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An Investigation Of Laryngeal Emg Activity And Its Relation To Reading

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AN INVESTIGATION OF LARYNGEAL EMG ACTIVITY AND ITS RELATION TO READING

by

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ABSTRACT

The occurrence of substantial increases in laryngeal motor activity in some individuals during reading has been an intriguing phenomenon. The purpose of the present study was to investigate two questions suggested by a review of previous studies in the area. The first question was whether auditory feedback of laryngeal emg activity would be more efficaceous in the reduction of such activity than asking the subjects to suppress the activity during reading. Second, what is the effect of reducing or eliminating this activity on reading rate and comprehension?

In a random sample of 103 university students, 32 were identified as those who consistently showed significant laryngeal emg activity when reading light prose (SV-subjects) and 48 were identified as those who consistently failed to show these increases (NSV-subjects). Each group then was subdivided into experimental groups (n=16), equated with respect to reading speed and comprehension. The treatments were: auditory feedback plus information; information-only; and (for the NSV-group) control. Significant increases in laryngeal emg activity were evoked in NSV-subjects by presenting them with blurred reading material throughout the experiment.

For the SV-subjects, the auditory feedback plus information treatment was significantly ($p<.01$) more effective in reducing laryngeal emg activity than information-only.

For NSV-subjects no significant differences among treatments were found. The hypothesis that laryngeal motor activity during reading facilitates decoding of the text and that temporary reduction of such activity therefore would be detrimental to the reading rate and comprehension was not supported.

No evidence was found that, for this sample of college students, laryngeal motor activity interfered with reading. Furthermore, no significant differences were found between the mean reading performance (comprehension, vocabulary, reading rate, and eyemovements) of SV- and NSV-subjects.

The hypothesis that increased laryngeal emg activity observed for SV-subjects in Experiment 1 was related to the language component and not to a general state of arousal elicited by the visual scanning aspect of the task, was tested and confirmed in a second experiment.

A program of future research was suggested along three major lines: (1) the collection of additonal normative data describing the evidence of significant subvocal activity during reading for various levels of development and correlating these data with reading performance; (2) investigating the possibility that NSV- and SV-subjects may differ in their ability to form auditory images without the use of peripheral motor activity; (3) correlating the parts of the text read with corresponding emg activity so that general trends may emerge regarding the classes of words that evoke laryngeal emg activity in some readers.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

One of the most intriguing problems that for decades has interested research workers in the field of reading relates to the extent to which subvocal behaviour or movement of the muscles of the speech mechanism occurs during silent reading and the relationship of this motor activity to the reading process. The early research in this area was the by-product of attempts to explain thinking in terms of motor activity, a topic which generated numerous studies during the latter part of the 19th century and culminated in Watson's (1930) famous hypothesis that:

> all of the so-called "higher thought" processes go on in terms of faint reinstatements of the original muscular act (including speech here)...
> (Watson, 1930, p. 239)

Parallel with this development was a similar line of research in the U.S.S.R. which held that the speech processes taking part in intellectual operations are gradually condensed and converted into contracted internal verbal schemes (Vygotsky, 1934, 1956). Luria (1960) in an overview of this research, comments that the results of the studies show that the kinesthetic impulses flowing from the speech organs to the cerebral cortex represent a significant factor in the mechanisms of complex intellectual operations.

A favourite experimental strategy in these studies was to have the subject perform various mental tasks while the experimenter monitored by various means the degree to which the subject exhibited motor activities such as lip and tongue movements, laryngeal motor activity, etc. Since the experimenters often used the silent reading of a passage as one of their mental tasks, this line of research was one of the first sources of information on the occurrence of motor activity, especially laryngeal motor activity, during silent reading. Unfortunately, however, as Edfeldt (1960) and McGuigan (1970) pointed out in their critical reviews of the literature in this area, many of the early studies were characterized by conflicting and inconclusive findings, probably due to the inadequacies of methods then available for the detection of fine motor movements. A methodological breakthrough in the study of subvocal behaviour occurred with the development of electromyographic (emg) techniques for the recording of muscle movements of the speech mechanism.

In spite of the continued scientific interest in the occurrence of subvocal behaviour during reading and other intellectual operations, the functional significance of subvocalization is still unclear. It is generally agreed that the manifestation of such activity follows a developmental pattern, that is, articulatory motor activity is most prominently manifested during the early stages of reading acquisition but gradually declines as the individual becomes more skilled. It is also clear, however, that some individuals, in spite of considerable practice and skill, maintain their motor responses during reading. And it has been shown by various studies (Edfeldt, 1960; Hardyck and Petrinovich, 1970; Novikova, 1966) that silent readers show increased articulation where the reading task is difficult, either syntactically or due to unfamiliarity or poor legibility. As Conrad (1973) pointed out:

> There are indeed so many good studies reporting the presence of articulation during silent reading that we might be justified in concluding that the case is proved. But of course, the case that appears proved is that silent reading is accompanied by articulation. What is far from proved is that articulation is necessarily involved in silent reading.
> (Conrad, 1973, p. 209)

In answer to the question: What is the relationship between articulatory motor activity during reading and the reading process, it is possible to identify in the literature at least two different theoretical positions. The first of these positions may be labelled the "interference hypothesis".

Although educators have recognized the beneficial effects of articulatory activity during the early stages of reading acquisition, the observation that those individuals with persistent reading problems tend to display a considerable amount of speech motor activity during reading has led to the belief that the persistence of this activity interferes with the rate of reading and is detrimental to reading comprehension. The following quote is a classic example of this viewpoint:

> In the primary grades pupils are likely to articulate words quite definitely and fully in their silent reading. In the early stages this habit does no harm for the reason that the student can articulate words quite as rapidly as he is capable of reading them.. The habit, however, may become fixed, and definite, complete articulation of each word may persist... In any case, time is taken to produce in some

> form the motor organization or the sound of the word. A child subject to any of these habits cannot read more rapidly than the speed with which he can articulate. When his silent reading (speed) reaches that level, it is likely to remain until the habit of articulating or imaging the word sounds is eliminated.
> (Gates, 1947, p. 438)

It is interesting to note that Gates, after specifying "definite, complete articulation of each word", generalized the assumed harmful factors to include all articulatory activity and the thinking (imaging) of word sounds. As a consequence of these assumptions, a considerable, teacher-oriented literature had advocated de-emphasizing oral reading in the elementary classroom (McDade, 1950; Buswell, 1947; Gates, 1947; Betts, 1950). In recent years, considerable moderation of this viewpoint has taken place and subvocal activity during reading seems now to be regarded as a symptom rather than a cause of reading disability.

The second theoretical position holds that articulatory activity during reading actually facilitates the reading process. While there is little evidence that bears directly on this question, there is some evidence that is suggestive.

Specifically in short-term memory (STM) experiments where verbal items are visually presented, it has been shown that recall is severely impaired when articulation is effectively suppressed during the presentation of the items. A number of studies have also shown that when verbal items (words, consonants, etc.) are visually presented for immediate recall or for recall after a brief delay, this material is encoded by the subjects in phonological form (Conrad, 1962; Hintzman, 1967; Murray, 1966; Sperling, 1963).

Experimenters were so intrigued by this phenomenon that they devised STM-tasks in which the subjects were required to read silently test items which were phonologically very similar. If the subjects persisted in using a phonological code, using either articulation or auditory imagery, impairment of recall would be expected. Since the test items were visually quite dissimilar, however, recall would not be expected to suffer if the subjects used a visual code. The results of these experiments suggest that the subjects continued to use the phonological code in spite of the impairment of recall (Baddeley, 1966; Conrad, 1963, 1965; Murray, 1967). Collectively, this evidence provides support for the view that speech coding is important in silent reading. In reviewing the evidence from these STM-studies, Conrad (1973) says:

> This evidence tells us that normal adults using vision to take in verbal information go to what appears to be considerable neurological bother to recode it out of the input stage.
> (Conrad, 1973, p. 216)

It may be that speech, coded either as articulatory activity or auditory imagery, is the most preferred way to sustain the STM-processes. Laberge (1972) while pointing out the danger of generalizing the results from STM-studies (where the "reading material" consists of independent bits of information) to the fluent reading of text, remarks that:

> Conrad's emphasis on the widespread preference for the phonological code is appealing on at least two counts over and above the fact that subjects prefer it in STM-experiments. We learned our language in this mode, and presumably the deeper wirings are already attached to it in a special

> way (Liberman, Cooper et al., 1967). Second, even if the visual code were comparable to the phonological code in almost all other respects, the fact that we can rehearse in this mode much more effectively than in the visual mode would compel a person to choose the phonological code over the visual code when he has the choice.
> (Laberge, 1972, p. 244)

To summarize, it has been found that silent reading is possible without phonological coding but that the use of such coding in silent reading is nearly universal. Also, for most people interference with phonological coding during reading seems to impair recall. One might hypothesize that the perception of meaning (semantic coding) depends primarily on such a basic holding and rehearsal mechanism and that this is the function of subvocalization. A reader then would use subvocalization where necessary to store and rehearse parts of the text until the information can be chunked into a larger, more meaningful unit.

A third possible interpretation of the occurrence of laryngeal motor activity during reading might be that the activity is a parallel process without any single functional relationship to the reading process per se.

Recent Studies

Faaborg-Anderson (1957) was one of the first investigators to use the electromyographic technique in relation to silent speech when he studied the functioning of the inner laryngeal muscles in humans. He reported that when subjects were instructed to think about phonation of the vowel "e", without audible phonation, an increase in the electrical activity of both the cricothyroid and the vocal muscles could be observed.

Probably the most extensive investigation of subvocalization[1] in relation to reading behaviour using emg techniques was carried out by Edfeldt (1960). Using precise placement of needle electrodes in the mylohyoid muscle, the following hypotheses were tested and confirmed:

(1) In general, the better a subject scores on a standardized reading test, the less laryngeal motor activity he displays during silent reading.

(2) The reading of an easy text results in less subvocalization than does the reading of a difficult text.

(3) The reading of a clear text results in less subvocalization than does the reading of a blurred text.

Edfeldt claimed that the occurrence of laryngeal motor activity during reading is probably universal and that this behaviour in itself is not detrimental to the reading performance but should be seen as a symptom of a reader's difficulty to grasp the content of a text. These difficulties may arise either due to poor reading skills or because the text presents special problems, i.e., is either hard to read or difficult to understand.

In a later study, Hardyck, Petrinovich and Ellsworth (1966) reported that immediate and longlasting cessation of subvocalization, while reading silently, had been obtained by providing subjects with auditory feedback of the electromyographic activity of the laryngeal muscles. The dependent variable in the study by Hardyck et al. was the amplitude of electrical activity recorded

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[1] Subvocalization is defined here as a significant increase in the amplitude of the laryngeal emg signal from a resting level, due to silent reading.

from surface electrodes placed over the thyroid cartilage. A significant increase in the amplitude of the activity during reading was reliably detected in 17 of the 50 subjects. In a second phase of the experiment these 17 subjects received auditory feedback of their subvocal activity and were able to inhibit this activity, while reading, within one 30-minute experimental session. When retested after 30 and 90 days, none of them showed subvocal activity during reading. Unfortunately, Hardyck et al. did not report quantitative data nor did they test for possible changes in reading performance following treatment. Their experiment, however, suggests an interesting technique to investigate the functional properties of the subvocalization phenomenon. Whereas most studies so far employed the correlational method, the use of the auditory feedback technique may enable the experimenter to control subvocal activity as an independent variable and subsequently to observe possible related changes in reading performance.

In a criticism of the above study Camacho (1967) pointed out that by failing to measure reading performance, Hardyck et al. did not substantiate the conclusions; namely, that after subvocal activity had ceased, reading was still going on. He suggested that the subjects might have concentrated on the suppression of laryngeal motor activity to the detriment of reading. Hardyck et al. (1967) replied that they had recently completed an experiment relevant to this question using a group of persons who did not subvocalize when reading light prose. They presented this group with reading material scaled for conceptual difficulty, providing auditory feedback of the laryngeal emg activity for half the subjects. Without the auditory feedback, the laryngeal emg activity increased as a function of the difficulty level of reading material. This increase was not shown by feedback subjects but their comprehension of the material decreased "slightly" (No statistical test reported). Both groups, however maintained a high degree of comprehension, even when reading the most difficult material. This study seems to show that in subjects who normally do not subvocalize when reading light prose, the occurrence of subvocal activity can be reduced or prevented by means of auditory feedback. Unfortunately, however, the subjects in this study had to attend to feedback at the same time that they were reading the material of which the comprehension was being measured. Thus it is not clear whether the observed slight decrease in comprehension was due to the absence of subvocal activity or to the extra task posed by the feedback.

McGuigan (1967) questioned whether the auditory feedback was the critical variable in the procedure used by Hardyck <u>et al</u>., since he (McGuigan) in an exploratory study (N=3) obtained a similar rapid reduction in the amplitude of emg activity when the subjects read without receiving auditory feedback. In this case, however, the signals were obtained from the lips and chin muscles. He suggested that a number of extraneous variables such as instructions or the placement of electrodes on the throat, which focussed attention on the speech mechanism, played a large role in the reduction of the response amplitude. In a reply, Hardyck <u>et al</u>.(1967) pointed out that McGuigan's equation of the various response measures used in these studies is not justified, especially since Hardyck <u>et al</u>. found that during silent reading, emg measures of chin and lip activity were not related to laryngeal motor activity. Therefore, according to Hardyck _et al._, it is quite possible that after lip and chin activity had ceased in McGuigan's study, laryngeal activity was still present.

The same authors (Hardyck and Petrinovich, 1969) treated habitual subvocalization during silent reading in college and high school students using the auditory feedback technique. Again, no quantitative evidence was presented but the authors reported that one session of auditory feedback treatment successfully eliminated subvocal activity for 48 out of 50 college students. For the high school students the results were different: those of average and above average I.Q. responded to the treatment in the same manner as did the college students, but those with below average I.Q. needed many extra practice sessions to eliminate subvocalization.

In this report, Hardyck and Petrinovich discussed the effect of cessation of subvocal behaviour on reading speed. They observed no immediate changes in reading speed following the treatment but suggested that for students of "average to above average intellectual ability" in high school and college, subvocalization may be a redundant activity which interferes with the reading speed so that elimination of this activity would lead to faster reading. How the treatment affected reading comprehension was not mentioned.

In a subsequent study Hardyck and Petrinovich (1970) investigated the relationship of subvocal speech (as measured by laryngeal emg activity) to the conceptual difficulty level of reading material and to its comprehension. Emg activity was recorded from three locations - larynx, lip-chin and forearm flexor. The subjects were 18 college freshmen who had been screened to eliminate those who habitually subvocalized during reading. Three experimental groups of 6 subjects each were established: (1) In the normal condition subjects read an easy selection followed by a difficult one while emg activity from the three locations was recorded; (2) In the feedback condition emg activity from the same three locations was recorded but in addition the subjects received auditory feedback of increases in laryngeal emg activity while reading; and (3) In the control condition the subjects received auditory feedback from the forearm flexor while reading. Hardyck and Petrinovich postulated that subvocal speech acts as a mode of processing information and that substantial increases in laryngeal activity could be expected during the reading of the difficult material for the normal and the control group but not for the laryngeal feedback condition. In addition, they hypothesized that the latter group would show a lower comprehension of the difficult material than the normal and control groups, due to the suppression of laryngeal emg activity. It should be noted that (1) the subjects in this study again received auditory feedback at the same time that their reading comprehension was measured and (2) that this hypothesis was a reversal of Hardyck and Petrinovich's (1969) suggestion that subvocal activity during reading may be a redundant activity. Their hypotheses were confirmed but it is curious, in light of their earlier suggestions (Hardyck and Petrinovich, 1969) that no mention is made of the effects of the treatments on reading speed. It is also suprising that Hardyck and Petrinovich did not include a group of habitual subvocalizers in this study. If the occurrence of laryngeal emg activity during reading is in some way related to reading performance, then one would expect that any investigation that studies the effects of suppressing that activity should include that extreme group of habitual subvocalizers in addition to the intermediate group who only occasionally displays this activity.

The Present Study

This study set out to investigate a number of questions raised by the research discussed earlier, more specifically that reported by Hardyck et al. (1966, 1967, 1969, 1970) and McGuigan (1967, 1970). First, there is the methodological question of the efficacy of the auditory feedback technique in reducing articulatory motor activity during reading in comparison to a non-feedback (control) condition. The hypothesis tested was that the auditory feedback technique would be more effective in reducing laryngeal emg activity during reading than simply instructing subjects to suppress subvocalization (information-only). As noted previously, there is a further complication in that McGuigan recorded emg activity from the chin muscles while Hardyck's findings were based on emg activity recorded from the laryngeal muscles. Since laryngeal activity may be regarded as more fundamental to speech than the activity from the chin muscles, the laryngeal measure was used in the present study.

The second question raised by earlier research concerns the function of articulatory activity during reading. If it is possible to reduce or eliminate this motor activity, this provides an opportunity to study the effect of such a manipulation on reading comprehension and reading rate.

In the present study both questions, the efficacy of the auditory feedback treatment and the effects of reducing or eliminating laryngeal emg activity were studied in two distinctly different groups. One group was a group of college students who had been identified as those who showed consistently significant increases in laryngeal emg activity during the reading of light prose (SV-subjects). The other group contained those who consistently failed to show increases in laryngeal emg activity while reading similar material (NSV-subjects). The latter group was exposed to blurred reading material which evoked increases in laryngeal emg activity, and then given the feedback treatment. Following the treatment, their reading speed and comprehension were remeasured using blurred materials again. Consistent with the hypothesis that this activity serves as a short-term memory and rehearsal mechanism, it was predicted that the reduction or cessation of this activity would be detrimental to the reading speed and comprehension of both groups of subjects. This hypothesis is contrary to the so-called "interference hypothesis" which holds that the occurrence of laryngeal motor activity during reading slows the reader down since he cannot read faster than the speed with which he articulates.

In addition to the two primary questions of this study, there were some secondary issues. The first of these concerned the incidence of habitual subvocalization and possible differences in reading achievement between so-called habitual subvocalizers and those who barely display articulatory activity during reading.

Secondly, the present study was based on the assumption that the observed changes in laryngeal emg activity were due specifically to the language component of the task and not to a general state of arousal elicited by the task. To test this assumption, a second experiment was performed comparing increases laryngeal emg activity during a reading task as used in Experiment 1 with those occurring in a similar task without the language component.

Hypotheses

For both, SV- and NSV-groups, it was predicted that: (1) reading practice with continuous auditory feedback of laryngeal emg activity following a verbal statement to the subject (information), would be more effective in reducing laryngeal emg activity than either the verbal statement alone or, for NSV-subjects, reading practice with neither the verbal statement nor the auditory feedback (control). The statement (information) informed the subject that he or she displayed laryngeal motor activity during reading and instructed the subject to try and suppress this activity. This prediction was based on evidence that aural or visual emg feedback from delicate motor responses can produce, within very short time, accurate control of these responses by the subject (Basmajian, 1963, 1967; Carlsoo and Edfeldt, 1963).

For the NSV-group it was predicted that: (2) the reading of blurred text would elicit a significant increase in laryngeal emg activity when compared to a rest condition.

For the SV-group it was predicted that: (3) the reduction or elimination of this activity would be detrimental to reading rate and comprehension. This prediction is based on the hypothesis that the perception of meaning in silent reading is for most people primarily mediated by the use of phonological coding as a temporary holding and rehearsal mechanism. In case of the habitual subvocalizers this phonological coding is manifested in its most peripheral form; namely, articulatory activity, when reading easy prose. The reduction or cessation of this activity would disrupt the process of chunking the information into larger, more meaningful units and thus interfere with the reading speed and comprehension of the material.

For the NSV-group it was predicted that: (4) the reduction or elimination of evoked increases in laryngeal emg activity during reading would be detrimental to reading rate and comprehension during the reading of blurred text.

The rationale for hypothesis #2 is that subjects, who under normal reading conditions, e.g., light prose, are capable of processing this information without manifest articulatory activity, fall back on the use of articulatory activity when the reading material is "difficult", defined as either syntactic complexity, unfamiliarity, or poor legibility. Under those conditions, the subjects should increase their short-term holding span by rehearsing subvocally and thereby increasing both the distinctiveness and the meaningfulness of the visual stimulus input. Assuming that this rationale is correct, the reduction or cessation of these evoked increases in laryngeal emg activity would be detrimental to reading speed and comprehension. As in case of the habitual subvocalizers, the chunking of information into larger, more meaningful units would be disrupted and reading performance would suffer.

CHAPTER II

METHOD

Experiment 1

Subjects

The subjects were 103 first-year college students (60 males and 43 females) randomly recruited from introductory psychology classes at the University of Western Ontario. The sample was restricted to students with an English-speaking background.

Apparatus

The laboratory included two adjacent sound-deadened rooms, one for the S, the other for the E and recording equipment. The S's room contained a regular wooden chair and table. An Opthalmograph[1], to which the input-terminal assembly of a Grass Polygraph Model 5A was attached, was placed on the table. The room and opthalmograph were shielded to prevent electromagnetic and electrostatic interference. A one-way mirror enabled the E to observe the S during the experimental session.

The emg signal was picked up by miniature skin electrodes

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[1] The "Reading Eye" opthalmograph, manufactured by Educational Developmental Laboratories Incorporated, Huntingdon, New York.

(Beckman Instruments Inc. #650414), amplified by a pre-amplifier (Grass model 5P3) and recorded on one channel of the 2-channel Grass Polygraph at a speed of 2 1/2 cm/sec and a sensitivity setting of 20 µV/cm. In addition, the output signal from the pre-amplifier was fed through a Darlington-type coupling amplifier to a stereo tape recorder (Sony, TC-230) and recorded on magnetic tape at a speed of 7 1/2 inch/sec. An electronic filter (Dytronics 724) limited the frequency band of the signal from 60 to 600 Hz, thereby reducing amplifier "noise" and movement artifact without significant loss of motor unit potentials (Hayes, 1960). The second channels of both polygraph and tape recorder were used for marking the onset and offset of reading and resting periods during the experimental sessions. A tone of 1000 Hz, used for this event marking, was produced by an audio frequency generator (General Radio Company, Canada, 1304-B). The tone generator also provided auditory feedback of emg activity to certain groups of Ss. For this purpose, a Schmitt trigger connected to the output terminals of the coupling amplifier monitored the amplitude of the emg signal as required, and when this amplitude exceeded the level set by E (just above "relaxation" level) a 1000 Hz tone (90 db, ref. .0002 d/cm^2) was presented to the S through the loudspeaker system of the tape recorder.

Procedure

The experimental procedure consisted of three sessions for each S. In the first session the Ss, in groups of approximately 25, were told that the purpose of the experiment was to evaluate the reading effiency of a large group of college students by means of various tests and, after successful completion of all three sessions, each participant would receive a self-interpreting reading profile showing his percentile standing on vocabulary, reading rate and comprehension. Following this introduction, the Ss were given the Nelson-Denny Reading Test (Form A) followed by the Raven's Progressive Matrices (1958), both administered according to the instructions provided in the test manuals. (See Appendices A and B for copies of the two tests). The total length of this session was approximately 90 minutes.

The purpose of the second session was to obtain two photographic records of the S's eyemovements[2] and two records of the S's laryngeal emg activity during reading. The S was introduced to the experimental situation, seated in front of the opthalmograph and familiarized with the use of the instrument. The apparatus was adjusted to ensure a comfortable reading position. The S was then told that, in addition to eyemovement, electrical activity of neck muscles would be measured during the session and permission was obtained to attach the emg surface electrodes.

Attachment of Emg Electrodes[3]

The area of application was wiped with 85% alcohol to remove surface oils, rubbed briskly with abrasive electrode paste

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[2]The rationale of this measurement is described in Appendix C.

[3]For placement of electrodes in relation to anatomy of larynx see Appendix D.

(Sanborn's "Redux") and dried with tissue paper. After attaching the adhesive collar to the electrode, the electrode cavity was filled with electrode cream (Beckman Instruments Inc. #650425) and the electrode was attached to the S. The resistance between electrodes was then measured using a multimeter (Simpson Model 270) and where this resistance was found to be in excess of 10 K-ohm the electrodes were removed and reapplied, following the same procedure, until a resistance of less than 10 K-ohm between the electrodes was indicated.

After attaching the electrodes, the S's head was positioned in the opthalmograph and restrained by chin rest and brackets so that minimal head movement was possible. Employing the procedure outlined in the opthalmograph manual, the corneal reflections of the S's eyes were focussed in the camera and the S was given the following instructions:

> Please close your eyes and keep your head as still as possible. A reading selection of the same format as has been shown to you before will be placed in the apparatus. When I tell you, open your eyes and read the selection carefully. Read it only once. When you come to the end of the passage, close your eyes again. After the reading you will be asked to answer some questions about the content of the passage. [4]

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[4]Test selections and questions were taken from the Reading Eye file, form 1-8, college/adult level, Educational Development Laboratories Incorporated, Huntingdon, New York.

After these instructions, the S was given five trials. Each trial consisted of a reading period, preceded and followed by a 20 second rest period during which the S's eyes were closed. For each trial a different text selection was used. During the first trial, the S read the card placed in the apparatus and immediately after the rest period answered the ten questions (supplied by the publisher) for this selection. This trial was to adapt the S to the experimental procedure. No recordings were made during this trial.

On trial 2 and 3, the same procedure was followed except that on these trials eye movements were photographed during the reading period. The S's corneal reflections were refocussed at the beginning of each of these trials.

During trial 4 and 5, the rest periods were extended to last 40 seconds both before and after reading. During these rest periods and the actual reading periods, emg activity from the larynx was recorded on both the penwriter and magnetic tape. Also, the S was observed during the recording, and motor behaviour involving the larynx such as coughing, swallowing, etc., was marked on the pen record. When such behaviour occurred during a rest period, that period was extended by the duration of the disturbance so that a resting signal of equal length was ensured. Prior to trial 5 the S was told that there would be no questions to answer following that trial. At the end of the session, resistance between electrodes were remeasured to ensure that no critical changes in electrode position had taken place.

Classification of Ss and Assignment to Experimental Groups

After the second session, emg recordings were quantified[5] by computer analysis. The computer was programmed to sample the recorded signal at a rate of 2000 samples per second for a period of 6 seconds. Following this, an additional 4 seconds were required to calculate and print out the RMS value of the signal for that particular period. Thus, for every 10 seconds of recorded signal, a measure was obtained. Only those measures which clearly covered a rest or reading period and did not include such artifacts as coughing and swallowing were used. This resulted in a total of eight emg measures per S for each of the two recording trials. The first three measures were sampled from the pre-reading rest period, the next three from the reading period, and the final two measures from the post-reading rest period. To determine whether the emg measures observed during reading differed significantly from those observed during rest, three one-way analyses of variance were performed for each S, i.e., one for each trial and one for both trials combined. Preliminary inspection of the data suggested that most subjects showed a considerable increase in laryngeal emg activity during the post-reading (rest) period of trial 4, that is, the trial followed by questions to test the comprehension of the passage read. The increased activity suggested that many of the Ss were occupied during the final rest period of this trial with rehearsing the

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5 See Appendix E

content of the passage read. This period, therefore, could not be considered as a true 'rest' period, i.e., relatively free of subvocalization and for this reason these rest measures were not included in the above analyses. On the basis of the results of the analyses, the Ss were distributed into the following three categories:

(1) Subvocalizers (SV)

Those Ss showing a statistically significant ($p<.05$) increase in laryngeal emg activity during reading for each trial and on the test for both trials combined, were classified as subvocalizers. Each of these Ss (N=32) was then assigned to one of two groups, namely, the "information and feedback" group (n=16), and the "information-only" group. There were no significant differences between the subgroups with respect to mean performance on the Nelson-Denny comprehension and rate-of-reading tests (see Appendix F, Tables F-1 and F-2).

(2) Non-Subvocalizers (NSV)

Ss whose laryngeal emg activity did not significantly increase during reading in either of the two trials were classified as non-subvocalizers. These Ss (N=48_ were randomly divided into three equal sub-groups:

(a) Information-only

(b) Information and feedback

(c) Control group

There were no significant differences among the groups with respect to the mean performance on the Nelson-Denny comprehension and rate of reading measures (see Appendix F).

(3) Undetermined

There were twenty-three Ss who, given their basal level of laryngeal emg activity, failed to show consistently either an increase or no increase of this activity during reading on both trials. Since categorization of them as subvocalizers or non-subvocalizers was not possible on the basis of obtained data, and no time was available for further testing, this group did not participate in the remainder of the study.

Final Session

In the final session (for an overview see Table 1) Ss were first retested for increases in laryngeal emg activity during reading following the same procedure as for trial 5. Next all Ss were given a pre-treatment Cloze test; one of the experimental treatments; a post-treatment Cloze test. The purpose of the Cloze tests was to measure the reading rate and comprehension of each S before and after treatment. Each Cloze test[6] consisted of three parts:

1) A prose passage (approximately 300 words, taken from a short story) from which every fifth word was deleted. The S was asked to fill in the missing words by using the context.
2) A different prose passage of similar nature and length but without deletions. The S was asked to read this passage.
3) The latter passage which now had every fifth word deleted. The S was asked to fill in the missing words.

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6. For a more complete description of these tests see Appendix G.

Table 1

Overview of Experimental Treatments During Final Session

SV Group 1 n=16	Retest for Laryngeal emg activity during reading	Cloze test 1 measurement of: 1. Laryngeal emg activity 2. Comprehension and rate of reading	Information-Only Treatment	Cloze test 2 measurement of: 1. Laryngeal emg activity 2. Comprehension and rate of reading
SV Group 2 n=16	Same as Above	Same as Above	Information and Feedback Treatment	Same as Above
NSV Group 1 n=16	Same as Above	Same as Above*	Information-Only Treatment*	Same as Above*
NSV Group 2 n=16	Same as Above	Same as Above*	Information and Feedback Treatment*	Same as Above*
NSV Group 3 n=16	Same as Above	Same as Above*	Control Treatment*	Same as Above*

* using blurred reading materials

For each experimental group (n-16), the order of the Cloze tests was counter-balanced within the group.

The second part of each Cloze test, where the S read the prose passage without deletions was also utilized to measure the laryngeal emg activity before and after the treatment. For this purpose the undeleted passage of each test was mounted on cardboard and placed for the reading in the opthalmograph. The procedure for emg-recording was identical to the one used in the earlier trials. Electrodes were attached, the S was seated at the opthalmograph with the head restrained to prevent movement. Each reading period was again preceded and followed by a 40 second rest period during which the S's eyes were closed.

It should be noted that for NSV-Ss all reading materials during the final session were covered with frosted plexiglass (5 mm thick) in order to evoke subvocal activity.

During the final session three different experimental treatments were used for the NSV-group and two for the SV-group. NSV-Ss in the "information-only" group were told of their laryngeal motor activity during reading of the blurred material and asked to practice inhibiting this activity while reading similar material.

NSV-Ss in the "information and feedback" group received the same information as the previous group and, in addition, were told that they would be able to hear feedback from the induced laryngeal muscle activity while reading. The signal detection system was briefly explained to each one and feedback was demonstrated by channeling the output of the coupling amplifier to the Schmitt trigger. S was then asked to relax and, after a steady relaxation signal was obtained, the triggering threshold of the device was adjusted to just above the relaxation level so that as soon as the S increased his laryngeal motor activity, the tone was heard through the loud-speaker which was placed on the table in front of the S. The S was then requested to "experiment" with the sound by talking and eliminate it by relaxing. Once he had achieved control, he was given the reading materials and instructed to read this material silently while trying to keep the feedback to a minimum, that is, to maintain silence in the loud-speaker.

NSV-Ss in the control group were merely asked to read the material. For all NSV-Ss, the blurred material consisted of difficult passages from reading tests, which were covered with frosted plexiglass (5 mm thick). The practice periods lasted 30 minutes.

For SV-Ss in the "information only" and "information and feedback" groups, the experimental treatment was identical to that used for the respective NSV-groups with one exception: the reading material consisted of light prose without the plexiglass covering. There was no SV-control group.

Experiment 2

Subjects

The subjects were 24 first-year college students (11 females and 13 males) selected from the subvocalizing group of the previous experiment on the basis of availability. Fourteen of these Ss had received the "information-only" treatment. The remaining 10 Ss came from the "information and feedback group".

Apparatus

Apparatus and laboratory were the same as used in experiment 1 with the exception of a modification to the card-holder of the opthalmograph. A black ceramic bead (15 mm) was suspended from a point 30 cm above the centre of the card-holder by a white nylon thread. A card (25 x 30 cm) was cut for the card-holder providing a uniform white background for a 50° excursion of the bead through an arc with the card centre as mid-point.

Procedure

This experiment was performed approximately 3 weeks following experiment 1. Each S received one trial and the general procedure was identical to that used in the previous experiment for measuring the laryngeal emg activity. After familiarization with the apparatus and attachment of the electrodes, etc., the S was instructed to relax and close his eyes, to open his eyes when instructed to do so and to follow the movement of the bead through its arc while keeping his head as still as possible. After 40 seconds he was asked to close his eyes again and to remain relaxed for another 40 seconds. Thus a 40-second period of visual tracking of the bead was bracketed by two 40-second rest periods. Quantification of the signal resulted in nine emg measures for each S, namely, three for each period with each measure representing the RMS value of the emg signal for a period of 6 seconds.

CHAPTER III

RESULTS

Experiment 1

Retest Trial: Figure 1 plots the average laryngeal emg activity for both the SV- and NSV-group during each of the sampling periods of the retest trial. The figure clearly indicates a consistent increase in average laryngeal emg activity during reading for the SV-group; whereas for the NSV-group the activity remained at the resting level during the same period. A two-way analysis of variance was computed to test this difference in laryngeal emg activity between the SV- and the NSV-group. The criterion measures used for this analysis were the mean of all rest measures and the mean of all activity measures for each subject. A highly significant interaction (Table F-6, F 43.7, df 1, 78; $p < .01$) was found between groups and increases in laryngeal emg activity during reading, thereby confirming the reliability of the classification of subjects in SV- and NSV-groups. (A summary of this analysis and all subsequent analyses appear in Appendix F).

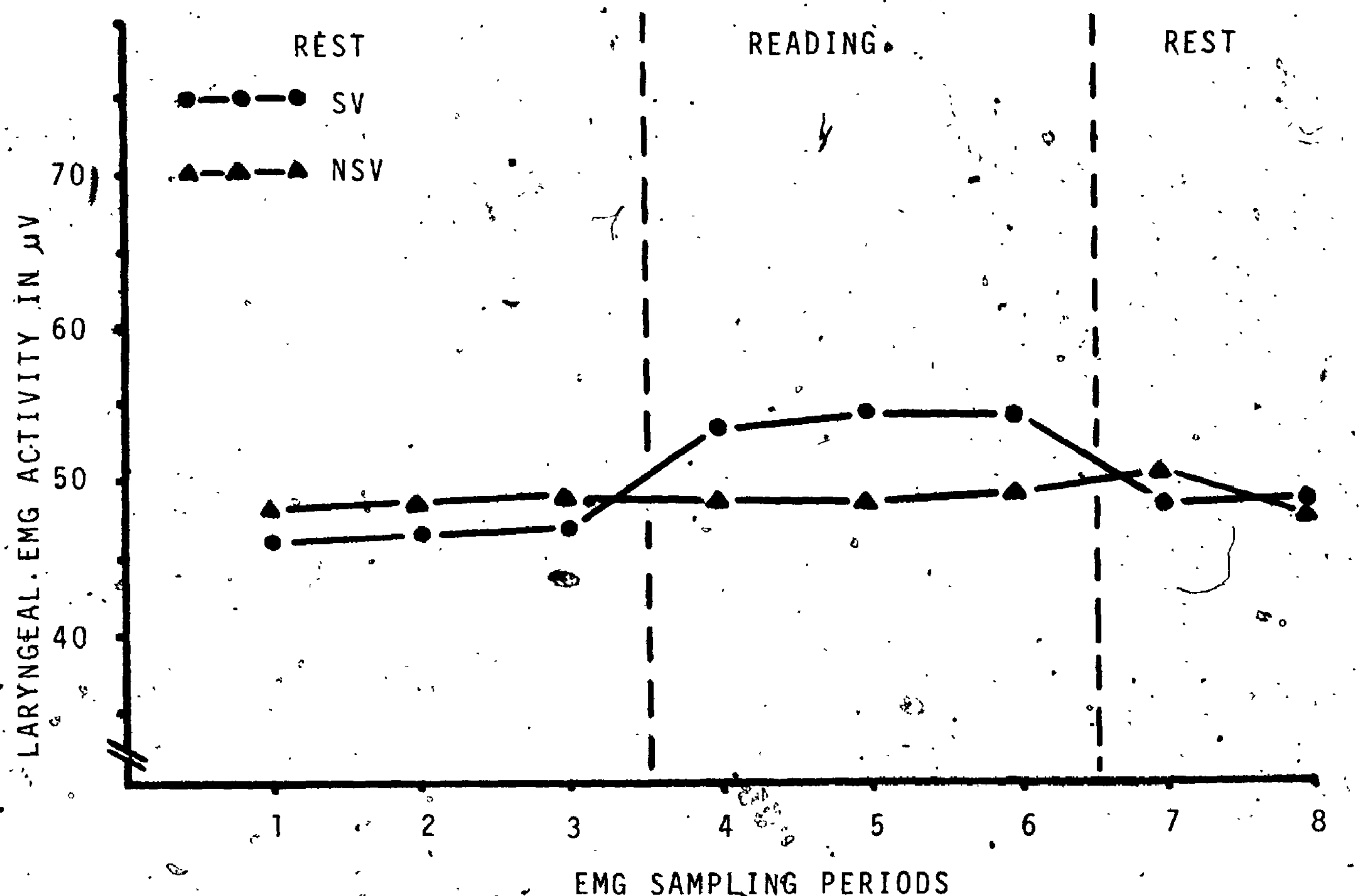

FIGURE 1. AVERAGE (RMS) LARYNGEAL EMG ACTIVITY PER SAMPLING PERIOD FOR SV AND NSV GROUPS DURING RETEST TRIAL, SESSION 3.

Evaluation of the Efficacy of the Auditory Feedback Technique

Performance of SV-Groups: The effects of the experimental treatments on average increases in laryngeal emg activity during reading are shown in Figure 2 and 3. Before treatment, group 1 (information-only) showed a mean increase of 9.3 µV when reading, while group 2 (information and feedback) increased 12.1 µV. After treatment, however, there was a pronounced difference between the two groups. The mean increase for group 1 diminished only slightly during reading (from 9.3 to 6.9 µV), whereas group 2 displayed virtually no increase while reading (dropping from 12.1 to 0.7 µV). To evaluate the effects of the experimental treatments statistically, a two-way analysis of variance was computed comparing treatments and the before/after treatment condition. The criterion measures used in this analysis were logarithms of the emg difference scores. This transformation of scores was undertaken to reduce the variance since the results of Hartley's Fmax test (Winer, p. 93) had confirmed the observation that the group variances were not homogeneous.

The results of the analysis revealed a significant main effect of the before/after treatment condition (Table F-8, F 20.9, df 30, 1, $p<.01$) confirming the reduction of emg activity following treatment. Although the main effect of the treatments was not significant, there was a significant interaction (Table F-8, F 9.02, df 30, 1, $p<.01$) between the treatments and the before/after treatment condition which permits the rejection of the null-hypothesis for treatments and supports the hypothesis that the

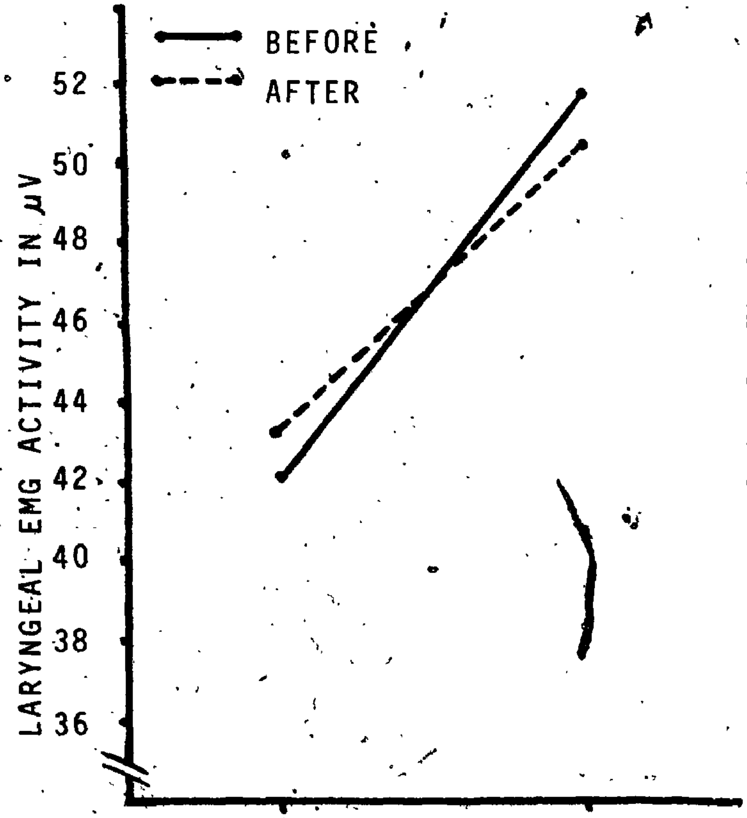

FIGURE 2 LARYNGEAL EMG ACTIVITY DURING REST AND READING, BEFORE AND AFTER TREATMENT FOR SV INFORMATION-ONLY GROUP.

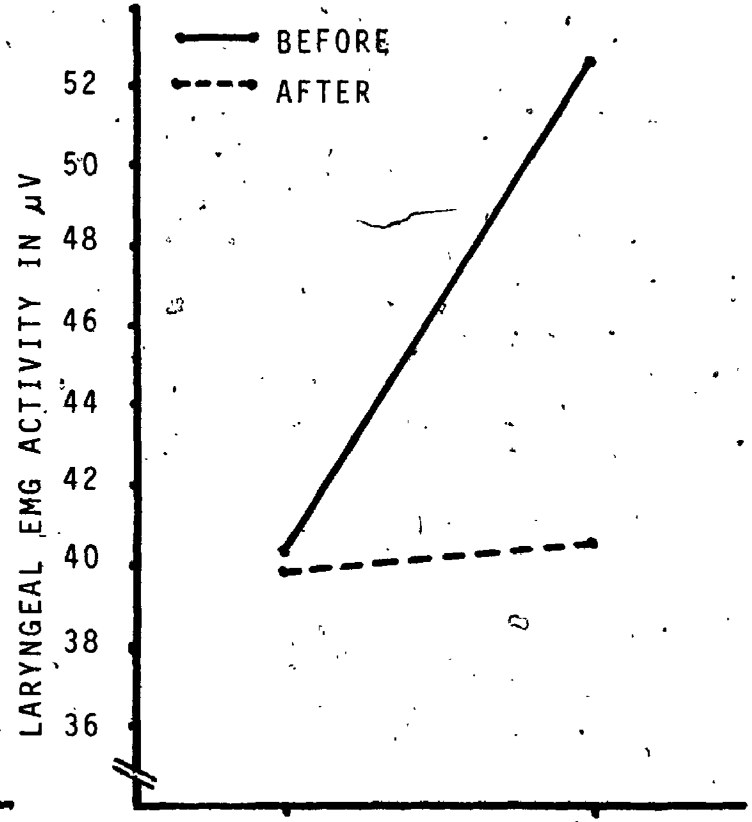

FIGURE 3 LARYNGEAL EMG ACTIVITY DURING REST AND READING, BEFORE AND AFTER TREATMENT FOR SV INFORMATION AND FEEDBACK GROUP.

information and feedback treatment was more efficacious in reducing the occurrence of laryngeal emg activity during reading than the information-only treatment.

To evaluate the post hoc hypothesis that subjects in the SV-groups, who performed above average on the Nelson-Denny reading comprehension test, were responding to the treatments differently from those who scored below average on this test, the analysis of variance was repeated with reading comprehension as a third factor. Using individual scores on the Nelson-Denny comprehension test[7] each treatment group was sub-divided into a high reading comprehension group (the 8 subjects scoring above the median for that group) and a low reading comprehension group (the 8 subjects scoring below the group median). Since no significant main effect or interactions due to comprehension skill were found, this corrollary hypothesis was rejected.

Performance of NSV-Groups: The reading of blurred text by the NSV-groups resulted in considerable increases in laryngeal emg activity. For all groups, the heightened activity immediately followed the onset of reading and tended to increase throughout the period. This was especially true before treatment. An analysis of variance comparing the emg rest values with the emg reading values for the three groups before treatment confirmed that these increases had occurred reliably (Table F-12, F 41.6, df 47, 1, $p<.01$).

[7] It was intended to use Raven's Progressive Matrices Scores for this purpose but due to lack of variance among the scores it was decided to abandon the use of these scores.

Following treatment the increases in emg activity from rest to reading were lessened for all three treatment groups.

To evaluate these changes in emg activity statistically, the same procedure was used as with the SV-groups. A two-way analysis of variance was computed using logarithms of emg difference scores. These scores were arrived at by deducting for each subject the total mean of all rest measures for that subject from the mean of his activity measures. Table 2 shows the grand means of logarithms of these difference scores for each of the treatment groups before and after treatment. The increases after treatment were consistently lower than the increases before treatment. This difference between the before and after conditions was statistically significant (Table F-14, F 11.2, df 45, 2, $p<.01$). But in spite of the lower mean for group 2 (information and feedback) no statistically significant main effect or interaction due to treatments was found. Thus the hypothesis that the information and feedback treatment would be more effective than the information-only and control treatments in reducing laryngeal emg activity in NSV-subjects during reading was not statistically supported.

To test the possibility that the reduction of emg activity during the reading following the treatment may be related to prior comprehension skill, the above analysis was repeated with comprehension skill added as the third factor. Using the subject's scores on the Nelson-Denny comprehension test, each NSV-treatment group was sub-divided into a high reading comprehension group (the 8 subjects scoring above the median of that group) and a low

Table 2

Mean EMG-Increases* for NSV-Groups
During Reading

	Before Treatment	After Treatment
Group 1 (Information only)	1.169	1.035
Group 2 (Information and Feedback)	1.129	0.874
Group 3 (Control)	1.115	1.043

*Note: - Values in Log_{10} µV

reading comprehension group (the 8 subjects scoring below the group median). The results were the same as those for the SV-groups. No significant effects involving comprehension skill were found to be related to the ability to decrease laryngeal emg activity.

Relationship Between Laryngeal Emg Activity and Reading Performance

SV-Groups: To test the hypothesis that the reduction or elimination of consistently occurring laryngeal emg activity during reading was detrimental to subsequent reading performance, mean comprehension scores and rates of reading were calculated for the group of SV-subjects whose laryngeal emg activity following treatment had declined to non-significant levels (n=14). Table 3 shows these means both before and after treatment. Following treatment, the mean comprehension of this group declined slightly (from 50.0 to 49.1) whereas the mean reading speed increased by 5 words per minute (from 211 to 216). For both measures the difference between the pre- and post-treatment means was tested by a t-test and found to be statistically insignificant. The hypothesis, therefore, was not confirmed. It should be noted that the results of this analysis also fail to support the so-called "interference" hypothesis, namely, that the reduction of laryngeal motor activity during reading would facilitate reading performance.

NSV-Groups: The hypothesis that the reduction or elimination of the evoked increases in laryngeal emg activity would be detrimental to the NSV-subjects' reading rate and comprehension during the reading of blurred prose following treatment was tested by

Table 3

A Comparison of Reading Performance Before and After Treatment for SV-Subjects Whose Laryngeal EMG Activity During Reading Had Declined to Non-Significant Levels (N=14).

	Before Treatment	After Treatment
Mean Comprehension Score	50.0	49.1
Mean Reading Rate in Words per Minute	211	216

the same procedure as used for the SV-group. Mean comprehension scores and rates of reading were calculated for the group of NSV-subjects who, following treatment read the blurred material without displaying significant increases in laryngeal emg activity (n=21). Table 4 shows these means both before and after treatment. Following the treatment, the mean comprehension of this group increases from 48.9 to 50.2. The rate of reading also increased by 5 words from 180 to 185 words per minute. These differences between the means were, however, found to be statistically insignificant when tested by t-tests. The hypothesis, therefore, was not supported and, as was the case with the analysis for SV-subjects, the results of this analysis fail also to support the contrary hypothesis, namely, that the reduction of laryngeal motor activity during reading facilitates reading performance.

Secondary Issues

To test the commonly held hypothesis that those who subvocalize while reading are poor readers, the subvocalizing (SV) group (n=32) was compared with the non-subvocalizing (NSV) group (n=48) with respect to their performance on the Nelson-Denny reading test and eye movement measures[8]. Analyses of variance computed for each of these measures revealed no statistically significant mean differences between the two groups (see Appendix F, Table F-5). It may be concluded, therefore, that for this group

[8]Eyemovement data were scored in accordance with the manual for the use of the "Reading Eye" opthalmograph, which is available from Educational Development Laboratories Inc., Huntingdon, New York.

Table 4

A Comparison of Reading Performance Before and After Treatment for NSV-Subjects Whose Laryngeal EMG Activity During Reading Declined to Non-Significant Levels (n=21)

	Before Treatment	After Treatment
Mean Comprehension Score	48.9	50.2
Mean Reading Rate in Words per Minute	180	185

of subjects, the presence of subvocal behaviour during reading is not indicative of poor reading performance. Aarons (1972) also found this was true of a group of medical school students. These findings, in fact, refute the interference hypothesis for this particular group of students. If laryngeal motor activity during reading interferes with reading performance, the SV-group would have been expected to perform less well than the NSV-group.

Experiment 2

To test the hypothesis that the observed increases in laryngeal emg activity during the reading tasks in Experiment 1 were specifically a function of the verbal component of the task and not due to a general state of arousal elicited by the visual scanning aspect of the task, Experiment 2 used a nonverbal task which required eye movements somewhat similar to those required for the tasks in Experiment 1. Two sets of data were examined. The first set was the final (post-treatment) emg measures during rest and reading from Experiment 1 for the group of subjects participating in Experiment 2. The respective rest and reading means for this group were 43.8 µV and 48.9 µV. An analysis of variance was computed comparing the emg rest measures with the emg reading measures. The results of the analysis confirmed that the difference between the rest and reading means was significant (Table F-18, F 11.3, df 1, 23, $p<.01$). Thus these subjects as a group showed a significant increase in laryngeal emg activity when reading <u>before</u> Experiment 2.

The second set of data examined was the laryngeal emg measures for the rest and tracking conditions in the nonverbal task of the present experiment. For these data the group mean for the rest condition was 55.2 uV and the group for the tracking condition was 54.8 uV. An analysis of variance computed for these measures, showed that the difference between the means was not significant (Table F-19). The absence of significant laryngeal emg activity during the scanning condition of the task, therefore, tends to support the experimental hypothesis.

CHAPTER IV

DISCUSSION

The purpose of this study was twofold. Firstly, the study attempted to clarify a methodological issue, namely, the question of the efficacy of auditory feedback in reducing or eliminating laryngeal emg activity. Secondly, the study examined the functional relationship between such activity and reading performance. In this chapter the results of the study will be discussed following the same order, namely, first the methodological issue and, second, the effects of manipulating laryngeal emg activity on reading performance. Finally, some results secondary to the purpose of the study will be discussed.

The efficacy of the auditory feedback technique: The first hypothesis that for both SV- and NSV-groups, the information and auditory feedback treatment would be more effective in reducing laryngeal emg activity than the other treatments was only partially supported. For the SV-group, the comparison between treatments showed clearly that the use of the auditory feedback technique is more efficacious in reducing the laryngeal emg activity during reading than asking the subjects to suppress this activity without the aid of feedback. This finding supports the claim by Hardyck et al. (1966) that rapid extinction of laryngeal emg activity in college students during reading had been achieved by the use of auditory feedback. Evidence from the present study suggests, however, that although the auditory feedback facilitated the reduction of laryngeal motor activity, it was not a necessary condition since four subjects in the "information-only" group also had reduced their laryngeal emg activity to non-significant levels following treatment. It seems therefore, that McGuigan (1967) was justified in suggesting that extraneous variables such as the placement of electrodes in the throat area or instructions to the subjects may play a role in the reduction of the response amplitude.

The significant increases in laryngeal emg activity that occurred for the NSV-groups during the reading of the blurred text, support the second hypothesis of the present study, and sustain Edfeldt's (1960) and McGuigan's (1970) hypothesis that this activity plays a supportive role in the reading process. For this group of subjects, however, the results failed to support the hypothesis that the auditory feedback treatment is more efficacious in reducing the laryngeal emg activity than the other treatments. The data suggest that the lack of a significant difference among these treatments is not due to a failure of the feedback treatment to reduce the activity but rather to the fact that in both of the other treatments decreases in emg activity also took place. One might speculate that for NSV-subjects the use of articulatory motor activity only marginally assists in the decoding of the text and that there is a greater propensity to reduce this activity than there is among SV-subjects.

The relationship between laryngeal emg activity and reading performance: It was predicted (hypotheses #3 and #4) that for the SV- as well as for the NSV-subjects, the reduction or elimination of laryngeal emg activity during reading would be detrimental to their reading rate and comprehension. The results did not support these hypotheses. For both groups of subjects no significant changes in the mean reading rate and comprehension were detected when the laryngeal emg activity during reading had declined to non-significant levels following treatment.

This finding raises some doubt that for the sample of college students used in this experiment, laryngeal motor activity plays an essential role in the reading process. This is still not conclusive evidence that for this group the comprehension of the written material was possible directly from the visual input since the absence of detectable speech motor activity does not rule out the occurrence of laryngeal motor activity below detection level or in the form of a more central activity, e.g., speech imagery. As Conrad (1973) has pointed out: it is easier to prove the presence of a phenomenon than its absence.

In addition to the lack of support for the hypothesis that the occurrence of laryngeal motor activity is beneficial to reading, it should be noted that the results also fail to support, for this group of college students, the so-called "interference" theory. No significant increase in reading rate or comprehension was observed for the two groups of subjects whose laryngeal emg activity had declined following treatment. Also, if the occurrence of laryngeal motor activity interferes with reading performance, one would expect that the subvocalizing (SV) group would score significantly below the non-subvocalizing (NSV) with regard to mean reading performance (comprehension, reading rate, vocabulary, or eyemovements). In the present study no such significant differences were found.

This latter finding also casts doubt on the utility of subvocal behaviour during reading as a symptom of reading disability, at least for college students. College students, by virtue of their educational attainment, statistically represent the upper end of the reading competence distribution and represent a more homogeneous population. At this level true reading disability is rare or non-existent. At the elementary and high school levels, however, where the incidence of reading disability is relatively high, laryngeal emg activity during reading may indeed be highly correlated with reading disability.

The above interpretation seems contrary to Edfeldt's (1960) report that laryngeal emg activity in college students was highly correlated with their scores on a standardized reading test. It should be noted, however, that Edfeldt (1960) recruited his subjects on the basis of their interest in possible improvement in their reading ability. In this way, he may have inadvertently selected those college students who in fact had experienced significant reading problems. In the present study, subjects were chosen at random from the student population. The different sampling procedures may account for the discrepancy in the findings.

Further Findings

The data from the two screening trials clearly demonstrated that significant increases in laryngeal emg activity occurred during the reading of light prose in 31% of the students. This finding is in agreement with the results reported by other studies. Hardyck, Petrinovich and Ellsworth (1966) reported detection of this activity in 34% of their sample of college students and, in a later study (Hardyck and Petrinovich, 1969) they classified 21.5% of the 200 college students sampled as "habitual subvocalizers". Although the criteria for classifying subjects as such may have differed among studies, the available evidence strongly suggests that even in college students, a population which has been exposed to considerable reading practice, the occurrence of significant increases in laryngeal emg activity during reading is common. It has been assumed that such increases are a function of the language component of the task and this assumption was tested in Experiment 2 of the present study. An earlier review of the literature (McGuigan, 1970) showed that although the majority of studies failed to test this assumption, eight studies confirmed that such increases do not take place under non-language conditions and three studies reported evidence to the contrary. Two of the later studies (Wycozoikowska, 1913; Scheck, 1925) recorded tongue movements. Tongue movement is commonly known to be associated not only with verbal behaviour but also with non-verbal tasks requiring precise motor co-ordination. The third study (Sokolov, 1969) used as one of the non-verbal tasks solving Raven's Matrices. Most subjects when solving these matrices, however, carry on with themselves, covertly or overtly, a considerable monologue relating to strategy. This seems to nullify the claim that such a task is essentially non-verbal. For the present research, the reading conditions, including eyemovements, were carefully simulated in a task which required a minimum of covert self-instructions and did not include overt language components. The results supported the assumption that the increased laryngeal emg activity observed in Experiment 1 was related specifically to the language component of the task.

The data of the present study suggest at least two directions for possible future research. First, the evidence suggests that the relation between laryngeal emg activity and reading performance may have an important developmental parameter. It is apparent from the data that,at the college level, the presence of laryngeal emg activity during reading is not a reliable correlate of poor reading performance. Considering the prevailing opinion of teachers that overt speech activity during reading is symptomatic of reading disability, it is suggested that future studies determine the incidence of laryngeal emg activity during reading for different levels of development and correlate this activity with reading performance.

Second, a potential useful approach for future research may be to focus on possible differences in the way NSV- and SV-subjects recode verbal materials during reading. In particular, it may be useful to determine whether these two groups of subjects differ in their ability to use auditory images. Sperling (1967) and Conrad (1973) have shown that short term memory involves the rehearsal of verbal material in the form of either auditory images or, auditory images and articulatory activity. Conrad (1973) has urged the consideration of the significance of short term memory in reading. He emphasizes that in reading we need to hold on to one or more words or to a group of words while considering the related implication of subsequent words or ideas.

Given the findings of STM research, it is plausible that NSV-subjects as a group may be more capable of rehearsing verbal materials in the form of auditory imagery than SV-subjects who may require the additional peripheral motor activity to make the rehearsal effective.

Finally, although not a direct implication of the present study, it is suggested that a more detailed analysis of the reading material associated with variations in laryngeal emg activity may be informative. For example, it may be possible to differentiate certain semantic or syntactic dimensions of written material that correlate with significant increases in laryngeal emg activity. The information yielded by such an analysis may clarify what coding strategies are used during reading.

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APPENDICES

APPENDIX A

The Nelson-Denny Reading Test (Form A)

Previously copyrighted material
in Appendix A not microfilmed.

Leaves 55-61.

APPENDIX B

Samples of Raven's Progressive Matrices (1958)

THE DESIGN AND USE OF THE SCALE

> *"... To understand the respective natures of eduction and reproduction—in their trenchant contrast, in their ubiquitous co-operation and in their genetic inter-linkage—to do this would appear to be for the psychology of individual abilities and even for that of cognition in general, the very beginning of wisdom."* (C. SPEARMAN.)

While the Mill Hill Vocabulary Scale is designed to assess a person's ability to recall acquired information, Progressive Matrices (1938) was constructed on the *a priori* assumption that if Spearman's principles of noegenesis were correct, it should provide a test suitable for comparing people with respect to their immediate capacities for observation and clear thinking. Reported investigations show how far, and under what conditions, these two complementary tests provide a practical means of assessing a person's intellectual development, trainability or mental impairment.

Progressive Matrices (1938) is a test of a person's capacity at the time of the test to apprehend meaningless figures presented for his observation, see the relations between them, conceive the nature of the figure completing each system of relations presented, and, by so doing, develop a systematic method of reasoning.

The scale consists of 60 problems divided into five sets of 12. In each set the first problem is as nearly as possible self-evident. The problems which follow become progressively more difficult. The order of the tests provides the standard training in the method of working. The five sets provide five opportunities for grasping the method and five progressive assessments of a person's capacity for intellectual activity. To ensure sustained interest and freedom from fatigue, the figures in each problem are boldly presented, accurately drawn and, as far as possible, pleasing to look at. The scale is intended to cover the whole range of intellectual development from the time a child is able to grasp the idea of finding a missing piece to complete a pattern, and to be sufficiently long to assess a person's maximum capacity to form comparisons and reason by analogy without being unduly exhausting or unwieldy. The scores obtained by adults tend to cluster in the upper half of the scale, but there are enough difficult problems to differentiate satisfactorily between them.

Everyone, whatever his age, is given exactly the same series of problems in the same order and is asked to work at his own speed, without interruption, from the beginning to the end of the scale. As the order of the problem provides the standard training in the method of working, the scale can be given either as an individual, a self-administered or as a group test. A person's total score provides an index of his intellectual capacity, whatever his nationality or education.* The contribution which each of the five sets makes to the total provides a means of assessing the consistency of the estimate and the psychological significance of discrepancies in the test results.

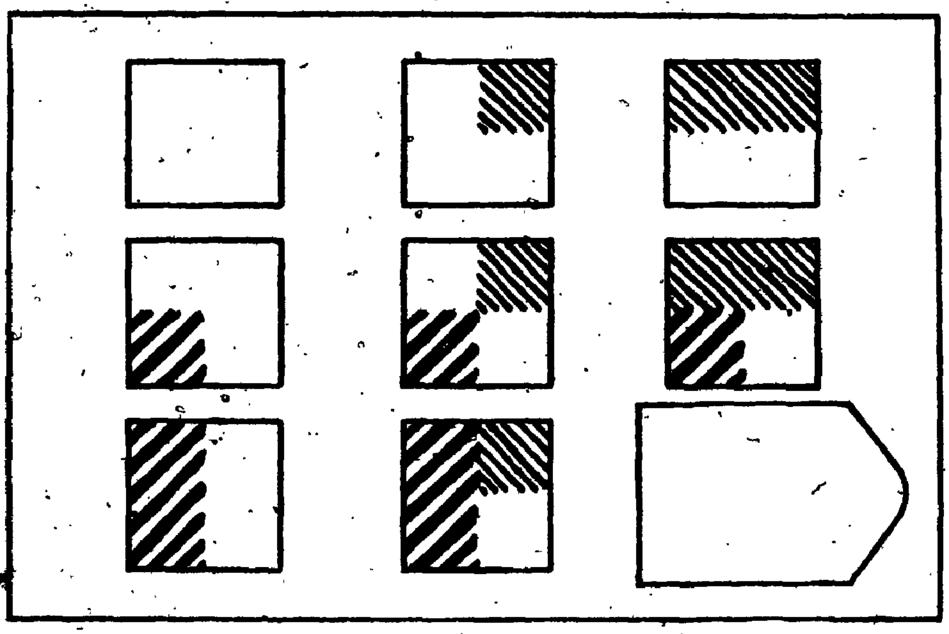
* From published correlations between children's scores on Progressive Matrices (1938) and tests of reading, spelling and elementary arithmetic, the scale appears to justify this claim, although conclusions based on score correlations can never be accepted uncritically.

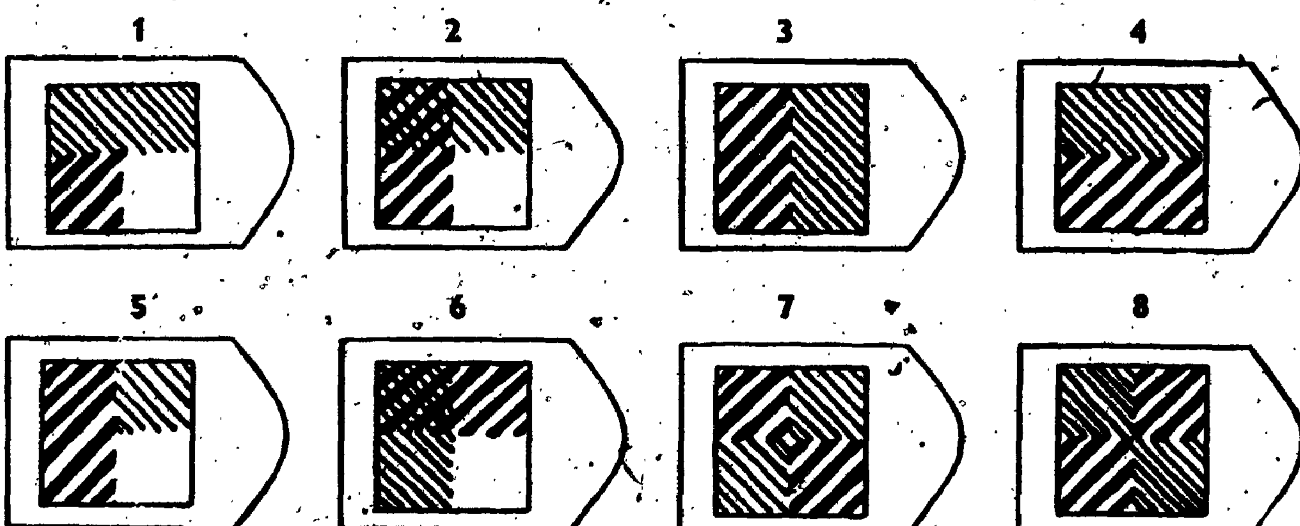
It is often useful to describe the scale as a test of observation or clear thinking. *By itself* it is not a test of "general intelligence" and it is always a mistake to describe it as such. Each problem in the scale is really the "mother" or "source" of a system of thought—hence the name "Progressive Matrices". The scale has a re-test reliability varying, with age, from 0.83 to 0.93. It correlates 0.86 with the Terman-Binet test, and has been found to have a G saturation of 0.82.†

Young children, mentally defective persons and very old people are not expected to solve more than the problems in Sets A and B of the scale and the easier problems of Sets C and D, where reasoning by analogy is not essential. After they can no longer solve the problems, they may still choose the correct answer by chance. For normal adults, Sets A and B provide little more than training in the method of working. If a person is allowed only a limited time and does not complete the easy problems of Sets D and E before stopping, the total estimate is not necessarily valid. When the 1938 scale was constructed, these limitations were known. Enquiries carried out since 1938 have shown that in practice, as an untimed capacity test and also as a 20-minute speed or "efficiency" test, the results obtained with adults are more reliable and psychologically valid than one might expect from so few effective problems arranged in sets of overlapping difficulty. As originally intended, the scale has in practice proved to be suitable for use with both adults and children.

† Professor Sir Cyril Burt—Data based on test results of 1,000 seamen placed before the War Cabinet Expert Committee on the work of psychologists and psychiatrists in the Services.

C 12





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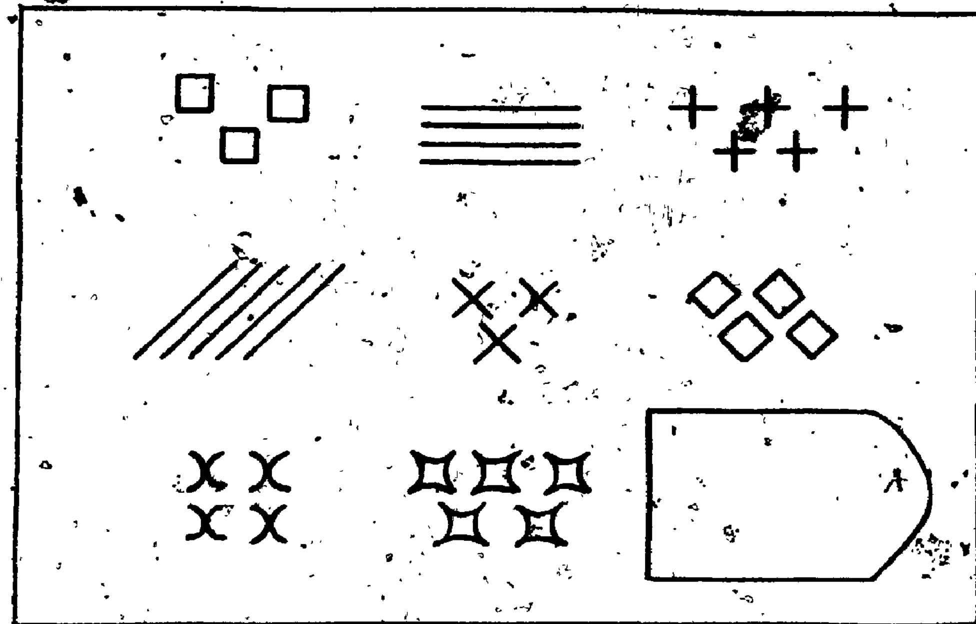

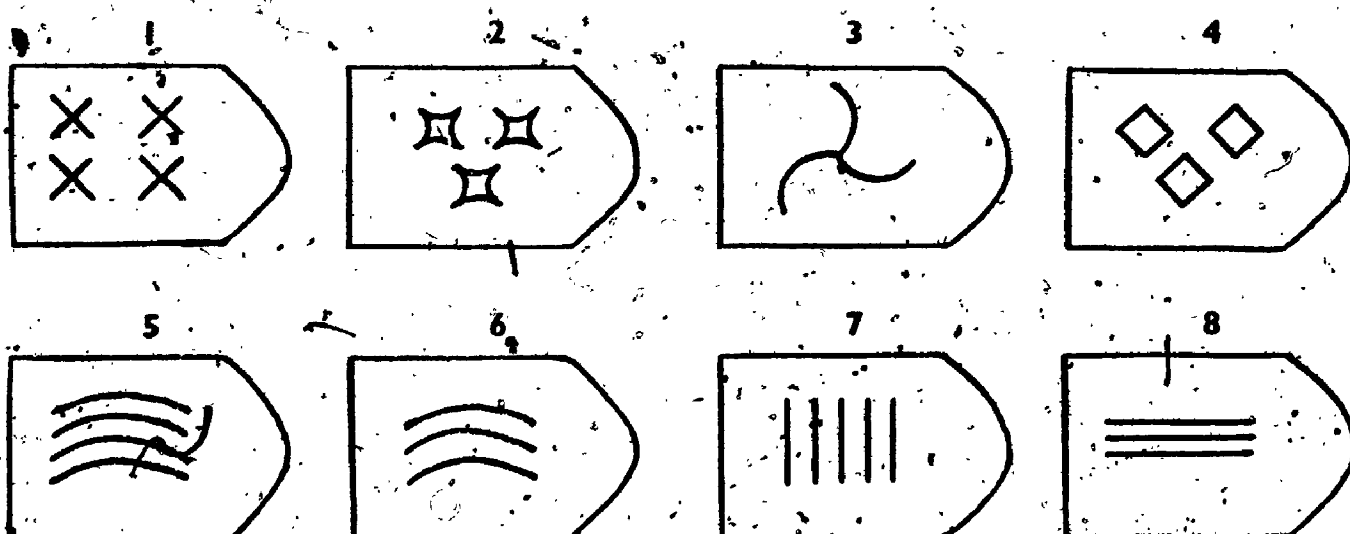

APPENDIX C

Eyemovement Photography

Eyemovement Photography

An additional aspect of reading performance which can be measured is the movement of the eyes across the reading material. Photographing these movements not only indicates the occurrence of reading but is also generally accepted as a useful aid in the diagnosis of reading difficulties. Early studies of eye movements during reading reviewed by Taylor (1959) showed that all people read with a series of stops, or fixations between movement of the eyes along the print and that for most people reverse movements or regressions are interspersed with forward eye movements.

The validity of eyemovement photography as a technique of studying these movements was investigated by Gilbert and Gilbert (1942) and Tinker (1934, 1958). Their research indicated that good and poor readers can be differentiated in terms of their eye movements, e.g., poor or beginning readers make more fixations per line, take more time per fixation, and have less well-organized patterns of movement than do good or experienced readers. Many individuals who show fairly normal performance on standardized tests of comprehension and who apparently can read materials appropriate to their education nevertheless have been shown to employ ineffectual habits of eye movement. They may consistently show excessive regressions or abnormal duration of fixation pauses, or a very high number of fixations and a small recognition span.

In the present study eyemovement measures were recorded for several reasons. First, the use of these measures provided additional information about the subjects' reading performance. Second, the use of the camera provided an ideal situation for distracting the Ss' attention from the objective of the study, namely, the recording of articulatory motor activity. Thirdly, the use of the eyemovement camera with its fixed reading stand, illumination, and headrest helped to control for movement of the neck muscles, the distance between the subject's eyes and the reading material, and the illumination of the reading material.

APPENDIX D

Placement of EMG Electrodes

Placement of the Electrodes in Relation to the Anatomy of the Larynx.

As Edfeldt (1960) has pointed out, if any speech movement occurs when the subject reads silently, it should be demonstrated in the musculature of the larynx. The larynx, under normal conditions, produces the basic sound which is modified by the other parts of the speech mechanism such as the pharynx, tongue, lips, etc., into distinctive speech. The larynx itself consists of the cricoid cartilage, the thyroid cartilage, the arytenoid cartilages, the outer laryngeal muscles which move or fix the whole larynx and the intrinsic laryngeal muscles which move the vocal cords. Faaborg-Anderson (1957), using needle electrodes placed directly into the muscles, found that in the latter group of muscles, the vocal muscle and the cricothyroid showed an increase in emg activity during silent reading while the crico-arytenoid showed a decrease in activity. The present writer, in a preliminary study using miniature surface electrodes, found that a maximum increase of emg activity during speech was recorded when both active electrodes were placed over the cricothyroid interval with the centre of each electrode 1 cm lateral of the inferior horn of the thyroid cartilage. Placement at this point ensures that each electrode is located directly above a cricothyroid muscle and within short distance (approximately 2 cm) of the vocal muscles.

APPENDIX E

Quantification of EMG Recordings

Emg Quantification

A brief account of some of the aspects of the evaluation of electromyograms may be useful considering recent developments in this area. The psychologist generally is most interested in the quantitative aspect of the emg record, i.e., how well it represents muscular effort in a given unit of time. The reduction of the raw emg signal with its many positive and negative spikes into a smoothly varying d.c. signal is accomplished by electronic integrators, and the process is referred to as integration. The most commonly used integration technique utilizes the continuous definite integral. Acting as a running averager, this technique gives an analogue approximation of the electrical energy represented in the raw emg signal. This permits sampling of the amplitude at given intervals and an approximate measure of muscular activity during those periods. Bigland and Lippold (1954) have shown that integrated potentials vary directly with the strength of muscular contraction.

An accurate method of quantification of the emg signal has become available with the development of high-speed digital computers. This method employs the computer to sample the raw emg signal at an extremely high rate and to calculate and print out, at specified intervals, the average RMS value of the signal. Information theory states that a band-limiting signal can be represented by samples taken at two per cycle at the highest frequency to be used (Turski, 1964). Since 1000 Hz is an acceptable upper limit of the band width for emg signals (Basmajian, 1967), the sampling rate of 2000 samples per second was chosen for quantification of the emg data collected in the present study.

APPENDIX F

Summaries of Statistical Analyses

Table F-1

Summary of analysis of variance of comprehension scores (Nelson-Denny Reading Test) for subvocalizing (SV) college students as a function of treatment groups.

Source	df	MS	F
Treatments	1	72.0	.607
S's W.	30	118.6	
Total	31		

Table F-2

Summary of analysis of variance of reading rates (Nelson-Denny Reading Test) for subvocalizing (SV) college students as a function of treatment groups.

Source	df	MS	F
Treatments	1	3549.03	.287
S's W.	30	12365.07	
Total	31		

Table F-3

- Summary of analysis of variance of comprehension scores (Nelson-Denny Reading Test) for non-subvocalizing (NSV) college students as a function of treatment groups.

Source	df	MS	F
Treatments	2	17.06	.184
S's	45	92.52	
Total	47		

Table F-4

Summary of analysis of variance of reading rates (Nelson-Denny Reading Test) for non-sub-vocalizing (NSV) college students as a function of treatment groups.

Source	df	MS	F
Treatments	2	4966.94	.608
S's W.	45	8171.63	
Total	47		

Table F-5

Comparison of mean scores for subvocalizing (SV) and non-subvocalizing (NSV) college students for the Nelson-Denny Reading Test and Eyemovement Measures.

Measure	SV-Mean	NSV-Mean	t	df	p
N.D.-Reading Rate	363.0	325.0	1.61	69	N.S.
N.D.-Comprehension	52.1	51.7	.20	69	N.S.
N.D.-Vocabulary	49.3	48.4	.32	69	N.S.
Fixations p.100.W.	84.4	88.0	.95	69	N.S.
Regressions p.100.W.	11.7	12.5	.77	69	N.S.
Av. Span of Recogn.	1.2	1.2	.00	69	N.S.
Av. Duration of Fix.	28.8	28.0	1.09	69	N.S.
Reading Rate	280.9	256.5	1.22	69	N.S.

Table F-6

Summary of analysis of variance of the magnitude of increases in laryngeal emg-activity in college students as a function of two levels of classification (SV or NSV) and two experimental conditions (rest or reading).

Source	df	MS	F
Classification (A)	1	98.24	.29
Subj. within groups	78	342.00	
Experimental Cond. (B)	1	290.25	27.15**
A x B	1	466.91	43.67**
B x subjects w. groups	78	10.69	

** p <.01

Table F-7

Computation of Hartley's F_{max} test for homogeneity of variance for emg difference scores for SV-subjects, before and after treatment.

SV Group 1	Before Treatment	S^2 = 3201.3
	After Treatment	S^2 = 5740.1
SV Group 2	Before Treatment	S^2 19905.6
	After Treatment	582.2

$$\text{Observed } F_{max} = \frac{99905.6}{582.2} = 171.6$$

$$\text{Critical Value } F_{max .99} \ (k=4, n=15) = 5.5$$

Table F-8

Summary of analysis of variance of magnitude of increases in laryngeal emg-activity in subvocalizing college students as a function of treatment (information-only or feedback-and-information), and experimental condition (before or after treatment).

Source	df	MS	F
Treatment (A)	1	.105	2.349
Error Between	30	.044	
Total	31		
Experimental Cond. (B)	1	.573	20.919 **
A x B	1	.247	9.023 **
Error Within	30	.027	
Total Within	32		
Total	63		

** p<.01

Table F-9

Summary of analysis of variance of magnitude of increases in laryngeal emg-activity in subvocalizing college students as a function of treatment (information-only or feedback-and-information), experimental condition (before and after treatment), and comprehension skill (above or below median).

Source	df	MS	F
Treatment (A)	1	.140	
Skill (B)	1	.004	
A x B	1	.133	
Error Between	28	.036	
Total Between	31		
Exp. Condition (C)	1	.652	25.76 **
A x C	1	.200	7.91 **
B x C	1	.017	
A x B x C	1	.017	
Error Within	28	.025	
Total Within	32		
Total	63		

** $p<.01$

Table F-10

Summary of analysis of variance of changes in the reading rate of selected college students as a function of changes in laryngeal emg-activity (decline or no-decline).

Source	df	MS	F
Between	1	59826.70	14.83 **
Within	28	4034.05	
Total	29		

**$p < .01$

Table F-11

Summary of analysis of variance of changes in reading comprehension of selected college students as a function of changes in laryngeal emg-activity (decline or no decline).

Source	df	MS	F
Between	1	7374.06	55.77 **
Within	28	132.22	
Total	29		

**p<.01

Table F-12

Summary of analysis of variance of changes in laryngeal emg activity of NSV college students as a function of experimental condition (rest or reading) before treatments.

Source	df	MS	F
Experiment Cond. (A)	1	2311.8	41.59 **
Subjects (B)	47	490.2	
A x B	47	55.6	
Total	47		

$^{**}p<.01$

Table F-13

Computation of Hartley's F_{max} test for homogeneity of variance for emg difference scores for NSV-subjects, before and after treatment.

NSV Group 1	Before Treatment	S^2 = 3384.9
	After Treatment	S^2 = 361.8
NSV Group 2	Before Treatment	S^2 = 581.7
	After Treatment	S^2 = 653.6
NSV Group 3	Before Treatment	S^2 = 1664.2
	After Treatment	S^2 = 1645.2

Observed $F_{max} = \frac{3384.9}{581.7} = 5.8$

Critical Value $F_{max\ .99}$ (k=6, n=15) = 4.7

Table F-14

Summary of analysis of variance of differences in laryngeal emg activity of NSV college students as a function of treatments (information-only, information and feedback, or control) and experimental condition (before or after treatment).

Source	df	MS	F
Treatments (A)	2	0.088	1.48
Error between	45	0.059	
Exp. Condition (B)	1	0.567	11.19 **
A x B	2	0.069	1.37
Error within	45	0.050	
Total	95		

**p<.01

Table F-15

Summary of analysis of variance of differences in laryngeal emg activity of NSV college students as a function of treatment (information-only, information and feedback, or control), experimental condition (before or after treatment), and comprehension skill (above or below the median).

Source	df	MS	F
Treatment (A)	2	0.088	1.59
Compr. Skill	1	0.044	0.80
A x B	2	0.155	2.79
Error between	42	0.055	
Exp. Condition (C)	1	0.567	11.20 **
A x C	2	0.069	1.37
B x C	1	0.032	0.64
A x B x C	2	0.060	1.19
Error within	42	0.050	
Total	95		

**$p < .01$

Table F-16

Summary of analysis of variance of changes in reading rate of NSV college students as a function of changes in laryngeal emg activity (decline or no-decline).

Source	df	MS	F
Between	1	4629.49	1.20 N.S.
Within	33	3850.99	
Total	34		

Table F-17

Summary of analysis of variance of changes in reading comprehension of NSV college students as a function of changes in laryngeal emg activity (decline vs no-decline).

Source	df	MS	F
Between	1	2.63	0.018 N.S.
Within	33	140.79	
Total	34		

Table F-18

Summary of analysis of variance of differences in laryngeal emg activity as a function of experimental condition (rest or reading) at the conclusion of Experiment 1 for the subjects participating in Experiment 2.

Source	df	MS	F
Exp. Condition (A)	1	307.55	11.25 **
Subjects (B)	23	235.39	
A x B	23		
Total	47		

**p<.01

Table F-19

Summary of analysis of variance of differences in laryngeal emg activity as a function of experimental condition (rest or tracking) for subjects in Experiment 2.

Source	df	MS	F
Treatments (A)	1	1.80	0.8
Subjects (B)	23	751.31	
A x B	23	2.24	
Total	47		

2 OF/DE 2

APPENDIX G

Measurement of Reading Performance

and Copies of Cloze Tests

Measurement of Reading Performance

The most commonly used measures of reading performance are rate of reading, i.e., the number of words an individual reads in a given time unit, and the individual's comprehension of the written material. The latter measure is a more difficult one. Although a great number of reading comprehension tests are available, the test constructors have failed to provide a theoretical framework for measuring reading comprehension and the concept itself seems to be composed of at least nine factors, the most important ones of which are: (1) knowledge of word meaning, and (2) the ability to select the appropriate meaning for a word or a phrase in the light of its contextual setting (Davis, 1944). The general method of measuring reading comprehension has been to provide the student with a number of passages which are read under timed conditions and followed by multiple-choice type of tests. The typical scoring formula provides for a compilation of scores. Usually no effort is made to determine whether an individual has previous knowledge of the subject matter. Research has shown that college students taking the test without reading the passages achieve considerably better than chance (Preston, 1964). It seems then that the results of such comprehension tests reflect a combination of knowledge possessed before reading plus knowledge gained while reading. In addition, the actual skills measured vary from test to test depending on the materials used and the construction of the items.

For the purpose of the present investigation a method of measuring reading comprehension developed by Wilson Taylor (1953) was thought to have several desirable characteristics. This method is called the Cloze procedure and the test is produced by deleting every n-th word from a written passage and instructing the subject to fill in the missing blanks by utilizing the clues available in the remaining context. The Cloze procedures can be used to measure the amount of information <u>gained</u> through reading by administering a pre-Cloze test,[1] having the <u>S</u> then read an article, and, finally, administering a post-Cloze test based on that article. The difference between pre- and post-test performance is considered a measure of gain in comprehension.

The concurrent validity of the Cloze procedure as a measure of specific reading comprehension was determined by correlating Cloze test results with scores on traditional comprehension tests covering the same material as the Cloze test. Taylor (1957) reported a correlation of .80 between a post-Cloze, any-word deletion test and a comprehension test. Rankin (1959) obtained a correlation of .78 between a post-Cloze, noun-verb deletion test and a criterion test. Jenkinson (1957) found a

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1 The term "pre-Cloze" test refers to a Cloze test which is taken before reading the original, unmutilated passage. The "post-Cloze" test is taken after reading the unmutilated article upon which the test is based. Various types of deletions refer to the grammatical forms of the words that are deleted. An "any-word" deletion, for example, refers to a Cloze test formed by deleting words without regard to the grammatical form.

correlation of .82 between a pre-Cloze, any-word deletion test and a comprehension test. Bormuth (1962) correlated 9 pre-Cloze, any-word deletion tests with criterion tests and found correlations ranging from .73 to .84. The correlation between combined Cloze tests and comprehension tests was .93. In addition, he found the Cloze tests to be influenced by the same variables (e.g., educational levels of the readers, difficulty of materials, and subject matter) as the criterion tests. He found also substantial correlations between the Cloze test results and each of nine different aspects of comprehension measured by his criterion tests. In summary, the Cloze procedure appears to be a highly valid measure of specific reading comprehension of a particular passage and since the tests are also easily constructed and scored, this technique seemed an appropriate choice for the measurement of comprehension in the present investigation.

CLOZE TEST FORM 1

(from "The Devil and Daniel Webster" by S. V. Benét)

He'd been contented enough, the first few years. It's a great thing when bad luck turns; it drives most other things out of your head. True, every now and then, especially in rainy weather, the little white scar on his finger would give him a twinge. And once a year, punctual as clockwork, the stranger with the handsome buggy would come driving by. But the sixth year, the stranger lighted and, after that, his peace was over for Jabez Stone. The stranger came up through the lower field, switching his boots with a came; they were handsome black boots, but Jabez Stone never liked the look of them, particularly the toes. And, after he'd passed the time of day, he said, "Well, Mr. Stone, you're a hummer. It's a very pretty property you've got here Mr. Stone."

"Well, some might favour it and others might not," said Jabez Stone, for he was a New Hampshireman. "Oh, no need to decry your industry," said the stranger, very easy showing his teeth in a smile. "After all, we know what's been done, and it has been according to contract and specifications. So when the mortgage falls due next year, you shouldn't have any regrets." "Speaking about that mortgage, Mister," said Jabez Stone, and he looked around for help to the earth and sky, "I am beginning to have one or two doubts about it."

"Doubts?" said the stranger, not quite so pleasantly. "Why, yes." said Jabez Stone. "This being the U.S.A. and me having been a religious man." He cleared his throat and got bolder. "Yes, sir," he said, "I'm beginning to have considerable doubts as to that mortgage holding in court." "There's courts and courts," said the stranger, clicking his teeth. "Still, we might as well have a look at the original document." And he hauled out a big black pocketbook, full of papers. "Sherwin, Slater, Stevens, Stone," he muttered, "I, Jabez Stone, for a term of seven years; it is quite in order, I think."

CLOZE TEST FORM 1 - deleted version

He'd been contented ______, the first few ______. It's a great thing ______ bad luck turns; it ______ most other things out ______ your head. True, every ______ and then, especially in ______ weather, the little white ______ on his finger would ______ him a twinge. And ______ a year, punctual as ______ the stranger with the ______ buggy would come driving ______. But the sixth year, ______ stranger lighted and, after ______, his peace was over ______ Jabez Stone. The stranger ______ up through the lower ______, switching his boots with ______ cane; they were handsome ______ boots, but Jabez Stone ______ liked the look of ______, particularly the toes. And, ______ he'd passed the time of day, he said, "Well, ______ Stone, you're a hummer. It's a very pretty ______ you've got here Mr. ______."

"Well, some might favour ______ and others might not," ______ Jabez Stone, for he ______ a New Hampshireman. "Oh, ______ need to decry your ______," said the stranger, very ______ showing his teeth in ______ smile. "After all, we ______ what's been done, and ______ has been according to ______ and specifications. So when ______ mortgage falls due next ______, you shouldn't have any ______." "Speaking about that mortgage, ______," said Jabez Stone, and ______ looked around for help ______ the earth and sky," ______ am beginning to have ______ or two doubts about ______."

"______?" said the stranger, ______ quite so pleasantly. "Why, ______," said Jabez Stone. "This ______ the U.S.A. and me having been a religious _____." He cleared his throat ______ got bolder. "Yes, sir," _____ said, "I'm beginning to ______ considerable doubts as ______ that mortgage holding in ______." "There's courts and courts," ______ the stranger, clicking his ______. "Still, we might as ______ have a look at ______ original document." And he ______ out a big black ______, full of papers. "Sherwin, ______, Stevens, Stone," he muttered, "______; Jabez Stone, for a ______ of seven years; it ______ quite in order, I ______."

CLOZE TEST FORM 2

(from "The Devil and Daniel Webster" by S. V. Benét)

It was something that looked like a moth, but it wasn't a moth. And as Jabez Stone stared at it, it seemed to speak to him in a small sort of piping voice, terribly small and thin, but terribly human. "Neighbour Stone," it squeaked. "Neighbour Stone. Help me, for God's sake, help me." But before Jabez Stone could stir hand or foot, the stranger shipped out a big bandanna handkerchief.

"As I was saying." But Jabez Stone was shaking all over like a scared horse. "That's Miser Stevens' voice," he said, in a croak. "And you've got him in your handkerchief." The stranger looked a little embarrassed. "Yes, I really should have transferred him to the collecting box," he said with a simper, "but there were some rather unusual specimens there and I didn't want them crowded. Well, well, these little contretemps will occur." "I don't know what you mean by contertan," said Jabez Stone, "but that was Miser Stevens' voice. And he ain't dead. You can't tell me he is. He was just as spry and mean as a woodchuck, Tuesday."

"In the midst of life," said the stranger, kind of pious. "Listen." Then a bell began to toll in the valley and Jabez Stone listened, with the sweat running down his face. For he knew it was tolled for Miser Stevens and that he was dead. "These long-standing accounts," said the stranger with a sigh; "one really hates to close them. But business is business." He had still the bandanna in his hand, and Jabez Stone felt sick as he saw the cloth struggle and flutter. "Are they all as small as that?" he asked hoarsely. "Small?" said the stranger. "Oh, I see what you mean. Why, they vary." He measured Jabez Stone with his eyes, and his teeth showed. "Don't worry, Mr. Stone," he said. You will go with a very good grade. I wouldn't trust you outside the collecting box.

CLOZE TEST FORM 2 - deleted version

It was something that _____ like a moth, but _____ wasn't a moth. And _____ Jabez Stone stared at _____, it seemed to speak _____ him in a small _____ of piping voice, terribly _____ and thin, but terribly _____. "Neighbour Stone," it squeaked. "_____ Stone. Help me, for _____ sake, help me" But _____ Jabez Stone could stir _____ or foot, the stranger _____ out a big bandanna _____.

"As I was _____." But Jabez Stone _____ shaking all over like _____ scared horse. "That's Miser _____ voice," he said, in _____ croak. "And you've got _____ in your handkerchief." The _____ looked a little embarrassed. "_____, I really should have _____ him to the collecting _____," he said with a _____, "but there were some _____ unusual specimens there and _____ didn't want them crowded. _____ well, these little contretemps _____ occur." "I don't know _____ you mean by contertan," _____ Jabez Stone, "but that _____ Miser Stevens' voice. And _____ ain't dead. You can't _____ me he is. He _____ just as spry and _____ as a woodchuck, Tuesday."

"_____ the midst of life," _____ the stranger, kind of _____. "Listen." Then a bell _____ to toll in the _____ and Jabez Stone listened, _____ the sweat running down _____ face. For he knew _____ was tolled for Miser _____ and that he was _____. "These long-standing accounts," _____ the stranger with a _____; "one really hates to _____ them. But business is _____." He had still the _____ in his hand, and _____ Stone felt sick as

_____ saw the cloth struggle _____ flutter. "Are they all _____ small as that?" he _____ hoarsely. "Small?" said the _____. "Oh, I see what _____ mean. Why, they vary." _____ measured Jabez Stone with _____ eyes, and his teeth _____. "Don't worry, Mr. Stone," he said., You will go with a _____ good grade. I wouldn't _____ you outside the collecting _____.

CLOZE TEST FORM 3

(from "Just Before the War with the Eskimos" by J. D. Salinger)

Left alone, Ginnie looked around, without getting up, for a good place to throw out or hide the sandwich. She heard someone coming through the foyer. She put the sandwich in her polo-coat pocket. A young man in his early thirties, neither short nor tall, came into the room. His regular features, his short haircut, the cut of his suit, the pattern of his silk tie gave out no real information. He might have been on the staff, or trying to get on the staff, of a newsmagazine. He might have just been in a play that closed in Philadelphia. He might have been with a law firm.

"Hello," he said, cordially, to Ginnie.

"Hello."

"Seen Franklin?" he asked.

"He's shaving. He told me to tell you to wait for him. He will be right out."

"Shaving. Good heavens," the young man looked at his wrist-watch. He then sat down in a red damask chair, crossed his legs, and put his hands to his face. As if he were generally weary, or had just undergone some form of eyestrain, he rubbed his closed eyes with the tips of his extended fingers. "This has been the most horrible morning of my entire life," he said, removing his hand from his face. He spoke exclusively from the larynx, as if he were altogether too tired to put any diaphram breath into his words. "What happened?" Ginnie asked, looking at him.

"Oh......It's too long a story. I never bore people I haven't known for at least a thousand years." He starred vaguely, discontentedly, in the direction of the windows. "But I shall never again consider myself even the remotest judge of human nature. You may quote me wildly on that." "What happened?" Ginnie repeated. "Oh, God. ~~This~~ person ~~who's been sharing~~ my apartment for months and months and months; I don't even want to talk to him..... This writer," he added with satisfaction, probably remembering a favourite anathema from a Hemingway novel.

CLOZE TEST FORM 3 - deleted version

_____ alone, Ginnie looked around, _____ getting up, for a _____ place to throw out _____ hide the sandwich. She _____ someone coming through the _____. She put the sandwich _____ her polo-coat pocket. A _____ man in his early _____, neither short nor tall, _____ into the room. His _____ features, his short haircut, _____ cut of his suit, _____ pattern of his silk _____ gave out no real _____. He might have been _____ the staff, or trying _____ get on the staff, _____ a newsmagazine. He might _____ just been in a _____ that closed in Philadelphia. _____ might have been with _____ law firm.

"Hello," he said _____, to Ginnie.

"Hello."

"Seen _____?" he asked.

"He's shaving. _____ told me to tell _____ to wait for him. _____ will be right out."

"_____. Good heavens," the young _____ looked at his wristwatch. _____ then sat down in _____ red damask chair, crossed _____ legs, and put his _____ to his face. As _____ he were generally weary, _____ had just undergone some _____ of eyestrain, he rubbed _____ closed eyes with the _____ of his extended fingers. "_____ has been the most _____ morning of my entire _____," he said, removing his _____ from his face. He _____ exclusively from the larynx, _____ if he were altogether _____ tired to put any _____ breath into his words. "What happened?" Ginnie asked, looking _____ him.

"Oh.....It's too long a _____. I never bore people _____ haven't known for at _____ a thousand years." He _____ vaguely, discontentedly, in the _____ of the windows. "But _____ shall never again consider _____ even the remotest judge _____ human nature. You may _____ me wildly on that." "_____ happened?" Ginnie repeated. "Oh, _____. This person who's been _____ him...... This writer," he _____ with satisfaction, probably remembering _____ favourite anathema from a _____ novel.

CLOZE TEST FORM 4

(from "Just Before the War with the Eskimos" by J. D. Salinger)

"What'd he do?"

"Frankly, I'd just as soon not go into details," said the young man. He took a cigarette from his own pack, ignoring a transparent humidor on the table, and lit it with his own lighter. His hands were large. They looked neither strong nor competent nor sensitive. Yet he used them as if they had some not easily controllable aesthetic drive of their own. "I've made up my mind that I'm not even going to think about it. But I'm so furious," he said. "I mean here's this awful little person from Altoona, Pennsylvania, or one of those places. Apparently starving to death. I'm kind and decent enough; I'm the original Good Samaritan to take him into my apartment, this microscopic little apartment that I can hardly walk around in myself. I introduce him to all my friends. Let him clutter up the whole apartment with his horrible manuscript papers, and ciagrette butts and radishes, and whatnot. Introduce him to every theatrical producer in New York. Haul his filthy shirts back and forth from the laundry. And on top of it all," the young man broke off. "And the result of all my kindness and decency," he went on, "is that he walks out of the house at five or six in the morning without so much as leaving a note behind, taking with him anything and everything he can lay his filthy, dirty hands on." He paused to drag on his cigarette, and exhaled the smoke in a thin, sibilant stream from his mouth. "I don't want to talk about it. I really don't." He looked over at Ginnie. "I love your coat," he said, already out of his chair. He crossed over and took the lapel of Ginnie's polo-coat between his fingers. "It's lovely. It's the first really good camel's hair I've seen since the war. May I ask where you got it?"

"My mother brought it back from Nassau."

CLOZE TEST FORM 4 - deleted version

"What'd _____ do?"

"Frankly, I'd just _____ soon not go into _____," said the young man. _____ took a cigarette from _____ own pack, ignoring a _____ humidor on the table, _____ lit it with his _____ lighter. His hands were _____. They looked neither strong _____ competent nor sensitive. Yet _____ used them as if _____ had some not easily _____ aesthetic drive of their _____. "I've made up my _____ that I'm not even _____ to think about it. _____ I'm just so furious," _____ said. "I mean here's _____ awful little person from _____, Pennsylvania, or one of _____ places. Apparently starving to _____. I'm kind and decent _____; I'm the original Good _____ to take him into _____ apartment, this microscopit little _____ that I can hardly _____ around in myself. I _____ him to all my _____. Let him clutter up _____ whole apartment with his _____ manuscript papers, and cigarette _____ and radishes, and whatnot. _____ him to every theatrical _____ in New York. Haul _____ filthy shirts back and _____ from the laundry. And _____ top of it all, " _____ young man broke off. "_____ the result of all _____ kindness and decency," he _____ on, "is that he _____ out of the house _____ five or six in _____ morning without so much _____ leaving a note behind _____ with him anything and _____ he can lay his _____, dirty hands on." He _____ to drag on his cigarette, _____ exhaled the smoke in _____ thin, sibilant stream from _____ mouth. "I don't want _____ talk about it. I _____ don't." He looked over

_____ Ginnie. "I love your _____," he said, already out _____ his chair. He crossed _____ and took the lapel _____ Ginnie's polo-coat between his _____. "It's lovely. It's the _____ really good camel's hair _____ seen since the war. _____ I ask where you _____ it?"

"My mother brought _____ back from Nassau."

APPENDIX H

Raw Scores and Computations for Reading Performance

on Cloze Tests 1 and 2

Computation of Reading Performance Measures

To evaluate possible changes in the subjects' reading performance following treatments, two measures were used. The first measure: "change in comprehension" was obtained by computing the residual gain score, per treatment group, for each of the subjects on each of the two Cloze tests. The use of the residual gain score is a statistical technique which permits the measurement of differences in improvement with subjects who have been equated statistically on the basis of pre-training measurement. (Rankin and Tracy, 1965). The computational formula for this score is:

$$Zy.x = Zy - r_{xy} Zx$$

where Zy represents the post-test score in Z-score form, rxy is the correlation between pre- and post-tests, and Zx represents the pre-test score in Z-score form. Thus in essence the residual gain score is the difference between a predicted and an observed score for a particular individual. Each residual gain score was then transformed into a t-score ($\bar{x}$ = 50.0, SD = 10.0) based on the performance of the treatment group. For each subject the t-score on the post-treatment test was deducted from the t-score on the pre-treatment test and to the resulting algebraic difference a constant of 30.0 was added to remove negative signs. The obtained value expressed the subject's gain or loss of performance. The second measure: rate of reading gain was determined by subtracting the subject's rate of reading (words/min.) on the pre-treatment Cloze passage from his rate of reading on the post-treatment Cloze passage from his rate of reading on the post-treatment Cloze passage and adding a constant of 100.0 to remove the sign.

Table H-1

Reading Rates in Words per Minute for SV-Group 1

(Information-Only) Cloze Tests 1 and 2

SUBJECT #	PASSAGE A	PASSAGE B
13	228	117
27	243	189
34	114	136
40	260	178
42	126	227
43	182	170
48	202	200
56	214	117

SUBJECT #	PASSAGE B	PASSAGE A
20	377	303
60	283	280
79	283	243
66	283	243
91	283	280
68	154	214
26	227	152
12	266	182

Table H-2

Reading Rates in Words per Minute for SV-Group 2 (Information and Feedback), Cloze Tests 1a and 2

SUBJECT #	PASSAGE A	PASSAGE B
5	303	243
28	165	155
32	140	136
41	165	189
69	243	309
93	214	340
94	192	179
98	303	117

SUBJECT #	PASSAGE B	PASSAGE A
85	227	182
58	213	214
63	309	404
77	179	192
33	155	126
10	155	130
100	170	182
49	425	331

Table H-3

Reading Rates in Words per Minute for NSV-Group 1

(Information-Only), Cloze Tests 1 and 2

SUBJECT #	PASSAGE A	PASSAGE B
4	158	117
6	152	227
19	158	189
37	140	200
52	228	266
53	121	170
64	101	121
103	228	227

SUBJECT #	PASSAGE B	PASSAGE A
1	178	152
14	126	135
18	178	140
24	213	165
51	227	243
72	117	173
74	142	140
97	200	243

Table H-4

Reading Rates in Words per Minute for NSV-Group 2

(Information and Feedback), Cloze Tests 1 and 2

SUBJECT #	PASSAGE A	PASSAGE B
25	140	155
44	158	213
50	146	170
65	214	309
67	192	155
86	192	179
87	182	148
101	173	200

SUBJECT #	PASSAGE B	PASSAGE A
2	142	114
21	213	146
22	178	173
39	200	364
73	189	243
76	200	173
84	213	214
95	179	228

Table H-5

Reading Rates in Words per Minute for NSV-Group 3

(Control), Cloze Tests 1 and 2

SUBJECT #	PASSAGE A	PASSAGE B
3	83	131
8	192	155
15	130	179
16	266	243
35	182	213
36	303	178
71	214	118
83	146	131

SUBJECT #	PASSAGE B	PASSAGE A
7	179	146
9	155	146
29	266	182
28	136	152
45	178	146
57	89	76
80	227	192
89	148	182

Table 6

Raw Scores, Residual Gain Scores and T-Scores

for Cloze Test 1 (Order 1-2) for NSV-Subjects

Subject	Pre Raw Score (x)	Post Raw Score (y)	Predicted Post Z	Residual Gain	Derived Score
4.	30.000	48.000	0.069	1.094	63.222
6.	30.000	46.000	0.069	0.819	59.898
19.	32.000	36.000	0.202	-0.690	41.664
37.	40.000	36.000	0.735	-1.223	35.226
52.	43.000	52.000	0.935	0.779	59.411
53.	33.000	44.000	0.269	0.344	54.159
64.	8.000	27.000	-1.396	-0.329	46.016
103.	18.000	19.000	-0.730	-2.097	24.669
25.	36.000	46.000	0.469	0.419	55.06[illegible]
44.	23.000	31.000	-0.397	-0.778	40.595
50.	22.000	39.000	-0.463	0.389	54.699
65.	36.000	40.000	0.469	-0.406	45.095
67.	31.000	46.000	0.136	0.752	59.093
86.	33.000	39.000	0.269	-0.343	45.847
87.	36.000	40.000	0.469	-0.406	45.095
101.	26.000	42.000	-0.197	0.535	56.467
3.	16.000	39.000	-0.863	0.788	59.527
8.	38.000	47.000	0.602	0.424	55.122
15.	34.000	39.000	0.335	-0.410	45.042
15.	27.000	38.000	-0.130	-0.081	49.013
35.	32.000	37.000	0.202	-0.552	43.326
36.	18.000	37.000	-0.730	0.380	54.593
71.	31.000	34.000	0.136	-0.898	39.144
83.	22.000	47.000	-0.463	1.490	67.998

Table 7

Raw Scores, Residual Gain Scores and T-Scores for Cloze Test 2 (Order 1-2) for NSV Subjects

Subject	Pre Raw Score (x)	Pre Raw Score (y)	Predicted Post Z	Residual Gain	Derived Score
4.	40.000	53.000	0.747	0.839	60.475
6.	37.000	47.000	0.404	0.197	52.462
19.	35.000	41.000	0.176	-0.559	43.024
37.	36.000	43.000	0.290	-0.345	45.695
52.	35.000	35.000	0.176	-1.544	30.735
53.	36.000	42.000	0.290	-0.509	43.647
64.	25.000	44.000	-0.966	1.075	63.419
103.	36.000	37.000	0.290	-1.330	33.406
25.	37.000	48.000	0.404	0.361	54.510
44.	27.000	36.000	-0.737	-0.466	44.184
50.	27.000	41.000	-0.737	0.354	54.424
65.	41.000	45.000	0.861	-0.587	42.666
67.	34.000	51.000	0.061	1.196	64.929
86.	34.000	47.000	0.061	0.540	56.737
87.	29.000	35.000	-0.509	-0.858	39.286
101.	38.000	54.000	0.518	1.232	65.373
3.	30.000	40.000	-0.395	-0.152	48.101
8.	45.000	52.000	1.318	0.104	51.302
15.	34.000	48.000	0.061	0.704	58.785
16.	24.000	36.000	-1.080	-0.123	48.459
35.	33.000	39.000	-0.052	-0.659	41.778
36.	27.000	36.000	-0.737	-0.466	44.184
71.	32.000	40.000	-0.166	-0.380	45.251
63.	31.000	50.000	-0.280	1.375	67.156

Table 8

Raw Scores, Residual Gain Scores and T-Scores for Cloze Test 2 (Order 2-1) for NSV-Subjects

Subject	Pre Raw Score(x)	Post Raw Score(y)	Predicted Post Z	Residual Gain	Derived Score
1.	37.000	47.000	0.563	-0.090	48.812
14.	37.000	46.000	0.563	-0.265	46.525
18.	30.000	44.000	-0.681	0.631	58.267
24.	29.000	37.000	-0.859	-0.412	44.591
51.	36.000	45.000	0.385	-0.261	46.569
72.	34.000	46.000	0.029	0.268	53.518
74.	31.000	50.000	-0.504	1.500	69.657
97.	36.000	40.000	0.385	-1.134	35.136
2.	35.000	44.000	0.207	-0.258	46.613
21.	31.000	43.000	-0.504	0.278	53.649
22.	31.000	42.000	-0.504	0.104	51.363
39.	29.000	42.000	-0.859	0.459	56.024
73.	25.000	25.000	-1.571	-1.795	26.473
76.	34.000	42.000	0.029	-0.429	44.371
84.	41.000	52.000	1.274	0.070	50.727
95.	31.000	50.000	-0.504	1.500	69.657
7.	34.000	39.000	0.029	-0.953	37.516
9.	36.000	49.000	0.385	0.436	55.716
29.	35.000	42.000	0.207	-0.607	42.040
28.	39.000	48.000	0.919	-0.271	46.437
45.	36.000	44.000	0.385	-0.436	44.283
57.	35.000	46.000	0.207	0.090	51.187
80.	37.000	53.000	0.563	0.956	62.532
89.	33.000	47.000	-0.148	0.620	58.135

Table 9

Raw Scores, Residual Gain Scores and T-Scores for Cloze Test 1 (Order 2-1) for NSV-Subjects

Subject	Pre Raw Score(x)	Post Raw Score(y)	Predicted Post Z	Residual Gain	Derived Score
91.	30.000	49.000	-0.069	1.894	69.033
14.	31.000	31.000	-0.037	-1.873	31.176
18.	34.000	44.000	0.059	0.727	57.313
24.	35.000	35.000	0.091	-1.172	38.222
51.	34.000	36.000	0.059	-0.932	40.631
72.	35.000	39.000	0.091	-0.342	46.563
74.	27.000	43.000	-0.166	0.745	57.492
97.	29.000	35.000	-0.101	-0.978	40.164
2.	29.000	39.000	-0.101	-0.148	48.504
21.	28.000	41.000	-0.134	0.298	52.998
22.	30.000	31.000	-0.069	-1.841	31.499
39.	32.000	33.000	-0.005	-1.490	35.023
73.	33.000	39.000	0.026	-0.277	47.210
76.	32.000	43.000	-0.005	0.584	55.875
84.	35.000	45.000	0.091	0.903	59.075
95.	33.000	44.000	0.026	0.760	57.636
7.	31.000	38.000	-0.037	-0.420	45.772
9.	38.000	46.000	0.187	1.014	60.189
29.	32.000	44.000	-0.005	0.792	57.960
28.	27.000	44.000	-0.166	0.953	59.577
45.	32.000	43.000	-0.005	0.584	55.875
57.	32.000	42.000	-0.005	0.377	53.789
80.	37.000	43.000	0.155	0.423	54.257
89.	36.000	38.000	0.123	-0.581	44.155

Table 10

Raw Scores, Residual Gain Scores and T-Scores

For Cloze Test 1 (Order 1-2) for SV- Subjects

Subject	Pre Raw Score(x)	Post Raw Score(y)	Predicted Post Z	Residual Gain	De Sc
5.	34.000	39.000	0.032	-0.251	47.
28.	31.000	43.000	-0.011	0.727	57.
32.	37.000	39.000	0.075	-0.294	47.0
41.	30.000	40.000	-0.026	0.041	50.41
69.	31.000	35.000	-0.011	-1.141	38.57
93.	31.000	48.000	-0.011	1.895	68.976
94.	27.000	42.000	-0.070	0.552	55.529
98.	33.000	32.000	0.017	-1.871	31.260
13.	32.000	43.000	0.002	0.712	57.135
27.	31.000	32.000	-0.011	-1.842	31.553
34.	30.000	41.000	-0.025	0.274	52.750
40.	24.000	38.000	-0.114	-0.338	46.613
42.	30.000	42.000	-0.025	0.508	55.089
43.	37.000	40.000	0.075	-0.061	49.385
48.	37.000	45.000	0.075	1.106	61.080
56.	34.000	40.000	0.032	-0.017	49.825

Table 10

Raw Scores, Residual Gain Scores and T-Scores

For Cloze Test 1 (Order 1-2) for SV- Subjects

Subject	Pre Raw Score(x)	Post Raw Score(y)	Predicted Post Z	Residual Gain	Derived Score
5.	34.000	39.000	0.032	-0.251	47.486
28.	31.000	43.000	-0.011	0.727	57.282
32.	37.000	39.000	0.075	-0.294	47.046
41.	30.000	40.000	-0.026	0.041	50.411
69.	31.000	35.000	-0.011	-1.141	38.570
93.	31.000	48.000	-0.011	1.895	68.976
94.	27.000	42.000	-0.070	0.552	55.529
98.	33.000	32.000	0.017	-1.871	31.260
13.	32.000	43.000	0.002	0.712	57.135
27.	31.000	32.000	-0.011	-1.842	31.553
34.	30.000	41.000	-0.025	0.274	52.750
40.	24.000	38.000	-0.114	-0.338	46.613
42.	30.000	42.000	-0.025	0.508	55.089
43.	37.000	40.000	0.075	-0.061	49.385
48.	37.000	45.000	0.075	1.106	61.080
56.	34.000	40.000	0.032	-0.017	49.825

Table 11

Raw Scores, Residual Gain Scores and T-Scores for Cloze Test 2 (Order 2-1) for SV- Subjects

Subject	Pre Raw Score(x)	Post Raw Score(y)	Predicted Post Z	Residual Gain	Derived Score
5.	37.000	49.000	0.044	0.507	55.167
28.	35.000	45.000	-0.098	-0.279	47.156
32.	38.000	56.000	0.116	2.062	71.013
41.	41.000	44.000	0.331	-0.941	40.404
69.	31.000	45.000	-0.385	0.007	50.079
93.	35.000	48.000	-0.098	0.418	54.260
94.	36.000	47.000	-0.026	0.114	51.162
98.	37.000	41.000	0.044	-1.352	36.222
13.	38.000	49.000	0.116	0.435	54.436
27.	33.000	43.000	-0.242	-0.600	43.882
34.	42.000	48.000	0.403	-0.083	49.145
40.	36.000	37.000	-0.026	-2.209	27.481
42.	36.000	46.000	-0.026	-0.118	48.793
43.	35.000	50.000	-0.098	0.882	58.996
48.	37.000	50.000	0.044	0.739	57.535
56.	35.000	48.000	-0.098	0.418	54.260

Table 12

Raw Scores, Residual Gain Scores and T-Scores for Cloze Test 2 (Order 2-1) for SV- Subjects

Subject	Pre Raw Score(x)	Post Raw Score(y)	Predicted Post Z	Residual Gain	Derived Score
12.	34.000	41.000	0.155	-0.454	44.455
20.	25.000	34.000	-0.907	-0.438	44.646
26.	29.000	41.000	-0.435	0.136	51.663
60.	33.000	36.000	0.036	-1.084	36.755
66.	28.000	43.000	-0.553	0.553	56.757
68.	29.000	34.000	-0.435	-0.911	38.879
79.	36.000	47.000	0.391	0.207	52.529
91.	39.000	44.000	0.745	-0.595	42.726
10.	37.000	40.000	0.509	-0.958	38.304
17.	30.000	35.000	-0.317	-0.879	39.264
33.	37.000	43.000	0.509	-0.509	43.783
49.	30.000	47.000	-0.317	0.915	61.179
58.	28.000	47.000	-0.553	1.152	64.062
63.	42.000	58.000	1.099	1.144	63.968
85.	37.000	53.000	0.509	0.986	62.045
100.	29.000	45.000	-0.435	0.734	58.968

Table 13

Raw Scores, Residual Gain Scores and T-Scores

for Cloze Test 1 (Order 2-1) for SV- Subjects

Subject	Pre Raw Score(x)	Post Raw Score(y)	Predicted Post Z	Residual Gain	Derived Score
12.	37.000	42.000	0.760	-0.113	48.466
20.	30.000	45.000	-0.013	1.045	64.177
26.	29.000	40.000	-0.124	0.516	57.002
60.	26.000	32.000	-0.456	-0.175	47.623
66.	17.000	31.000	-1.451	0.692	59.394
68.	20.000	20.000	-1.120	-1.046	35.806
79.	33.000	47.000	0.318	0.968	63.149
91.	30.000	37.000	-0.013	0.021	50.296
10.	34.000	35.000	0.428	-0.676	40.822
17.	27.000	22.000	-0.345	-1.564	28.771
33.	28.000	34.000	-0.235	-0.140	48.092
49.	32.000	37.000	0.207	-0.199	47.294
58.	29.000	40.000	-0.124	0.516	57.002
63.	40.000	45.000	1.092	-0.061	49.170
85.	31.000	44.000	0.096	0.80[illegible]	60.941
100.	39.000	40.000	0.981	-0.590	41.995