76-3084

BILLMAN, Joe Thomas, 1925-
THE EFFECTS OF IRRELEVANT CONCURRENT PSYCHOMOTOR ACTIVITY ON THE ABILITY TO COMPREHEND COMPRESSED SPEECH.

The University of Oklahoma, Ph.D., 1975
Education, theory and practice

Xerox University Microfilms, Ann Arbor, Michigan 48106

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE EFFECTS OF IRRELEVANT CONCURRENT PSYCHOMOTOR ACTIVITY ON THE ABILITY TO COMPREHEND COMPRESSED SPEECH

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

JOE THOMAS BILLMAN

Norman, Oklahoma

1975

THE EFFECTS OF IRRELEVANT CONCURRENT PSYCHOMOTOR

ACTIVITY ON THE ABILITY TO COMPREHEND

COMPRESSED SPEECH

APPROVED BY

Tillman J. Ragan

W R Fulton

Thomas Wiggins

Loy E Prickett

DISSERTATION COMMITTEE

ACKNOWLEDGEMENT

I wish to express my appreciation to Dr. Tillman J. Ragan and Dr. William R. Fulton whose challenge provided the impetus for this study and to the other members of the committee, Dr. Loy E. Pricket and Dr. Thomas W. Wiggins who provided valuable suggestions and criticism.

I also wish to express appreciation to Dr. John A. Ludrick, Dr. William H. Graves, Jr. and Mrs. Lynna J. Ausburn for the special assistance they rendered.

A very special debt of gratitude is due Mr. David G. Bormet and Mr. Floyd B. Ausburn who advised and assisted with photographic work and to Mr. Duke Giles and Mrs. Ann A. Rounds for the loan of equipment.

Another special debt of gratitude is due Col. Frederick C. Meir, Commander of the Communications Computer Programming Center, Tinker AFB and Dr. Ben D. Duncan, Director of Research, Oscar Rose Junior College for extending the resources of their institutions to facilitate this research.

In addition, I wish to thank my wife, Alice, for her considerable forebearance and toleration throughout my graduate study and the period of this research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

THE EFFECTS OF IRRELEVANT CONCURRENT PSYCHOMOTOR ACTIVITY ON THE ABILITY TO COMPREHEND COMPRESSED SPEECH

CHAPTER I

INTRODUCTION

Background of the Problem

Concern for mankind's ability to cope with the ever increasing amount of change in society has been expressed by many. Toffler invented the term "future shock" to describe the shattering stress and disorientation induced by subjecting the individual to too much change in a short period of time. He warned that we must manage change in beneficial ways or suffer the consequences of catastrophic adaptational breakdown. Toffler (1970) expressed particular concern about the psychological dimension:

> The limitations of the sense organs and nervous system mean that many environmental events occur at rates too fast for us to follow, and we are reduced to sampling experience at best . . . .

> This may explain why, when we experience sensory overstimulation, we suffer confusion, a blurring of the line between illusion and reality. (p. 350)

Toffler also suggested that cognitive overstimulation may interfere with the ability to think and make realistic decisions. He urged education to seek its objectives and methods in the future instead of the past. According to Toffler, education must increase the individual's "cope-ability"--his speed and efficiency in adapting to continual change. By being critically selective about societal changes man, therefore, consciously prepares for future coping and adaptation with creative strategies for controlling change to his own liking and which he can accommodate within his physiological and psychological limits. Toffler (1970) further suggested that a dramatically different type of education would be needed along with new technological aids to increase human adaptivity.

McLuhan (1965) believed that very large structural changes were taking place in society because of the impact of media which bring about new perceptual habits and create new environments.

According to McLuhan:

> By continuously embracing technologies, we relate

> ourselves to them as servomechanisms. That is why we must, to use them at all, serve these objects, these extensions of ourselves, as gods or minor religions. (p. 55)

McLuhan criticized reliance on current educational practices and recommended the assistance of newer media forms to translate the data of our technological society in the electronic age.

Compressed speech is a technological aid that has been developed to cope with the increasing amount of information that man must use. It is the product of electronically modifying recorded speech so that listening time is reduced without eliminating elements necessary to listening comprehension. According to Foulke (1971, p. 3), experimental evidence indicates that recorded compressed speech may be comprehended satisfactorily at a rate of approximately 275 words per minute (WPM), and that with appropriate training experiences, comprehension at much higher word rates may also be possible.

Speech compression equipment presently available can reproduce a recording with shorter duration by reducing the time span of pauses and speech sounds through a sampling process that discards portions of the speech wave while retaining sufficient elements to provide intelligibility and comprehension. The literature suggests a broad range of time saving possibilities for the use of compressed speech. The literature does not, however, provide any substantial body of information relating to the long-term use of compressed speech. Armsey and Dahl (1973) caution that newer instructional forms may not pay off as handsomely as expected at first:

> Almost all research on instructional technology concludes that more data are needed on this subject; and that additional subjects--related, remote, or totally irrelevant--demand study. (p. 17)

If compressed speech is to become a viable instructional aid in the long-run, much additional research will be required. If the use of compressed speech pervades the instructional spectrum, how will it compliment or accommodate other media forms such as projectors and viewers, particularly if manual operation is involved? Will it be necessary to automate other media items to preclude overloading the individual with competing psychomotor tasks which, in some ways at least, must share the brain's capacity?

This study examined the effects of concurrent psychomotor activity on the ability to listen to and comprehend compressed speech. Hopefully, it will provide some useful information in respect to managing learning activity involving compressed speech in conjunction with other media forms.

Statement of the Problem

The problem of this study was: Is the performance of irrelevant psychomotor activity concurrent to listening to compressed speech associated with a reduction in listening comprehension?

More specifically, the study investigated the effects of performing various levels of psychomotor activity (converting random digits, presented visually, into a response code at three information levels) on the ability to comprehend compressed speech listened to at 250 and 275 words per minute.

Purpose of the Study

The purpose of this study was to examine the effects, if any, of performing varying amounts of irrelevant concurrent psychomotor activity while listening to compressed speech at various information rates to determine:

1. If performance of varying amounts of activity effects the ability to comprehend compressed speech.

2. If the performance of psychomotor activity concur-

rent to listening to compressed speech would impose an unacceptable information load upon a listener.

3. If listening to compressed speech at various rates effects the ability to perform various levels of psychomotor activity.

Four hypotheses were tested:

Ho_1 - There will be no difference in listening comprehension between subjects who listen only, to compressed speech, and those who also perform psychomotor activity.

Ho_2 - There will be no difference in the threshold for the rapid decline of listening comprehension between subjects who listen only, to compressed speech, and those who also perform psychomotor activity.

Ho_3 - There will be no interaction between the amount of information which must be handled in psychomotor activity and compressed speech listening comprehension.

Ho_4 - There will be no association between the amount of psychomotor activity performed correctly and the compressed speech listening rate.

Population

The subjects used in this study were 120 male and female students, aged 19-26, enrolled in third and fourth year level courses in the College of Education at the University of Oklahoma, Norman, Oklahoma. The study took place during the Fall, 1974 academic semester. See Chapter IV for a detailed description.

Definition of Terms

1. Comprehension - Ability to decode information into meaning.

2. Compression Rate - A measure of the amount of time reduction in a compressed recording; expressed as a fraction, as a percent of the original time saved, as a percent of the original time used, or as an acceleration factor.

3. Filter - An analyzer or mechanism which allows some classes of information to pass but not others.

4. Human Channel Capacity - The maximum amount of information that can be discriminated and processed by the central nervous system under stated conditions.

5. Information Bit - The basic unit or quantity of information necessary to make a decision between two equally probable alternatives in a two-choice situation.

6. Irrelevant Concurrent Psychomotor Activity - Activity

which is attendant to learning activity but which does not provide information to be learned.

7. Intelligibility - The capacity of information elements and units to be decoded into meaning.

8. Modality - Form or mode of information transmission, such as visual or aural. May express or denote an information subsystem.

9. Psychomotor - Perception and central processing of stimuli from sensory inputs and the response control of bodily movement based on those stimuli. The terms sensory-motor and perceptual motor will be encompassed within this definition.

10. Simultaneous Information Load - Information from concurrent or simultaneous activity which requires central processing at the same time.

Significance of the Study

It has been demonstrated that compressed speech may save time in the transmission of certain types of information and that it can work effectively in a learning situation involving other media items, such as visuals and programmed texts. The theoretical base suggested, however, that at the higher information rates associated with compressed speech, certain criteria and cautions would be necessary.

The questions of redundancy, equivocation (ambiguity) and simultaneity of information presented within or between channels become more important because the processing mechanisms of the brain will be working at higher capacities. Redundancy of material may be more or less desirable within and between channels to facilitate comprehension. Certain information may be facilitated by simultaneous presentation in multiple channels to minimize the effects of alternating attention at high information rates. Some content may not be appropriate for adaption to compressed speech. These considerations will require that the information input be adapted and designed for compressed speech to facilitate transfer of the information and to insure that time is available to perform all necessary processing operations.

The literature reviewed was substantially devoid of studies dealing directly with the effects of irrelevant or attendant psychomotor activity on the ability to comprehend compressed speech. Several studies have, however, provided some indirect information. Peters (1972) reported that notetaking has a harmful effect on comprehension. Watts (1969) found that the use of visuals with compressed speech did not enhance learning. Ludrick (1974) reported that students preferred television for presentation of visuals used with compressed speech because it provided a more automated format which minimized equipment manipulation and thereby facilitated concentration on the content.

This study has examined the effects of irrelevant psychomotor activity (such as advancing a film strip viewer to the next frame) which is attendant to the delivery of but not a part of the content.

A significant association between listening comprehension and amount of psychomotor activity performed was not found at the listening rates of 250 and 275 words per minute. The analysis did suggest that interaction was beginning to take place at a listening rate of 275 words per minute for subjects performing three bits of psychomotor activity. From this tentative inferences can be made in respect to the following:

1. Channel loading; auditory, visual and motor, at various information rates.

2. Desirability of redundancy and simultaneity, i.e., in visuals and programmed texts.

3. Possibilities for appropriate response activity, i.e., complexity, time required.

This study has also demonstrated a method for investigating the effects of irrelevant or attendant psychomotor activity. This method could also be useful for investigating the value and impact of various media forms and techniques used to transmit information in the auditory and visual channels. If the brain is required to work at or near its capacity the relative impact or effectiveness of a media form to transfer information to the brain would be more noticeable.

CHAPTER II

REVIEW OF RELATED LITERATURE

This study was designed to determine if the use of compressed speech in a learning situation, incorporating other media items which require performance of psychomotor activity, will impose an unacceptably high information load on the individual learner. Usage of compressed speech has demonstrated the ability to save considerable listening time, but it has also demonstrated that at higher levels of compression both intelligibility and comprehension decline rapidly.

The information handling abilities of the human system have only recently begun to be studied in information system theory terms to quantify modalities and capacities. Everyday experience, however, makes it clear that the human information system has general and specific limits. Therefore, this finite capacity may be a very critical consideration in learning situations using compressed speech.

In addition to handling a higher level of information input, manipulation of audiovisual equipment, the performance of overt response activity and the attendant alternation of attention among various learning tasks may lower comprehension and resultant learning. The following literature was, therefore, reviewed to place those aspects of human information handling into a related and unified context.

Human Information System

Special sense organs, called transducers, transform sensory input energy into a series of nerve impulses which are transmitted by the afferent fibers to the higher centers of the nervous system.

Information may be uncoded (no meaning to the individual) or coded information which has meaning based on past experience. Receptors do not seem to provide a reversible code: one that permits reconstruction of the original message at the output (Travers, p. 31). This is an indication that the nervous system and the brain have finite capacities and are selective in respect to information handled.

Evidence indicates that receptor organs fire at intervals, even when not exposed to external energy sources (Travers, 1970, p. 33). Responses to external stimuli produce a neural discharge rate which is superimposed upon the base rate of firing. Impulses travel at rates which vary from about 3 to 400 feet per second (Travers, 1970, p. 20). Nerve cells transmit information from one to another through axons (long lines of communication) and are interconnected by relay organs known as nuclei which have common proximal locations (synapses).

Transmission of information appears to be regulated by lateral inhibition from neighboring receptors as well as by central processes in the brain. Hartline and Ratliff (1957) demonstrated lateral inhibition of visual receptor units in a simple organism called "Limulus," when exited individually or together. Evidence also suggests that synapses act as on-off switches and may be the seat of memory storage by some undetermined process of molecular change (Travers, 1970, p. 21).

Smith and Smith (1966, pp. 202-211) described the individual from a cybernetic viewpoint as homeokinetic--a system whose optimal state is always active in feedback generating activity. Responses are multi-dimensional: Body movements involve postural, transport, and manipulative movements to position and manipulate limbs and organs (in speech to propel syllable pulses) necessary to perform responses. Information to carry out a response is transmitted by the efferent fibers to the effector organs which must perform the responses. Knowledge of response activity is detected by the perceptual systems' receptor monitoring activity and additional messages are transmitted to the brain for further response or modification of the response pattern in progress.

Quantification and Capacities

The human nervous system was estimated to have about eleven billion cells; an extraordinary amount but one which nevertheless implies a finite capacity (Travers, 1970, p. 21).

Shannon and Weaver (1964, p. 9) defined a "bit" as the basic unit of information necessary to make a decision between two equally likely alternatives in a two-choice situation. The number of bits needed to resolve uncertainty with additional numbers of choices increases at a logarithmic rate. Pollack (1953) demonstrated the utility of experimental use of information theory, in a listening experiment, as an objective quantification in units (bits) not specific to any particular experiment.

Jacobson (1951) reported the maximum information transmissible through the human eye to be 4.30×10^6 bits/sec., when considered as an information channel.

Jacobson (1950) estimated the capacity of the ear to handle independently distinguishable tones to be 50,000 bits/sec. He lowered his estimate to 8,000 bits/sec. (10,000 for intense sounds) because of physiological masking and interference within the ear. Licklider and Miller (1951) provided a similar estimate. Jacobson (1950) suggested a relative difference between the handling capacities of the eye and ear to be about the order of 430 to one.

According to Travers (1970):

> What is more important is the fact that the brain is capable of utilizing at the highest levels less than one percent of the information provided by the ear and perhaps only one part in 250,000 for the eye. (pp. 76-77)

Quastler and Wulff (1955) found an average rate of six to 12 bits/sec., with a maximum of 25 bits/sec., for continuous reception of speech after considering the redundancy of the English language. Garner (1962, p. 239) estimated sequential redundancy at a little over 50 percent; an estimate in agreement with that of Shannon and Weaver (1964),

p. 13). Garner (1962, p. 239) estimated total redundancy at nearly 60 percent.

Listening ability, prior to speeded and compressed speech, was limited to the rate of the unaided speaker's ability to produce words. Pierce and Karlin (1957) estimated an information rate of 43 bits/sec. for a person speaking rapidly.

Of greatest significance is the ability of the human brain to process and utilize information. Pollack (1952) and Garner (1953) estimated that 2.2 to 2.3 bits of information per unidimensional stimulus is transferred, equivalent to the ability to make about four to five absolute judgments. Hartman (1954) reported that identification of tones, facilitated by practice and with "white noise" separation, was on the order of 10 or less absolute judgments.

Pollack and Fricks (1954) estimated that up to 6.9 bits of information would be transferred by stimulus having multidimensional properties. Based on unidimensional stimuli, Miller (1956) took the position that the average human could make accurate judgments about only seven, plus or minus two, categories of stimulus variables, equal to a range of about

2.2 to 3.2 bits of input. Miller suggested that greater amounts could be transferred by multi-dimensional stimuli. He cited an experiment in which 7.2 bits of information were transferred, equal to about 150 different categories. In respect to speech, Miller (1951) suggested that five syllables per second was a reasonable estimate for the human speech masculature, equating to 12.5 speech sounds per second. Based on the use of 39 speech sounds he estimated the information per second at 67 bits/sec. Miller reduced this to 46 bits/sec. because of the redundancy of speech sounds. On the basis of word and other redundancies he finally lowered his estimate to 10.6 bits/sec.

According to Hsia (1971) most studies dealing with unidimensional input found rates in the range between slightly below two bits/sec. and slightly above three bits/sec. With multidimensional stimuli rates went up to a point of slightly over seven bits/sec. and then leveled off.

Single-channel and Multiple-channel Theories

Broadbent (1958, p. 42) theorized that the brain functions as a single-channel receiving system with input regulated by a "filter" or analyzer which like a Y valve accepts information from only one leg of the Y at any given time.

Garner (1962, p. 116) took a multiple-channel position. He suggested that multi-dimensional stimuli produce an increase in information transfer, therefore, additional central mechanisms, beyond Broadbent's single filter, are necessary to account for this phenomenon.

Crossman (1964) supported Broadbent's position in respect to there being only one central organizing channel for new external information but he suggested that feedback may be processed in parallel. Others (Allport, Antonis and Reynolds, 1972; Deutsch and Deutsch, 1963) also challenged the single-channel position. They tentatively concluded that all messages reach the central perceptual and discriminatory mechanisms whether or not attention is paid to them. They suggested that the brain has several independent, special purpose computer-like mechanisms operating in parallel.

Hsia (1971) pointed out that the seemingly divergent views might not be incompatible. He suggested that the brain is a multiple-channel organism when input is optimal but that when input is far higher then the brain may act as a single-channel receiver.

Hartman (1961) generalized that interference between information presented simultaneously by multiple-channels may be expected if the information in the several channels is unrelated, contradictory, or if the difficulty or rate of presentation precluded successful alternation of attention among channels. He suggested that an increase of learning by using multiple channels may only be facilitated by presenting redundant information and if association among the information units is assisted by a cognitive relationship such as a verbal label on an ambiguous drawing.

According to Fassard (1961) information is processed "in the form of trains of impulses" (p. 590).

Travers (1970) pointed out that,

> Since there is substantial evidence that the analysis of information occurs to some degree, in a sequential procedure within the nervous system, there is considerable speculation about where the various steps in the analysis occur. (p. 40)

Role of Attention

Norman (1968) stated that a common framework for attention theory is that a human's capacity to process information is limited. He proposed an attention mechanism which selects, from among sensory inputs, those which are most important by considering stored information or attributes pertaining to each input. He speculated that Broadbent's

(1958) selective filter was the selective-attention system involved.

Treisman (1964, 1969) defined attention as the selection aspect of perception and response. The existence of separate perceptual analyzers was presumed. Four types of selection were suggested which might determine attention: selection of outputs, selection of inputs, selection of properties or dimensions for analysis, or selection of targets. Division of attention between two or more inputs or targets was considered difficult or impossible when no time was provided for alternation of attention.

Deutsch and Deutsch (1963) took the position that there is a limit to the number of things to which a person can attend and that this difficulty in processing information from multiple sources occurs even if no overt response is required.

According to Broadbent (1958), it is impossible to handle more than a critical amount of information in a given time. This suggested that up to certain critical levels, several message sources could be attended to by rapid alternation of attention. At higher levels the demands become too great, and the individual is either confounded or is forced to attend to only one source. Broadbent (1958) estimated the time necessary for alternation of attention or switching channels (from one source to another and back again) to be between one and two seconds (p. 211). Time to switch from one source to another would be about 0.5 to 1.0 seconds. Broadbent (1958) also speculated that irrelevant stimuli may be passed (sampled) by the filter for a second or two. This would cause a pause or error in perception if a continuous task was being performed.

According to Craik (1948):

> The results of Telford and of the writer suggest a refactory period of about 0.5 sec., such that a stimuli presented within this interval after the preceding one is responded to later, or may be missed. If, again, the second stimulus succeeds the first very rapidly--within about .05 sec.--it and the first may be apprehended together and responded to as a single one, as if it had registered before the computing system had started to operate. Stimuli coming in between these two time-intervals are either disregarded, responded to after the first, or cause general disturbance and conflict in the operator. The result is to set up a response frequency of about two per sec. (p. 147)

Cherry and Taylor (1954), in an experiment in which prose reception was switched from ear to ear, calculated switching time to be 167 milliseconds. Reid and Travers (1968) computed switching time to be 168 milliseconds, and

and that switching from perceptual system to perceptual system involved about the same time loss as switching from one message source to another. After considering the research by Cherry and Taylor, Broadbent reinterpreted his results to concur that one channel switch required approximately 167 milliseconds (Reid and Travers, 1968).

Despite this indication of substantial agreement in regards to switching time, Moray (1970) cautioned:

> . . ., it seems at the moment that there is not enough evidence to argue for a fundamental periodicity, or to give a firm estimate concerning switching time in attention, except for the fixation changes accompanying the overt switching of visual attention. (p. 156)

Human Memory

Von Neumann (1958, p. 64) estimated the total memory capacity for a human lifetime of 60 years to be 2.8×10^{20} bits of information. This and the foregoing suggests that human information processing capacity is not limited by storage capacity but by those mechanisms which process and analyze data.

Travers (1970, p. 144) identified three memory systems which held information: a memory trace of only a few seconds, a short-term memory of up to 30 minutes, and a permanent memory. Travers (1970, p. 148) suggested that information, both auditory and visual, is stored in an auditory form:

> This kind of evidence suggests that, in the case of at least some material, the visual information received is recoded into an auditory form of information and is retained in this form, at least in short-term memory. If the information were to be retained in long-term memory, it hardly seems likely that it would be recoded again into a form that in some direct way represented visual information. This leads us to the interesting speculation that much of the long-term memory system may involve the storage of auditory verbal information. (p. 148)

Norman (1968) suggested one large dual-process storage system with a transient mode for immediate memories (primary memory) and a permanent mode for long-term (secondary memory) memories. Capacity of primary memory seemed to be determined by the number of meaningful units in it; information in it started to disappear after four or five other items had been presented. Garner (1962) also presented information which tended to confirm that decay of immediate memory is quite rapid.

Work by Hebb (1968) also supported the existence of a primative form of long-term visual or "iconic" memory system.

Miller (1956) made a significant distinction between the span of immediate memory which appeared to be limited by the number of items or "chunks" of information and the span of absolute judgment which appeared to be limited by the amount of or "bits" of information.

Crossman (1964) analyzed memory in terms of immediate storage for perceptual processes and permanent storage for predicting and acting on future inputs. By this analysis, seven or eight digits can be repeated back after one presentation. He termed this the span of immediate memory. He also described a temporary storage system for information output from the central processes to the effector system, such as the continuation of writing after dictation has ceased. This capacity was termed the eye-hand, or eye-voice span. Crossman also suggested that information was converted from the visual to the auditory before storage.

Broadbent (1958, p. 216) speculated that the brain has an "S" (sensory) system for short-term storage of sensory data and a "P" (perception) system for long-term storage necessary to information analysis. It was suggested that after once entering the P system, information could be recirculated back to the S system if the load on the P system was very high.

Travers (1970, pp. 153-154) also considered that transfer of information to permanent storage was a slow process, involving consolidation, probably on the order of 20 minutes, and that if disruption occurred during this period it might never reach permanent memory.

Compressed Speech

According to Pierce and Karlin (1957), reading aloud is the fastest rate at which a human can transmit information in interpersonal communication. Johnson, Darley and Spriesterbach (1963) reported the median oral reading rate to be 176.5 WPM. Foulke (1967) reported a rate of 177 WPM for professional readers. Pierce and Karlin (1957) reported that reading rate is independent of vocabulary size (number of distinct words used in an experiment) up to 256 words but decreases with larger vocabulary sizes. They estimated that information transmitted is equal to $\log_2 n$ bits/word, where n is number of words in the vocabulary and if all words are chosen with equal probability and read correctly.

For prose, Shannon (1951) estimated about 1 bit/letter for a 27 word alphabet including one space, or 5.5 bits/word for the average of 4.5 letters/word plus one space following a word. Pierce and Karlin (1957) cautioned, however, that it was uncertain what the true value might be.

Carroll (1967) recommended the syllable as the unit of speech output for measuring rate. According to Foulke and Sticht (1967), "specification in terms of word rate appears to be necessary, and it is probably sufficient" (p. 6). Amount of compression may be specified several ways: by a fraction, expressed as a percent of the original time saved, as a percent indicating the portion of original time used, or in terms of the acceleration factor (Foulke and Sticht, 1967, p. 6).

Several methods have been used to provide accelerated speech. The earliest method was simply to reproduce recorded speech at a higher speed (Fletcher, 1929; McLain, 1962; Foulke, 1966), however, frequency shifts of the voice signal components caused significant degradation of intelligibility. Miller and Licklider (1950), by interrupting recorded speech and discarding small segments, produced speech with intelligibility which did not fall below 90% until 50% of the voice signal had been eliminated.

By cutting out tape segments and splicing retained segments together, Garvey (1953a) demonstrated accelerated and compressed speech free of distortion. Fairbanks, Everitt and Jaeger (1954) described an electromechanical design which provided compression, or expansion, of recorded speech by use of a rotating, cylindrical, multiple recording head which discarded segments not touching one of the heads. Graham (1971) described an electronically improved version of the basic Fairbanks design. Various word rates are possible and intelligibility is preserved if retained segments are of sufficient duration to provide representation of every speech sound (Foulke, 1969).

Breuel and Levens (1971) described a harmonic speech compressor which accelerates a speech wave, divides it into harmonically related frequency components and then recreates it at a lower frequency rate. Frequency periods are eliminated in the process.

Quereshi and Kingma (1971) described a technique for producing compressed speech with a small computer. According to Foulke (1967, p. 6), a more selective process of voice signal sampling and deletion is possible because a great variety of sampling and deletion rules can be used. Thus far, computer time has proven too expensive except for research purposes.

Intelligibility depends upon method used for compression. The duration of discarded segments must be short relative to duration of speech sounds sampled, otherwise a sound might be completely removed. Garvey (1953b) found that intelligibility remained at about 95% for discard intervals of 40, 60, and 80 milliseconds, but dropped to 85.6% for an interval of 100 milliseconds. Fairbanks and Kodman (1957) found a similar loss with intervals above 80 milliseconds. Garvey (1953b) found a 10% loss of intelligibility for words compressed to 60% of original duration using the manual sampling method. Kurtzrock (1957) found 50% intelligibility for monosyllabic words compressed to 15% of original duration using the electromechanical sampling method. Fairbanks and Kodman (1957) found 50% intelligibility with only 13% of the original time retained (87% compression).

Intelligibility and comprehension do not decline at the same rate. Foulke and Sticht (1967) found that intelligibility of single words was always superior to that of connected discourse, and declined gradually as compression increased from 225 to 425 WPM. Comprehension, however, declined moderately from 225 to 325 WPM, but very rapidly thereafter. Foulke, Amster, Nolan, and Bixler (1962) found that comprehension was slightly effected by word rates up to 275 WPM but declined rapidly thereafter for both literary and technical material. Fairbanks, Guttman, and Miron (1957), investigated word rates of 141, 201, 282, and 470 WPM. They found little difference in comprehension through 282 WPM, however, comprehension scores declined from 58% at 282 WPM to 26% (near chance) at 470 WPM.

The above suggests that comprehension declines more rapidly than intelligibility, and that comprehension shows a slight decline up to 275 WPM but declines rapidly thereafter.

Fairbanks, Guttman, and Miron (1957), Goldstein (1940), and Nelson (1948) all found a positive correlation between ability to comprehend accelerated speech and intelligence. Goldstein (1940), and Orr, Friedman, and Williams (1965) all found a significant positive correlation between reading ability rate and comprehension of accelerated speech.

Foulke and Sticht (1967) analyzed the ability to comprehend compressed speech in terms of a concept of channel capacity and processing capacity analogous to computer processing. Their results supported the relevance of the concept of channel capacity (Miller, 1953), that a listener has a limited capacity for handling information. Overmann (1969) re-established pause time that had been eliminated by compression. Results indicated that at rates above 250 to 300

WPM inadequate time is available for complete processing of information necessary to comprehension.

In assessing the value of compressed speech plus augmenting visuals and handouts, Watts (1969) concluded that printed handouts aided comprehension but findings on the visuals was mixed. Results indicated the visuals did not aid comprehension, but it was suggested that it may have been an artifact of the visuals used. Challis (1973) found the use of compressed speech with filmstrips, in an audiotutorial environment, to be as effective as normal speech recordings. Challis reached no conclusion in respect to the value of the visuals and suggested that this area needed further study. Peters (1972) reported that note-taking had a harmful effect on comprehension. Ludrick (1974) reported that forced-pacing was as effective as self-pacing using visuals on video tape with compressed speech and that subjects preferred the television mode because it left them free to concentrate on learning rather than equipment operation.

Psychomotor Activity

Singer (1972, p. 12) identified three categories of motor skills: fine motor skills, manual skills, and gross motor skills. He provided a further breakdown into discrete, serial, and continuous tasks.

Fitts (1954) took the position that the processes underlying motor behavior are similar to those which underlie language behavior. Fitts and Seeger (1953) found the information processing capacity, in three experiments, to be within the range of 10.3 to 11.5 bits/sec.

There is substantial evidence which indicates that motor activity is highly dependent on feedback and that this is continuous. According to Welford (1960), effector organs (limbs and muscles) are activated by impulses from central mechanisms which determine the coordination and phasing of muscular action. Time consumed by central processes is considered the most important and critical element. Crossman (1964) agreed that feedback was essential and so important that it might sometimes be processed in parallel with new outside information. Pierce and Karlin (1957) suggested that this might be true for simultaneous verbal and manual physical activity.

Broadbent (1958, pp. 56, 138-139) suggested that most physical tasks, even highly practiced and predictable ones, would produce some interference to other activity because some minimal amount of information would be processed. Beir (1951) pointed out, that under stress of information overloading, behavior disorganization might be manifested by reduction of abstract ability, or in the ability to shift from one activity to another.

Adiseshiah (1957) found that accuracy of decision to information signals breaks down seriously beyond a rate of six decisions per minute. Kalsbeek (1964), in a dual task experiment involving auditory and motor activity, reported disintegration of behavior. Errors which occurred on both tasks were thought to represent attempts to make two simultaneous decisions. Brown (1964) took the position that performance on two or more tasks concurrently is an appropriate method of assessing the perceptual load and/or reserve capacity of an individual.

There is some disagreement about the role of short-term memory in respect to competition between motor and other types of activity. Poulton (1963) demonstrated that short-term memory was involved in motor skills. Although acknowledging that short-term memory was involved, Henry (1960) suggested a separate nonconscious type of neuromotor memory which may function without perceptual activity for tasks already highly learned. This suggested that previous practice and the complexity of a motor task would determine the amount of interference with ideational or perceptual information handling. Results found by Fitts (1954) tend to support Henry's theory.

According to Melton (1947, p. 35), the basic intent of the Armed Forces psychomotor testing in World War II was to measure perceptual-motor ability with a minimum involvement of intellectual factors. Apparatus tests were preferred to pencil-and-paper tests for that reason. It is interesting to note, however, that subsequent research reported by Passey and McLaurin (1966), and Sanders, Valentine, and McGrevy (1971), indicated continuing interest in the development of pencil-and-paper tests after World War II.

Summary

The total capacity of the brain for storage and retrieval of information is extraordinary. However, its ability to discriminate and process information at any one time is finite: somewhere in the range of 2.2 to 3.2 bits of information or about seven, plus or minus two, categories of unidimensional stimulus variables. With additional discrimination cues, provided by multidimensional stimuli, it appears that over seven bits of information may be handled. There is yet no substantial amount of evidence to conclude that an extraordinary increase can be provided by improved coding or by practice.

Information appears to be processed in a sequential manner, however, no conclusion is justified as to whether the brain functions as a single-channel or a multiple-channel receiver. A more plausible conclusion is that the brain is flexible and may function in the multiple-channel mode when inputs are within optimal limits but change to a single-channel mode when inputs are high. It is reasonable to conclude that only a limited amount may be processed at any one time, whether it is being received from one or more channels. It is clear that the brain is capable of a rapid alternation of attention from one channel or message source to another. Approximately 170 milliseconds to alter attention from one channel to another is indicated as a reliable estimate.

It can be concluded that higher information transmission rates are possible and practical with the use of compressed speech. Various methods for the compression of speech appear suitable. The critical parameters, frequency of sampling and length of discarded segments, must be controlled to preclude elimination of complete speech sounds. Words per minute is a suitable and meaningful measure of information transfer and is the most commonly used throughout the literature.

Long-term effects are not yet well documented to permit drawing any conclusions. It is indicated that comprehension will remain fairly well intact up to about 275 WPM but will begin to drop off rapidly thereafter. It is indicated that 275 WPM may be accepted as channel capacity for reception of compressed speech and also as the threshold for a rapid decline in comprehension.

The studies indicate that psychomotor activity will compete with other activity, such as auditory or visual reception and for use of short-term memory and central mechanisms, at higher information rates. This interference may result in inadequate time for consolidation in short-term memory and for central processing, thus lowering comprehension. Disintegration of behavior, comprehension of speech or performance of psychomotor activity would also be expected.

There is very little information in respect to the performance of psychomotor activity concurrent to listening to compressed speech. The literature suggests that, at higher information rates, the ability to alternate between several sources may pose some limiting considerations on the use of compressed speech in conjunction with other media forms. Findings in respect to combined use are mixed but do suggest that other attendant activity such as note-taking or manipulation of equipment will be deleterious to the comprehension of compressed speech. The latter provides the basis for this study to examine the effects of irrelevant psychomotor activity on the ability to comprehend compressed speech.

CHAPTER III

THEORETICAL FRAMEWORK AND HYPOTHESES

Theoretical Framework

This study is based primarily on the single-channel (filter theory) position of Broadbent (1958, p. 42) and the opposing multiple-channel processing theory of Garner (1962, p. 116).

Modes

A consensus has not been reached as to whether the brain functions as a single-channel or a multiple-channel information processing system. A synthesis of the various positions expressed in the literature suggests three possible modes of channel operation:

1. Single-channel (Broadbent, 1958, p. 42; Crossman, 1964; Hsia, 1971). Information is processed from only one input at a time. Attention is alternated or switched between inputs very rapidly by a selective filter or analyzer at the entrance to the central processing mechanisms. Conscious

attention can be given to only one input channel at any one time (Norman, 1968). Henry (1960) and Crossman (1964) suggested that an individual's own feedback might be processed in parallel with other activity. Attention would be paid to the most important channel input or alternated between the most important channel inputs.

2. Multiple-channel (Garner, 1962, p. 116; Deutsch and Deutsch, 1963; Allport, Antonis and Reynolds, 1972). Information may be processed from several inputs at the same time. All messages are assumed to reach the central processing mechanisms. Division and alternation of attention is possible, providing adequate time is available for the switching (Treisman, 1969). Attention is paid the most important inputs during optimal loads but could be expected to concentrate on one input under heavy load conditions (Deutsch and Deutsch, 1963).

3. Flexible-mode. Information may be processed from multiple channels, if total input load is within information processing capacity. If inputs become greater than the total processing capacity, the brain may act as a single-channel system, selecting the most important input. One important distinction is necessary. Hsia (1971) inferred that in the

single-channel mode, only one selected input would reach the central processing mechanisms at any one time; other inputs would be filtered or inhibited at the entrance to the central processing mechanisms. Alternation of attention would be accomplished as before.

Switching Time

Alternation of attention (from one source to another and back again) was estimated to be approximately one-third of a second or about 334 to 336 milliseconds (Cherry and Taylor, 1954; Reid and Travers, 1968). This estimate will be accepted, however, Moray's (1970) caution will be observed, that at the present time all such estimates must be considered tentative.

Memory

The literature suggested that memory trace and short-term memory (Miller, 1956; Broadbent, 1958, p. 216; Crossman, 1964; Norman, 1968; Travers, 1970, p. 144) are essential to the acquisition of information in any processing mode. Inputs, single or multiple, which exceed optimal loads will produce dysfunctional processing of information and a consequent reduction of accurately decoded information to control behavioral response. In any case, the literature indicated that at higher than optimal information loads, insufficient time would be available for accurate processing of information.

<u>Capacity and Quantification</u>

Hsia (1968) provided an equation for expressing multi-channel capacity: $C(M) \leq C(A) + C(V) - BCR$, where $C(A)$ and $C(V)$ represent capacities for the auditory and visual channels, respectively, and BCR represents between-channel redundancy. A modification of Hsia's equation to include the capacity of the neuromotor channel, $C(NM)$, should define capacity when motor activity is involved, i.e., $C(M) \leq C(A) + C(V) + C(NM) - BCR$.

Hsia (1971) expressed central nervous system capacity as $C(C) \leq C(M) + ERROR - EQUIVOCATION - BCR$.

Several formulas are available to estimate speech rates in information theory terms (Miller, 1951; Shannon, 1951; Pierce and Karlin, 1957). Shannon's estimate that there is approximately one (1) bit/letter, or 5.5 bits/word (average of 4.5 letters per word plus one space) transmitted by the English language will be accepted.

Speech rates are expressed in words per minute (WPM). Speech compression rates are expressed in terms of a percent to indicate the portion of the original time saved, i.e., 20% compression would indicate a 10 minute tape had been compressed to eight minutes.

Psychomotor Activity

It can be concluded from the literature that all types of activity require the processing of information. It is not clear, however, how much activity, such as psychomotor activity, may be accomplished without conscious attention being paid. If a separate, nonconscious neuromotor memory (Henry, 1960) exists, then it would reduce the conscious processing load. This would facilitate the concurrent performance of psychomotor activity and listening to compressed speech.

The various studies (Pollack, 1952; Garner, 1953; Pollack and Fricks, 1954; Miller, 1956; Hsia, 1971) suggested that the maximum range of information processing ability associated with making absolute judgments was two bits/sec. to seven bits/sec., depending on dimensionality of stimuli used. The requirement to perform irrelevant psychomotor activity in this range would be expected to cause interference to other activity such as listening to compressed speech.

Compressed Speech

Overmann (1969) found that speech compression reduced the redundancy cues of individual words and the amount of processing time as word rate increased. This suggested that loss of processing time, as word rate increases, is the fundamental cause for the reaching of channel capacity. Overmann found that restoration of processing time improved comprehension.

The findings of Foulke and Sticht (1967) and Foulke, Amster, Nolan, and Bixler (1962), that comprehension declined more rapidly than intelligibility, that comprehension showed a slight decline up to 275 WPM, but declined rapidly thereafter was accepted as a basis for hypothesizing. This position also suggested that 275 WPM was an acceptable estimate for channel capacity and represents the threshold for a rapid decline in comprehension when listening to compressed speech.

The above findings strongly suggest that the intrusion of other activity, such as looking at visuals, manipulating equipment, and performing response activity would further impinge on processing time. It also suggested that other media forms might inject conflicting information, producing ambiguities, thus making the information processing task more difficult. Competition for memory could also be expected.

In the case of compressed speech, the additional factor of processing time (PTF) would have to be added to Hsia's (1971) equation, i.e., C(C) $\leq$ C(M) + ERROR - EQUIVOCATION - BCR - PTF. This relationship would predict, in the case of other media forms used in conjunction with compressed speech, that channel capacity and the onset of a sharp reduction in listening comprehension would be reached at word rates below 275 WPM.

Assumption

The theoretical base provided a general consensus that the brain would have difficulty processing more than one channel of communication at any one time, particularly at high information rates. The following assumption was, therefore, made: That the brain is incapable of processing information from more than one channel at any one time at information rates at or near the compressed speech maximum listening capacity threshold of 275 WPM.

Research Questions and Hypotheses

The major research question examined was: Will the inclusion, in a compressed speech listening situation, of other media items which necessitate irrelevant psychomotor activity, produce degradation of listening comprehension?

Four null hypotheses were tested:

Ho_1 - There will be no difference in listening comprehension between subjects who listen only, to compressed speech, and those who also perform psychomotor activity.

Ho_2 - There will be no difference in the threshold for the rapid decline of listening comprehension between subjects who listen only, to compressed speech, and those who also perform psychomotor activity.

Ho_3 - There will be no interaction between the amount of information which must be handled in psychomotor activity and compressed speech listening comprehension.

Ho_4 - There will be no association between the amount of psychomotor activity performed correctly and the compressed speech listening rate.

The development of additional understandings in respect to the use of compressed speech in learning situations involving other media items and as a media research tool were secondary research interest areas.

CHAPTER IV

RESEARCH DESIGN

Pilot Studies

The review of literature did not reveal previous studies specifically investigating the effects of psychomotor activity on compressed speech listening comprehension. A pilot study was, therefore, performed to establish parameters and to select an appropriate type of psychomotor activity.

The results of the first pilot study (N = 40) indicated that the type of psychomotor activity selected (dotting - placing three dots in a small circle) was too simple and, consequently, too easily performed to provide a suitable instrument. Statistical analysis revealed no significant difference in listening comprehension (at 155 and 225 WPM) associated with performing the psychomotor activity ($\underline{P} < .05$). Additionally, it was decided that the listening rates used were too low to produce interaction. It was established, however, that simple, discrete, psychomotor activity could be performed at these levels, provided adequate pause time was provided, without degradation to listening comprehension.

The reason for providing pause time should be noted at this point. The assumption (previously stated in Chapter III) indicated the brain would have difficulty managing psychomotor activity and processing information from compressed speech at the same time. A decision was, therefore, made to provide pause time to perform the psychomotor activity. Although superimposing psychomotor activity on a listening activity would have a higher probability of producing interaction effects resulting in a loss of comprehension, results would be confusing and less precise. If, as the literature suggested, that time between speech elements was critical to recoding and processing information already received, it was reasoned that an effect produced by performing psychomotor during pause time would be more precise and powerful and would provide a more emperical basis for generalizing. (See Appendix A for a summary of this study.)

A second pilot study (N = 32) was performed using three levels of psychomotor activity (copying random binary digits from a projection screen) and two listening rates (250 and

275 WPM). Four seconds pause time was provided to perform each psychomotor sequence. Results indicated that the type of psychomotor activity was again too simple and unsuitable for use as a research tool. The listening rates of 250 and 275 WPM were retained. Statistical analysis revealed no significant difference in listening comprehension associated with performing the psychomotor activity ($\underline{P} < .05$). Again it was established that simple, discrete, psychomotor activity could be performed at these levels provided adequate pause time was provided, without degradation to listening comprehension (See Appendix B for a summary of this study).

Method

Pre-Experimental Considerations

As previously stated this study was designed to provide useful information in respect to managing learning activity involving compressed speech in conjunction with other media forms. This intended application made it necessary that current practices in multi-media instructional design be considered in the design of the experiment. The assumption made in Chapter III, Theoretical Framework and Hypotheses, "That the brain was incapable of processing information from more than one channel at any time at information rates at or near the compressed speech channel capacity threshold of 275 WPM," established a design consideration: that adequate pause time should be provided to perform psychomotor activity in the experiment.

Results of previous studies (Watts, 1969; Peters, 1972; Challis, 1973; Ludrick, 1974) suggested that specific criteria for use of other media forms in conjunction with compressed speech were necessary but did not establish an emperical basis for doing so. It should be noted that none of these studies were designed to specifically examine effects of psychomotor activity on the ability to comprehend compressed speech.

Overmann (1969) established that processing time normally available between speech elements was a significant factor in information processing and consequently comprehension of compressed speech. The psychomotor stimuli was, therefore, presented during what would normally be pause time in a listening task to provide more precise data and a more powerful basis for generalizing.

Another consideration was the amount of time to be established for each experimental session. The desirability of examining several levels of psychomotor activity and listening rates dictated that a multi-cell research design requiring a large number of testing sessions be used. The test session was also designed to be accomplished within a normal class meeting period of 50 minutes.

The question of using apparatus versus pencil-and-paper to perform the psychomotor activity was also considered. A decision was made to use pencil-and-paper to eliminate problems associated with calibration of electromechanical devices. This also eliminated the variable of individual differences in general familiarity with apparatus. To incorporate a switching of channels (from auditory to visual and back) the visual channel was selected to present the stimulus items for the psychomotor activity.

A decision was also made not to assess the hearing ability of subjects. Before volunteering for the experiment subjects were advised that they would need normal hearing to participate. Random assignment to groups was accepted as an adequate control for individual differences in hearing ability.

Standardization of test materials was accomplished by using master recordings of the listening materials. This included practice material, actual test material and general instructions.

Variables

Two independent variables were used:

1. X_A - Psychomotor Activity - a discrete activity involving converting a group of random binary digits, projected on a screen, into a response code to be written on a response sheet.

2. X_B - Listening Rate - Controlled by rate of prerecorded material on audio tape. Rates used were 250 and 275 WPM.

Two dependent variables were measured:

1. Y_A - Psychomotor Activity - Number of correct sequences performed.

2. Y_B - Listening Comprehension - Determined by scores on multiple-choice test of comprehension.

Subjects

The sample population consisted of 120 volunteer subjects, 98 females and 22 males, aged 19 to 26 years. The average age was 21. All were enrolled in the College of Education at the University of Oklahoma in the Fall of 1974 in the following courses:

Educ. 3812	Education of the Exceptional Child
Educ. 3422	Psychology in Education
Educ. 3433	Psychology of Childhood
Educ. 3463	Psychology of Adolescence
Educ. 4414	Curriculum and Instruction in the Secondary School
Educ. 4160	Media and Technology in Teaching

There were six sophomores, 63 juniors and 51 seniors. None had previous experience with compressed speech. Only subjects who professed to have normal hearing were selected. Monetary renumeration was not made for participation.

Environment

All testing was accomplished during morning hours (9:30 to 11:30 A.M.) in an air conditioned and sound-deadened 20' by 22' conference/seminar room. The room was paneled, had accoustical ceiling tile, wall-to-wall carpeting and heavy double drapes over the windows. Lighting was provided by florescent panels in the ceiling. Only one door was used for access. Background noise was insignificant because of the room construction and the fact that testing took place during normal class periods when personnel movement in the building was at a minimum. Ambient noise was further reduced by the cushioned ear pieces of the headsets used by the subjects. Some noise was introduced by the operation of the slide projector but this was of a very low level and was uniform for all groups performing the psychomotor activity. There were no interruptions of any sort during any of the test sessions.

Apparatus

A Wollensak, Model 2551, cassette recorder provided the audio and controlled a Kodak Ecktagraphic, Model AF2 (F 2:8 lens) slide projector. The audio was distributed by shielded audio cable through jackboxes to 600 ohm headsets. Each subject had an individual volume control. Slides were projected on a wall mounted, white matte, 40" x 50" projection screen. The slide projector was positioned approximately eight feet from the screen. A small cardboard enclosure screen was installed around the back of the projector to reduce operating noise and to shield light glare eminating from the cooling grill. Memorex MRX_2 Oxide, 90 minute, one-eighth inch audio cassettes were used. Tape transport speed was one and seven-eighths inches per second.

A Variable Speech Control Copycorder, Model CC-103, manufactured by the Magnetic Video Corporation was used to compress the listening material. This recorder provides compression by use of a patented circuit module, which samples the speech wave and extracts many small samples. The retained segments are linked together and smoothed electronically before playback. The CC-103 will compress speech up to 2.5 times (60% compression) its original rate. It is also capable of expansion or slowing speech down to .5 (50% expansion) times its original rate.

To achieve compression the tape transport speed is increased, and the speech wave is sampled every 20 milliseconds. Every other 20 millisecond segment is separated into a number of separate voltages (charges) and stored in a shift register. The other segments are discarded. The stored charges are retrieved at a slower speed, than they were stored. They then occupy a longer time span and restore the frequencies of the original recording but without the discarded segments. Transfer of the speech information is thus speeded up according to the compression setting but without pitch distortion. Segments discarded are essentially redundant, therefore, playback time is reduced without sacrificing intelligibility.

Test Instruments

The experimental listening material consisted of an audio recording of the Listening subtest of the Sequential Tests of Educational Progress (STEP), Form 1A (Educational Testing Service, 1957). The Form 1A was designed for use with grades 13 and 14. This test, divided into two parts, consisted of 10 short listening selections. Selection 3, Part One, a short poem, was not used. (See Appendix C for information pertaining to the listening selections.)

The ability to provide consistent results was considered to be of prime importance. Reliability for Form 1A, of the STEP Listening subtest was estimated at .90 with the Kuder-Richardson Formula 20 (Educational Testing Service Technical Report, 1957).

The test was constructed by well qualified persons to insure content validity. According to the Manual for Interpreting Scores: Listening (Listening Catalog No. 380-007, Educational Testing Service, 1957),

> The Tests in each area were developed by the joint effort of two groups: (a) a committee of outstanding leaders and teachers from many sections of the country for each subject-matter area and (b) ETS staff members who are both subject-matter and test-construction specialists. (p. 8)

The STEP Listening Test material contains directions and simple explanations, exposition, narration, argument, and persuasion, and aesthetic material. A classification scheme was provided by Kegler (Cooperative, Sequential Test of Educational Progress: Teachers Guide, pp. 29-31).

Lorge (1959) reported:

> The tests were well prepared, adequately item analyzed and well normed. . . . The correlations with intelligence (SCAT-V) average around .75 within grades - an anticipated result in view of the nature of the test. (p. 655)

Duker (1974, p. 182, Vol. III) cited 10 studies in which various levels of the STEP Listening Test were used in compressed speech research.

The psychomotor activity used was suggested by experiments which quantified stimulus and response variables in information theory terms (Jacobson, 1950; Pollack, 1953; Pollack and Fricks, 1954; Hsia, 1971).

According to information theory the amount of information contained in one message is equal to the number of decisions, D, made between equally probably alternatives that a listener must make correctly in order to tell which of the M, possible messages was sent. This may be expressed as $D(\text{Info}) = \log_2 M$.

Levels used were computed as follows:

D(1 bit of info) = $\log_2 2$

D(2 bits of info) = $\log_2 4$

D(3 bits of info) = $\log_2 8$

Random binary digits, 0 and 1, were used to construct visual stimulus code groups for information levels of 1 bit, 2 bits and 3 bits. (See Appendix D for a listing of the stimulus and response code groups.) At the 1 bit psychomotor activity level, the stimulus items were 0 and 1. At the 2 bit level, the stimulus items were 00, 01, 11, and 10. At the 3 bit level, the stimulus items were 000, 001, 011, 111, 100, 110, 101, and 010. Each stimulus code had a corresponding three-letter response code. Responding with the correct response code, from among the equally probable alternatives, constituted operating at the level concerned.

The psychomotor activity was constructed to represent attendant activity such as looking at visuals, switching perceptual channels and making responses. This type of activity would be required in a self-study situation to manipulate audio visual equipment or other media items provided the learning environment was not automated. It should be noted that the responses required were compound--part psychological and part motor. Beyond standardization, no attempt was made to quantify the motor activity. Subjects were given the codes for their particular level of psychomotor activity prior to the test session to permit memorization.

The psychomotor stimulus items were contained on 2" x 2", 35 MM, high contrast, black and white slides.

Individual Test Materials

All subjects were provided a test booklet containing:

1. General instructions and the answers to the multiple-choice test of comprehension.

2. IBM-type scoring sheet.

3. Psychomotor response sheet (Groups III through VIII).

(See Appendix E for samples of test materials.)

Experimental Design

The subjects were randomly assigned, using a table of random numbers, to eight experimental groups of 15 each:

Group I-- E_1 - Listening rate of 250 WPM without PMA.

Group II-- E_2 - Listening rate of 275 WPM without PMA.

Group III-- E_3 - Listening rate of 250 WPM with PMA level of 1 bit.

Group IV-- E_4 - Listening rate of 275 WPM with PMA level of 1 bit.

Group V-- E_5 - Listening rate of 250 WPM with PMA level of 2 bits.

Group VI-- E_6 - Listening rate of 275 WPM with PMA level of 2 bits.

Group VII-- E_7 - Listening rate of 250 WPM with PMA level of 3 bits.

Group VIII-- E_8 - Listening rate of 275 WPM with PMA level of 3 bits.

Experimental Design Paradigm

A 2 x 4 Factorial design was used:

I	X_{A1B1}--Y_1	V	X_{A3B1}--Y_5
II	X_{A1B2}--Y_2	VI	X_{A3B2}--Y_6
III	X_{A2B1}--Y_3	VII	X_{A4B1}--Y_7
IV	X_{A2B2}--Y_4	VIII	X_{A4B2}--Y_8

Listening Rate

		250 WPM		275 WPM	
PMA		B_1		B_2	
Without	A_1	I	A_1B_1	II	A_1B_2
1 bit	A_2	III	A_2B_1	IV	A_2B_2
2 bits	A_3	V	A_3B_1	VI	A_3B_2
3 bits	A_4	VII	A_4B_1	VIII	A_4B_2

Procedure

Subjects were instructed how to use the headsets and volume control. Subjects performing psychomotor activity were tested on memorization of response codes. All other instructions and listening material were recorded on one-eighth inch audio tape. (See Appendix E for a copy of the instructions.) The audio was provided by a cassette recorder and distributed to subjects by audio cables and jackboxes with individual volume controls. Standard settings were used for the audio volume for all groups. All instructions were provided at normal speech rates.

The psychomotor activity stimulus groups were presented in the visual channel with 2' x 2" high contrast black and white slides. (See Appendix G for slide format.) The digits were projected as a positive black image, approximately 2" high with a white background approximately 19" x 28" on a white matte projection screen. Subjects were seated 12 to 18 feet from the screen. Slide advancement was controlled by an inaudible sync pulse from the tape recorder. The psychomotor activity digit sequences were arranged in random order by use of a table of random numbers.

Listening comprehension was measured by administration of Part Two of the Listening test. Part One (Selections 1, 2, 3, and 5) was used for practice in listening to compressed speech. The four practice selections were compressed to 175, 225, 300, 225 WPM respectively. Selection 5 also served as a rehearsal for the actual experiment. Nine (9) psychomotor activity sequences were performed and six (6) practice multiple-choice questions were presented. Approximately 10 minutes of practice was provided. Total listening time for the five test selections was 7 minutes and 59 seconds at 250 WPM and 7 minutes and 18 seconds at 275 WPM. (See Appendix H for details on time and comprehension of the listening material.)

In the test (Selections 6, 7, 8, 9, and 10), Groups I, III, V and VII listened at 250 WPM. Groups II, IV, VI, and VIII listened at 275 WPM. Fifty (50) sequences of psychomotor activity, interspersed throughout the listening material, at the end of sentences, was required for Groups III through VIII. A 1000 hertz tone instructed subjects to perform the sequences. A four second pause was provided to perform each sequence. Psychomotor response codes were written in a 3/4" x 3/4" square on the psychomotor activity sheet. At 250 WPM a psychomotor sequence was performed every 9.2 seconds; at 275 WPM, every 8.8 seconds.

All groups were tested for comprehension by 36 multiple-choice questions spaced at the end of each selection. Questions were heard at normal speech rates. Subjects answered questions by circling the correct letter response in the test booklet. Answers were later transcribed to the IBM score sheets by the examiner.

CHAPTER V

RESULTS

Analysis of the total data did not reveal a significant association between performance of psychomotor activity and listening comprehension. The data was analyzed using the raw scores obtained from the 36 item test of comprehension and the 50 psychomotor sequences required. The data is summarized in Tables 1 and 2.

Table 1

Summary of Means, Standard Deviations and Standard Error for Psychomotor Activity

	Mean	Std. Dev.	Std. Err.
Group I and II	-		
III	49.933	0.249	0.064
IV	50.000	-	-
V	50.000	-	-
VI	49.666	1.011	0.261
VII	49.533	0.884	0.228
VIII	49.733	0.573	0.148
Column (250 WPM)	49.822		
Column (275 WPM)	49.799		
Row (0-PMA)	-		
Row (1-bit PMA)	49.966		
Row (2-bits PMA)	49.833		
Row (3-bits PMA)	49.633		

Table 2

Summary of Means, Standard Deviations and Standard Error for Listening Comprehension

	Means	Std. Dev.	Std. Err.
Group I	26.133	3.931	1.015
II	26.933	4.450	1.149
III	25.066	6.170	1.593
IV	26.933	4.312	1.113
V	28.533	4.897	1.264
VI	26.733	4.389	1.133
VII	26.800	4.534	1.171
VIII	24.733	6.298	1.626
Column (250 WPM)	26.633		
Column (275 WPM)	26.333		
Row (0-PMA)	26.533		
Row (1-bit PMA)	25.999		
Row (2-bit PMA)	27.633		
Row (3-bit PMA)	25.766		

Comprehension

Performance on listening comprehension was generally close except for Groups V and VIII. Figure 1 shows an

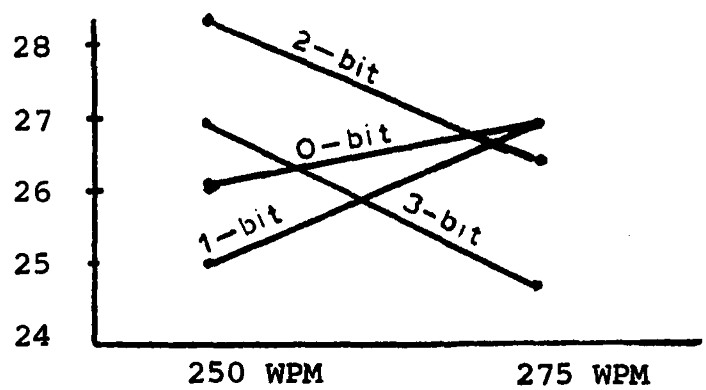


Figure 1. Interaction plot of comprehension means by listening rate over psychomotor activity levels.

interaction plot of the mean comprehension scores over the two listening rates and the four psychomotor activity levels. The higher mean score for Group V suggested that this group was not equivalent to the others. The lower performance by Group VIII was consistent with the expected interaction of the higher listening rate and the highest psychomotor activity level. Comprehension scores for the groups listening at 250 WPM did not reveal any pattern, i.e., Group VII which performed at the 3 bit psychomotor activity level did better than Group I which did not perform psychomotor activity. Listening comprehension data for the groups listening at 275 WPM evidenced a pattern. Group means were identical at the 0 and 1 bit psychomotor activity levels but decreased at the 2 and 3 bit levels. There was no strong evidence of a pattern for comprehension mean scores between the listening rates.

Psychomotor Activity

Of the 90 subjects performing psychomotor activity, only 10 failed to perform all of the required 50 sequences. A total of only 16 sequences were performed incorrectly: one at the 1 bit level, 5 at the 2 bit level, and 10 at the 3 bit level. Figure 2 shows an interaction plot of the number of sequences performed incorrectly over the psychomotor activity levels. The plot indicates an approximate logarithmic progression in the number of sequences incorrectly performed over the psychomotor activity levels.

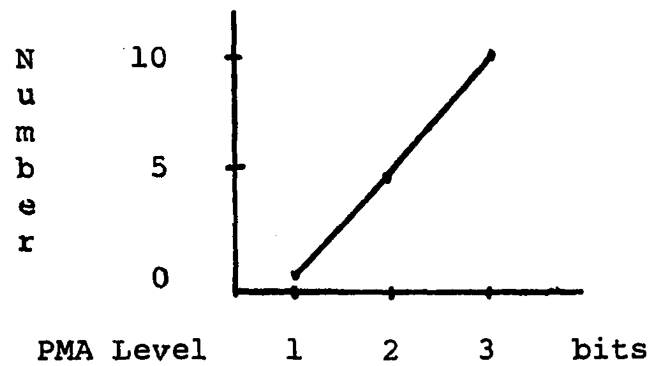


Figure 2. Interaction plot of number of psychomotor activity sequences performed incorrectly over psychomotor activity levels.

Results of Testing Hypotheses

To test the first three hypotheses:

Ho_1 - There will be no difference in listening comprehension between subjects who listen only, to compressed speech, and those who also perform psychomotor activity;

Ho_2 - There will be no difference in the threshold for the rapid decline of listening comprehension between subjects who listen only, to compressed speech, and those who also perform psychomotor activity;

Ho_3 - There will be no interaction between the amount of information which must be handled in psychomotor activity and compressed speech listening comprehension,

a two-way analysis of variance for listening comprehension was computed. A summary is provided in Table 3.

Table 3

Two-way Analysis of Variance for Listening Comprehension Versus Psychomotor Activity

Source of Variation	SS	df	MS	F	P
Between Rates	2.695	1	2.695	0.1030	0.7476
Between Modes	62.169	3	20.723	0.7920	0.5037
Interaction (R X M)	84.492	3	28.164	1.0764	0.3626
Error Variance	2930.59	112	26.166		
Total	3079.95	119			

The variation in listening comprehension caused by performance of psychomotor activity was not significant ($\underline{P} < .10$). Ho_1, Ho_2, and Ho_3 were, therefore, not rejected. An α level of .10 was selected to reduce the possibility of type II error.

To test the fourth null hypothesis:

Ho_4 - There will be no association between the amount of psychomotor activity performed correctly and the compressed speech listening rate,

a two-way analysis of variance for psychomotor activity performed was computed. A summary is provided in Table 4.

Table 4

Two-way Analysis of Variance for Psychomotor Activity Performed Versus Listening Rate

Source of Variation	SS	df	MS	F
Between Rates	0.352	1	0.352	0.8966
Between Modes	1.992	2	0.996	2.5403
Interaction (R X M)	0.762	2	0.381	0.9713
Error Variance	32.928	84	0.392	
Total	36.034	89		

The variation in the amount of correct psychomotor activity performed due to interaction with the listening rate was not significant ($\underline{P} < .10$). Ho_4 was, therefore, not rejected. An α level of .10 was selected to reduce the possibility of type II error. The F ratio of 2.54 obtained between modes was significant ($\underline{P} < .05$) but because of the small amount of variation in the row means was considered unimportant.

Since all four null hypotheses were not rejected this indicated that the several levels of psychomotor activity performed did not produce significant degradation to listening comprehension at 250 and 275 WPM.

Examination of the data shows that listening comprehension for Group VIII (275 WPM and 3 bits of psychomotor activity) was the lowest of all groups (24.733). Although significance ($\underline{P} < .10$) was not obtained this suggested that there was some basis for rejecting the first three null hypotheses in favor of their alternatives. A further analysis was, therefore, made of Groups I, II, VII, and VIII with a two-way analysis of variance. Summary is provided in Table 5.

Table 5

Two-way Analysis of Variance for Listening Comprehension Versus Psychomotor Activity

Source of Variation	SS	df	MS	F
Between Rates	6.024	1	6.024	0.2356
Between Modes	8.826	1	8.826	0.3451
Interaction (R X M)	30.806	1	30.806	1.2047
Error Variance	1431.98	56	25.571	
Total	1477.64	59		

The variation in listening comprehension caused by the performance of psychomotor activity was not significant ($\underline{P} < .10$). No further basis for rejecting Ho_1, Ho_2 and Ho_3 was found. An α level of .10 was selected to reduce the possibility of type II error. This further indicated that performance of the highest level of psychomotor activity (3-bits) did not produce significant degradation to listening comprehension at 250 and 275 WPM when compared to listening only at those rates.

Equivalence of Subject Groups

Examination of the data also suggested that despite randomization of assignment to groups, the equivalency of the subject groups was questionable. A one-way analysis of variance was, therefore, computed on Grade Point Averages (GPA) of the subjects for all groups. The cumulative GPA for all course work accomplished at the University of Oklahoma was considered the most meaningful information to analyze. (A summary is provided in Appendix I). The analysis indicated that Groups V and VII were the highest in terms of mean GPA. A significant F ratio was not obtained, however ($p < .05$). It was, therefore, concluded that the groups were essentially equal in respect to GPA.

Information Transmission Rates

The five test selections (6-10) averaged 4.508 letters per word. Using Shannon's (1951) estimate of 5.5 bits/word, based on an average of 4.5 letters per word, the information transmission rate averaged approximately 23.1 bits/sec. at 250 WPM and 25.3 bits/sec. at 275 WPM. The transmission rate of 25.3 bits/sec. is very close to the maximum rate for reception of speech suggested by Quastler and Wulff (1955).

Considering the variability of speech and the variety of processing modes possible by different individuals, no inference can safely be made from this information. It does suggest, however, that approximately 25 bits/sec. is the information rate at which the threshold for a rapid decline in listening comprehension might be expected. This is based on the general consensus drawn from the literature, that approximately 275 WPM is the threshold for a rapid decline in listening comprehension.

CHAPTER VI

SUMMARY, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Summary

Purpose

The purpose of this study was to examine the effects, if any, of performing varying amounts of irrelevant concurrent psychomotor activity while listening to compressed speech at various information rates to determine:

1. If performance of varying amounts of activity effects the ability to comprehend compressed speech.

2. If the performance of psychomotor activity concurrent to listening to compressed speech would impose an unacceptable information load upon a listener.

3. If listening to compressed speech at various rates effects the ability to perform various levels of psychomotor activity.

More specifically, the problem of this study was to see if the performance of irrelevant psychomotor activity concurrent to listening to compressed speech would be associated with a reduction in listening comprehension. This was accomplished by investigating the effects of performing various levels of psychomotor activity (converting random binary digits, presented visually, into a response code at three information levels) on the ability to comprehend compressed speech listened to at 250 and 275 words per minute.

The ultimate question examined was: Will the inclusion, in a compressed speech listening situation, of other media items which necessitate irrelevant psychomotor activity, produce degradation of listening comprehension?

Procedures

Two pilot studies (N=40 and N=32) were performed to determine methodology and to select the type of psychomotor activity and listening rates. The type of psychomotor activity used--dotting and digit copying--proved unsuitable for further experimental use. The analysis of the data did not reveal a significant association between performance of psychomotor activity and listening comprehension ($\underline{P} < .05$). The pilot studies indicated that simple, discrete psychomotor activity could be performed at 225, 250 and 275 WPM, provided adequate pause time was provided, without unacceptable degradation to listening comprehension. Based on the pilot studies the type of psychomotor activity was made more complex. The listening rates of 250 and 275 WPM, used in the second pilot study, were retained.

In the main study a sample population of 120 subjects was drawn from Sophomores, Juniors and Seniors enrolled in the Fall Semester, 1974, in the College of Education at the University of Oklahoma. The Listening Test of the Sequential Tests of Educational Progress (STEP) was used to provide pre-recorded listening material. Part One of the Listening Test provided approximately 10 minutes practice in listening to compressed speech and in experimental procedure. Part Two of the Listening Test, consisting of five selections, was administered to measure listening comprehension at 250 and 275 WPM over four psychomotor activity levels. Listening material was compressed using a Model CC-103, Variable Speech Control Copycorder, manufactured by the Magnetic Video Corporation.

The psychomotor activity used was based upon information theory and was quantified at three levels: 1 bit, 2 bit, and

3 bit. Stimulus code groups were presented in the visual channel by the use of 35 MM slides. Subjects were required to respond with a response code group. Fifty psychomotor sequences were interspersed throughout the listening material of the test.

All experimental listening material and instructions were presented by pre-recorded audio tape. The subjects were assigned to eight experimental groups: Four listened at 250 WPM, and four listened at 275 WPM. The four groups within each listening rate performed at separate levels of psychomotor activity: 0 level (without), 1 bit, 2 bit, and 3 bit. Subjects listened with headsets and were provided separate volume controls. The stimulus code groups were projected on a white matte screen. Subjects were instructed to perform the psychomotor activity sequences by 1000 hertz tones interspersed throughout the listening material. Psychomotor response codes were written in a block on a response sheet. Subjects answered 36 multiple-choice questions over the listening material by circling the letter of the correct response in a test booklet.

<u>Results</u>

The data analyzed consisted of the raw scores for the number of correct responses on the psychomotor activity and the listening comprehension tasks.

A 2 x 4 factorial analysis of variance paradigm was used. The results of a two-way analysis of variance for comprehension, by listening rate, versus psychomotor activity level were as follows:

1. At listening rates of 250 and 275 WPM the performance of up to 3 bits of psychomotor activity did not produce a significant effect on comprehension.

2. Evidence obtained was not sufficient to indicate that there was a significant difference in the threshold for a rapid decline of listening comprehension between subjects who listened only and those who also performed psychomotor activity.

3. The data did not show significant interaction between the amount of psychomotor activity performed and listening comprehension at either 250 or 275 WPM.

4. The data analysis did not indicate that listening to compressed speech at 250 and 275 words per minute and performing up to 3 bits of psychomotor activity imposed an unacceptable information load upon the listener.

5. Competition for short-term memory and switching of channels were not significant problems as evidenced by the fact that, except for Group VIII, comprehension remained quite level.

The results of a two-way analysis of variance for psychomotor activity correctly performed by listening rate indicated:

There was not a significant difference between the amount of psychomotor activity performed correctly by groups which listened at rates of 250 and 275 WPM.

A separate two-way analysis of variance for listening rate versus psychomotor activity level for Groups I and II, which listened only, and Groups VII and VIII, which also performed the highest level of psychomotor activity indicated:

That interaction was present as evidenced by an interaction F ratio of 1.2047 but that it was not sufficient to alter previous findings.

Discussion

Some aspects of the study are difficult to interpret. The provision of pause time to perform the psychomotor activity reduced the probability of interaction taking place.

Despite this fact, the comprehension mean scores for the group which listened at 275 WPM and performed the highest level of psychomotor activity (Group VIII) evidenced a marked reduction in Pilot Study Number Two and in the Main Study. This strongly suggested that channel capacity had been reached and that a sharp decline in listening comprehension had begun. This further suggested that the performance of the 3 bit level of psychomotor activity was responsible because there was no evidence at other levels of such a marked reduction. Variations at the other levels of psychomotor activity, and for Group VII, which listened at 250 WPM, would appear to be associated more with differences between the groups in terms of ability.

Although the analysis did not indicate that the information loads imposed by the dual task activity were unacceptable, this result must be interpreted in light of the fact that pause time was provided. The analysis, particularly of the performance by Group VIII, suggests that without pause time the probability of the dual task activity information loads becoming unacceptable would have been more probable. The lowering of comprehension as indicated by the mean score of 24.733, which is the lowest for all of the groups, indicates that Group VIII was operating at or near channel capacity in respect to listening comprehension. The data suggested that performance of the psychomotor activity was beginning to interfere with processing of the speech input. Without the provision of pause time to perform the psychomotor activity a further reduction would have been very probable. It is also suggested that even with pause time, comprehension would decline further with higher psychomotor activity levels or listening rates. Competition for short-term memory and channel switching would also have become more critical. The results tend to agree with findings by Overmann (1969) that processing demands increase with word rates.

The analysis does not, however, support a firm conclusion in respect to the addition of a processing time factor (PTF) to Hsia's equation $C(C) \leq C(M) + ERROR - EQUIVOCATION - BCR$, as discussed in Chapter III, Theoretical Framework and Hypotheses.

It should be noted that the psychomotor activity stimulus items were multidimensional. The literature indicates that an individual can process over 7 bits/sec. of multidimensional stimuli (Hsia, 1971). Making absolute judgments about eight stimulus variables is also within the range of seven plus or minus two, suggested by Miller (1956). The fact that most of the subjects performed all of the psychomotor activity agrees well with that finding. It also agrees well with suggestions that highly practiced psychomotor tasks contain a considerable element of unconscious control (Henry, 1960). The psychomotor activity performed was highly similar to activity previously performed by students, i.e., alternation of attention, reading numbers and writing letters of the alphabet.

Because performance of the psychomotor activity and listening comprehension did not significantly deteriorate with increasing levels, it is suggested that listening to compressed speech improves attention. At lower levels of information reception sufficient time is available to alternate attention and sample other information inputs that may or may not be relevant. At higher levels this is not possible. This suggests that the brain may operate as Hsia (1971) suggested by functioning as a multiple-channel processor at lower levels and as a single-channel processor at higher levels of information reception.

The data suggested that except for Group VIII (275 WPM and three bit Psychomotor activity level) the groups were operating at or below channel capacity in respect to comprehension. The data suggested that Group VIII had begun to exceed channel capacity because of the combined processing demands of listening at 275 WPM and performing three bits of psychomotor activity.

The general logarithmic increase in the number of psychomotor activity sequences performed incorrectly appeared to be a result of the information processing demands of the individual psychomotor activity levels because of the lack of interaction with the listening rates as indicated by the analysis of variance.

Conclusions

The following conclusions are drawn from the analysis:

1. The performance of simple, discrete psychomotor activity such as copying will not significantly effect listening comprehension at rates of 250 and 275 words per minute provided adequate pause time is provided.

2. The performance of complex psychomotor activity, up to a level of three bits per sequence will not significantly

effect listening comprehension at 250 and 275 words per minute provided adequate pause time is provided.

3. The ability to correctly perform up to three bits of psychomotor activity will not be significantly effected by listening to compressed speech at rates of 250 and 275 words per minute provided adequate pause time is provided.

4. That performance of psychomotor activity sequences, up to a level of three bits per sequence, between speech elements, does not significantly interfere with information processing related to speech reception.

The above conclusions are further predicated on the assumption that the number of psychomotor sequences or tasks would be kept to a reasonable number. In this study psychomotor sequences were performed every 9.2 seconds at 250 WPM and every 8.8 seconds at 275 WPM.

Implications

The following implications are drawn from the analysis. Generalization beyond the type of population sampled in the study is not implied:

1. Students will be able to listen to compressed speech at 250 and 275 words per minute and also perform simple, discrete, concurrent psychomotor activity, such as manipulation of viewers, recorders, and projectors without unacceptable degradation to comprehension provided adequate pause time is provided.

2. Students will be able to listen to compressed speech and also perform complex, concurrent psychomotor activity, such as switching perceptual channels, observing visuals, copying data and making overt responses without degradation to comprehension provided adequate pause time is provided. This statement is made only in respect to psychomotor activity levels up to and including three bits of activity.

3. If students are expected to accomplish complex psychomotor activity rapidly, in conjunction with compressed speech listening, with only minimal pause time provided, some deterioration in performance of the psychomotor activity should be expected, particularly at higher listening rates. This statement is made in respect to psychomotor activity levels up to and including three bits of activity.

Recommendations

Based on the results of the study the following recommendations are made:

1. Educational institutions considering the use of compressed speech should recognize that although compressed speech has proven to be a viable technique for accelerating transfer of information, little research has been accomplished in respect to its use with other media forms.

2. Educational institutions planning to convert or design instruction using compressed speech should consider a). converting only that content to compressed speech format which lends itself to accelerated information rate transfer, b). providing good instructional design to insure adequate time is provided to the learner to accomplish all task activity, c). the automation of attendant activity such as control of viewers, projectors and other audiovisual equipment, d). incorporating covert response activity as opposed to overt responding, and e). evaluating the use of compressed speech, both objectively and subjectively to provide feedback to modify instructional design.

3. Educational institutions recognize that compressed speech has the ability to cause the learner to reach and

exceed information reception channel capacity and that, therefore, special instructional design and evaluation considerations are necessary.

Recommendations for Further Study

Because previous studies had not been conducted in this specific area, this study of necessity proceeded in an evolutionary mode based on the theoretical framework. The performance of subjects, in each study, exceeded the expectations suggested by the theoretical framework, particularly in respect to accomplishment of psychomotor activity. The theoretical framework and this study suggest the possibility for numerous additional studies, particularly studies examining higher listening rates and psychomotor activity levels. The following general recommendations are made in respect to areas which need further study:

1. The effects of performing higher levels of psychomotor activity on listening comprehension above and below the general channel capacity of 275 words per minute.

2. The effects of various listening rates on the ability to perform various levels of psychomotor activity above and below the general channel capacity of 275 words per minute.

3. The differential effects on listening comprehension of various instructional design techniques, such as automation of audiovisual equipment, mode of response activity, pacing techniques, and media forms such as color versus black and white.

4. The differential effects, on listening comprehension, of various techniques for coordinating the concurrent presentation of information in the visual and aural channels, i.e., use of redundancy and simultaneity.

5. Subjective evaluation of compressed speech used in an automated format versus manual format.

6. Development of compressed speech research tools to examine the differential effects of information transfer by the auditory and visual perceptual systems.

7. Comparative evaluation studies of devices for speech compression in respect to manipulation of pause time and other speech elements as applied to the requirements of instructional design.

BIBLIOGRAPHY

Books

Broadbent, D. E. Perception and communication. New York: Pergamon Press, 1958

Duker, Sam. Time-compressed speech: An anthology and bibliography in three volumes. Metuchen, New Jersey: Scarecrow Press, Inc., 1974.

Fassard, A. The role of neuronal network in sensory communication within the brain. In W. A. Rosenblith (Ed.), Sensory Communication. Cambridge, Mass.: MIT Press, 1961.

Fitts, P. M. Perceptual-motor skill learning. In A. W. Melton (Ed.), Categories of human learning. New York: Academic Press, 1964.

Fletcher, H. Speech and hearing. New York: Van Nostrand Co., 1929.

Garner, W. R. Uncertainty and structure as psychological concepts. New York: John Wiley, 1962.

Hays, William L. Statistics. New York: Holt, Rinehart & Winston, Inc., 1963.

Johnson, W., Darley, F., & Spriesterbach, D. C. Diagnostics in speech pathology. New York: Harper & Rowe, 1963.

Kerlinger, Fred N. Foundations of behavioral research. New York: Holt, Rinehart & Winston, Inc., 1964.

Kirk, Roger E. Experimental design: Procedures for the behavioral sciences. Belmont, California: Brooks Cole Publishing Company, 1968.

Licklider, J. C. R., & Miller, G. A. The perception of speech. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: Wiley, 1951.

Lorge, Irving. The sequential tests of educational progress. Fifth Mental Measurement yearbook. Highland Park, New Jersey: The Gryphon Press, 1959.

McLuhan, Marshall. Understanding media: The extensions of man. New York: McGraw-Hill Book Co., 1965.

Melton, A. W. (Ed.). Army air forces aviation psychology reports: Aparatus tests (Report No. 4). Washington, D. C.: U. S. Government Printing Office, 1947.

Miller, George A. Speech and language. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: Wiley, 1951.

Moray, N. Attention: Selective processes in vision and hearing. New York: Academic Press, 1970.

Shannon, Claude E., & Weaver, Warren. The mathematical theory of communication. Urbana, Illinois: The University of Illinois Press, 1964.

Singer, R. N. The psychomotor domain: General considerations. In The psychomotor domain. Washington, D. C.: Gryphon House, 1972.

Smith, Karl U., & Smith, Margaret Foltz. Cybernetic principles of learning and educational design. New York: Holt, Rinehart & Winston, Inc., 1966.

Toffler, A. Future Shock. New York: Random House, Inc., 1970.

Travers, Robert M. W. Man's information system. Scranton, Pa.: Chandler Pub. Co., 1970.

Von Neumann, J. The computer and the brain. New Haven: Yale University Press, 1958.

Periodicals

Adiseshiah, W. T. V. Speed in Decision Taking Under Single Channel Display Conditions. Indian Journal of Psychology, 1957, 32, 105-108.

Allport, Alan D., Antonis, Barbara & Reynolds, Patricia. On the Division of Attention: A Disproof of the Single-Channel Hypothesis. Quarterly Journal of Experimental Psychology, 1972 (May), 24(2), 225-235.

Beier, E. G. The Effect of Induced Anxiety on the Flexibility of Intellectual Functioning. Psychological Monographs, 1951, 65(9, Whole No. 326).

Cherry, E. Colin & Taylor, W. K. Some Further Experiments Upon the Recognition of Speech with one and with Two Ears. The Journal of the Acoustical Society of America, July 1954, 26, 554-559.

Craik, K. J. W. Theory of the Human Operator in Control Systems. British Journal of Psychology, 1947-48, 38, 142-149.

Crossman, E. R. F. W. Information Processes in Human Skill. British Medical Bulletin, 1964, 20, 32-37.

Deutsch, J. A., & Deutsch, D. Attention: Some Theoretical Considerations. Psychological Review, 1963, 70, 80-90.

Fairbanks, G., Guttman, N., & Miron, M. S. Effects of Time Compression Upon the Comprehension of Connected Speech. Journal of Speech and Hearing Disorders, 1957, 22, 10-19.

Fairbanks, G., & Kodman, F., Jr. Word Intelligibility as a Function of Time Compression. Journal of the Acoustical Society of America, 1957, 29, 636-641.

Fitts, P. M., & Seeger, C. M. Journal of Experimental Psychology, 1953, 46, 199.

Fitts, P. M. The Information Capacity of the Human Motor System in Controlling the Amplitude of Movement. Journal of _Experimental Psychology_, 1954, _47_(6), 381-392.

Foulke, Emerson. Comparison of Comprehension of Two Forms of Compressed Speech. _Exceptional Children_, 1966, _33_, 169-173.

Foulke, Emerson, Amster, C. H., Nolan, C. Y., & Bixler, R. H. The Comprehension of Rapid Speech by the Blind. _Exceptional Children_, 1962, _29_, 134-141.

Garner, W. R. An Information Analysis of Absolute Judgment of Loudness. _Journal of Experimental Psychology_, 1953, _46_, 373-380.

Garvey, W. D. The Intelligibility of Abbreviated Speech Patterns. _Quarterly Journal of Speech_, 1953, _39_, 296-306.

Garvey, W. D. The Intelligibility of Speeded Speech. _Journal of Experimental Psychology_, 1953, _39_, 296-306.

Hartline, H. K., & Ratliff, Floyd. Inhibitory Interaction of Receptor Units in the Eye of Limulus. _Journal of General Physiology_, 1956-57, _40_, 357-376.

Hartman, E. B. The Influence of Practice and Pitch Distance Between Tones on the Absolute Identification of Pitch. _American Journal of Psychology_, 1954, _67_, 1-14.

Hartman, Frank R. Single and Multiple Channel Communication: A Review of Research and a Proposed Model. _AV Communications Review_, November-December 1961, _9_(6), 235-262.

Harwood, K. A. Listenability and Rate of Presentation. _Speech Monographs_, 1955, _22_, 57-59.

Hebb, D. C. Concerning Imagery. _Psychological Review_, 1968, _75_, 466-477.

Henry, F. M. Increased Response Latency for Complicated Movements and A "Memory Drum" Theory of Neuromotor Reaction. _Research Quarterly_, 1960, _31_, 448-458.

Hsia, H. J. The Information Processing Capacity of Modality and Channel Performance. AV Communications Review. Spring 1971, 19(1), 51-75.

Jacobson, H. The Information Capacity of the Human Ear. Science, 1950, CXII, 143-144.

Jacobson, H. The Information Capacity of the Human Eye. Science, 1951, CXIII, 292-293.

Kalsbeek, J. W. H. On the Measurement of Deterioration in Performance Caused by Distraction Stress. Ergonomics, 1964, 7, 187-195.

Kefauver, Grayson N. Relationship of the Intelligence Quotient and Scores on Mechanical Tests With Success in Industrial Subjects. Vocational Guidance Magazine, February 1929, 7, 198-203.

Kurtzrock, G. H. The Effects of Time and Frequency Distortion Upon Word Intelligibility. Speech Monograph, 1957, 24, 94.

MacQuarrie, T. W. A Mechanical Ability Test. Journal of Personnel Research, January 1927, 5(9), 329-337.

McLain, Julie R. A Comparison of Two Methods of Producing Rapid Speech. International Journal Education Blind, 1962, 12, 40-43.

Miller, G. A. What is Information Measurement? American Psychologist, 1953, 8, 3-11.

Miller, G. A., & Licklider, J. C. R. The Intelligibility of Interrupted Speech. Journal of the Acoustical Society of America, 1950, 22, 167-173.

Miller, George A. The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. The Psychological Review, March, 1956, 63, 81-96.

Nelson, H. E. The Effect of Variations of Rates on the Recall by Radio Listeners of Straight Newscasts. Speech Monographs, 1948, 15, 173-180.

Norman, D. A. Toward a Theory of Memory and Attention. Psychological Review, 1968, 75, 522-536.

Orr, D. B., Friedman, H. L., & Williams, J. C. C. Trainability of Listening Comprehension of Speeded Discourse. Journal of Educational Psychology, 1965, 56(3), 148-156.

Peters, D. L. Effects of Note Taking and Rate of Presentation on Short-Term Objective Test Performance. Journal of Educational Psychology, 1972, 63, 276-280.

Pierce, J. R., & Karlin, J. E. Reading Rates and the Information Rate of Human Channels. Bell Systems Technical Journal, 1957, 36, 497-516.

Pollack, I. The Assimilation of Sequential Encoded Information. American Journal of Psychology, 1953, 66, 421-435.

Pollack, I. The Information of Elementary Audio Displays. Journal of Acoustical Society of America, 1952, 24, 745-750.

Pollack, I., & Fricks, L. Information of Elementary Multidimensional Auditory Displays. Journal of Acoustical Society of America, 1954, 26, 155-158.

Poulton, E. C. Sequential Short-term Memory: Some Tracking Experiments. Ergonomics, 1963, 6, 117-132.

Reid, I., & Travers, R. M. W. Time Required to Switch Attention. American Educational Research Journal, 1968, 5, 203-211.

Shannon, C. E. Prediction and Entropy of Printed English. Bell System Technical Journal, 1951, 30, 50-64.

Shartle, Carroll L. A Selection Test for Electrical Troublemen. Personnel Journal, October, 1932, 11(3), 177-183.

Treisman, A. M. Strategies and Models of Selective Attention. Psychological Review, 1969, 76(3), 282-299.

Treisman, A. M. The Effect of Irrelevant Material on the Efficiency of Selective Listening. American Journal of Psychology, 1964, 77, 533-546.

Welford, A. T. The Measurement of Sensory-motor Performance: Survey and Reappraisal of Twelve Year's Progress. Ergonomics, 1960, 3, 189-230.

Miscellaneous

Armsey, James W., & Dahl, Norman C. An Inquiry Into the Uses of Instructional Technology, A Ford Foundation Report. New York: The Ford Foundation, 1973.

Breuel, John W., & Levens, Leo M. The A. F. B. Harmonic Compressor. Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech. Louisville, Kentucky: Center for Rate-Controlled Recordings, University of Louisville, February 1971, 185-192.

Brown, I. D. The Measurement of Perceptual Load and Reserve Capacity. The Transactions of the Association of Industrial Medical Officers, 1964, 14, 44-49.

Carroll, J. B. Problems of Measuring Speech Rate. Proceedings of the Louisville Conference on Time Compressed Speech. Louisville, Kentucky: Center for Rate-Controlled Recordings, University of Louisville, 1967, 88-94.

Challis A. J. The Effect of Fixed and Learner Selected Rates of Compressed Speech in an Audio-Tutorial Learning Environment on the Achievement of College Level Students. Unpublished Dissertation, University of Oklahoma, 1973.

Clark, Willis W. Unpublished Study for the California Test Bureau, 1948.

Duran, June C. Summary of Investigations, Number Two: MacQuarrie Test For Mechanical Ability. Los Angeles, Ca.: California Test Bureau, 1950.

Educational Testing Service, Sequential Tests of Educational Progress: Listening (Catalog No. 380-007). Princeton, New Jersey: Cooperative Test Division, Educational Testing Service, 1957.

Educational Testing Service, Sequential Tests of Educational Progress: Teachers Guide. Princeton, New Jersey: Cooperative Test Division, Educational Testing Service, 1959.

Educational Testing Service, Sequential Tests of Educational Progress: Technical Report (Catalog No. 031-00-9). Princeton, New Jersey: Cooperative Test Division, Educational Testing Service, 1957.

Educational Testing Service, Sequential Tests of Educational Progress, Technical Report. Princeton, New Jersey: Cooperative Test Division, Educational Testing Service, 1957.

Fairbanks, G., Everitt, W. L., & Jaeger, R. P. Method For Time or Frequency Compression-expansion of Speech. Transactions of the Institute of Radio Engineers Profession Group on Audio, January-February 1954, 7-12.

Foulke, Emerson. The Comprehension of Rapid Speech by the Blind: Part III (Final Progress Report, Cooperative Research Project No. 2430). Washington, D.C.: United States Department of Health, Education, and Welfare, Office of Education, 1969.

Foulke, Emerson. The Comprehension of Rapid Speech by the Blind (Final Progress Report, Project No. 1370, Part II). Washington, D.C.: U. S. Department of Health, Education and Welfare, Office of Education, 1964.

Foulke, Emerson. Introduction. Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech. Louisville, Kentucky: Center for Rate Controlled Recordings, University of Louisville, 1971.

Foulke, Emerson, & Sticht, Thomas G. The Intelligibility and Comprehension of Time Compressed Speech. Proceedings of the Louisville Conference on Time Compressed Speech. Louisville, Kentucky: Center For Rate Controlled Recordings, University of Louisville, 1967.

Foulke, Emerson, & Sticht, Thomas G. A Review of Research on Time Compressed Speech. Proceedings of the Louisville Conference on Time Compressed Speech. Louisville, Kentucky: Center For Rate Controlled Recordings, University of Louisville, 1967.

Goldstein, H. Reading and Listening Comprehension at Various Controlled Rates. Teachers College Contributions to Education, No. 821. New York: Bureau of Publications Columbia University, Teachers College, 1940.

Graham, Wayne W. The Graham Compressor, A Technical Development of the Fairbanks Method. Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech. Louisville, Kentucky: Center for Rate-Controlled Recordings. University of Louisville, February, 1971.

Kegler, Stanley B. Classification Scheme. Sequential Tests of Educational Progress: Teacher's Guide. Princeton, New Jersey: Cooperative Test Division, Educational Testing Service, 1959.

Ludrick, John A. A Study of the Effects of Controlled Delivery Instructions Upon the Achievement of College Students Using Compressed Speech, Audio and Television Pictorials. Unpublished Doctoral Dissertation, University of Oklahoma, Norman, Oklahoma, 1974.

Overmann, R. A. Processing Time as a Variable in the Comprehension of Time-Compressed Speech. Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech. Louisville, Kentucky: Center For Rate Controlled Recordings, University of Louisville, 1969.

Passey, G. E., & McLaurin, W. A. Perceptual-Psychomotor Tests in Aircrew Selection: Historical Review and Advanced Concepts, (DDC Document AD-636-606). Springfield, Va.: National Technical Information Service, 1966.

Quastler, H., & Wulff, V. J. Human Performance in Information Transmission. The University of Illinois Report No. R62. Urbana, Illinois: Control System Laboratory, 1955.

Qureshi, S. U. H., & Kingman, Y. J. Time Compression of Speech on a Small Computer. Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech. Louisville, Kentucky: Center For Rate-Controlled Recordings, University of Louisville, February, 1971.

Sanders, J. H., Valentine, L. D., & McGrevy, D. F. The Development of Equipment for Psychomotor Assessment, (DDC Document AD-732-210). Springfield, Va.: National Technical Information Service, 1971.

Watts, M. W., Jr. Using Compressed Speech to Teach Instructional Techniques to Air Force Officers. Department of Instructional Technology Report. Alabama: Maxwell AFB, 1969.

APPENDICES

APPENDIX A

PILOT STUDY NUMBER 1

PILOT STUDY NUMBER 1

The specific purpose of this study was to establish parameters and to devise an appropriate type of psychomotor activity. The general purpose and problem of the study were the same as those of the main study.

Two independent variables were used:

1. X_A Psychomotor Activity - A discrete, simple dotting activity performed with pencil and paper. Number of sequences predetermined.

2. X_B Listening Rate - Controlled by rate of pre-recorded material on audio tape. Rates used were 155 and 225 WPM.

Two dependent variables were measured:

1. Y_A Psychomotor Activity - Number of correct sequences performed.

2. Y_B Listening Comprehension - Number of correct responses on multiple-choice tests of comprehension.

One hypothesis was tested:

Ho_1 - There will be no difference in listening comprehension between subjects who listen only, to compressed speech, and those who also perform psychomotor activity.

Several questions were examined:

1. Was the type and amount of psychomotor activity performed appropriate?

2. Were the listening rates (155 and 225 WPM) appropriate for demonstrating interference/interaction affects?

3. Was the Listening Test an appropriate instrument?

4. Was the overall design and methodology satisfactory, i.e., instructions, listening material, timing, response sheets, scoring sheets?

The performance of psychomotor activity at the normal speech rate of 155 WPM was not expected to produce any significant effect on listening comprehension. The effects at the listening rate of 225 were expected but not considered as highly probable. It was anticipated that subjects would accomplish most of the psychomotor activity required. Pause time of two seconds was considered adequate for subjects to alternate attention and perform the psychomotor activity.

Method

Subjects

The sample population consisted of 40 volunteer subjects, 18 female and 22 male, aged 18 to 55. All were first and second year students enrolled in psychology courses at Oscar

Rose Junior College, Midwest City, Oklahoma, during the Summer, 1974 semester.

Environment, Apparatus, and Materials

All testing was accomplished during morning hours (8:00-11:30 AM) in a modern, air conditioned and sound deadened language laboratory. Each subject was seated in an individual listening carrel with headset and volume control. The test session took approximately 50 minutes.

The experimental materials consisted of an audio tape recording of the Listening Test of the Sequential Tests of Educational Progress (STEP), Form 1A (Educational Testing Services, 1957). This test, divided into two parts, consisted of 10 short listening selections. Selection 3, Part One, a short poem, was not used.

The normal speech rate (uncompressed) recording time was 25 minutes and 20 seconds at an average of 155 WPM. The compressed speech version was 17 minutes and 25 seconds at an average of 225 WPM (See Chapter IV for details on equipment used to compress material). With instructions and other information, the total listening times were approximately 50 minutes for the normal speech rate version and 40 minutes for the compressed version.

Information on reliability and validity of the STEP Listening Test is contained in Chapter IV of the main study.

The psychomotor sequences performed were adapted from the Dotting subtest of the MacQuarrie Test for Mechanical Ability (California Test Bureau, 1950). MacQuarrie (1927) reported reliability, by the test-retest method, of .74 for the Dotting Test. Duran (1950) also cited a number of studies (Kefauver, 1929; Shartle, 1932; Clark, 1948) supporting the validity of the MacQuarrie Test.

Subjects were provided a psychomotor response sheet (8½ x 11") with rows of ½" diameter circles, a test booklet, and an IBM type answer sheet.

Procedure

The subjects were assigned to four experimental groups of 10 each:

Group I -- E_1 - Normal speech rate (155 WPM) without psychomotor activity.

Group II -- E_2 - Compressed speech (225 WPM) without psychomotor activity.

Group III -- E_3 - Normal speech rate (155 WPM) with psychomotor activity.

Group IV -- E_4 - Compressed speech (225 WPM) with psychomotor activity.

Experimental Design Paradigm: A 2 x 2 Factorial Analysis of Variance was used.

I	X_{A1B1} Y_1	II	X_{A1B2} Y_2
III	X_{A2B1} Y_3	IV	X_{A2B2} Y_4

Listening Rate

Psychomotor Activity		155 WPM B_1		225 WPM B_2	
Without	A_1	I	A_1B_1	II	A_1B_2
With	A_2	III	A_2B_1	IV	A_2B_2

Subjects were instructed how to use the headsets and volume control. All other instructions and listening materials were recorded on one-eighth inch audio tape. The audio was provided by a Sony TC 110A cassette recorder and distributed to the subjects by the language lab circuitry. All instructions were provided at normal speech rate.

Listening comprehension was measured by administration of Part Two of the Listening Test. Part One (Selections 1, 2, 3, and 5) were used as practice in listening to compressed speech. The four practice selections were compressed to 175, 225, 300, and 225 WPM respectively. Approximately 10 minutes practice was provided. The total listening time for the five test selections at 225 WPM was 8 minutes and 57 seconds.

Fifty sequences of psychomotor activity interspersed throughout the listening material were required. An audible tone instructed subjects to perform a sequence - place three dots in a one-half inch diameter circle on a response sheet. All groups were tested for comprehension by 36 multiple-choice questions spaced at the end of each selection. Questions were heard at normal speech rate. Subjects answered questions by circling the correct letter response in the test booklet. Answers were later transcribed to the IBM score sheets by the examiner.

Results

Analysis of the data did not reveal a significant association between performance of psychomotor activity and listening comprehension. The data was analyzed using the raw scores from the 36 item test of comprehension. The amount of psychomotor activity performed was not analyzed as a dependent variable because all subjects performed all of the required sequences. The data is summarized in Table A.

TABLE A

SUMMARY TABLE OF MEANS, STANDARD DEVIATION AND STANDARD ERROR

	Mean	Std. Dev.	Std. Err.
Group I	22.4	4.45	1.41
Group II	18.0	5.46	1.73
Group III	20.9	6.08	1.92
Group IV	21.5	5.04	1.59
Column (Normal Rate)	21.65		
Column (225 WPM)	19.75		
Row (without PMA)	20.2		
Row (with PMA)	21.2		

The data was analyzed with a two-way analysis of variance summarized in Table B.

TABLE B

TWO-WAY ANALYSIS OF VARIANCE FOR LISTENING RATE VERSUS PSYCHOMOTOR ACTIVITY

Source of Variation	SS	df	MS	F
Between Rates	36.102	1	36.102	1.290
Between Modes	10.000	1	10.000	0.357
Interaction (R x M)	62.500	1	62.500	2.233
Error Variance	1007.801	36	27.994	
Total	1116.402	39		

The F ratios obtained were not significant ($\underline{P} < .10$). Although the F ratio for interaction, 2.233, is significant, ($\underline{P} < .25$), this is attributed to the non-homogeneity of the groups.

Discussion

Although the failure to obtain a significant F ratio ($\underline{P} < .10$) suggested a basis to accept the null hypothesis, acceptance was withheld on both the null and alternative hypotheses because of the suspected non-homogeneity of the groups. The directional nature of the means and the significant interaction F ratio ($\underline{P} < .25$) were attributed to the non-homogeneity of the groups because of the inability to randomly assign subjects to groups. The small F ratios obtained did, however, suggest that the type and amount of psychomotor performed did not significantly effect the ability to comprehend speech at the two listening rates used (155 and 225 WPM).

The only inference suggested from the study was that the simple psychomotor activity performed was not sufficient to interfere with information processing between speech elements at the rates used. The study further indicated that the amount and complexity of the psychomotor activity and the listening rates should be increased in further experimentation. The study further indicated that the STEP test and the overall design and methodology of the experiment were satisfactory.

APPENDIX B

PILOT STUDY NUMBER 2

PILOT STUDY NUMBER 2

The specific purpose of this study was to examine revised parameters and to devise an appropriate type of psychomotor activity. The general purpose and problem were the same as those of the main study.

Two independent variables were used:

1. X_A Psychomotor activity - A discrete copying activity involving copying random binary digits. Number of sequences was predetermined.

2. X_B Listening Rate - Controlled by rate of pre-recorded material on audio tape. Rates used were 250 and 275 WPM.

Two dependent variables were measured:

1. Y_A Psychomotor Activity - Number of correct sequences performed.

2. Y_B Listening Comprehension - Number of correct responses on multiple-choice test of comprehension.

One hypothesis was tested:

Ho_1 - There will be no difference in listening comprehension between subjects who listen only, to compressed speech, and those who also perform psychomotor activity.

Several questions were examined:

1. Was the type and amount of psychomotor activity used appropriate?

2. Were the listening rates (250 and 275 WPM) appropriate for demonstrating interference/interaction affects?

3. Was the Listening Test an appropriate research tool?

4. Was the overall design and methodology satisfactory, i.e., instructions, listening materials, timing, response sheets, scoring sheets?

The performance of psychomotor activity at both 250 and 275 WPM was expected to produce a significant effect on listening comprehension. The probability of the effects at 250 WPM being significant was not considered to be as probable as those at 275 WPM. It was anticipated that subjects would accomplish most of the psychomotor activity at the listening rate of 250 WPM but that some deterioration would be found at 275 WPM. Pause time of four seconds was considered adequate for subjects to alternate attention and perform the psychomotor activity.

Method

Subjects

The sample population consisted of 32 volunteer subjects, all male, aged 24 to 45. The average age was 34 years. The subjects were officers, non-commissioned officers and civilians assigned to the U.S. Air Force Communications Computer Programming Center, Tinker AFB, Oklahoma during August, 1974. The educational level ranged from 12 to 18 years, with an average of 14.4 years.

Environment, Apparatus and Materials

All testing was accomplished during morning hours (8:00 to 11:45 AM) in an air conditioned and sound-deadened training room. Subjects were seated at a table with headset and individual volume controls. The test session took approximately 50 minutes.

The experimental materials consisted of an audio recording of the Listening Test of the Sequential Tests of Educational Progress (STEP), Form 1A (Educational Testing Service, 1957). This test, divided into two parts, consisted of 10 short listening selections. Selection 3, Part One, a short poem, was not used.

The normal speech rate (uncompressed) recording time was 22 minutes and 24 seconds, at an average word rate of 175.2 WPM. The two compressed speech total recording times were 15 minutes and 44 seconds for an average of 250 WPM, and 14 minutes and 17 seconds for an average of 275 WPM. The listening materials were compressed with a VSC Copycorder Model CC-103 cassette recorder made by the Magnetic Video Corporation. (For further details on equipment used to compress material, see Chapter IV.) With instructions and other information, the total listening times were approximately 40 minutes for the 250 WPM version and 41 minutes for the 275 WPM version.

See Chapter IV for information pertaining to validity and reliability of the test instruments.

The psychomotor sequences performed were changed to increase the amount of activity required. The type of activity was suggested by studies on the ability to process sequentially coded information (Pollack, 1953), the ability to switch channels (Reid and Travers, 1968), and total processing capacities (Hsia, 1971).

Subjects were provided a psychomotor response sheet (8½ x 11") with rows of squares (3/4 x 3/4"), a test booklet, and an IBM-type answer sheet.

A Wollensack Model 2551 cassette recorder provided the audio and controlled a Kodak Ektagraphic Model AF2 (F 2:8

lens) slide projector. The audio was distributed through jackboxes to 600 ohm headsets. Fifty-nine black and white slides (2 x 2") provided the psychomotor stimulus materials. Slide images were projected onto a 40 x 50" white matte screen.

Procedure

The subjects were randomly assigned using a table of random numbers to eight experimental groups of four each:

Group I -- E_1 - Listening rate of 250 WPM without PMA.

Group II -- E_2 - Listening rate of 275 WPM without PMA.

Group III -- E_3 - Listening rate of 250 WPM with PMA of one digit.

Group IV -- E_4 - Listening rate of 275 WPM with PMA of one digit.

Group V -- E_5 - Listening rate of 250 WPM with PMA of two digits.

Group VI -- E_6 - Listening rate of 275 WPM with PMA of two digits.

Group VII -- E_7 - Listening rate of 250 WPM with PMA of three digits.

Group VIII -- E_8 - Listening rate of 275 WPM with PMA of three digits.

Experimental Design Paradigm:

A 2 x 4 Factorial Analysis of Variance was used.

I	X_{A1B1}--Y_1	V	X_{A3B1}--Y_5
II	X_{A1B2}--Y_2	VI	X_{A3B2}--Y_6
III	X_{A2B1}--Y_3	VII	X_{A4B1}--Y_7
IV	X_{A2B2}--Y_4	VIII	X_{A4B2}--Y_8

	Listening Rate	
	250 WPM	275 WPM
Psychomotor Activity	B_1	B_2
Without A_1	I A_1B_1	II A_1B_2
1 Digit A_2	111 A_2B_1	IV A_2B_2
2 Digits A_3	V A_3B_1	VI A_3B_2
3 Digits A_4	VII A_4B_1	VIII A_4B_2

Subjects were instructed how to use the headsets and volume control. All other instructions and listening material were recorded on one-eighth inch audio tape. The audio was provided by a Wollensack Model 2551 cassette recorder and distributed to subjects by audio cables and jackboxes with individual volume controls. All instructions were provided at normal speech rates.

An Ektagraphic Model AF2 (F 2:8 lens) was used to project the psychomotor stimulus items on a white matte screen (40" x 50"). The projected image was 19 x 28". The stimulus digits were approximately 2" high. Subjects were seated 12 to 18 feet from the screen. Slide advancement was controlled by an inaudible sync pulse from the tape recorder. The psychomotor digit sequences were arranged in random order by use of a table of random numbers.

Listening comprehension was measured by administration of Part Two of the Listening Test. Part One (Selection 1, 2, 3, and 5) was used for practice in listening to compressed speech. The four practice selections were compressed to 175, 225, 300, and 225 WPM respectively. Approximately 10 minutes of practice was provided. Total listening time for the five test selections was 7 minutes and 19 seconds at 250 WPM and 7 minutes and 18 seconds at 275 WPM.

Fifty sequences of psychomotor activity, interspersed throughout the listening material at the end of sentences, were required. A 1000 hertz audible tone instructed the subjects to perform a psychomotor sequence. At the 1 digit level, the stimulus items were 0 and 1. At the 2 digit level, the items were 00, 10, 11 and 01. At the 3 digit level the items were 000, 001, 011, 111, 100, 110, 101, and 010. Subjects copied the digits in 3/4 x 3/4 inch squares on the psychomotor activity response sheet.

All groups were tested for comprehension by 36 multiple-choice questions, spaced at the end of each selection. Questions were heard at normal speech rates. Subjects answered by circling the correct letter response in the test booklet. Answers were later transcribed to the IBM score sheet by the examiner.

Results

Analysis of the total data did not reveal an association between performance of psychomotor activity and listening comprehension. The data was analyzed using the raw scores from the 36 item test of comprehension. The amount of psychomotor activity performed was not analyzed as a dependent variable because all subjects performed all of the required sequences. The data is summarized in Table A.

The data was analyzed with a two-way analysis of variance, summarized in Table B.

The F ratios obtained were not significant ($\underline{P} < .10$). Based on an examination of the cell means, particularly the

TABLE A

SUMMARY OF MEANS, STANDARD DEVIATION AND STANDARD ERROR

	Mean	Std. Dev.	Std. Error
Group I	26.500	6.456	3.228
Group II	26.750	1.893	0.947
Group III	25.000	2.944	1.472
Group IV	26.750	3.948	1.974
Group V	26.750	4.574	2.287
Group VI	27,000	4.690	2.345
Group VII	27.750	6.946	3.473
Group VIII	24.750	7.411	3.705
Column (250 WPM)	26.500		
Column (275 WPM)	26.313		
Row (0-PMA)	26.625		
Row (1-bit)	25.875		
Row (2-bits)	26.875		
Row (3-bits)	26.250		

TABLE B

TWO-WAY ANALYSIS OF VARIANCE FOR LISTENING COMPREHENSION VERSUS PSYCHOMOTOR ACTIVITY

Source of Variation	SS	df	MS	F
Between Rates	0.281	1	0.281	0.010
Between Modes	4.594	3	1.531	0.057
Interaction (R x M)	24.094	3	8.031	0.298
Error Variance	646.750	24	26.948	
Total	675.719	31		

reduction of listening comprehension in Group VIII, a further analysis was made of Groups I, II, VII, and VIII as summarized in Table C.

TABLE C

TWO-WAY ANALYSIS OF VARIANCE FOR LISTENING COMPREHENSION VERSUS PSYCHOMOTOR ACTIVITY

Source of Variation	SS	df	MS	F
Between Rates	7.563	1	7.563	0.204
Between Modes	0.563	1	0.563	0.015
Interaction (R x M)	10.563	1	10.563	0.285
Error Variance	445.250	12	37.104	
Total	463.938	15		

The F ratios obtained were not significant ($\underline{P} < .10$).

Discussion

Although the failure to obtain a significant F ratio ($p < .10$) suggested a basis to accept the null hypothesis, acceptance was withheld on both the null and the alternative hypothesis because of the small size of the groups and the total sample. The small F ratios obtained did, however, suggest that the type and amount of psychomotor activity performed did not significantly effect the ability to comprehend compressed speech at the listening rates used (250 and 275 WPM).

The only inference suggested from the study was that the simple psychomotor activity performed was not sufficient to interfere with information processing between speech elements at the rates used. The study further indicated that the amount and complexity of the psychomotor activity should be increased in further experimentation. A decision was made to retain the compressed speech listening rates of 250 and 275 WPM for the main experiment. The study further indicated that the STEP Listening Test and the overall design and methodology were satisfactory.

APPENDIX C

LISTENING SELECTIONS

LISTENING SELECTIONS

Educational Testing Service would not permit reproduction of the listening selections in this paper. Copies are available from Educational Testing Service, Princeton, New Jersey 08540.

The following list provides a general description of the content and gives the number of words in each of the nine selections used in this study:

Selection 1 - It is a college lecture on hypnotism (516 Words).

Selection 2 - It describes the use of a rare carbon for estimating the age of prehistoric remains (396 Words).

Selection 4 - It is a speech about the difference between liberty and freedom (647 Words).

Selection 5 - It is the opening section of a story (353 Words).

Selection 6 - It is a college lecture on an aspect of language (698 Words).

Selection 7 - It is a talk about the American party system (493 Words).

Selection 8 - It is a conversation between two characters in a novel (242 Words).

Selection 9 - It is an explanation (116 Words).

Selection 10 - It is a speech about effective communication (464 Words).

APPENDIX D

PSYCHOMOTOR ACTIVITY

Psychomotor Activity

Stimulus/Response Code Groups

Level	Stimulus Group	Response Group	Memory Aid
1 bit	0	SUB	Subtract
	1	ADD	Add
2 bits	00	SUB	Subtract
	01	DIV	Divide
	11	ADD	Add
	10	MUL	Multiply
3 bits	000	SUB	Subtract
	001	DIV	Divide
	011	WRI	Write
	111	ADD	Add
	110	LOO	Loop
	100	MUL	Multiply
	101	CLO	Close
	010	OPN	Open

APPENDIX E

TEST BOOKLET

COMPRESSED SPEECH

LISTENING EXPERIMENT

This is a test of how well you can understand the kinds of things that are often spoken aloud to you. You should take the test in the same way that you would work on any new and interesting assignment. Here are a few suggestions which will help you to earn your best score.

1. Make sure you understand the test directions before the actual experiment begins. There will be a period for asking questions.
2. You will make your best score by answering every question because your score is the number of correct answers you mark. If a question seems to be too difficult, make the best guess you can; you will have a limited amount of time to answer each question.

GENERAL DIRECTIONS

A number of short selections will be read aloud to you from a recording. After each selection, you will hear a group of questions or incomplete statements. Four suggested answers are given for each question or incomplete statement. You are to decide which of these answers is best. Remember to listen carefully because each selection and each question will be heard only once and they are not printed in your test booklet. The four suggested answers to each question are printed in your test booklet. They will not be read aloud to you.

You will mark your answers in your test booklet by circling the letter of the answer which you think is correct.

For example, suppose the following selection and question were heard:

Selection: The moment a bolt of lightning strikes a power line carrying high voltage electricity, giant switches take the current off the line. Within a fraction of a second, the effect of the lightning passes and the switches automatically turn the current on again.

Question number 0: What will probably happen to the electric lights if a powerline serving an area is struck by lightning? Your test booklet would look like this:

0 A The lights will brighten.
  B The lights will flicker.
  C The lights will burn out.
  D Nothing will happen to the lights.

When lightning strikes, the giant switches turn the current off for a fraction of a second, causing the electric lights to flicker. Therefore, you should choose the answer lettered B. In your test booklet you would circle the letter for the answer you have chosen.

Circle only one answer for each question. If you decide to change an answer, erase your first answer completely or put an X thru it.

Use the pencils provided. Your answers will be transcribed later to your answer sheet by the examiner.

<u>Note to Readers</u>: Educational Testing Service would not permit reproduction of the test questions in this paper. Copies are available from Educational Testing Service, Princeton, New Jersey 08540.

The following provides general information on the test questions.

PRACTICE SELECTION

This selection was used as a rehearsal for the actual experiment. Six multiple-choice questions, each having four possible answers, were used to measure comprehension. Format was the same as that used in the illustrative question presented in the general directions.

TEST SELECTIONS

Five selections were used in the actual experiment. Thirty-six multiple-choice questions, each having four possible answers, were used to measure comprehension. Format was the same as that used in the illustrative question presented in the general directions.

NAME ______________________________
(print) last first m-initial

DATE ____________________
month day year

AGE ________________
YEARS MONTHS

CLASS ___________

No. Right

Sample

	A	B	C	D
0		▮		

PRACTICE WORK ONLY

1	A	B	C	D
2	E	F	G	H
3	A	B	C	D
4	E	F	G	H
5	A	B	C	D
6	E	F	G	H

EXPERIMENT

1	A	B	C	D	21	A	B	C	D
2	E	F	G	H	22	E	F	G	H
3	A	B	C	D	23	A	B	C	D
4	E	F	G	H	24	E	F	G	H
5	A	B	C	D	25	A	B	C	D
6	E	F	G	H	26	E	F	G	H
7	A	B	C	D	27	A	B	C	D
8	E	F	G	H	28	E	F	G	H
9	A	B	C	D	29	A	B	C	D
10	E	F	G	H	30	E	F	G	H
11	A	B	C	D	31	A	B	C	D
12	E	F	G	H	32	E	F	G	H
13	A	B	C	D	33	A	B	C	D
14	E	F	G	H	34	E	F	G	H
15	A	B	C	D	35	A	B	C	D
16	E	F	G	H	36	E	F	G	H
17	A	B	C	D	37	A	B	C	D
18	E	F	G	H	38	E	F	G	H
19	A	B	C	D	39	A	B	C	D
20	E	F	G	H	40	E	F	G	H

COMPRESSED SPEECH LISTENING COMPREHENSION

____
Last Name, First, MI

PSYCHOMOTOR RESPONSE SHEET

_____ Number performed

Practice Selection

Experimental Selections

APPENDIX F

INSTRUCTIONS FOR EXPERIMENTAL GROUPS

GENERAL INSTRUCTIONS

Please adjust your headsets for a comfortable position.

Now adjust your volume control for a comfortable level. You may need to readjust the level as you listen to the material.

Now look at your test booklet. Please print your last name, first name, and middle initial; your age, in years and months; and your class level, such as Sophomore. In addition please print your last name, first name and middle initial on the top front of the other sheets provided.

Now look at Page 1 in your test booklet. Read the general directions as they are read to you.

A number of short selections will be read aloud to you from a recording. After each selection, you will hear a group of questions or incomplete statements. Four suggested answers are given for each question or incomplete statement. You are to decide which of these answers is best.

Remember to listen carefully because each selection and each question will be heard only once and they are not printed in your test booklet. The four suggested answers to each question are printed in your test booklet. They will not be read aloud to you.

You will mark your answers in your test booklet by circling the letter of the answer which you think is correct.

For example, suppose the following selection and question were heard:

Selection: The moment a bolt of lightning strikes a power line carrying high voltage electricity, giant switches take the current off the line. Within a fraction of a second, the effect of the lightning passes, and the switches automatically turn the current on again. Question number 0: What will probably happen to the electric lights if a high-power line serving an area is struck by lightning?

Your test booklet would look like this:

0 A The lights will brighten.
  B The lights will flicker.
  C The lights will burn out.
  D Nothing will happen to the lights.

When lightning strikes, the giant switches turn the current off for a fraction of a second, causing the electric lights to flicker. Therefore, you should choose the answer lettered B. In your test booklet you would circle the letter for the answer you have chosen. Circle only one answer for each question. If you decide to change an answer, erase your first answer completely or put an X thru it. Use the pencils provided. Your answers will be transcribed later to your answer sheet by the examiner.

SPECIAL INSTRUCTIONS--GROUP I AND II

Here are the special instructions for experimental groups I and II. You will now listen to four short selections to acquaint you with listening to compressed speech. These selections are provided for practice only.

Here is the first selection. It is a college lecture on hypnotism. It has been compressed to a rate of approximately 225 WPM.

(Read Selection 1.)

Here is the second selection. It describes the use of rare carbon for estimating the age of prehistoric remains. It has been compressed to a rate of approximately 275 WPM.

(Read Selection 2.)

Here is the third selection. It is a speech about the difference between liberty and freedom. It has been compressed to a rate of approximately 300 WPM.

(Read Selection 4.)

The next selection will be used as further practice in listening to compressed speech and also to acquaint you with the actual experiment.

Here is Selection 4. It is the opening section of a story. It has been compressed to a rate of approximately 250 to 275 WPM.

(Read Selection 5.)

You will now hear six questions. Each question will be read only once. Four suggested answers are given on Page 1 in your test booklet, for you to select your answer from. Remember to listen carefully to the questions because they are read only once and are not printed in your booklet. They will be read at normal speech rate. Select the answer you think is correct, and circle the letter for that answer in your test booklet.

(Read questions for Selection 5.)

We will now take a short rest to answer questions.

Please readjust your headset and volume control.

Now turn to Page 2 of your test booklet and listen carefully. The listening test will now begin. You will hear all of the material at a rate of 250 to 275 WPM. You will be tested for comprehension at the end of each of five selections. Questions will be read at normal speech rate. Do not attempt to answer the questions until the answers are read to you at the end of each selection.

Here is the first selection. It is a college lecture on an aspect of language.

(Read Selection 6 and questions.)

Here is the second selection. It is a talk about the American party system.

(Read Selection 7 and questions.)

Here is the third selection. It is a conversation between two characters in a novel.

(Read Selection 8 and questions.)

Here is the fourth selection. It is an explanation.

(Read Selection 9 and questions.)

Here is the fifth selection. It is a speech about effective communication.

(Read Selection 10 and questions.)

That is the end of the experiment. Close your booklets. Be sure you have printed your name and other data on your test papers.

Thank you for your time and cooperation.

SPECIAL INSTRUCTIONS--GROUPS III THROUGH VIII

Here are the special directions for experimental groups III thru VIII.

You will now listen to four short selections to acquaint you with listening to compressed speech. These selections are provided for practice only.

Here is the first selection. It is a college lecture on hypnotism. It has been compressed to a rate of approximately 225 WPM.

(Read Selection 1.)

Here is the second selection. It describes the use of rare carbon for estimating the age of prehistoric remains. It has been compressed to a rate of approximately 275 WPM.

(Read Selection 2.)

Here is the third selection. It is a speech about the difference between liberty and freedom. It has been compressed to a rate of approximately 300 WPM.

(Read Selection 4.)

The next selection will be used for further practice in listening to compressed speech and to also acquaint you with the psychomotor activity to be performed in the actual experiment. Place the Psychomotor Response Sheet before you in a comfortable position. At points in the selection you will hear a tone, like the following: tone---. That will be your signal to look at the projection screen, and then copy the binary digits, that you have seen, in a block on your response sheet. Use the blocks from left to right by horizontal rows.

Here is selection four. It is the opening section of a story. It has been compressed to a rate of approximately 250 to 275 WPM.

(Read Selection 5.)

You will now hear six questions. Each question will be read only once. Four suggested answers are given on Page 1, in your test booklet. Remember to listen carefully to the questions because they are read only once and are not printed in your test booklet. They will be read at normal speech rate. Select the answer you think is correct, and circle the letter for that answer in your test booklet.

(Read questions for Selection 5.)

We will now take a short rest to answer questions.

Please readjust your headset and volume control.

Now turn to Page 2, of your test booklet and listen carefully. We will now begin the actual experiment. It contains the same types of material as the practice material. You will hear all of this material at a rate of 250 to 275 WPM. You will also perform psychomotor activity. You will be tested for comprehension at the end of each of five short selections. Questions will be read at normal speech rate. You should attempt to perform all psychomotor activity and to answer all questions. Now place the psychomotor response sheet before you in a comfortable position. Pause time will be provided for you to perform the psychomotor activity.

Here is the first selection. It is a college lecture on an aspect of language.

(Read Selection 6 and questions.)

Here is the second selection. It is a talk about the American party system.

(Read Selection 7 and questions.)

Here is the third selection. It is a conversation between two characters in a novel.

(Read Selection 8 and questions.)

Here is the fourth selection. It is an explanation.

(Read Selection 9 and questions.)

Here is the fifth selection. It is a speech about effective communication.

(Read Selection 10 and questions.)

That is the end of the experiment. Close your test booklets. Be sure you have printed your name and other data on your test papers.

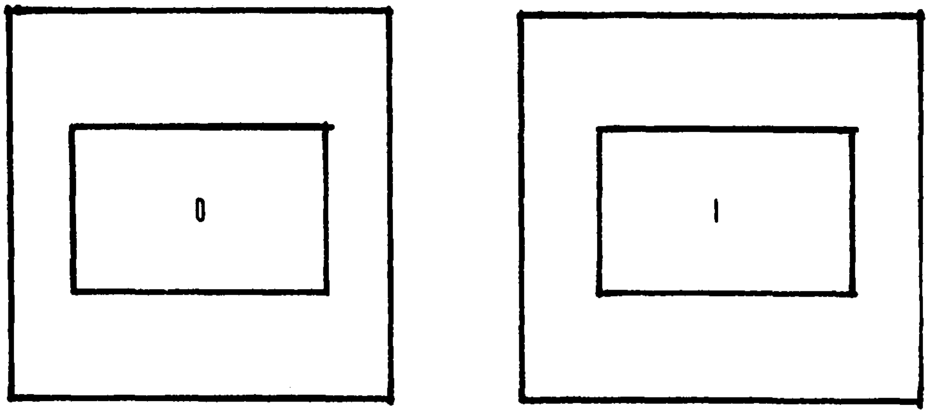
Thank you for your time and cooperation.

APPENDIX G

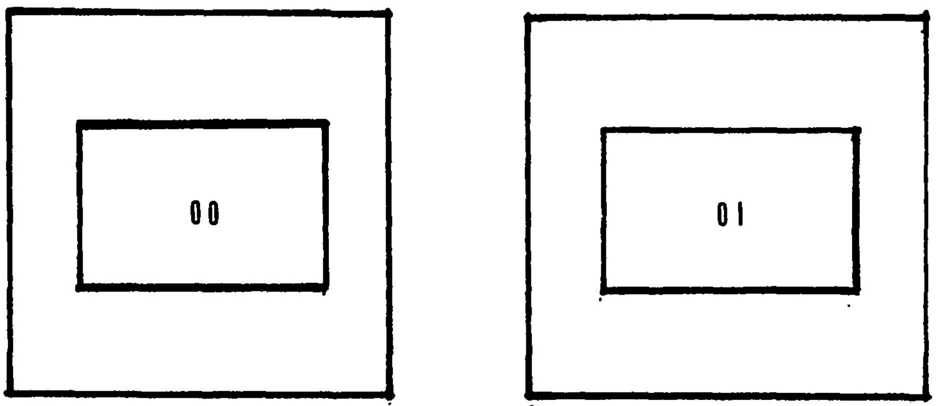
SLIDE FORMAT

SLIDE FORMAT

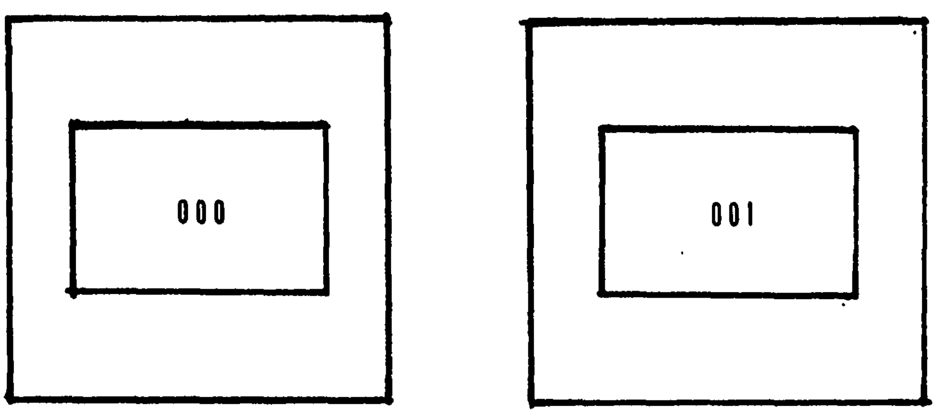
1 Bit Level



2 Bit Level



3 Bit Level



APPENDIX H

LISTENING SELECTION DETAILS, RECORDING TIMES AND COMPRESSION RATES

LISTENING SELECTION DETAILS, RECORDING TIMES AND COMPRESSION RATES

	UNCOMPRESSED			COMPRESSED					
				250 WPM			275 WPM		
	Words	Time	WPM	Time	WPM	%	Time	WPM	%
Sel. 1	516	3'27"	150	2'20"	225	32	Same as 250 WPM		
2	396	2'30"	158	1'30"	275	40			
4	647	3'59"	162	2'10"	300	46	Used for Practice		
5	353	2'	177	1'20"	250	33			
Total	1912	10'57"		7'20"					
				Test Selections					
6	698	4'	175	2'47"	251	30	2'32"	275	37
7	493	3'	164	2'	250	33	1'49"	276	40
8	242	1'22"	177	58"	250	29	53"	275	35
9	116	40"	174	26"	250	35	25"	278	37
10	464	2'37"	185	1'48"	250	29	1'39"	278	34
	2013	11'33"		7'59"			7'18"		

APPENDIX I

ANALYSIS OF GRADE POINT AVERAGES

TABLE A

SUMMARY OF MEANS, STANDARD DEVIATION AND STANDARD ERROR FOR GRADE POINT AVERAGES

	Mean	Std. Dev.	Std. Error
Group I	2.989	0.377	0.097
II	3.217	0.427	0.110
III	2.959	0.300	0.077
IV	2.985	0.464	0.119
V	3.380	0.487	0.125
VI	3.037	0.573	0.147
VII	3.277	0.400	0.103
VIII	3.096	0.437	0.113

TABLE B

ONE-WAY ANALYSIS OF VARIANCE OF GRADE POINT AVERAGES

Source of Variation	SS	df	MS	F
Between Groups	2.493	7	0.356	1.845
Within Groups	21.617	112	0.193	
Totals	24.110	119		