THE EFFECT OF ELIMINATION OF SUBVOCALIZATION

WITH ELECTROMYOGRAPHIC FEEDBACK ON

READING SPEED AND COMPREHENSION

THESIS

Presented to the Graduate Council of the

North Texas State University in Partial

Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

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Denton, Texas

May, 1974

Ninness, Herbert Arthur Christian, The Effect of
Elimination of Subvocalization with Electromyographic
Feedback on Reading Speed and Comprehension. Master of
Science (Clinical Psychology), May, 1974, 35 pp., 1 table,
4 illustrations, references, 29 titles.

The purpose of this experiment was to study the effect
of audio feedback from an electromyograph on reading speed
and comprehension. The subject reduced as much audio feed-
back, and thus laryngeal tension, as possible, thus permit-
ting more efficient reading.

After baseline, the subject received twelve half-hour
practice sessions, six ten-minute testing sessions on easy,
or light, material and six ten-minute testing sessions on
difficult material. A post-test without feedback was given
after training and a follow-up test, without feedback, was
given.

This method of training permits a higher rate of read-
ing speed, while allowing the subject to process complex
information and maintain a constant level of recall.

LIST OF TABLES

iii

LIST OF ILLUSTRATIONS

THE EFFECT OF ELIMINATION OF SUBVOCALIZATION

WITH ELECTROMYOGRAPHIC FEEDBACK ON

READING SPEED AND COMPREHENSION

Subvocalization is operationally defined here as the emission of laryngeal muscular activity which approximates articulation of the written word during silent reading. The problem as to whether subvocal speech is a necessary part of efficient silent reading has probably been a subject of some controversy since the educational process began. Some have indicated that the relationship between subvocal speech and learning is such that suppression of subvocal activity should result in less rapid learning and reduced comprehension (Ribot, 1879). Opposed to this conception is the belief that laryngeal muscle activity actively intereferes with covert learning processes and thus suppression of such covert speech would facilitate speed and understanding (Dodge, 1896).

The critical assumption here is that if covert speech processes do cause interfering effects, then reduction of laryngeal activity should allow faster interpretation of the written word and greater capability of synthesizing and comprehending the text.

The question arises as to whether this process of understanding the written word without peripheral

1

concomitants opposes a behavioral interpretation of think-
ing. Though the following experiment was not designed to
argue the merits of either centralist or peripheralist
positions, it will be noted here that Watson's (1924) in-
terpretation of "thinking," i.e., the occurrence of covert
language responses, is not the only behavioral explanation
available to describe the phenomena. For if Skinner (1957)
is accurate in stating that there is no unique subclass of
stimulus-response laws that correspond to what we tradi-
tionally call "thinking," then covert vocal concomitants
may be only one of many and varied physiological represent-
atives that may or may not play an integral role in silent
mentation.

At the beginning of this century, researchers started
analyzing the concomitants that might play a role in some
of the peripheral processes of reading. Morgan (1916) re-
ported that when interfering auditory stimuli were produced
while a subject was reading, breathing changes occurred.
He interpreted this as an indication of subvocal articula-
tion. A systematic analysis of the phenomena was undertaken
by Pinner (1913). As with most studies since, in this area,
his primary criterion for efficiency was rapidity and com-
prehension. In that study, each subject served as his own
control when first, he read a specified amount of materials
while timed, and second, practiced reading similar kinds
of material, each subject repeating aloud the consecutive

digits of 13, 14, 15, and 16. This process of repeated overt speech during reading was an attempt to reduce as much covert (subvocal) speech as possible. Of special importance to note here is the fact that subjects continually "practiced" reading over many tested and timed trials before becoming proficient at this method of silent reading. For all subjects a steady decrease in time to read occurred, while the comprehension level steadily gained. The only question Pinner leaves is whether the habit of subvocal articulation will not tend to reoccur. He states, "It is questionable whether such a habit, that is of such long standing and so deeply rooted in the adult, can be permanently overcome."

This question plagued many of those who were to continue studying covert oral behavior until Hardyck and Petrinovich reported in 1966 that after only thirty minutes of electromyographic (EMG) audio feedback of subvocalization, laryngeal tension decreased to normal relaxation levels during reading. All of the subjects were given follow-up tests one to three months after the original thirty-minute training session. None exhibited any tendency to regress to subvocal speech while reading, even though no feedback apparatus was used after the initial conditioning.

Such quick adjustment to breaking old habits may seem startling, but the author explains the immediate change in

terms of placing the overlearned response of subvocalizing

in conflict with a second, more strongly learned response

and attending to auditory cues which are activated as a

function of the subvocalization the subject is emitting.

Feedback was essential to the reduction of subvocalization;

merely telling the subject he was subvocalizing had no ef-

fect.

McGuigan (1967) suggests that Hardyck's 1966 study may

have confounded an independent variable by allowing subjects

to acquire a set on which verbal behaviors might be expected

of them. Many subjects, eager to please the experimenter,

could easily ascertain the examiner's intentions and attempt

relaxation of vocal areas irregardless of feedback opera-

tions. McGuigan had two of three subjects hook electrodes

on their vocal apparatus and chin-lip areas while reading

and gave no feedback to two subjects while feedback was

given to a third. The curves for all three subjects are

practically identical. All show rapid reduction in EMG

amplitude for the vocal apparatus hook-up. This effect

occurred regardless of the fact that subjects were in no

way intentionally made aware of the behavior expected of

them. Later, however, Locke (1971) reported his efforts

to discover whether subvocalization actually existed inde-

pendent of the subject's intentional manipulation. He

used naive subjects with electrode placement at various

irrelevent positions over and above the throat. EMG

records indicated significant amplitudes during silent
reading of high labial material.

This electromyographic technique of defining speech
muscle activity while reading began with Faaborg-Anderson
(1957). Originally needle electrodes were directly in-
serted into the laryngeal muscle surgically. Edfeldt
(1960) also inserted needle electrodes deep into the my-
loboid musculature to record eighty-seven students who
were reading silently. In general he found that subvo-
calization increased as material became more difficult
and as the subject's ability decreased. He further rec-
ommended disgarding any training aimed at elimination of
subvocalization.

The process of needle electrode placement requires
the assistance of an onotolaryngological surgeon and is
a rather painful procedure despite the use of anaesthesia
(Hardyck, 1966). Thus this method of investigation also
dissuaded many subjects from volunteering for such research.
However, with the advent of more highly sophisticated elec-
tromyographic equipment, needle electrodes are no longer
necessary. They can now be replaced with surface elec-
trodes which are sensitive enough to detect muscle impul-
ses from the exterior thyroid area. Surface EMG electrodes
are capable of picking up electro-muscular impulses from
any vocal activity.

For studying amplitudes produced from silent reading, location is of major importance. According to Aarons et al. (1971), covert reading corresponds to incipient, fractional articulatory movements or low-level isotonic muscle activity. During speech, adductor muscle activity increases impulses of the larynx while decreasing abductor muscles. In covert speech crico-thyroid, inter-arytnoid, and lateral crico-orytnoid are abductors which increase laryngeal function. The greatest amplitude for covert speech using EMG measures of the vocal and myloboid muscles are found to be time-correlated and concomitant with an inhibition of activity in the posterior crico-arytnoid muscles (Aarons, 1971).

Isotonic functions are controlled by exterior feedback cues while internal cues direct isometric laryngeal activity. Since general levels of laryngeal tension facilitate a certain amount of isotonic function, EMG feedback readings probably pick up a constant combination of both isotonic and isometric flexation. However, the isometric activity of subvocalization is of a more distinct and audible cue in the feedback system such as to allow recognition from the background isotonic and intrainstrumental static.

There are a number of possibilities as to the various roles played by kinesthetic potentials for internal representative ideation. It is upon the more valid interpretations of these roles that the ultimate utility of

subvocal feedback is dependent. If there is a positive relationship between learning and sub-articulatory responses, then any attempt to dispose of subvocalization might ultimately deter comprehension. In Hardyck et al.'s 1970 study it was concluded that feedback attempts to reduce subvocal emission resulted in a lower comprehension level for difficult reading material. Hardyck interprets his findings as an indication of an association between speech sounds and objects that are seen visually. Accordingly, these sounds further serve as a stimulus support for further responses. Auditory proprioceptive complexes thus act as a mediator when the individual is first learning to decipher written symbols. These are especially useful in comprehending a difficult text. In his earlier research,however, Hardyck found that subvocalization can at least be partially overcome without detrimental effect when the subject is reading simple material. He explains this discrepency by proposing that the auditory proprioceptive cue eventually becomes a redundant stimulus. Accordingly, only the visual stimulus is needed to facilitate understanding when the material is not difficult. Thus subvocalization would only be called into use when a specified amount of redundency is required to decode difficult material.

The subjects in this previously sighted experiment had no opportunity to be continually subjected to audio feedback with difficult material over an extended time

period. The possibility that further exposure to feedback might render the subject more capable of attending to and discriminating visual coded stimuli alone must be considered. It was only through practice that subjects originally learned to maintain any proficiency with the combination of auditory-proprioceptive and visual stimuli. It is not inconceivable therefore, that practice, with the visual stimuli alone while using auditory feedback as an index, may be sufficient for even difficult passages. Evidence for the possibility is illustrated in another experiment by McGuigan (1964), when subjects who were given feedback via electromyograph on chin-lip movements produced no more tendency to subvocalize while reading French than reading English, their native language. Evidently complexity and unfamiliarity were not critical variables which determine the need to subvocalize in this experiment. But the evidence on covert speech processes does not present a clear picture of what occurs. A study by Barlow (1928) revealed that subjects who memorized twenty nonsense syllables for four trials while intentionally emphasizing some subvocal speech patterns did slightly better than those who memorized the same material with a pencil between their teeth (supposedly preventing subvocal tendencies). However, contrary to this evidence, are finding by Underwood (1964). Four groups learned nonsense syllables: one with a wooden blade inserted in the mouth while learning, one while on

recall, another on both, and a fourth who learned normally. Acquisition curves for all groups showed no indication of variance attributable to learning conditions. An experiment conducted by Mechanic (1971) indicated that learning increased with the amount of pronouncing as opposed to just viewing the visual configuration of words. The subjects who were told to merely study the word's visual attractiveness did significantly worse than that group which was told to study the attractiveness of the sound a word produced. Since the former subjects were not expected to attend or concentrate on the words, it is unlikely that they would be forming the same kinds of impressions as those who actually read the material aloud. At any rate, such viewing of words is not to be compared with an active process of reading. Even Hardyck's 1970 study indicated that nonsubvocalizing readers of light material comprehended at about the same level as subvocalizers.

The four previously described experiments leave themselves open to some question as to how well covert speech may have been controlled. None of these last four studies place any emphasis on the role of practice in overcoming covert speech and it might also be noted that all four measures used to control subvocalization were operating above the level of the thyroid and were thus incapable of registering any mediating concomitants at a laryngeal level. A study conducted by Sokolov (1966) does consider such

subvocalization at the laryngeal level. His study indicated
that solving more difficult mathematical formulations corre-
lated with high amplitudes on laryngeal electromyography.
However, here as in Hardyck's 1970 study there was no oppor-
tunity for the subject to obtain continual feedback over
many practice trials in order to treat the possibility that
such feedback might eventually fascilitate problem solving.

It was the purpose of this study to ascertain the feas-
ibility of minimizing subvocalization, and to accomplish
this by way of a shaping process that increases the diffi-
culty of various selections over many practice trials.
This was done in order to test the maximum amount of read-
ing speed while maintaining at least a constant level of
comprehension as a function of decreasing laryngeal EMG
amplitudes.

Method

Subjects

The subject was a twenty-four-year-old male graduate
holding a bachelor's degree in biology from North Texas
State University. The subject volunteered for the EMG
feedback program in hope of improving his reading ability.

Instrument

Determination of the electrode sites was accomplished
according to the procedure employed by the Hardyck et al.
(1969) study. A monopolar placement was arranged on both
sides of the thyroid cartilage and a ground lead was

situated on the lateral area of the neck. This allowed a large portion of the larynx to be recorded while permitting signals to be attenuated via common mode rejection. Placement of the ground electrode on the neck reduced the possibility of cardiac artifact. The subject was situated adjacent to the loudspeaker so he would be particularly able to attend to any audio distortions that indicated fluctuation in laryngeal tension. Lighting was arranged with a series of fluorescent lights above the subject such that his vision was never impaired by shadows. Noise in and around the laboratory were kept at the lowest possible level in order to avoid extraneous audio artifact.

The active electrodes which measured one centimeter were silver-plated copper. The reference electrode was of the same quality and dimension. All electrodes were connected to co-axial cable which shielded the signal from electrical interference in the atmosphere. The signal was initially amplified fifty times with the use of a Solid State Stereo Pre-Amplifier. This pre-amplifier was designed to adapt a magnetic cartridge to any high level input. After pre-amplification, the signal was further amplified five hundred times by the Newport Laboratories Integrating Bioelectric Monitor. Frequency band passes within this unit were adjusted for 300 Hertz high pass and 100 Hertz low pass. The use of 300 Hertz attenuates high frequency electricl noise, while the 100 Hertz low

pass filters 60 cycles per secound electrical power noise
and also reduces cardiac artifact.

At this stage the EMG unit was divided into four seg-
ments which relayed the signal back to both the subject
and experimenter. The subject only had access to the audio
segment of this feedback. This was accomplished by run-
ning a lead from the amplitude output of the EMG unit into
a Solid State Amplifier which in turn lead to a loudspeaker
adjacent to the subject. The loudspeaker gave an indica-
tion of bioelectric activity which, though not precise,
was immediate and easily interpreted by the subject. As
this audio signal was amplified the subject was readily
made more aware that his laryngeal impulses had increased.
The experimenter had access to the other three feedback
segments. The oscilloscope, also connected at the ampli-
fier output was used to obtain a picture of the data wave-
form. This was useful for acquiring information concerning
possible artifact and insuring that amplifier gain was set
for optimal signal to noise ratios. Another output seg-
ment for the experimenter, the Hewlett Packard Electronic
Pulse Counter, produced root mean square voltage on digital
readout. This was accomplished by means of a voltage-con-
trolled oscillator (VCO) contained with the EMG monitor.
The VCO converts input signal to frequency that is related
in terms of the amplitude of the input signal.

The output of the VCO is used to drive the signal of the frequency measuring counter. The last segment of the feedback output is produced by the Voltage Meter which corresponds linearly to the digital readout. This meter was adjustable to use in voltage units for voltage measurements and in ohmic units for impedance measurement. Using this device the experimenter was made aware of any rapid high increases in voltage that indicated laryngeal artifact. A complete diagram of the EMG instrumentation is illustrated in Figure 1.

Procedure

The subject was positioned comfortably in a contoured vinyl chair. Body position was maneuvered so that there was little strain on the upper extremities, particularly the neck area. This was accomplished in order to decrease the isometric laryngeal artifact. In order to prepare the electrode site, the subject's skin surface over the thyroid cartilage was lightly sanded with fine grade sandpaper. This removed any dead skin. Epidermal oils were then cleansed with alcohol pads. The area was lightly punctured with a series of needles protruding about one-sixteenth inch from a small round cork. These penetrations caused little discomfort, but did substantially reduce skin resistance. A location on the extreme lateral area of the neck was similarly prepared for placement of

oscilloscope

| raw signal display | gain adjust |

LOUD SPEAKER

AMPLIFIER

HEWLETT - PACKARD
PULSE COUNTER

Newport Laboratories
Integrating Bioelectric
Monitor Model 100

VCO

FILTER

100
low
-
300
High

Hz Pass

AMP

gain=

500
times

Solid
State
Pre-AMP

INTEGRATOR

CO-AXIAL
CABLES

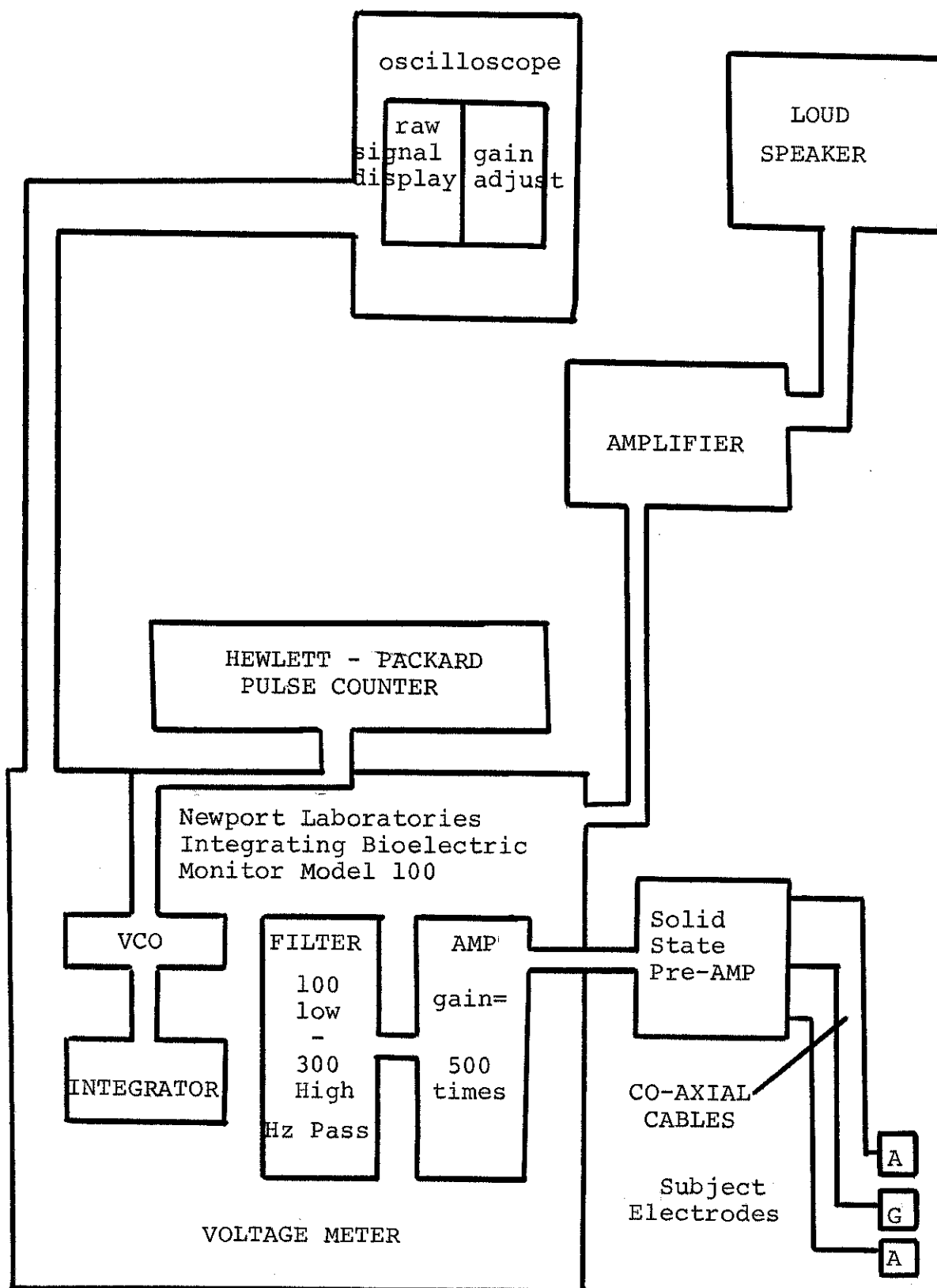Subject
Electrodes

A

G

A

VOLTAGE METER

Fig. 1--EMG Feedback Instrument

the ground electrode. Adhesive electrode washers were
then attached to the plastic perimeter of the silver-plated
copper electrodes, which measured one centimeter. The elec-
trodes were then made conductive with electrolytic solution
applied in small quantities to the center of the electrodes
and placed on the prepared sitings.

On almost every occasion skin impedance fluctuated
dramatically so that no standard comparison of impedance
was possible. The alternative to this dilemma was to con-
struct a ratio of variances taking into consideration the
various levels of resistance of the subject during each
separate practice session. Impedances fluctuated between
200 and 3,000 ohms. On occasion skin impedance was too high
for adequate measuring. If on any given session skin re-
sistances measured higher than 5,000 ohms, training was
terminated for that day. The process of repreparing the
electrode site for the same session was aversive and
caused the subject undue distress, which would have ulti-
mately interfered with training. When electrode sitings
were satisfactorily prepared, sensitivity of the instrument
was adjusted. Raw amplified signals were displayed on the
oscilloscope and signal-to-noise ratios were observed for
artifact. A constant amount of 60 Hertz electrical noise
was always in the background but this was kept at the low-
est possible level with the given instrumentation.

Baseline data for rest were recorded via a Hewlett-Packard electronic counter which displayed pulse frequency over ten-second intervals with root mean square voltage on the digital readout. Rest data were obtained for comparison to voltage levels at light and difficult readings. Rest was defined as that constant level of laryngeal tension which the subject exhibits as a function of sitting in the chair calmly with an effort to keep a blank mind. No feedback, either video or audio, was relayed to the subject. The subject was then given a light text to read for a period of ten minutes. This material consisted of excerpts from an elementary psychology text by Whaley and Malott, entitled _Elementary Principles of Behavior_. During the baseline period the subject's laryngeal muscle tension was recorded and averaged over ten-second intervals from the digital readout, which was visible only to the experimenter. Swallowing artifact was eliminated by having the experimenter continually monitor the voltage meter on the EMG unit. On occasions when the needle jumped sharply due to swallowing, the digital readout was not calculated. After completing ten minutes of light reading, the last word read was designated and the average words per minute were calculated by means of the formula:

Words Per Minute = A (total number of words per five
               lines)

                B (that number divided by five)

                C (multiplied by total number of
                  lines read)

The subject was then quizzed over the material read by means
of questions already prepared in the text at the end of
each chapter. At this point the subject was permitted to
relax for a period of about five minutes so that he might
perform at optimal levels in the next section of baseline
reading. The subject was then given a copy of How to Pass
High on the Graduate Record Exam and instructed to read a
specified section for another ten minutes. This book is
composed of selections which approximate the scope and dif-
ficulty of reading selections from the Graduate Record Exam-
ination. Such material was defined for testing purposes as
difficult. During the reading of this material the sub-
ject's throat tension was again computed, and upon conclu-
sion his reading location was designated. Words per minute
were again calculated and the subject was asked to answer
questions which were prepared at the end of each selection.
This process of reading the above-mentioned material for
ten-minute intervals, measuring throat tension, computing
words per minute, and testing was performed on three con-
secutive occasions in order to acquire a stable baseline.

    At the beginning of subvocal elimination training the
subject was given an opportunity to acquaint himself with

the EMG audio feedback apparatus. Tone volume was adjusted
to his satisfaction so that background static was minimal
and signal amplitudes were easily discernible. The subject
was encouraged to swallow, yawn, cough, speak at various
degrees of loudness, and otherwise become acquainted with
the effects laryngeal tension would have on the audio signal.
The feedback apparatus would produce a higher and more audi-
ble amplitude on those occasions when the subject's laryng-
eal tension increased. Any act of subvocalization while
reading would immediately be translated into a high-ampli-
tide garble and indicate to the subject that throat muscles
were activating above rest.

The subject was instructed to begin reading a light
novel and to try to keep the audio signal at rest levels.
Two practice sessions of one-half hour each were conducted
during which time he continually read at his own speed and
always attempted to keep the signal at the lowest possible
level. Extraneous noise in and around the laboratory were
kept minimal. At the beginning of the next session the
subject was similarly prepared for feedback and positioned
for reading. He was reintroduced to a copy of Elementary
Principles of Behavior and told to read at a comfortable
rate for ten minutes while keeping the audio feedback down.
During this time the experimenter positioned himself so
that he was capable of maintaining good visual contact with
the digital readout and the voltage meter. Digital

calculations were averaged on ten-second intervals and logged. At the end of the ten-minute reading interval these measures were averaged and entered into the final computation. At this time the subject's exact reading location was specified and his words per minute were calculated and recorded. Finally, the subject was tested for comprehension.

At this point the subject was permitted to rest for approximately five minutes. He then received a copy of How to Pass High on the Graduate Record Examination and was similarly instructed to read while keeping the audio feedback level as low as possible. Scores were again obtained on laryngeal tension, reading rate, and comprehension.

This method of first having the subject practice reading at various levels of difficulty for two separate but consecutive sessions followed by a third session of testing both light and difficult levels was repeated for a series of six separate trials. The subject was tested only on every third session,when he would have an opportunity to read selections from Elementary Principles of Behavior and How to Pass High on the Graduate Record Examination.

The other two half-hour practice sessions were conducted solely for the purpose of training the subject to reduce as much subvocalization, via EMG feedback, as possible. Reading material for these practice sessions was

composed of a wide variety of fiction, academic, and tech-
nical literature. The subject was originally exposed to
the least strenuous of these readings. As he became more
adept at maintaining low levels of subvocalization he was
gradually introduced to more complicated selections. This
permitted a gradual shaping procedure through which he was
able to adjust his speed and concentration.

At the conclusion of the training phase the subject
was given a post-test over the same materials without the
benefit of feedback. His reading rate and comprehension
levels were measured and compared with previous levels
obtained during acquisition and baseline. A follow-up
study was conducted four weeks after the post-test in order
to discern the subject's capability to retain the effects
of EMG feedback training over time. Measures were again
taken on reading rates, comprehension, and laryngeal ten-
sion without feedback. This final testing served as an
index of the potential adequacy of such training and indi-
cated whether such training had any real educational purpose.

Results

An analysis of the three graphs dealing with laryngeal
tension, reading rate, and comprehension is a direct index
of the effects of this program. Laryngeal muscle relaxa-
tion curves are plotted directly from the digital readout
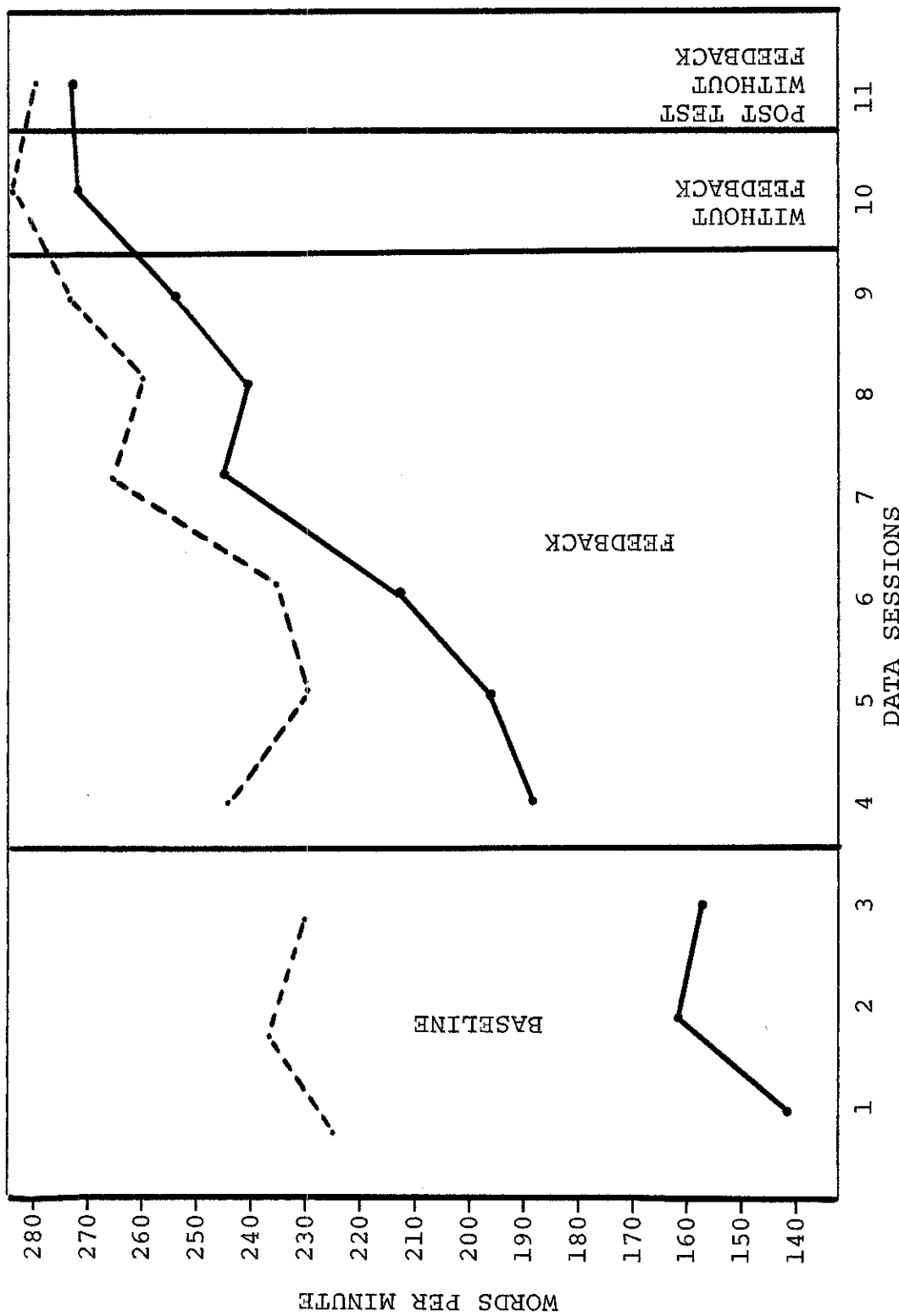and averaged over a period of the ten-minute reading session.

Fig. 2--Reading rate curves for light and difficult texts indicating
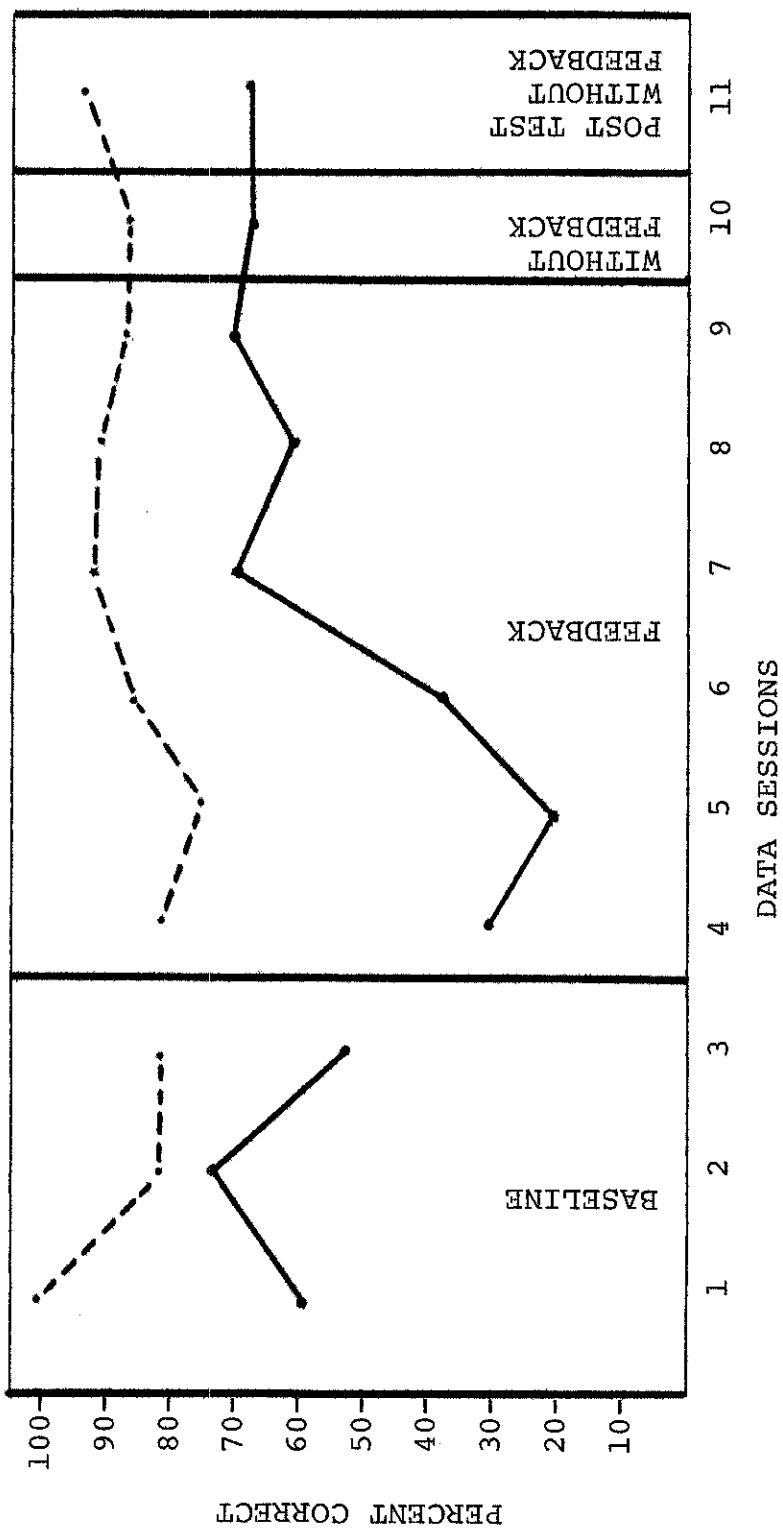word per minute. (------light ———difficult)

Fig. 3--Comprehension curves for light and difficult texts indicating
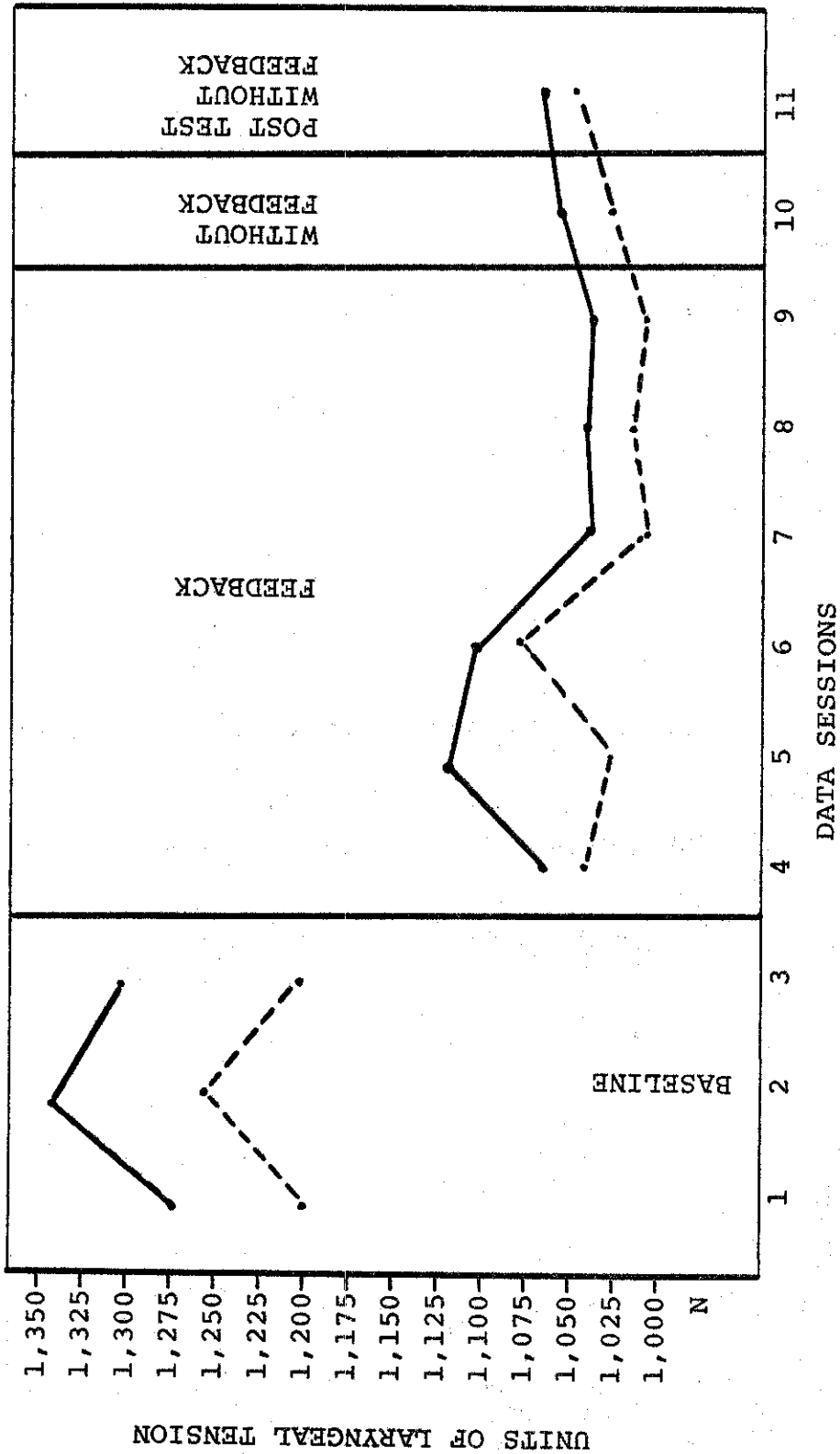percent correct. (---- light ——— difficult)

Fig. 4--Laryngeal tension curves for light and difficult material. N indicates approximate instrumental noise level. (------ light ―――― difficult)

The ordinate displays a ratio of light and difficult read-

ing material using rest levels as the denominator. Using

these ratios, it is possible to determine the increase in

mean voltage regardless of impedance fluctuations from ses-

sion to session. Base rate for all three graphs include

the first three sessions. These are followed by six test-

ing sessions during the feedback acquisition phase. A

post-test without feedback and a follow-up test three to

four weeks later also without feedback conclude the testing

procedure. It should again be emphasized that no measures

on laryngeal tension, reading rate, or comprehension are

given for the two separate half-hour practice sessions

which precede each of the six tests in acquisition. An

inspection of the laryngeal tension data (Fig. 4) reveals

an exceptionally high rate of subvocalization for diffi-

cult material during baseline. Even light material forced

the subject to emmit a considerable amount of subvocaliza-

tion. Upon introduction of the audio feedback the subject's

laryngeal impulses for both sets of data decreased immedi-

ately. Tension reduction over the first three training

sessions is more substantial with light reading. The

remaining sessions reveal a stable low level of laryngeal

tension for both types of reading. An examination of the

adjacent chart (Table 1) indicates that mean tension levels

for sessions four through eight are only a few hundredths

of a millovolt above rest level. It is therefore assumed,

Table 1

Mean Resistances in Millivolts and Tension Ratios

Data Session	Rest	Light	Difficult	Light Ratio	Difficult Ratio
1	2.406	2.624	3.061	1.091	1.272
2	.509	.638	.682	1.253	1.339
3	1.837	2.012	2.378	1.095	1.294
4	.717	.742	.762	1.035	1.063
5	1.405	1.434	1.561	1.021	1.111
6	.222	.237	.242	1.068	1.090
7	.937	.951	.955	1.015	1.019
8	.952	.969	.973	1.018	1.022
9	.985	.998	1.002	1.013	1.017
10	.833	.851	.857	1.022	1.029
11	1.514	1.554	1.561	1.026	1.031

for the purpose of this experiment, that subvocal emissions

during reading were being kept to a minimal level. This is

especially apparent when comparing them with tension levels

obtained at baseline. One of the most relevant and valuable

indications of this data is the fact that laryngeal tension

maintains a constant low level even after audio feedback is

terminated. As in the Hardyack (1967) study, it was found

here that an overlearned response of subvocalizing, when

placed in conflict with a more strongly learned response

of attending to auditory cues, permits the subjects to gain

control of laryngeal impulses without feedback.

The critical difference found in the present study is

that even difficult material is kept below subvocal thresh-

olds.

The data obtained on reading rate (Fig. 2) is similarly

impressive. Although the subject's initial reading rate

for the difficult text was especially slow when compared

to the more easily assimilated light material, as feedback

was introduced there occurred a small improvement in speed,

and with each succeeding session a gradual increase can be

seen. After the second training session the slope of the

functions appears similar. Both curves show an accelera-

tion with the addition of each test. Though increase in

speed for light reading is not extreme, the rate for the

difficult materials has grown well over one hundred words

per minute. Again, what is most significant is that this rate is maintained after feedback is withheld.

As elaborated on earlier in this paper, Pinner, in 1913, found a steady decrease in time to read while comprehension level steadily gained when his subjects tried to reduce subvocalization. In 1970, Hardyck et al., using an infinitely more sophisticated technique for eliminating subvocalization, found an inverse effect. His subjects' comprehension level dropped when they tried to stop this subvocal phenomenon. One is easily tempted to suggest that the discrepancy can be accounted for by the intervention of modern technological know-how. A more critical analysis of the tactics employed by these researchers reveals at least one other major inconsistency in the two designs. Hardyck's subjects were divided into three experimental groups, one of which was given feedback on subvocal emissions. That group's comprehension dropped as a function of increased difficulty. Pinner's subjects, on the other hand, were continually exposed to a series of practice trials. Using various levels of difficulty, he found that though comprehension dropped at the beginning of training, the subjects' ability to retain information grew as the amount of practice increased. This was the same effect that occurred in the present data (Fig. 3). Comprehension level dropped almost seventy per cent with the introduction of laryngeal

muscle feedback. However, as the subject read a continual progression of easy to difficult materials, his ability to retain information gradually accelerated. This was a slow and arduous shaping process. During the two separate one-half-hour practice sessions between testing, the subject was, by degrees, exposed to a series of progressively more difficult texts. As he became adept at reading one range of difficulty, he was introduced to a slightly more difficult selection. It was only after about six separate hours of practice that the subject was able to return to his former level of comprehension prior to feedback intervention.

Conclusion

The effect of many consecutive practice trials with EMG feedback from laryngeal muscle activity has allowed the subject to increase his reading speed and maintain a constant level of comprehension. The most dramatic effect, however, is the fact that the subject has been able to maintain both of these abilities even with difficult material while independent of the EMG feedback apparatus.

A follow-up study at a much later date may reveal some loss of these abilities. If such a study indicated any significant reduction in speed or comprehension as a function of regressing to subvocalization, reconditioning of the subject's reading proficiency would be necessary. However, the experimenter anticipates that this will not occur.

This supposition is based on the data derived from the Hardyck et al. 1967 study, which displayed no regression to subvocalization, as indicated by a follow-up study three months post-training. Also, the subject in this study has been given a follow-up test almost one month after training, with no indication of regression.

Speed reading has evolved into a national, if not international, fad in recent years. Private speed reading institutes, individual texts, and even authorized university speed reading courses have been promoted in an effort to increase and expand man's capacity to acquire knowledge. In an age of rapid cultural transition it has become increasingly important to keep abreast of current events, technological developments, and educational advances. Speed reading has been heralded by many as the ideal method for quick learning. However, recent psychological investigations (Graf, 1973) have begun to dispute the potnetial benefits of this method of absorbing information. Behavioral scientists have been most critical about the speed reader's ability to maintain comprehension while reading at a rate of above four or five hundred words per minute. This is an especially questionable process in the area of learning difficult texts. It has been alleged by these psychologists that speed reading is nothing more than skimming. The method of reading advanced in this paper does not advocate speed reading in the traditional sense.

The only aspect that is related is the common belief in eliminating subvocalization. The subject in this experiment was only taught how to concentrate on the written word without resorting to laryngeal concomitants (subvocalization). It is an open question as to whether typical speed readers ever truly acquire this ability. Indeed, if they have, they have never been able to demonstrate this within the confines of an empirical setting. The method prescribed in this paper does not rely on such dubious speed reading techniques as skipping words, backward reading, reading more than one line at a time, or otherwise taking shortcuts that might ultimately be counterproductive to maintaining recall.

The emphasis in this experiment has been to demonstrate the individual's ability to acquire an accelerated reading skill with difficult material while maintaining comprehension. An increase of one hundred words per minute has permitted the subject to almost double his initial reading rate, while allowing adequate time for information processing.

The reading acquisition curve indicates a slow but continual acceleration. The question arises as to whether this one-hundred-word increase, over a period of eight practice hours, is the ultimate potential gain using this method. It is highly conceivable that with the implementation of even more sophisticated instrumentation, allowing

a greater signal-to-noise ratio, subjects may someday
acquire greater powers of concentration and thus a higher
level of reading efficiency.

References

Aarons, L. Subvocalization: Aural and EMG feedback in
   reading. Perceptual and Motor Skills, 1971, 33, 271-306.

Barlow, M. D. The role of articulation in memorizing.
   Journal of Experimental Psychology, 1928, 22, 306-312.

Dodge. Die motorischen wortuorstelungen. Review by Dela-
   barre in Psychological Review, 1897.

Edfeldt, A. S. Silent speech and silent reading. Chicago:
   University of Chicago Press, 1960.

Faaborg-Anderson, K. Electromyographic infestigation of
   intrinsic largeal muscles in humans. Aeta Physiologica
   Scandinavica, 1957, 41, Supplement 140.

Gilbert, D. W. Power and speed in reading. Englewood
   Cliffs, N. J.: Prentice-Hall, 1973.

Graf, R. G. Speed reading: Remember the tortoise. Psy-
   chology Today, 1973, (Dec.), 112-113.

Gray, W. S. Standardized oral reading paragraphs. Chi-
   cago: Public School Publishing Co., 1915.

Greene, H. A., Jorgensen, A. N., and Kelly, V. H. Iowa
   Silent Reading Tests, Advanced Test: Forms Am. (Rev.).
   New York: World Books, 1943.

Gruber, E. C. How to pass high on the Graduate Record
   Examination. New York: ARCO Publishing Company, Inc.,
   1970.

Hardyck, C., and Petrinovich, L. Subvocal speech and com-
prehension level as a function of the difficulty level
of reading material. Journal of Verbal Learning and
Verbal Behavior, 1970, 9, 647-652.

Hardyck, C., and Petrinovich, L. Treatment of subvocal
speech during reading. Journal of Reading, 1969, (Feb.),
361-368.

Hardyck, C., and Petrinovich, L., and Ellsworth, D. Feed-
back of speech muscel activity during silent reading:
Rapid extinction. Science, 1966, 154, 1467-1468.

Locke, J. L. Phonemic processing in silent reading. Per-
ceptual and Motor Skills, 1971, 32, 905-906.

Lucksinger, R., and Arnold, G. E. Voice-speech-language.
Belmont, Calf.: Wadsworth Publishing Company, 1965.

McGuigan, F. J. Feedback of speech muscle activity during
silent reading: Two comments. Science, 1967, 157, 579-
581.

McGuigan, F. J., and Rodier, W. I. Effects of auditory
stimulation on covert aural behavior during silent read-
ing. Journal of Experimental Psychology, 1968, 76, 649-
655.

McGuigan, F. J., Keller, B., and Stanton, E. Covert lan-
guage responses during silent reading. Journal of Edu-
cational Psychology, 1964, 55, 339-343.

Mechanic, A., and D'Andrea, J. Visual and pronouncing responses, and the relationship between orienting task and presentation in incidental learning. Journal of Experimental Psychology, 1966, 71, 343-349.

Morgan, J. J. B. The overcoming of distraction and other resistances. Archives of Psychology, 1916, 35, 1-84.

Murray, E. J. The effect of white noise upon the recall of vocalized list. Canadian Journal of Psychology, 1965, 19, 333-345.

Neisser, J. Cognitive Psychology. New York: Appleton-Century-Crofts, 1967.

Pinner, R. Inner speech during silent reading. Psychological Review, 1913, 20, 129-153.

Ribot. 'les mouvements et leur importance psychologique. Revue philosophique, Tome VIII, 1879.

Schmit, O. H. Biological transducers and coding. Review of Modern Physics, 1959, 31, 492-503.

Skinner, B. F. Verbal behavior. New York: Appleton-Century-Crofts, 1957.

Sokolov, A. Parole interieure dans la pensee concrete. In Recherches Psychologiques en U.R.S.S. les Editions du Progres, U.R.S.S., 1966.

Underwood, D. J. Articulation in verbal learning. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 146-169.

Whaley, D. L., and Malott, R. W. _Elementary Principles of Behavior_. Ann Arbor, Mich.: Edward Brothers, Inc., 1968.

Watson, J. B. _Behaviorism_. Chicago: University of Chicago Press, 1967.