THE EFFECTS OF COMPRESSION RATES AND METHODS OF COMPRESSION ON THE COMPREHENSION OF AUDIOTAPED MATERIAL

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ABSTRACT

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The purpose of this study was to investigate the effects of two rates of time compressed speech and two methods of time compression on the comprehension of audiotaped material. Fifty subjects were randomly assigned to five treatment groups, each receiving a 1580 word text on electronic data processing controls. A control group heard this information at the originally recorded speed of 135 wpm. Two groups heard this information compressed by 39% (218 wpm), while two other groups heard it at a compression rate of 57% (311 wpm). One group in each of these two compression conditions received material which was compressed by the systematic deletion technique; the other group in each of these conditions received material compressed by the selective deletion technique. A fourteen item multiple choice test covering the contents of the listening selection was administered.

Results of the study indicate: (1) a significantly lower mean comprehension score in the control group as compared to the group which received material compressed by 57% using the selective deletion method ($p < .05$) (2) no significant effect of the method of compression ($p < .05$) (3) no significant interaction between the rate of compression and the method of compression ($p < .05$). Results are discussed in terms of their implications on education. Methodological drawbacks in the measurement of comprehension are briefly described.

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I. INTRODUCTION

THE STATE OF LISTENING IN THE 1970'S

Within the past two decades, there has been a marked increase in the emphasis placed upon the importance of human communication. A plethora of material has been written on its significance to the individual, to marriage, to family life, to community life, to national life and to international affairs (Duker, 1971). In each of these areas, communication must have as its prime requisite someone who either reads or listens to the message being transmitted.

It is not then surprising that educators should show concern about students' proficiencies in reading and listening comprehension. What is surprising, however, is that the major emphasis should be on reading, the lesser used of the two receptive communication modes.

Rankin (1928), for example, found that 7 out of 10 minutes of the average person's working hours were spent in communicating verbally in one of its forms; communication time was devoted 9% to writing, 16% to reading, 30% to speaking and 45% to listening. Arrasjid (1973) notes that more recent research has found that elementary school students spend more than one half of their school day listening, while the listeningtime of high school students ranges as high as 90%. The undergraduate spends about 42% of his time listening. Thus, the amount of oral communication, even in a so-called "literate" country, far exceeds the amount of written communication.

Despite these facts, the aural medium has traditionally received comparatively less attention than the visual medium. However, as can be evidenced from the accelerating pace at which literature on listening is being published, as well as from the appearance in educational curricula of programs aimed at the development of listening skills, this situation has undergone a substantial degree of change.

The realization of the importance of listening and the development of listening ability, has led educators and researchers to direct their attention to various audiotechniques of transferring information. At present, it is apparent that auditory educational methods are assuming a larger and larger role in the educational process. The new educational technologies such as computer assisted instruction, dial access tape lectures, telelectures, etc., all involve auditory presentations (Orr, 1968). As well, audiotape approaches have found increasing use in the presentation of review material and in the distribution of seminar and conference materials.

Of particular significance is the audio-tutorial system developed by Postlethwait. In this system, there is an audio-programming of learning experiences logically sequenced to produce effective student performance. In other words, the taped presentation represents a programming device which directs the student in a wide variety of integrated learning activities. In this approach:

(1) emphasis is placed on learning rather than teaching methodology

(2) study pace is under student control

(3) study time can be arranged according to student preference

(4) study conditions involve a minimum of distractions

(5) the student feels more keenly responsible for his own learning

(6) each student is essentially tutored by a senior staff member (Postlethwait et al, 1972).

Though this system has been utilized successfully (Postlethwait, 1965; Melaca, 1968; Tope, 1969; Stuck and Manatt, 1970), one drawback is that the listener's listening rate must be determined by the oral reader's speech rate. For some listeners, a faster word rate may be preferable. That is, a lecturer may deliver a lecture at 100 words per minute (wpm), while a student's thought may proceed much faster. Thus, as was the primary complaint of students who participated in an evaluation of an audiotutorial course (Libby, 1972), despite all the advantages of this approach, it did not save time over the conventional classroom lecture method.

Another consideration which Short (1975) has emphasized is that the discrepancy between the rate of presentation and the student's thought may result in inattention as well as other problems, which might be alleviated if the student could listen at faster speeds.

Shortcomings such as these have spurred research into the utilization of compressed speech, that is, speech which is reproduced in less time than was required for its original production, as an educational medium.

WHY COMPRESS SPEECH?

To shed light on the rationale behind the use of time compressed speech in education, it is useful to briefly describe how continuous speech is processed by introducing Miller's concept of "channel capacity" (Miller, 1956). According to this model, the listener is a communication system with a finite capacity for processing information. With an increase in the amount of input into the system, there is a concomitant increase in the amount of information transmitted (output) until "channel capacity" is reached. In Miller's terms, "the channel capacity is the upper limit on the extent to which the observer can match his responses to the stimuli we give him" (p. 82). At this point, an equilibrium is maintained between input and output. When the input rate is increased beyond channel capacity and cannot be handled by the system, information is lost. "Assuming" then, "that normal speech occurs at a rate below channel capacity, increasing the word rate should have little effect on listening comprehension until channel capacity is reached. Beyond this point, further increases in the word rate should result in progressively larger losses in listening"(Foulke, in Horton and Jenkins, 1971, p. 102).

In light of the fact that most evidence available suggests that human beings are, in fact, capable of assimilating information at a rate much higher than their vocal apparatus can produce (Duker, 1974), it would seem that compressed speech offers a feasible method of achieving learning economy.

Overview of Speech Compression Techniques

While it is true that speech can be speeded up by having a speaker speak faster, there are distinct limitations on the rate at which a human speaker can produce connected discourse with acceptable enunciation. These limitations prevent this from being a feasible method of achieving compressed speech.

The word rate of a recorded message may also be altered simply by reproducing it at a different speed from that used during recording; this normal speech rate fluctuates between 100 and 180 wpm. If playback speed is increased, word rate is increased and speech compression is produced. However, this technique not only effects a change in rate, but also an accompanying shift in the frequency of the voice signal which is proportional to the change in tape or record speed. This shift has been referred to as the "Donald-Duck effect".

Over the past 20 years, a number of alternate time compression devices have been developed which eliminate this effect and which are not subject to the severe limitations of requesting a speaker to increase his own speaking rate. (For a complete listing and description of these devices, the reader is referred to CRCR Newsletter, 1972, 6(5)). Thus, such devices decrease the playback time of a recorded communication without altering pitch characteristics or rhythm of the voice.

There are basically two speech compression methods used in available speech compressors. One method is called the sampling method or systematic deletion. In this method, compression is accomplished by taking regularly spaced samples of the recorded communication and playing them back, in proper sequence, with no gaps between them. These samples are called "sampling intervals" and the spaces between them are called "discard intervals" (Duker, 1974, p. 446). The second method of compression is called selective deletion. In this method, the temporal characteristics of components of the speech signal itself, e.g. pauses and vowel sounds, are altered and/or deleted. In both techniques, pitch is normal and stress and intonation are preserved. Audio quality is quite good up to twice normal rates, but begins to become distorted with increasingly higher degrees of compression.

SYSTEMATIC DELETION AND THE VARISPEECH I

The method which has been most widely used in studies pertaining to learning economy and instruction is systematic deletion (sampling method). In this method, segments of recorded passages are periodically deleted and the retained portions brought together. The discard interval is typically 20-40 milliseconds and the retained intervals are varied to achieve the desired amount of compression. This can be accomplished physically, by splicing tape, electromechanically or by means of a computer.

The Varispeech I, an electronic device developed at M.I.T. which employs this sampling technique, was one of two compression devices employed in the present study (See Appendix A). It includes a cassette transport on which a signal to be compressed is reproduced, and a small, special purpose computer which obtains samples from the input signal that are reproduced consecutively to yield the compressed output (CRCR Newsletter, 1972, 6(5), p. 2).

SELECTIVE DELETION AND THE VOCOM I

Initially, the sole method of achieving selective deletion was by physically splicing the tape or through the use of a computer, due to the necessity of identifying specific segments to be deleted. Because of high computer costs, little research utilizing this approach was conducted. In 1972, however, an electromechanical device, the Vocom I, was developed; it allows selective deletion to be achieved easily and relatively inexpensively. This machine was the second of two compressors used in the present study (See Appendix B).

Original material is fed into this device and recorded on a built-in audiocassette deck. The actual speech wave form is observed and pauses are thereby detected and shortened. For additional compression, vowels are also sensed and shortened. Consonant sounds are left unaltered. The tape drive motor of the Vocom I thus turns off when a pause or vowel sound is encountered and is not reactivated until the speech sound following the pause or vowel commences (Park, 1972).

Objectives

The objectives of this study were twofold. An attempt was made to determine (1) the differential effect of two rates of compression on the comprehension of audiotaped material (2) the differential effect of two methods of compression (systematic deletion and selective deletion) on the comprehension of this same audiotaped material.

A number of limitations were realized at the outset. As Carroll (1964) has pointed out, the comprehension of compressed speech may depend on a number of factors, among them the characteristics of the speech itself, the complexity of the grammar, the difficulty of the vocabulary used, the abstractness or technicality of the content, and the competence of the listener. As well, he has noted that one must depend largely on the listener's report concerning whether or not he can follow accelerated presentation. Obviously, the measurement of all these variables is beyond the scope of any one study.

Review of Literature

There are 3 fundamental types of variables which can be investigated in compressed speech research: variables in the material compressed; variables in the process of compression; and listener variables (Duker, 1974, p. 506). This study was primarily concerned with 2 aspects of the process of compression: (1) compression rate as it affects comprehension and (2) systems of compression as they affect comprehension. In the review of the literature to follow, studies pertinent to each of these two areas will first be discussed independently and subsequently be related to the research questions posed in the present study.

Comprehension and Compression Rate

An early study by Nelson (1948) in which 250 college students listened to recorded simulated newscasts presented at varying rates from 125-250 wpm, revealed no significant differences in comprehension in the range bounded by 125 and 225 wpm. Harwood (1955) assigned 487 tenth grade students to four groups, each receiving the same message at either 125, 150, 175 or 200 wpm. He found that comprehension scores at each of the four rates of presentation did not differ significantly. However, both Harwood and Nelson reported slight, though statistically nonsignificant losses in comprehension as word rate increased.

In a study conducted by Diehl et al (1959), college freshmen listened to records presented at 126, 135, 160 or 175 wpm. No significant differences in comprehension were found between any of these 4 groups or between these groups and a control group listening at the originally recorded rate of 145 wpm.

Fairbanks et al (1957) reported a study in which a group of air force trainees were assigned to 5 message test conditions and to a no-message condition. Results showed little difference in the comprehension of selections presented at compression rates of 0%, 30% or 50% or at 141, 201 and 282 wpm respectively. Comprehension scores did, however, decline from an average of 58% at 282 wpm to 45% at 353 wpm and then to 26% at 470 wpm.

In using both literary and technical listening selections, Foulke et al (1962) found that listening comprehension was only slightly affected by increasing word rate in the range between 175 and 275 wpm. Beyond this range, they found an accelerating loss as word rate increased. A later study conducted by Foulke and Sticht (in Foulke and Sticht, 1969), revealed a 6% loss in comprehension between 225 and 325 wpm and a loss of 14% in the range bounded by 325 and 425 wpm.

A much wider range of word rates than had previously been investigated, was subsequently looked at by Foulke (in Horton and Jenkins, pp. 91-92). Three hundred-sixty college students were assigned to 12 groups. Each group heard a listening selection which differed with respect to rate of presentation. These rates were between 125 and 400 wpm, and varied in increments of 25 wpm. Findings were in close agreement with those reported earlier; a rapid decline in comprehension occurred beyond 250 wpm.

Adelson (1972) found that college students who listened to a one hour lecture at the normal rate of 175 wpm comprehended significantly more than when they listened to a matched time-compressed lecture at 275 wpm for a duration of 40 minutes. The length of the material in this study was a critical factor. Though the length of required listening time was more realistically representative of college students' listening situations, it was nevertheless, considerably beyond the initial exposure time used in other studies and was an extremely intense introduction to compressed speech.

Skinner (1972) assigned a group of 290 randomly selected college students to 5 experimental groups, each receiving the same audio-taped material at a different compression rate within the range of 175 and 375 wpm. Results indicated that comprehension declined as a function of word rate, but only at 375 wpm as compared to 175 and 225 wpm.

In a study conducted by Langford (1968), a listening selection at one of 5 rates ranging between 175 and 375 wpm was presented to groups of high school students from four educational tracks (ability-achievement groupings). A drop in listening comprehension was found for students from all tracks when rate exceeded 275 wpm.

A pilot study by Cohen and Rich (1975) indicated no difference in comprehension scores of education technology students within the range of 193-253 wpm. Similar results were found by Bohlmeyer (1973) in a study with psychology and nursing students. Findings indicated no significant differences on the test scores of students who listened to the same recording at 130, 173, or 260 wpm.

When the results of the cited research are considered collectively, a general pattern emerges. That is, beyond a normal word rate, there is a slow but definite decline in comprehension which is followed by an accelerated decline. More accurately, "listening comprehension declines at a slow rate as word rate is increased, until a rate of approximately 275 wpm is reached, and at a faster rate thereafter" (Foulke & Sticht, 1969, p. 60). This is not to say that 275 wpm is the finite 'channel capacity' of most human beings, but rather, that it is generally the capacity of most untrained listeners on their initial exposure to compressed recordings.

Comprehension and Method of Compression

Although several studies comparing methods of compression appear in the literature, for the most part they have been concerned with comparing speed changing and sampling techniques. Comparatively little research has been conducted using selective deletion, and there appear to be no published studies to date which have compared this method, as used in the Vocom I compressor, with that used in any systematic deletion device. There has, however, been a good deal of investigation into the value of pause time in the decoding of speech, and into other areas which relate to the Vocom I technique of selective deletion. It is these studies which shall be succintly described.

Goldman-Eisler (1968) maintained that in speaking, pauses appear to reflect internal decision making processes. Her data also indicate the importance of pauses in providing time for the decoding of spoken information, as well as for the encoding of such messages. In light of this, it seemed a reasonable assumption that pauses inserted into time compressed recordings might increase their comprehensibility. A study conducted by Friedman and Johnson and reviewed by Sticht (in Carroll, J.B. and Freedle, 1972) supported this assumption. Pauses of 2 seconds duration were inserted into 3 categories of lexical strings (grammatical, ungrammatical or anomalous) which were presented at 175, 200, 235 and 400 wpm. They were inserted either at structural or non-structural loci within each string, and were inserted into ungrammatical strings so as to produce arbitrary segments of approximately equal length.

Results indicated a facilitative effect of spacing at structural boundaries in grammatical strings. This spacing resulted in the same level of recall for these strings across all 4 speech rates. In contrast, recall for non-structurally spaced and nonspaced grammatical strings declined at the 450 wpm rate. This same facilitative effect, though not as marked, was also obtained with ungrammatical and anomalous strings. Friedman and Johnson suggested that "the benefit of spacing between major constituents observed at extremely rapid word rates most likely occurs because such pauses aid in the identification of syntactic units" (in Carroll and Freedle, p. 304).

Results of this study indicate the dissimilarity in the two cognitive processes of recall and comprehension. Since recall of grammatical lexical strings was unaffected at the high word rates of 325 and 400 wpm, it can be assumed that the recall task is of a much different nature than tests of listening comprehension on which, as discussed previously, scores decline rapidly beyond a rate of 275 wpm. It should also be noted that the results Friedman and Johnson obtained using lexical strings are not generalizable to the connected discourse typically used in studies measuring comprehension.

Rocco (1969) sought to determine if it was the lack of information processing time in compressed speech discourse which caused loss in comprehension at word rates exceeding 275 wpm. He formulated two major hypotheses: a) the effect of pause time would be statistically significant; that is, comprehension would be positively affected by the presence and magnitude of pauses b) the interaction effect of pause time and compression rate would be statistically significant, greater comprehension being associated with longer pause times at higher rates of compression. A 1319 word fictional story was systematically compressed to word rates of 250, 300 and 350 wpm. Additional tapes were made in which pause times of 1, 2 and 3 seconds duration were added at 30 fixed intervals within the story. This resulted in 4 tapes at each of the 3 compression rates, or 12 tapes in all. Three hundred forty eight college students were assigned to the 12 treatment conditions. Upon completion of the listening task, they were requested to complete a 38 item multiple choice comprehension exam. An analysis of variance was conducted to determine if pause addition was beneficial to comprehension. Although results of the Anova did show a significant main effect of compression (comprehension scores of 250 and 350 wpm were significantly different, as were the 300 and 350 wpm scores), no significant difference was found for either the main effect of pause addition or the interaction of compression and pause addition. Thus, results proved contrary to the expectations of the experimenter.

Slauson (1973), concerned with the effects of strategic placement of pauses upon the comprehension of compressed speech, conducted a study in which the experimental variables included 2 compression rates (260 and 360 wpm), 2 grammatical placement strategies and 2 levels of pause durations. A 1530 word technical message was recorded and mechanically altered to fit the experimental conditions. One hundred-eight psychology students were assigned on a random basis to the 8 experimental treatment condition groups and to a ninth group which heard the untreated version of the discourse at the original rate of presentation. Following presentation of the recording, subjects were given a 55 item multiple choice comprehension test. Analyses of variance revealed a negligible decline in performance between subjects who heard the material at the normal rate, 180 wpm, and the slower experimental rate, 260 wpm. There was, however, a sharp decline in test scores from subjects who heard the material at 260 wpm to those who heard it at 360 wpm. When overall presentation time was considered, it was found that pause insertion at grammatical boundaries did not increase the efficiency of message transmission.

If one accepts the possibility of the comprehension of compressed speech, one must also accept the presence of redundancy in the original message (Duker, 1974, p. 554). An early study by Diehl et al (1959) was based on the premise that pause time might well be, to a great extent, the source of this redundancy. In this study, pause time was altered manually by the removal or addition of tape segments. Five reproductions of the original tape were made. In tape A, 75% of pause time was removed. In tape B, 50% of pause time was removed. In tape C, pause time was increased by 75%. In tape D, pause time was increased by 50%. Tape E was left unaltered. Rates were thus 172, 160, 135, 126 and 145 wpm respectively. Three hundred seventy one college students were divided into 4 experimental and one control group. They listened to a brief audiotape presentation and were administered a test of comprehension immediately thereafter. An analysis of variance of mean comprehension scores among the 5 groups showed no significant differences. The investigators therefore concluded that speech could be accelerated by reducing pause time with no detrimental effect on comprehension. It is important to note, however, that the study had two severe limitations which would seem to vitiate the conclusions reached by the experimenters. Compression was obtained by manual methods achieved through linear measurement of the tape. Second, and even more significant, is the fact that no substantial change in rate was obtained in any of the experimental conditions.

In a more elegant study reported by Miron and Brown (1968), 36 stimulus tapes representing a range of rates extending from approximately 100 - 900 wpm were prepared, according to 3 parameters, potentially critical in their control of compression effects: (1) speaking manipulated through a range attainable by a professional speaker (2) selective pause compression at 3 values: 100, 50 and 0% deletion and (3) random deletions at 4 values: 0, 30, 50 and 70%. Each of these tapes was analyzed with respect to the distribution of pause and phonation time in the 1540 word passage which was read.

Analysis revealed that at the slowest speaking rate, as much as 35% of the total message duration was devoted to pause time. At the fastest speaking rate, only 21% of the message time was devoted to pause. In short, the values found for pause and phonation time clearly indicated that the trained speaker disproportionately decreased the length of his pauses in relation to the length of his articulation. More specifically, "it was found that pause-to-phonation ratios in normally accelerated speech decrease logarithmically as speech rate increases. . ."(p. 219). Results also showed that the distribution of pause to phonation time in a connected message bore a non-linear relationship to comprehension. Disparately favourable comprehension scores were achieved by subjects in faster rate conditions produced by pause excision than by subjects under slower rate conditions with more normal pause-to-phonation ratios.

Miron and Brown's findings pertaining to pause-phonation distribution bear out the results of an earlier psychophysical study of speech rate conducted by Hutton (in Duker, 1974, pp. 268-290). He had documented the non-linearity of phonation-to-pause ratios in talkers who were instructed to accelerate their speaking rates. That is, when the speaker went from the slowest rate to the fastest rate, pause time was decreased by 85%, while the phonation time was decreased by only 50%.

In a more recent study, Brown (1973) sought to explore the effect of pause deletion schemes on speech comprehension under various time compression conditions. Four different pause manipulated versions of a 165 wpm recording were prepared via a 'cut and splice' method. These 4 stimulus tapes were time compressed to 6 wpm levels ranging from 225 to 350 wpm. One hundred-ninety-two college students were randomly assigned to the 24 experimental conditions. Following presentation of the recording, a 55 item multiple choice comprehension test was completed. As an additional inducement to high quality performance on the listening task, a $5.00 reward was offerred to students in the top 25% of each experimental condition population as ranked by comprehension test scores. Results showed no overall effect attributable to pause deletion in general as opposed to leaving pauses intact.

An unpublished pilot study conducted by Cohen and Rich (1975) investigated the effects of pause compression and pause and vowel compression via the Vocom I, on listening comprehension. Three versions of audiotaped material were presented. The first was left unaltered at 132 wpm. The second, using pause compression, was delivered at a rate of 193 wpm, while the third version, using both pause and vowel compression was presented at 243 wpm. Comprehension test scores indicated no differences in comprehension as a result of time compression within the range of 193-243 wpm. These results supported those obtained by Brown (1973) for selective deletion of pauses and extended them to vowel compression as well. Results also correspond to studies cited earlier employing systematic or random deletion at the same rate of delivery.

Though no specific body of literature exists on the effect of shortening vowel sounds and leaving consonants intact, as does the Vocom I, several studies pertaining to phonation time shed light on this approach. In an investigation by House (1961), durational characteristics of English vowels were estimated from time-sampling pulses on sound spectograms. The investigator reported the durations of vowels in various phonetic contexts as ranging from 70 - 410 milliseconds. In contrast, the duration of aspirated portions of stop consonants were reported to range from 5-20 milliseconds for voiced stops, and from 50 - 80 milliseconds for voiceless stops.

In a study of vowel recognition thresholds by Powell and Tosi (1970), a series of vowels were segmented into 15 different temporal segments ranging from 4 - 60 milliseconds and presented to subjects. To estimate recognition thresholds, subjects manipulated the delay control on a pulse generator to produce segments ranging from a 2 milliseconds up to a point where they could recognize the vowel correctly. The length of time was read from an oscilloscope and tabulated. Results showed the mean temporal segmentation threshold to be 15 milliseconds, with a range from 9.3 milliseconds to 27.2 milliseconds. Such results suggest that vowel sounds can be considerably shortened with no deleterious effect on word identification.

The data reported in these two studies implies that speech may best be accelerated by decreasing the duration of vowels and leaving consonants unaltered.

SUMMARY

The aforementioned studies were generally consistent in their findings that within the range bounded by 175 - 275 wpm, comprehension is not seriously affected by speech compression. This remains true under the numerous compression techniques employed in the cited research.

Research findings reveal an inverse relation between the proportions of phonation time and pause time in speeded speech (Miron and Brown, 1968; Hutton, in Duker, 1974). Evidence also suggests that pauses are not essential to the decoding process (Rocco, 1969; Slauson, 1973; Brown, 1973; Cohen and Rich, 1975) and that vowel sounds, being of much longer duration than consonant sounds, can be considerably shortened without sacrificing word identification (House, 1961; Powell and Tosi, 1970).

Problem Statement

The research question which then arises is whether two methods of deletion (Varispeech I and Vocom I) will differentially affect comprehension, especially at levels beyond those previously shown to be unaffected by compression.

It was the intent of this study to investigate this question and also to replicate findings of previous studies pertaining to the comprehensibility of materials presented within the 175 to 275 wpm range.

Hypotheses

Four hypotheses were formulated:

(1) Subjects presented with audiotaped material compressed by 39% (218 wpm) will achieve the same comprehension scores as subjects presented with this material at the originally recorded speed of 135 wpm.

(2) Subjects presented with audiotaped material compressed by 57%

(311 wpm) will achieve significantly lower comprehension scores than subjects presented with either uncompressed material or material compressed by 39% (218 wpm).

Rationale for hypotheses 1 and 2

As has been discussed, when the results of studies on the interaction between word rate and comprehension are viewed collectively, a general pattern emerges; comprehension shows no significant decline up to the rate of 275 wpm. Beyond this rate, comprehension scores drop at an accelerating pace. Since 218 wpm is well within the 'safe' range, it was expected that comprehension scores would not be significantly affected. On the other hand, since 311 wpm is well beyond this range, comprehension scores were expected to decline significantly.

(3) Subjects presented with audiotaped material compressed by 39% (218 wpm) using the selective deletion technique of the Vocom I will achieve the same comprehension scores as subjects presented with this material compressed at the same rate using the systematic deletion technique of the Varispeech I.

Rationale for hypothesis 3

Studies pertaining to the interaction between word rate and comprehension employed a number of techniques to achieve compression, and yet obtained similar results. It was thus assumed that if a level of compression was within the range found by research to affect comprehension only slightly, the method of compression would probably be insignificant. That is, due to a certain amount of redundancy in the English language, those who are fluent in it can deal with some degree of deletion whether it is accomplished randomly as in the Varispeech I, or according to contents of the speech sample as in the Vocom I. As Foulke notes:

> There is apparently enough redundancy in spoken language that many words can be transmitted imperfectly or not at all without interfering seriously with listening comprehension. . . The listener is able to use his information about the occurrence of words, phrases, and sentences in reconstructing imperfectly transmitted speech. (in Horton & Jenkins, 1971, pp. 98-99).

(4) Subjects presented with audiotaped material compressed by 57% (311 wpm) using the selective deletion technique of the Vocom I will achieve significantly higher comprehension scores than subjects presented with this material at the same compression rate, using the systematic deletion technique of the Varispeech I.

Rationale for hypothesis 4

Orr (in Horton and Jenkins, 1971, p. 113) points out that in systematic deletion, the retained sampling interval must of necessity vary with variations in compression, growing smaller as compression increases. That is, as compression increases, the discard interval is removed more frequently, so that the sampling intervals must become progressively smaller as compared to the discard interval. Because of the loss of speech sounds inherent in this method, and in light of the previously discussed research findings of Hutton (in Duker, 1974), Miron and Brown (1968), House (1961), and Powell and Tosi (1970), it was assumed that compression accomplished by deletion of pauses and shortening of vowel sounds preserved a more natural pattern of speech and, hence, one that would be more comprehensible at higher word rates.

SIGNIFICANCE OF THE STUDY

On a general level, this study is of significance in that it investigates a technique which may have widespread practical educational applications, such as the improvement of educational efficiency, the improvement of reading and listening skills, and the provision of an 'aural reading' form for the blind, visually handicapped, and dyslexic. Properly applied, time compression fits well with the current 'educational revolution', which is primarily directed at raising the efficiency of time spent in educational activities for the attainment of goals, skills, etc, and as Duker (1974, p. 40) states, "It should continue to fit well as we move into the era of improved audio technology, long-line transmission, inter-library networks and home information consoles".

On a more specific level, it was one contention of the present study to clarify some of the uncertainties regarding different compression devices. The importance of the study thus lies in its potential utilitarian function of providing educators with experimental evidence on comprehension as it is affected by a sampling device as compared to comprehension as it is affected by a selective deletion device. It was hoped that such evidence would aid the educator interested in incorporating compressed recordings into an academic program and who is confronted with the task of choosing which of a number of available compressors to purchase.

II. METHODOLOGY

SUBJECTS

Subjects were 27 male and 23 female students from Concordia University who volunteered to participate in this investigation; they were told it was a study in listening comprehension. Thirty-six subjects were graduate students in educational technology; 14 subjects were undergraduate students in the faculty of education. No subject had any known hearing deficit. All subjects were fluent in English. Subjects were asked whether they had knowledge of the areas covered; those who answered positively were eliminated from the study.

MATERIALS

Material presented to the subjects was a 1580 word text on processing controls for use during electronic data processing (see Appendix C). This material was one of eight modules on controls in electronic data processing utilized in a course designed by the Canadian Institute of Chartered Accountants. The material was written for presentation by audiotape and slide. The module which was used contained no direct references to material contained on the slides. All material in the associated slides was covered in the text. Since the slides were used only to reinforce material in the text, the audio portion alone constituted a complete presentation of the subject matter.

This material was selected in an attempt to present content in which pre-knowledge of students in education technology and education would be small, dependence on background information minimal, and levels of abstraction extremely low. Because the material consisted of straightforward expositions of factual information, including explanations of procedures and definitions of concepts, it was easily amenable to objective testing.

Five versions of the text were prepared. The first version was unaltered from the way it was originally recorded. It was read by a professional narrator and was recorded on an Ampex 440C tape recorder. It was presented at a rate of 135 wpm and was 11 minutes, 28 seconds in duration. The second version, compressed by 39% via the Vocom I, was recorded at a rate of 218 wpm and was 7 minutes in duration. The third version, compressed by 39% via the Varispeech I was of approximately the same duration.[1] The fourth version, compressed by 57% via the Vocom I, was recorded at a rate of 311 wpm and was 5 minutes in duration. The fifth version, also compressed by 57% via the Varispeech I, was of approximately the same duration. Word per minute rates were selected on the basis that they were within the ranges shown by the literature to be of importance to comprehension.

All versions were preceded by a 686 word introductory module on data processing controls (see Appendix D). The initial rate of presentation of this module was 135 wpm. It was gradually increased to the point at which the percentage of compression was equal to that contained in the particular version to follow. The purpose of this introductory

[1]Though control knobs on both compressors were set at the same levels of compression, the Varispeech I recordings proved to be approximately 1% faster than the Vocom I recordings.

material was to familiarize subjects with the subject matter, as well as to attune them to the rapid rate of presentation.

Recordings employing the Vocom I compressor were made at the sound studio of McGill University, as was the original recording. Recordings employing the Varispeech I were made at the sound studio of Lexicon, Incorporated (Waltham, Massachusetts), manufacturers of this machine.

Consideration was given to the determination of the difficulty level of this material. However, in light of previous research in this area, it was decided that such a procedure would not, in essence, enhance the validity of the study and hence should not be undertaken. For a detailed discussion of this topic, refer to Appendix E.

PROCEDURE

Subjects were assigned to one of 4 experimental groups or a control group on the basis of a table of random numbers. Each subject was tested individually in a small room equipped with desk, lamp, and an Ampex Micro 9 tape recorder. The following instructions were given by the experimenter to subjects in the four experimental groups:

> You will be hearing a recording which is presented at a rate faster than normal speech. The first section of this recording is just to acquaint you with the topic and get you accustomed to the new rate of presentation. When this is over, there will be a blank space on the tape lasting several minutes, at which time you can relax. Following this blank space, the second section of the recording will be presented at the rapid rate. Listen to this section

carefully. When it is over, please turn off the tape recorder and complete this test of comprehension on the second section. (test was wrong side up beside tape recorder).

Subjects in the control group were given basically the same instructions. Since their recording was not at a rapid rate, however, they were told that the first section was mainly to acquaint them with the topic and get them accustomed to listening to audiotaped material.

Each subject adjusted the volume on the headset for maximum comfort and auditory satisfaction. No time limit was placed on the completion of the comprehension test. Upon its completion, the experimenter informally discussed with each subject his/her reactions to this experience.

INSTRUMENTATION

Comprehension was measured by a 14-item multiple choice examination, each item having only one acceptable answer (Appendix F). All tests were hand scored by the investigator. Each correct answer was awarded 1 point. Incorrect responses and unanswered questions were scored as zero.

The Kuder-Richardson 20 method was used to establish internal consistency (Brown, 1970). Measures based on data from thirty completed tests selected at random from the experiment revealed a reliability of .61. KR-20 procedures are provided in Appendix G.

Content validity was verified by taking all test questions directly from the terminology and basic ideas covered in the text.

Research Design

A factorial design (3x2) with a single control group was used (Winer, 1962). There were three levels of the independent variable (percentage of compression) and two levels of the moderator variable (method of compression). This design is illustrated in Figure 1.

Variables

Independent - (1) 0% compression (X_0) - Learning material was presented at the normal rate of 135 wpm. It was 11 minutes, 28 seconds in duration.

(2) 39% compression (X_1) - Learning material compressed by 39% was presented at 218 wpm and was 7 minutes in duration.

(3) 57% compression (X_2) - Learning material compressed by 57% was presented at 311 wpm and was 5 minutes in duration.

Moderator - The moderator variable was the method of compression. Two speech compression devices, each achieving compression through different deletion techniques, were used to compress learning material at the two compression levels. The Vocom I compressor (Y_1) utilizes the selective deletion technique, while the Varispeech I compressor (Y_2) employs the systematic deletion technique.

Dependent - The dependent variable, level of comprehension attained as a result of listening to audiotaped material, was measured by scores (0) of the subjects on an untimed written multiple choice test.

STATISTICAL PROCEDURES

Means and standard deviations were determined for each of the five experimental groups. A two-way analysis of variance was used to analyze results. This was computed in accordance with the procedure presented by Winer (1962, p. 265) for analyzing the results of a factorial experiment with a single control group. This analysis indicated:

(1) the effect of the independent variable (percentage of compression) on the dependent variable (learning)

(2) the effect of the moderator variable (method of compression) on the dependent variable (learning)

(3) the interaction between percentage of compression and method of compression.

The Scheffé multiple comparison test (Ferguson, 1966) was used to compare the levels within significant factors.

R	X_1	Y_1	O_1
R	X_2	Y_1	O_2
R	X_1	Y_2	O_3
R	X_2	Y_2	O_4
R	X_0		O_5

<u>where</u>

R = random assignment of S's to treatments

X = treatment

O = observation

X_1 = 39% compression (218 wpm)

X_2 = 57% compression (311 wpm)

X_o = 0% compression—common control group receiving uncompressed message (135 wpm)

Y_1 = Vocom I (selective deletion)

Y_2 = Varispeech I (systematic deletion)

Figure 1

Research Design

III. RESULTS

Data was gathered for the fifty subjects in four experimental groups and one control group. A two-way analysis of variance was used to test the significance of effects. A critical region for rejecting the null hypotheses corresponding to the 5% level of significance was used.

Rate of Compression

Mean comprehension scores of the five groups are presented in Table 1. In general, students presented with uncompressed audiotaped material (135 wpm) achieved higher comprehension scores than did students presented with material compressed by 39% (218 wpm). Similarly, students presented with material compressed by 39% received generally higher comprehension scores than did students presented with material compressed by 57% (311 wpm).

A two way analysis of variance summary presented in Table 2 indicates significant overall effects of the compression, $F(2,54) = 8.756$. The means for each of the five treatment conditions were submitted to multiple comparison tests using the method described by Scheffé (Ferguson, 1966, p. 296). A significant difference was found only between the control group and the group receiving material compressed by 57% via the Vocom I, $F(4,45) = 14.48$, $p < .05$ (See Table 3).

Method of Compression

As indicated in Table 2, no significant machine effect was found.

Percentage of Compression	Mean	Standard Deviation
0%	9.8	1.549
39% Vocom I	8.5	2.593
39% Varispeech I	8.4	2.221
57% Vocom I	6.0	1.886
57% Varispeech I	7.7	2.263

Table 1

Mean Number of Correct Responses on Test of Comprehension

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F-Ratio
A (Method)	4.33	1	4.33	.868
B (Percent)	87.3	2	43.65	8.756*
AB	10.37	2	5.185	1.040
Within Cells	269.2	54	4.985	

*$p < .05$

Table 2

Analysis of Variance Summary Table

Variance	Degrees of Freedom	N	F′
4.985	4,45	50	10.30

Comparison between Groups	F
1 - 2	1.695
1 - 3	1.965
1 - 4	14.48*
1 - 5	4.423
2 - 4	6.268
2 - 5	.641
3 - 4	5.777
3 - 5	.491
4 - 5	2.898

*$p < .05$

Table 3

Multiple Comparison Between Rates of Presentation (Scheffé)

$$F = \frac{(X_1 - X_2)^2}{Sw^2(n_1 + n_2)/n_1 n_2}$$

$df_1 = k - 1 = \underline{4} \quad df_2 = N-k = \underline{45}$

$F' = (k-1)F = 4(2.575) = 10.30$

Group

1 = control

2 = 39% compression:Vocom I

3 = 39% compression: Varispeech I

4 = 57% compression: Vocom I

5 = 57% compression: Varispeech I

As can be seen from Figure 2, however, at the higher rate of compression, the mean comprehension score for subjects assigned to the Varispeech I ($\overline{X}$ = 7.7) condition was slightly higher than that obtained by subjects assigned to the Vocom I condition ($\overline{X}$ = 6.0).

Rate of Compression by Method of Compression Interaction

As indicated in Table 2, no significant interaction was found between the rate of compression and the method of compression. That is, the effect of rates of compression was not different for the two different speech compressors. This lack of interaction is illustrated in Figure 3.

Anecdotal Comments

A substantial body of anecdotal data was obtained in the course of this study. At the end of the comprehension test, subjects were provided with space in which to write any comments on the experiment. A summary of these comments appears in Appendix H.

For the most part, subjects complained about the material being unfamiliar. Several of those who listened to uncompressed material stated that their concentration levels dwindled due to the slow pace of the presentation. On the other hand, several subjects in the experimental conditions stated that their comprehension was hindered because the presentation was too fast, thereby negatively affecting their abilities to concentrate.

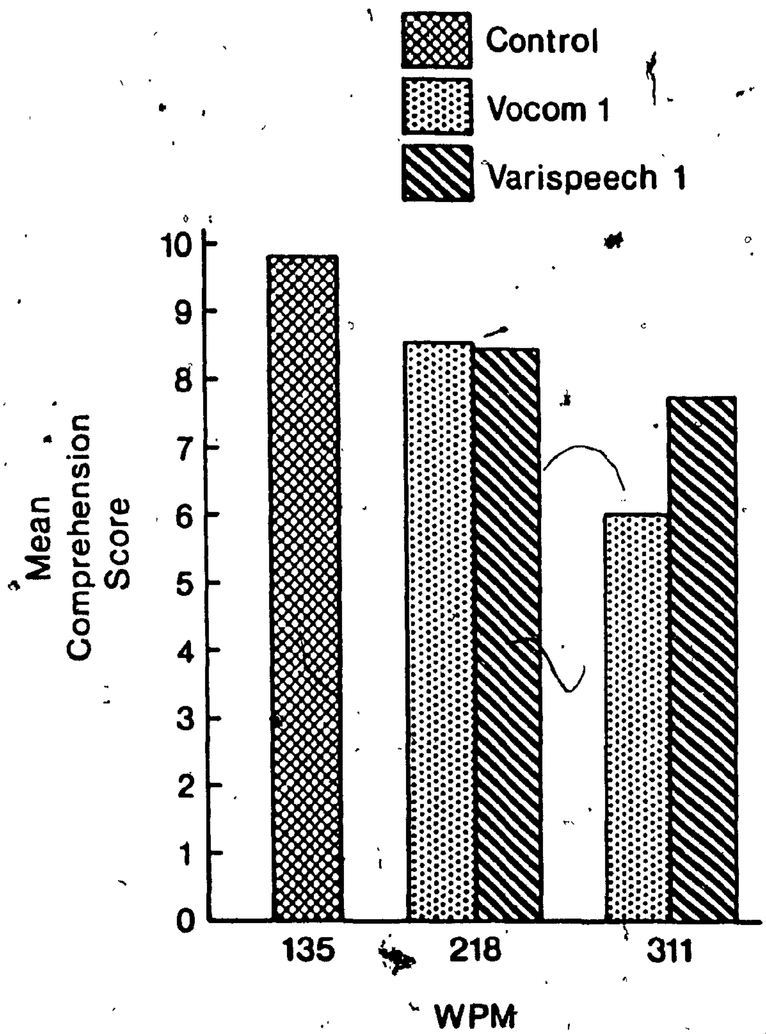

Figure 2

Performance as a Function of Rate of Presentation and Method of Presentation

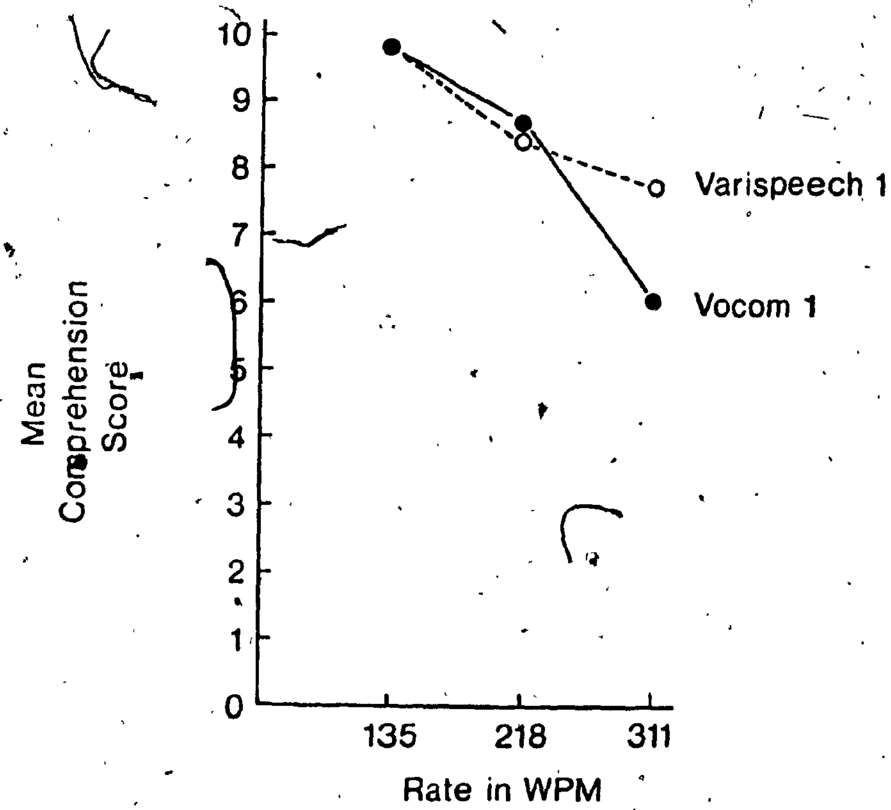

Figure 3

Relation Between Rate of Compression and Method of Compression in Terms of Comprehension

IV. DISCUSSION, CONCLUSIONS, RECOMMENDATIONS FOR FURTHER RESEARCH

DISCUSSION

This study was conducted in order to determine the effect of three rates of presentation on the comprehension of audiotaped material, as well as to determine the effect of two compression techniques on the comprehension of this same material. In the discussion which follows, the experimental results are re-examined in light of the four hypotheses which were formulated.

Hypothesis 1

> Subjects presented with audiotaped material compressed by 39% (218 wpm) will achieve the same comprehension scores as subjects presented with this material at the originally recorded speed of 135 wpm.

Results indicated that there was no significant difference between the mean comprehension scores of the control group and those of the two groups in the 39% compression condition. Statistically, therefore, hypothesis 1 was supported; results were consistent with most other reported findings (Nelson, 1948; Harwood, 1955; Diehl et al, 1959; Fairbanks et al, 1957; Adelson, 1972; Slauson, 1973; Cohen and Rich, 1975). It should be noted, however, that the score trend was not in a direction favoring this hypothesis.

Hypothesis 2

> Subjects presented with audiotaped material compressed by 57% (311 wpm) will achieve significantly lower comprehension scores than subjects presented with either uncompressed material or material compressed by 39%.

In that subjects who listened to material compressed by 57% via the Vocom I received a significantly lower mean score than subjects in the control group, this hypothesis was partially supported. In that subjects receiving 57% compression via the Varispeech I compressor did not attain significantly lower scores than the control group, and in that subjects in both 57% compression conditions did not receive significantly lower scores than subjects in the two 39% compression conditions, this hypothesis was not supported. The general trend of scores did, nevertheless, support the hypothesis; the accelerated decline in comprehension scores beyond a presentation rate of 275 wpm which has been reported in studies cited earlier, is particularly evident in the 57% Vocom I condition.

Hypothesis 3

> Subjects presented with audiotaped material compressed by 39% (218 wpm) using the selective deletion technique of the Vocom I will achieve the same comprehension scores as subjects presented with this material compressed at the same rate using the systematic deletion technique.

Results support hypothesis 3, revealing no difference between mean comprehension scores of the two groups assigned to the 39% compression condition. This finding is consistent with studies which collectively have employed a wide range of compression techniques and yet have reported similar findings regarding compression as it affects comprehension (Nelson, 1948; Harwood, 1955; Diehl et al, 1959; Fairbanks et al, 1957, Adelson, 1972; Langford, 1968; Cohen and Rich, 1975, Rocco, 1969, Slauson, 1973). Since the present study specifically explored the comparative effects of two methods of compression on the same material, its findings add another dimension of support to the supposition that, due to the redundancy in language, fluent speakers can handle some degree of deletion regardless of whether it is accomplished on a time sampling basis or on the basis of the contents of the speech sample itself.

Hypothesis 4

> Subjects presented with audiotaped material compressed by 57% (311 wpm) using the selective deletion technique of the Vocom I, will achieve significantly higher comprehension scores than subjects presented with this material at the same compression rate, using the systematic deletion technique of the Varispeech I.

Although the analysis of variance revealed no significant machine effect, mean comprehension scores at the 57% level of compression did, in fact, favor the Varispeech I compressor (sampling technique). These results did not support hypothesis 4. They did not support the assumption that selective deletion might be better at higher word rates because of the greater loss of speech sounds inherent in the systematic method, nor did they substantiate the findings of the studies conducted by House (1961), Powell and Tosi (1970), or Miron and Brown (1968).

Such results are interesting in that they closely parallel findings of earlier studies which were concerned with the speed changing technique vis a vis the sampling (systematic deletion) technique. McLain (1962) presented a 2100 word passage to 58 students who were naive with respect to compressed speech and unaccustomed to learning through listening to audiotapes. One half of the group heard the audiotaped material compressed to 46% of its original time, while the other half heard the same passage played faster than it was originally recorded, at the same speed as the compressed recording. A slight, though significant advantage was found for the sampling method. Similar results were found in a comparable experiment conducted by Foulke et al (1962). However, another study in which subjects were blind students, accustomed to reading by listening, revealed no significant difference in favor of either method (Foulke, 1966).

From the point of view of 'auditory aesthetics', such results are antithetical to what one might expect. Considering the fact that the speed changing method results in serious distortions of vocal quality which render the speaker unrecognizable, and turn all listening situations into encounters with a voice resembling that of Donald Duck, it is surprising that this technique does not have a more severe effect on comprehension. Since neither of the compressors under investigation in this study produced distortions as pronounced as the "Donald-Duck effect", it is much less surprising that no significant difference was found.

It is worthwhile to view these results in light of the motivational levels of subjects. In Foulke's study (1962), subjects were blind students. Considering that normal audio recording offers reading rates roughly two to three times the average Braille rate, compressed recordings, indeed, offer incredible advantages and opportunities to the blind. This factor, in itself, may produce motivational levels which are far greater than those of sighted students who may have any number of learning options. It is conceivable that such high motivation levels may, in fact, have counteracted the drawbacks associated with the speed changing technique, thereby producing results which were at par with those listening to material which was auditorally more pleasant and intelligible.

In regard to the present study, it is the observation of the experimenter that since learning was not related to success or failure in course work, motivation levels were reduced. By the same line of reasoning, it is thus also conceivable that these reduced motivation levels, coupled with the elevated anxiety levels produced in the high word rate conditions, may have offset any machine effects which might have otherwise occurred.

Conclusions, Recommendations For Further Research

The findings of the present study would appear to have significant implications for education. Since much of college pedagogy is conducted by the lecture method, the amount of material which can consequently be presented is limited by the lecturer's normal speaking rate. The general findings of this study have indicated that information can be imparted at rates substantially beyond the normal rate of presentation, without significantly affecting comprehension. Comments from a number of subjects suggested that their 'intrigue' with the medium itself interfered with their ability to concentrate on the actual listening selection. It is therefore suggested that the trend towards lower scores which accompanied increases in presentation rate, would have been narrowed even more so if subjects had been more familiar with the medium.

It should be noted that subjects who are naive to the method of presentation are used in studies of this nature in order to control for the variable of prior listening experience. However, in doing this, a situation is created which, perhaps, is analagous to conducting a study which investigates a particular visual medium on a population which has never received instruction in reading skills or has had little experience in reading. While it is an accepted fact that the ability to read and to develop reading skills does not simply happen by virtue of the fact that people possess eyes, it is generally assumed that because people can hear, they know how to listen. What is, in effect, being suggested is that the results of this experiment, as well as those of the studies cited in the literature review, should be viewed not as results of the effect of compression on comprehension, but as the results of the effect of compression on the comprehension of subjects who are unaccustomed to learning via audiotape and untrained in listening skills. Though the great capacity of the auditory mechanism is evident, and though untrained listeners can handle an accelerated presentation of information, it would seem that compressed speech harbors far greater potential for a student body which has experience in listening and/or which has been trained in listening skills.

Of course, behind this conjecture is the hypothesis that training will improve listening comprehension. In terms of Miller's model, training may assist in teaching people how to make the most of their innate channel capacities.

Much of the research conducted by Orr et al (Orr and Williams, 1965; Orr and Friedman, 1968; Friedman and Orr, 1967) has been devoted to the proposition that comprehension of compressed speech can be improved. Their results have shown that a variety of practice routines can significantly improve comprehension at high speeds. For the most part, however, studies which have tested actual training procedures are meager and results inconsistent.

It is important to note that in any study which investigates the efficiency of this type of instructional presentation, several problems arise which, to some extent, interfere with the accurate measurement of the treatment effect per se. One such problem involves difficulties which impair one's ability to draw dependable conclusions about comprehension. The major concern here is the extent to which performance on tests actually measures accurately the acquisition of information in listening selections. If this assumption is to be supported, Orr (in Horton and Jenkins, 1971, p. 112) specifies two conditions which must be true:

1. Test questions must cover and represent material contained in the selection.
2. Differential prior knowledge and experiences of various listeners must be entirely uncorrelated with test performance.

Orr's first condition appears to be related to content validity, which was assured in the present study. His second criterion, however, requires a more rigorous screening procedure than admittedly was undertaken.

Nevertheless, it should be pointed out that in meeting the second condition, the experimenter may engender yet another problem. Choosing a subject matter which is unknown to the population being tested in order to minimize contamination of listening comprehension scores, entails also increasing the risk of presenting material which subjects are either uninterested in, indifferent to, or 'turned-off' by - all of which may also distort the measurement of comprehension. The anecdotal comments received from subjects in the present study indicate that this may have occurred.

A number of comments were received by those in all groups indicating that they felt that their comprehension scores were not as affected by the medium as they were by a subject matter which they knew nothing about and which consequently elevated their anxiety levels. Even in the 57% compression conditions, several subjects stated that if the subject matter had been at all familiar, they could have handled the situation with greater facility.

What this information would seem to suggest is that the researcher is placed in a double bind situation—the closer the study comes to being experimentally 'pure', the more artificial it becomes, or in other words, the less it approximates what generally occurs in an educational milieu in which students have a certain degree of background knowledge plus interest in what they are learning, and where the stimuli and motivation are imbedded in a normal pattern of learning activities.

Another point to consider is that if imposed without preparation, as it was in the present study, speech compression could cause problems. Results of a study conducted by Orr et al (1969) suggest that if students are not antagonized by being forced into compression too rapidly, they will gradually come to find it both useful and desirable.

While such factors testify to the limitations of the present study, they also intimate the potential for utilizing compressed speech in a setting in which students are dealing with material with which they are familiar and in which they are interested. If gains in time and efficiency can be obtained in operational settings where the subject matter is 'real' and where students are engaged in a normal flow of curricular activities, then serious consideration should be given to compressed speech as a viable teaching strategy.

Finally, any judgement of the usefulness of compressed speech in education should consider information pertaining to its "attention holding power". In a study which investigated the effects of compression on comprehension and student attitudes, Gleason et al (in Duker, 1974, pp. 954-959) observed that the behaviour of a group provided with compressed recordings and that of a group provided with uncompressed recordings was markedly different. In the former group, there was little fidgeting, talking, etc. "Students were attentive, almost intense"(p. 958). In the latter group, there was much talking, smoking, reaction to the humor, etc. Since results showed that the compressed approach was just as effective and more efficient, the experimenters concluded that its attention holding power should be a prime consideration in evaluating its use in instructional materials or procedures.

In sum, it is not suggested that compressed speech is appropriate either for all kinds of material or for all educational situations. As Orr maintains (in Duker, 1974, p. 39), "There are many things which probably should not be compressed, both for esthetic and intrinsic reasons. . . And that which is to be compressed for popular consumption probably should be compressed only moderately to take advantage of the efficiencies of the process without creating comprehension difficulties." It remains the task of further research to ultimately define the precise conditions under which this technique may be applied to education. The present research has indicated but a few of the numerous aspects of this technique which should be investigated and a number of hypotheses with obvious implications for education. For example, it could be hypothesized that training might significantly improve auditory comprehension. It could also be hypothesized that interest in content and motivation levels affect comprehension outcomes to a greater extent than do accelerated rates themselves. The interaction patterns between such variables have yet to be described. Similarly, no definitive conclusions can be drawn regarding differential effects of the two compression techniques employed in this study--a topic of academic, as well as practical importance.

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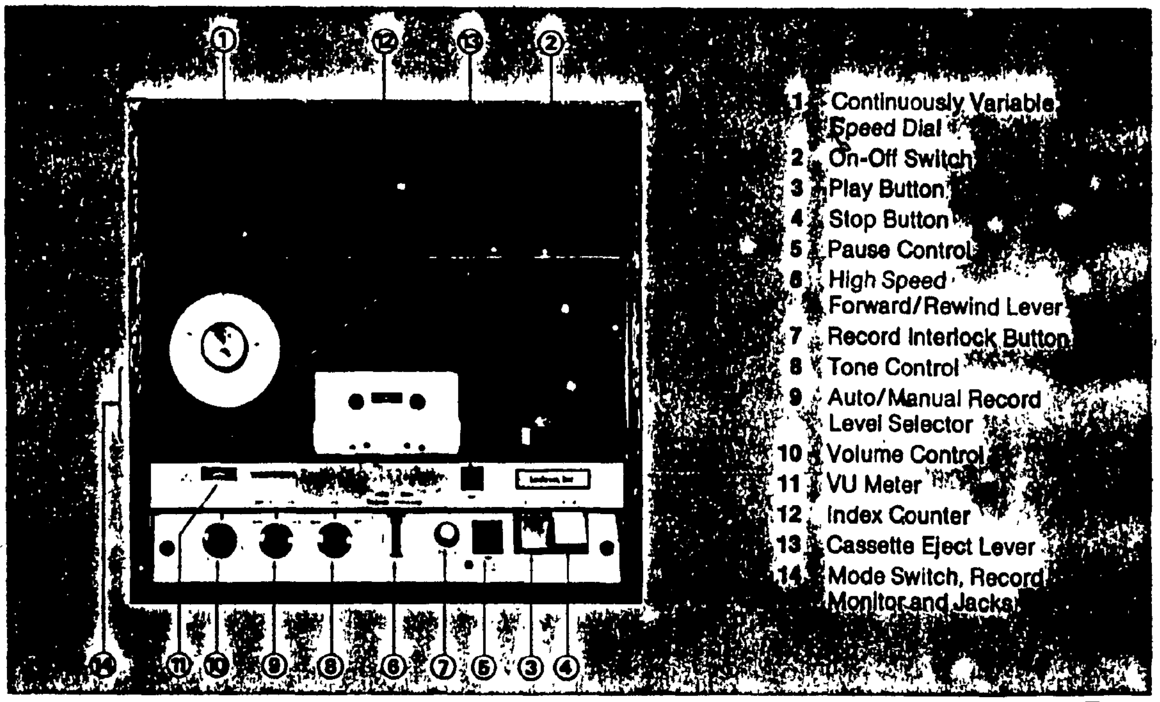
APPENDIX A

FEATURES OF THE VAPISPEECH I



APPENDIX B - FEATURES OF THE VOCOM I

LIGHTED PUSH BUTTON CONTROLS

1. POWER SWITCH
2. RECORD MONITOR - Provides for monitoring the recorded signals via the speaker. Light on when in record mode.
3. PAUSE COMPRESS--Shortens pauses when recording. Light on when in operation.
4. VOWEL COMPRESS--Shortens vowel sounds when recording. Light on when in operation.
5. PAUSE EXPAND--Lengthens pauses during playback. Light on when in operation.
6. PAUSE--Instantly stops and starts tape motion. Light on indicates no tape motion.

DIAL CONTROLS

7. LISTENING VOLUME--Adjusts loudspeaker and headphone volume.
8. LISTENING TONE--Provides for variable treble cut for loudspeaker and headphone.
9. NOISE REJECT--Usually in MIN position. Increase to reject background noise during expansion and compression.
10. RECORD/PLAY LEVEL--Adjusts record and playback level independent of listening controls. Set using VU meter.
11. PAUSE COMPRESS--Adjusts so that the shortest pause retained on compression is 70 milliseconds (max. compression) to 1.0 second (min. compression).
12. PAUSE EXPAND--Adjusts so that each pause in excess of 40 milliseconds on playback expand is increased by 100 milliseconds (min.) to 500 milliseconds (maximum).

TAPE TRANSPORT CONTROLS

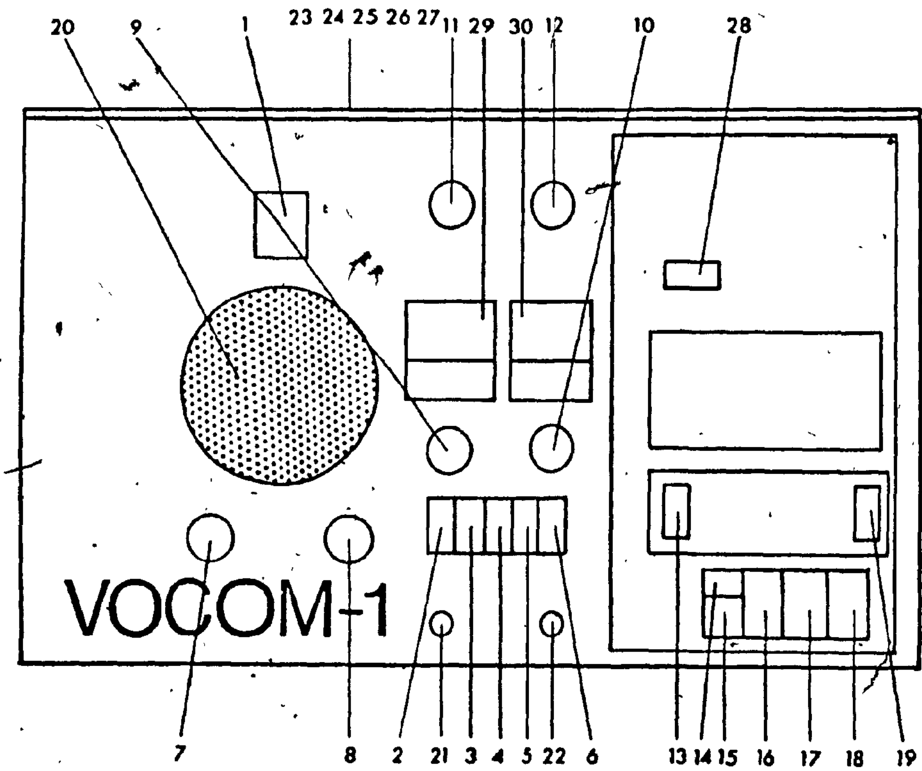
13. RECORD--Interlock to place machine in record mode.
14. REWIND--rewinds C-60 cassette in 55 seconds.
15. REVIEW--when in playback will backspace while depressed and immediately return to playback when released.
16. STOP
17. PLAY--for playback or record.
18. FORWARD--same speed as rewind.
19. EJECT-cassette eject.

INPUT/OUTPUT

20. 4" speaker--up to 2 watts undistorted output.
21. Headphone Jack.
23. Hi-Level In--sensitivity .7 volts rms..
22. Microphone Jack--Sensitivity .3mv.rms
24. Hi-Level Out--.7volts rms
25. AC Power Connector--. 117 VAC 40 Watts

MISCELLANEOUS

26. Remote Pause Jack.
27. Fuse Holder--.5A Slow Blow
28. 3-digit Index Counter with reset
29. % Compression/Expansion Meter--Average over about ten seconds of real time
30. V-U Meter



APPENDIX C

PROCESSING CONTROLS

Processing controls cover more than just the activities of the electronic data processing department. They cover all the activities in the EDP and user departments which are required to process transactions from their initiation to their appearance on the daily, weekly or monthly reports which are used to run the organization. For example, the preparation of sales orders, shipping documents, invoices, entries in the accounts receivable ledger and the aged receivable trial balance are all activities or components which should be subject to processing controls. There are four control objectives which must be satisfied in the area of processing controls:

(1) To ensure the completeness of data processed by the computer

(2) To ensure the accuracy of data processed by the computer

(3) To ensure that all data processed by the computer is authorized and

(4) To ensure the adequacy of management trails.

Data becomes incomplete when parts of it become lost at some point in the transaction stream. Documents can be physically lost in source departments, in transmission to the EDP department, or during the computer processing phases.

The loss of transactions from the processing stream results in misleading reports, whether they are of a financial or an operational nature. Decisions based on these reports will be in error if they assume that all transactions are reflected in the figures. As with completeness, the accuracy of data can be compromised at various points in the transaction stream. Data can be incorrectly coded or incorrectly processed by the computer. Inaccuracies which cause a customer's account to be charged with purchases made by another person, or which cause the incorrect calculation of volume discounts, may lead to customer alienation and the exposure of competitive disadvantage.

Data can be complete and accurate but still represent invalid or unauthorized transactions. We must ensure that all transactions comply with the policies laid down by management.

In the absence of controls to ensure that data is authorized, the way is opened for individuals who seek to use the system for their own gain; hence, the exposure to fraud.

Data may satisfy all other control objectives described here but may be inaccessible to management once it has been processed. This infamous 'loss of trail' occurs when transactions enter a system individually but lose their identity at some point during processing. They appear subsequently as one among many items included in a summary or total figure.

Requests from customers for details of individual items in their accounts occur frequently in most organizations. If this information is not available as a normal output from the application, much time and effort will be required to satisfy the request, leading to the exposure of Excessive Costs.

We will now examine some examples of what can go wrong in an application. Having established this we will apply controls to ensure that these errors do not occur or that, if they do occur, they will be detected and subsequently corrected. Our example is an accounts receivable application. It may not have all the characteristics of an accounts receivable application in your experience nor will it have all the controls you may think necessary. The example is used as a vehicle for describing certain controls and the reasons for their use.

In our accounts receivable application, invoices are prepared daily by the user department and sent to EDP for keypunching. The master file is updated daily with invoice transactions and at the end of each month an accounts receivable trial balance is printed. We will examine what can go wrong and the accompanying controls separately under each control objective.

The first control objective is to ensure the completeness of data. Therefore, we must first determine where data can be lost. Single invoices can be lost in the user department or during delivery to the EDP department. Once in EDP, transactions may be lost when they fail to be keypunched.

In the daily update, the invoice transactions are used to update the old accounts receivable master and create the new master file. Certain transactions are rejected if, for example, they find no matching record in the old master file. These rejects are printed out on a reject report. What can go wrong? First, transaction cards can be lost between the time they are keypunched and when they are entered into the update program. If rejects are not corrected and re-submitted they are in effect lost to the application. The use of an incorrect master file as input can mean the loss of one or more day's transactions. For example, if the master file created on Monday is used as input to Wednesday's update all the transactions for Tuesday will be lost. Again, if the incorrect master file is used to print the trial balance at the end of the month, one or more days transactions may be lost. What controls can we institute to prevent or detect this loss of data?

The anchor of our control system must be established in the user department. Invoices should be brought together into small groups or batches and an adding machine tape made of the invoice amounts, creating a batch control total.

This batch control is entered on a transmittal slip which will accompany the batch as it moves on for further processing.

The value on the transmittal slip is entered in a control log. The figures in the control log will be used in subsequent control procedures.

Since one could argue that a batch could be lost between the user department and EDP in the same way as a single invoice, we would serially number each batch before we sent it.

When the batch reaches keypunch, the sequence number will be checked to detect whether any batches have been lost.

Once the invoices have been keypunched, a batch control card will be prepared. This will contain the batch control total from the transmittal slip.

In order to check that all the individual invoice transactions still remain in a batch, we will institute the use of a new program before the update. The program will add up all the keypunched invoice amounts and compare that figure to the amount on the batch control card. Batches which do not balance will bo so indicated on the balance report.

Since many batches will be balanced in one run, we must create a control total of all transactions which are contained on the invoice transaction file. This control total which is printed on the balance report, will be used in subsequent control procedures.

The update program will add up the old master file as it reads it. As it writes the new master file after updating the pertinent master record, the program will add up the total value of the outstanding receivables. Thus, by adding the invoice transaction control total minus rejects to the old master file total, we can balance the resulting figure to the total value of the new master file. This procedure can, of course, be carried out manually or by the machine.

So much for the accepted transactions, but how are we to ensure that all rejects are reprocessed? We could print two copies of the reject report, one to be sent to the user department for correction and the other to be used as a control log by EDP. As corrections are received by EDP, they are merely marked off on the control log.

Another technique would be to have the computer maintain the control log. It would do so in the form of a suspence file and be identified with a unique number. When the corrected transaction had been processed, the reject number would be punched on the transaction card and be copied along with the rest of the transaction data onto the invoice transaction tape. When the update program detected a transaction with a reject number, it would remove the appropriate reject record from the suspence file.

The suspense file should, of course, be aged periodically to highlight any rejects which might remain uncorrected for an undue length of time.

To ensure that the appropriate file is used to prepare the monthly trial balance, we would check the total on the trial balance against the balance report from the most recent update of the month.

A final procedure should be instituted back in the user department in order that they can maintain overall control over the data for which they are responsible. When the accounts receivable trial balance is received it should be balanced to the control log in which all batches have been recorded. The total batches submitted less rejected transactions should equal the total on the trial balance. It is important to note that no financial reports based on receivable figures should be prepared before a thorough review of outstanding suspense file items is completed. If any material transactions remain uncorrected they should be manually adjusted for in the books of account.

In our example, we have identified the following elements subject to control. The invoice and invoice transactions are controlled on a daily basis through batching and balancing procedures. The use of correct master files from day to day is controlled by balancing. The re-submission of rejected transactions is controlled by the use of a control log of some type whether maintained manually or by the machine. Lastly, to ensure that monthly reports include all the month's transactions, we balance the total amounts entered into the transaction stream to the total on the monthly reports. We must keep in mind, of course, that outstanding rejects may require manual adjustment of material.

APPENDIX D

INTRODUCTION TO CONTROLS

The introduction of the computer within an organization involves change. To better illustrate what changes take place, we can relate the nature of computer systems back to various aspects of manual systems.

It is more expensive to design, implement and maintain a computer system, since doing so requires the hiring of computer systems analysts, programmers and operators. We must also purchase computer services. Computer systems should be cost justifiable but they are still more expensive to design and operate than manual systems.

Manual systems are more flexible than computer systems. One can instruct a clerk how to handle two out of the four types of transactions he is expected to process and then say "come back to me when either of the two other transaction types come up and I'll show you how to do them." But the computer must be instructed on all aspects of its work in advance. As well, changes to the manual system can be given verbally while changes in the computer system require programming, recompiling and retesting.

Errors occurring in a manual system tend to occur at random, that is, without a determinable pattern. One of the strengths of the computer is its ability to do things in the same way every time. However, therein also lies a weakness. Errors occurring in computer systems will recur continually each time the particular circumstances are encountered.

When several people are involved in processing a transaction, the control technique of division of duties takes effect. The computer can carry out many tasks in a short space of time. To make most effective use of the computer resources, we transfer to it many tasks previously carried out by separate individuals, thus reducing the effectiveness of the division of duties as a control technique.

If a posting clerk is off sick for a week, it is relatively easy to find a temporary replacement and give appropriate instructions for the task. Backing up a computer is not so easy. Even if the name on the front of the CPU is the same, there can be significant differences behind the front panel. Not only must the hardware and software be identical, time must be available on the back up computer when the emergency occurs.

The objectives of internal control in a business are to safeguard its assets, check the accuracy and reliability of its accounting data, promote operational efficiency and encourage adherence to prescribed management policies. These objectives do not change with the introduction of a computer.

It is the control techniques which change. Some techniques are altered and new ones are added to cope with the different nature of computer systems. Thus different techniques are used to achieve the same objectives.

APPENDIX E

MEASUREMENT OF DIFFICULTY LEVEL

Since much of the confusion regarding the generality of speech compression effects can be attributed to the lack of specification of stimulus attributes of compressed material, it would seem that the determination of the difficulty level of this material should be incorporated into the methodologies of compressed speech studies. For the most part, however, this has not been done. It is the purpose of this discussion to shed light on this supposed irony. In doing so, two areas of research are considered: (1) research on formulas used to measure difficulty and (2) research in which difficulty level of the message presented has been an independent variable.

In the absence of any established measures of 'listenability' researchers use 'readability' measures to evaluate orally presented texts. Since this measure concerns the ease with which a text is read, it is generally considered to be a measure of the difficulty level of a text. However, a wide range of definitions for this term have been offerred. Dale and Chall (in Gilliland, pp. 12-13) have proposed that:

> In the broadest sense, readability is the sum (including interactions) of all these elements within a given piece of printed material that affects the success which a group of readers have with it. The success is the extent to which they understand it, read it at optimum speed and find it interesting.

Other definitions of readability do not embody these same factors and thus do not embody comparable methods of readability assessment. Gilliland (1972, p. 83) has outlined the following 5 assessment methods: (1) subjective assessment (2) objective question and answer techniques (3) formulae (4) tables and charts (5) sentence completion and cloze procedure. All of these methods purport to measure readability and yet they are based on different considerations. For example, the estimate of reading difficulty obtained by the Flesch formula is primarily determined by word and sentence length, whereas the Dale-Chall formula largely depends upon the number of words which is not found in Dale's lists of vocabulary easily understood at various grade levels (Duker, 1974, p. 492).

One of the most widely used procedures for determining difficulty level has been the "cloze procedure". The use of this procedure involves the deletion of a number of words randomly determined or at fixed intervals, generally every fifth word. Subjects are then requested to complete the passages and the number of correct responses is scored. Passages on which higher scores are obtained are regarded as more readable or of lesser difficulty than passages on which lower scores were obtained. (Gilliland, p. 103). Despite the fact that this approach is used extensively, there is disagreement on the extent of its valid use as a determinant of readability. What it actually does determine has, in fact, been the question researched in a number of studies cited by Emmert and Brooks (1970, pp. 270-271).

In light of facts such as those which have been touched upon in this discussion, Gilliland comments that it is unfortunate that studies which have employed the various assessment alternatives have "all been grouped together under the heading of readability as if they were all dealing with the same issues. . . The criteria used in defining readability then are, regrettably, not comparable and . . . neither are the methods of measurement" (p. 84). What is then evident is that, in general, results of a study in which one assessment method has established a certain difficulty level cannot be freely compared with a study in which this level has been determined by an alternative method.

What these methods all have in common, however, is that they have been developed for use with visual rather than auditory material. To use them interchangeably in the assessment of reading and listening selections, as has been done in several studies of compressed speech, is to assume that the listening difficulty of a selection is the same as the reading difficulty of the same selection. A number of studies have illustrated that this is not a tenable assumption.

In a study conducted by Foulke et al (1962), a scientific and a literary selection which were estimated to be of equal difficulty according to the Dale-Chall formula for readability yielded listening comprehension scores which suggested that the scientific selection was relatively more difficult. A study by Enc and Stolurow (1960) revealed considerable variability in the mean comprehension test scores of 10 listening selections, despite the fact that they were rated as equal in difficulty by the Dale-Chall formula.

The explanation as to why the difficulty of an aurally received selection is not the same as the difficulty of that selection when visually received, lies in the differing nature of the two processes required. Because the printed page is a spatial display, it permits the performance of the operation which Miller (1956) refers to as "chunking". That is, in order to keep input rate below channel capacity, the reader learns to perceive not single words, but entire phrases or sentences. On the other hand, when language is displayed orally, it is displayed in a temporal dimension which does not permit the same "chunking" operation. Though there may be some chunking, for example, of phrases, it is probably different and more restricted. As Foulke and Sticht have maintained: "... unlike the visual reader, the listener must depend upon memory alone for the availability of speech that has already occurred. Furthermore, unlike the visual reader, he can exert no control over the order in which he encounters the syntactic and semantic components of sentences. The syntactical difference between two selections might be inconsequential when they are received visually, yet quite significant when they are received aurally". (p. 57).

Despite the problems associated with various methods for determining difficulty level and despite the fact that reading and listening to a certain body of information are not necessarily tasks involving equal difficulty levels, several compressed speech studies have specifically investigated difficulty (as determined by readability assessment methods) as an independent variable.

In a study conducted by Sticht (in Freedle and Carroll 1972, pp. 287-289) in which the effects of speech rate, message difficulty and aptitude in learning by listening were investigated, results indicated that there was no significant difficulty by speech rate interaction for high aptitude subjects; for low aptitude subjects this interaction was significant. In other words, high aptitude subjects gained as much when listening to the more difficult materials as when listening to the easier materials, at each of the five experimental rates of speech. It is important to note that Sticht's subjects consisted of U.S. Army personnel, half of whom were men with AFQT[1] (Armed Forces Qualifications Test) scores at the 30th percentile or below (low mental aptitude), while the other half were men with AFQT scores at the 80th percentile or above (high mental aptitude). In light of the wide variety of abilities and aptitudes found in any college population, it cannot be said unequivocally that such a population does not include some students with comparatively lower aptitudes; it does, however, appear to be a reasonable assumption that the college population in general is more closely akin to Sticht's high mental aptitude population.

A study by Fairbanks et al (1957) explored the interaction of time compression and message units varying in difficulty. Sixty multiple choice items on a test of listening comprehension were distributed equally among five categories of item difficulty. The listening selection was administered to five groups of subjects, each experiencing a different word rate (the range of word rates extended from 141-470 wpm). Each subject received five scores which were determined by his responses to the items in each of the five test-item categories. Results indicated that, assuming item difficulty to be a reflection of the difficulty of the message unit to which it pertained, the effect of time compression on listening comprehension did not depend upon the difficulty of the listening material within the range of word rates explored.

In order to investigate the effect of rate of presentation on the comprehension of materials which differed in grammatical complexity, Reid (1968) designed an experiment in which the comprehension-test portions of two equivalent forms of the Nelson-Denny Reading Test were rewritten.

[1]AFQT - This test consists of 4 parts: (1) vocabulary (2) arithmetic test using word problems (3) tool recognition test (4) spatial relations test.

This was done in an attempt to reduce grammatical complexity so as to make two different levels available. Four rates of presentation were used - 175, 275, 325, and 375 wpm. Results showed that comprehension varied as a function of grammatical complexity when one form of the reading test was used, but did not vary when the alternate equivalent form was used. A lack of interaction was also found between rate and grammatical complexity, suggesting that the decrease of comprehension was invariant with the level of grammatical complexity. This pattern did not, however, occur at the rates of 325 and 375 wpm. At these rates, comprehension dropped off considerably more when grammatical complexity was high, thus indicating that an interaction of these variables may occur only at very high rates of presentation.

It was in light of the cited observations and studies that the present investigator did not determine the difficulty of the presented listening selection. This decision was not based solely on evidence indicating that difficulty does not affect comprehension, for this evidence is not conclusive. Consideration was also given to the fact that formulas often produce different estimates and as Foulke and Sticht maintain (in Duker, 1974, p. 493), "the findings of a systematic interaction between difficulty and word rate for listening selections rated different in difficulty by a particular formula would provide a kind of natural validity for that formula."

In sum, difficulty is but one of the myriad of variables which may affect comprehension of compressed materials, and is thus a distinct area in which much research must yet be conducted. Until many of the unknowns are determined, the calibration of difficulty level of compressed materials according to a randomly chosen formula will not enhance the generalizability of compressed speech studies.

APPENDIX F

COMPREHENSION TEST ON PROCESSING CONTROLS

Rate ______________ Method of Compression ______________

Subject # __________ Faculty ______________ Sex __________

1. Which one of the following statement is true?

   a. Processing controls concern mainly the activities of the electronic data processing (EDP) department.

   b. Processing controls cover all the activities in the EDP and user departments which are required to process transactions.

   c. Processing controls are concerned primarily with accounts receivable and applications.

2. Which of the following is not one of the 4 control objectives which must be satisfied in the area of processing controls?

   a. To ensure the effectiveness of data processed by the computer.

   b. To ensure the accuracy of data processed by the computer.

   c. To ensure completeness of data processed by the computer.

   d. To ensure that all data processed by the computer is authorized.

3. Which one of these statements is true?

   a. A master file assures that data cannot become lost during the computer processing phases.

   b. Data becomes incomplete when parts of it become lost at some point in the transaction stream.

c. It is impossible for documents to be lost in transmission to the EDP department.

4. The loss of transactions from the processing stream results in . . . .

   a. faulty batch control

   b. incorrect balancing

   c. misleading reports

   d. a larger suspence file

5. Errors in coded data result in inaccuracies which. . . .

   a. are automatically recorded on the update program.

   b. are immediately corrected by the EDP department.

   c. can cause a customer's account to be charged with purchases he has not made.

   d. interfere with the number sequencing control system.

6. In the absence of controls to ensure that data is authorized...

   a. computer costs will double, thus increasing user charges

   b. the computer will reject invoice transactions

   c. the way is opened for individuals who seek to use the system for their own gain

   d. employees will be unable to spend the necessary time on the more important activities of the user department

7. "Loss of trail" occurs when transactions maintain their individual identity, but fail to become incorporated into the larger processing system. (True or False).

8. It is the function of the user department to keypunch all data which it receives from the EDP department. (True or false)

9. The anchor of the control system must be established in the EDP department. (True or False).

10. In order to control for loss of data . . . .

a. applications are carefully checked by personnel or by computers in the user department.

b. invoice transactions are controlled on a daily basis through batching and balancing procedures.

c. reject reports are always immediately corrected and resubmitted.

11. The use of correct master files from day to day is controlled by . . .

a. transmittal slips

b. balancing

c. a control log

12. The re-submission of rejected transactions is controlled by the use of a . . . .

a. master file

b. serial number sequencing system

c. control log

13. Which one of the following best describes "suspense file"?

a. a technique in which the computer maintains the control log

b. a file kept on those who have attempted faulty or illegal computer transactions

c. a technique in which all invoice transaction tapes are properly coded.

14. Which one of the following statements is true?

    a. With the use of a control log, no manual adjustments of outstanding rejects is ever necessary.

    b. Due to the use of transaction tapes, a thorough review of outstanding suspense file items is unnecessary.

    c. To ensure that monthly reports include all the months' transactions, total amounts entered into the transaction stream are balanced with the total monthly reports.

APPENDIX G
KUDER-RICHARDSON 20 PROCEDURES

Subject	Score X_t	X_t^2	S	Subject	X_t^2	Item	P_i	Q_i	$(P_i)(Q_i)$
1	5	25	16	9	81	1	.733	.267	.195
2	7	49	17	7	49	2	.766	.234	.179
3	9	81	18	7	49	3	.80	.20	.16
4	11	121	19	7	49	4	.40	.60	.24
5	14	196	20	8	64	5	.80	.20	.16
6	7	49	21	4	16	6	.633	.367	.232
7	8	64	22	6	36	7	.20	.80	.16
8	7	49	23	3	9	8	.566	.434	.245
9	5	25	24	8	64	9	.366	.634	.232
10	8	64	25	8	64	10	.80	.20	.16
11	11	121	26	10	100	11	.333	.667	.222
12	5	25	27	12	144	12	.30	.70	.21
13	10	100	28	8	64	13	.433	.567	.245
14	6	36	29	11	121	14	.90	.10	.09
15	9	81	30	12	144				

Calculation of Variance:

$\Sigma x = 242 \quad \Sigma x^2 = 2140 \quad N = 30$

$$\text{Variance} = \frac{\Sigma x^2}{N} - \left(\frac{\Sigma x}{N}\right)^2 = 6.26$$

Calculation of r_{k-r} using KR 20

$$KR = \frac{K}{K-1}\left(St^2 - \frac{\Sigma p_i q_i}{St^2}\right)$$

$K = 14 \quad \Sigma(P_i)(Q_i) = 2.73$

$r_{K-R} = .61$

APPENDIX H

SUMMARY OF ANECDOTAL COMMENTS

GROUP I: Uncompressed Recording (135 wpm)

- "It's much too slow and boring".
- "I found my mind wandering because it was so slow and 'draggy' ".

GROUPS II and III: Vocom I and Varispeech I, 39% compression (218 wpm).

- "The speed didn't bother me half as much as the material itself".
- "I could have done much better at this high speed if I was more familiar with the material".
- "I think I would like it much better if I had time to get accustomed to it."
- "I was fascinated by the sound".

GROUPS IV and V: Vocom I and Varispeech I, 57% compression (311 wpm).

- "The speed made me nervous and anxious. I couldn't relax at all".
- "It was so fast that I couldn't digest anything."
- "I found I was so 'caught up' on the technique that I wasn't really listening to the content".
- "The material was completely unfamiliar, so it was very difficult."

APPENDIX I

NUMBER OF CORRECT RESPONSES BY TEST ITEM BY GROUP

Test Item	Control (n = 10)	39% Compression Vocom I (n = 10)	39% Compression Var. I (n = 10)	57% Compression Vocom I (n = 10)	57% Compression Var. I (n = 10)
1	8	10	8	6	7
2	9	7	8	7	7
3	8	7	8	5	8
4	4	3	4	4	[illegible]
5	8	5	6	6	8
6	8	6	6	6	8
7	5	2	2	2	4
8	8	8	5	4	5
9	5	3	3	2	1
10	9	8	9	7	9
11	6	6	4	2	3
12	4	7	4	0	2
13	6	5	7	1	4
14	10	8	10	8	7

APPENDIX J

RAW SCORE BY GROUP

	Control		39% Compression — Vocom I		39% Compression — Var. I		57% Compression — Vocom I		57% Compression — Var. I	
	M	F	M	F	M	F	M	F	M	F
	10	10	7	8	10	11	8	4	11	4
	11	12	7	10	9	10	5	8	9	10
	8	12	6	5	8	9	7	4	5	7
	10		9	7		5	3	6	10	7
	8		2			7	8		6	8
	9		14			4	7			
	8					11				
Mean Scores	9.8		8.5		8.4		6.0		7.7	

M= male

F= female