packages crackle loudly.
2. Fragrant yellow roses bloom annually.
3. Foreign political ideas spread dangerously.
4. Healthy young babies sleep soundly.
5. All angry wildcats fight furiously.
6. The book explained the complicated mathematical formula.
7. The club elected the worst possible officers.
8. The bolt fastened the heavy oak door.
9. The President advocated the controversial health bill.
10. The musicians played the gay lilting waltz.

Anomalous:

1. Colorless yellow ideas sleep furiously.
2. Fragrant political babies fight loudly.
3. Foreign young wildcats crackle annually.
4. Healthy angry packages bloom dangerously.
5. All cellophane roses spread soundly.
6. The book elected the heavy health waltz.
7. The club fastened the controversial lilting formula.
8. The bolt advocated the gay mathematical officers.
9. The President played the complicated possible door.
10. The musicians explained the worst oak bill.

Ungrammatical:

1. Sleep roses dangerously young colorless.
2. Fight ideas soundly angry fragrant.
3. Crackle babies furiously cellophane foreign.
4. Bloom wildcats loudly yellow healthy.
5. Spread packages annually political all.
6. Explained the officers bold health gay the.
7. Elected the door President lilting complicated the.
8. Fastened the bill musicians mathematical worst the.
9. Advocated the waltz book possible heavy the.
10. Played the formula club oak controversial the.

SET 3**Grammatical:**

1. The academic lecture attracted a limited audience.
2. The odorless liquid became a filthy mess.
3. The wealthy child attended a private school.
4. The Holy Bible inspired a deep reverence.
5. The transparent wrapper fitted a chocolate bar.
6. The newly opened restaurant needed customers.
7. The nationally advertised cigarette caused cancer.
8. The cleverly disguised criminal fooled everybody.
9. The brightly colored toys pleased children.
10. The gently falling snow covered streets.

Anomalous:

1. The academic liquid attended a deep bar.
2. The odorless child inspired a chocolate audience.
3. The Holy wrapper attracted a filthy school.
5. The transparent lecture became a private reverence.
6. The newly advertised criminal pleased streets.
7. The nationally disguised toys covered customers.
8. The cleverly colored snow needed cancer.
9. The brightly falling restaurant caused everybody.
10. The gently opened cigarette fooled children.

Ungrammatical:

1. Attracted wrapper the reverence private odorless a.
2. Became lecture the bar deep wealthy a.
3. Attended liquid the audience chocolate Holy a.
4. Inspired child the mess limited transparent a.
5. Fitted Bible the school filthy academic a.
6. Heeded advertised cleverly the toys streets.
7. Caused disguised brightly the snow customers.
8. Fooled colored gentle the restaurant cancer.
9. Pleased falling newly the cigarette everybody.
10. Covered opened nationally the criminal children.

SET 4Grammatical:

1. The clock was built by a Swiss watch maker.
2. The crowd was awed by a daring lion tamer.
3. The event was foretold by a Gypsy fortune teller.
4. The blaze was extinguished by a volunteer fire fighter.
5. The trash was removed by a lazy garbage collector.
6. Union leaders call sudden strikes.
7. Bright flies lure rainbow trout.
8. Loud parties wake sleeping neighbors.
9. Tropical jungles challenge hardy explorers.
10. Compact cars use cheaper gasoline.

Anomalous:

1. The clock was awed by a Gypsy fire collector.
2. The crowd was foretold by a volunteer garbage maker.
3. The event was extinguished by a lazy watch tamer.
4. The blaze was removed by a Swiss lion teller.
5. The trash was built by a daring fortune fighter.
6. Union flies wake hardy gasoline.
7. Bright parties challenge cheaper strikes.
8. Loud jungles use sudden trout.
9. Tropical cars call rainbow neighbors.
10. Compact leaders lure sleeping explorers.

Ungrammatical:

1. The built a was tamer fortune blaze by lazy.
2. The awed a was teller fire trash by Swiss.
3. The foretold a was fighter garbage clock by daring.
4. The extinguished a was collector watch crowd by Gypsy.
5. The removed a was maker lion event by volunteer.
6. Call flies neighbors hardy compact.
7. Lure parties explorers cheaper union.
8. Wake jungles gasoline sudden bright.
9. Challenge cars strikes rainbow loud.
10. Use leaders trout sleeping tropical.

SET 5Grammatical:

1. The sticky humid weather frayed tempers.
2. The popular young actor signed autographs.
3. The frenzied Latin rhythm aroused passions.
4. The old gray mare ate hay.
5. The secret miracle ingredient worked wonders.
6. Gadgets simplify work around the house.
7. Accidents kill motorists on the highways.
8. Trains carry passengers across the country.
9. Bears steal honey from the hive.
10. Hunters shoot elephants between the eyes.

Anomalous:

1. The sticky young rhythm ate wonders.
2. The popular Latin mare worked tempers.
3. The frenzied gray ingredient frayed autographs.
4. The old miracle weather signed passions.
5. The secret humid actor aroused hay.
6. Gadgets kill passengers from the eyes.
7. Accidents carry honey between the house.
8. Trains steal elephants around the highways.
9. Bears shoot work on the country.
10. Hunters simplify motorists across the hive.

Ungrammatical:

1. Tempers young rhythm ate secret the.
2. Autographs Latin mare worked sticky the.
3. Passions gray ingredients frayed popular the.
4. Hay miracle weather signed frenzied the.
5. Wonders humid actor aroused old the.
6. Around accidents country honey the shoot.
7. On trains hive elephants the simplify.
8. Across bears eyes work the kill.
9. From hunters house motorists the carry.
10. Between gadgets highways passengers the steal.

APPENDIX B

Results of Follow-up Experiment

TABLE 1

Mean articulation scores in percentages and standard deviations for 6 conditions of linguistic masking. N, items/condition, 25; N, listener, 12.

Condition	Grammatical	Semantically Anomalous	Ungrammatical	Backward Grammatical	Backward Semantically Anomalous	Backward Ungrammatical
Mean ($\bar{X}$)	65.8	54.6	59.4	64.4	63.1	60.7
Standard Deviation (σ)	13.4	8.8	10.2	9.6	12.3	11.1

TABLE 2

Summary of analysis of variance. Six treatment conditions were forward grammatical, backward grammatical, forward semantically anomalous, backward semantically anomalous, forward ungrammatical, and backward ungrammatical. The dependent variable was mean articulation score computed in percentage points. N, 18.

Source	SS	df	MS	F
Subject	5,291.4	17	259.4	
Treatment	1,297.0	5	92.4	2.8*
Error	7,853.0	85		
Total	14,441.4	107		

*Significant at .05 level of confidence.

TABLE 3

t-values for 15 pairs of related measures, N,18; df, 17.

Condition	G	SA	UG	BG	BSA	BUG
G	-	3.7*	1.6	.46	.80	1.5
SA	3.7*	-	1.5	3.8*	3.3*	2.7*
UG	1.6	1.5	-	1.5	1.1	.43
BG	.46	3.8*	1.5	-	.45	1.2
BSA	.80	3.3*	1.1	.45	-	1.8
BUG	1.5	2.7*	.43	1.2	1.8	-

*Significant at the .05 level of confidence.

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