EFFECT OF SUBVOCALIZATION ON SILENT READING

COMPREHENSION OF COLLEGE STUDENTS IN

A DEVELOPMENTAL READING CLASS

DISSERTATION

Presented to the Graduate Council of the
North Texas State University in Partial
Fulfillment of the Requirements

For the Degree of

Doctor of Philosophy

By

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March, 1982
This study tested the effects of altering subvocalization patterns during silent reading on reading comprehension of college students from developmental reading classes. Electromyographic feedback modified subvocalization in a high subvocalizing group and a low subvocalizing group.

It was hypothesized that at close of training, high subvocalizers would significantly lower their subvocalization below that of their control. It would also be below that of the low subvocalizing experimental group. It was hypothesized that the low subvocalizing experimental group would raise significantly their subvocalization above that of their control group. Reading comprehension hypotheses stated that comprehension scores of high subvocalizers would drop after treatment and low subvocalizers' comprehension would rise.

Fifteen high subvocalizing experimental subjects with 15 control subjects and 15 low subvocalizing experimental subjects with 15 control subjects comprised the study. Students were screened for subvocalization. Those who
scored above or below predetermined criteria were included in the study. Subjects were then randomly assigned to groups. Subjects were pretested for reading comprehension using the Nelson-Denny Reading Test.

High subvocalizers in the experimental group were exposed to a 30-minute biofeedback session to suppress subvocalization while silently reading. It provided them with auditory feedback when they subvocalized. Electromyographic data were collected on control subjects, but no feedback given. The low subvocalizing experimental group received training in subvocalization through a shaping procedure then were exposed to EMG biofeedback designed to increase subvocalizing activity. Biofeedback data were collected on the low subvocalizing control group, but they were not exposed to auditory feedback. All subjects were posttested for reading comprehension after the experimental treatment then post-posttested one month later.

Analysis of covariance and a .05 level of significance were used to test the hypotheses. Subvocalization was significantly suppressed in high subvocalizers over either the control or low subvocalizers. The low subvocalizers did not significantly raise their subvocalization. Reading hypotheses were not confirmed.
# TABLE OF CONTENTS

LIST OF TABLES ........................................ iv

LIST OF ILLUSTRATIONS .............................. v

Chapter

I. INTRODUCTION ................................. 1

  - Statement of the Problem
  - Purpose of the Study
  - Hypotheses
  - Limitations of Study
  - Basic Assumptions
  - Definition of Terms

II. BACKGROUND AND SIGNIFICANCE .............. 10

III. PROCEDURES FOR COLLECTION OF DATA ....... 25

  - Subjects
  - Instruments
  - Procedures
  - Treatment of Data

IV. RESULTS ........................................ 34

  - Reading Comprehension Data
  - Electromyograph Data
  - Discussion

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS . 48

APPENDIX A ........................................... 55

APPENDIX B ........................................... 56

APPENDIX C ........................................... 57

BIBLIOGRAPHY ......................................... 58


**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Adjusted Means of Reading Comprehension Posttest Scores for Control and Experimental Treatments</td>
<td>35</td>
</tr>
<tr>
<td>II. Summary of Analysis of Covariance of Posttest Reading Comprehension Scores</td>
<td>36</td>
</tr>
<tr>
<td>III. Adjusted Means of Reading Comprehension Post-Posttest Scores for Control and Experimental Treatments</td>
<td>37</td>
</tr>
<tr>
<td>IV. Summary of Analysis of Covariance of Post-Posttest Reading Comprehension Scores</td>
<td>38</td>
</tr>
<tr>
<td>V. Adjusted Means of EMG Posttest Scores for Control and Experimental Treatments</td>
<td>40</td>
</tr>
<tr>
<td>VI. Summary of Analysis of Covariance of EMG Posttest Scores</td>
<td>40</td>
</tr>
<tr>
<td>VII. Newman-Keuls Test of EMG Adjusted Means</td>
<td>42</td>
</tr>
</tbody>
</table>
LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mean EMG Adjusted Scores as a Function of Level of Subvocalization</td>
<td>41</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

With the proliferation of community colleges across the nation and their policy of open door admissions, there has developed a relatively new challenge for higher education—how to provide services to poor readers. To a limited extent, senior colleges have been shielded from this problem by admission standards that screen out those students with significant reading handicaps. However, for community colleges who admit anyone with a high school diploma or its equivalent (and occasionally, not even that), the mandate is clear: either the weaknesses of the poor reader must be remediated, or the open door becomes merely a revolving door.

One reading weakness that, on the surface, appears most amenable to change is slow reading. College students are generally required to read and assimilate large masses of written information, usually much more than was required of them in high school. For the slow reader, this can become an overwhelming chore. An obvious solution appears to be to increase the students' silent reading speed. Educational and commercial enterprises have endeavored to do just that. Training in skimming and perceptual training \(^{(17)}\), use of the tachistoscope \(^{(22)}\), reading films and
reading rate accelerators (19), and reading exercises (6) have all been tried, most with remarkable success according to the proponents of the various methods.

The latest attempt to combat slow reading is the electromyogram (EMG). Observations of subvocalization (including lip, tongue, and larynx movement) were made before this century (2). Since only lip movement could be readily observed, it was the first target for reduction. However, as technology improved, efforts to study, control, or reduce extraneous muscular activity in reading was expanded to include the tongue (21), larynx (8), and respiratory system (7). Despite considerable early interest in covert muscular activity associated with reading, lack of technical sophistication limited its direct study. It was not until the perfection of the EMG (although a recent study indicates lip readers were more effective at detecting subvocal rehearsal (18) and its application to the problem (10) that it was possible to modify directly the muscular activity of the voice box). The EMG feedback is used to signal interfering muscle activity, (3) and with its aid and the feedback it provides, subvocalization can be eliminated in as little as 30 minutes (5, 15). The biofeedback technique is based on the fundamental learning principle that persons learn to perform a particular task when they receive feedback or information about the consequences of that response and then make the
appropriate compensatory behavioral adjustments (11). The result of its use in subvocalization is an increase in reading fatigue (4). However, the solution has not proven to be so simple. There is an ongoing debate concerning the role of subvocalization as a relevant source of sensory input in the reading process. In other words, this behavior may be an aid in reading comprehension rather than an artifact of being taught to read orally. Edfeldt (9) concluded that with regard to silent reading, "it seems quite clear that all kinds of training aimed at removing silent speech should be discarded." A number of studies have been undertaken to explore the role of subvocalization in reading comprehension (1, 14, 15, 20) as well as the role of reading speed in comprehension (16). Conclusions vary, and the role of subvocalization in silent reading is still far from being well understood. In some studies, comprehension dropped when subvocalization was extinguished (13, 23); in others, it remained unchanged (14, 20). Review of existing literature does not reveal studies that have dealt specifically with a community college population.

Statement of the Problem

Review of the studies in the area of subvocalization reveals that its role in silent reading comprehension remains in question. It appears clear that subvocalization
does occur during reading, usually among poorer readers or as reading becomes more difficult, and that it slows the reading process (12). However, how it affects reading comprehension, or if it affects reading comprehension, remains unclear. This study attempted to answer the question of whether subvocalization affects reading comprehension in an adult community-college population.

Purpose of the Study

The purpose of this study was to evaluate the effect of subvocalization on the reading comprehension of the community college students in developmental reading programs.

Hypotheses

Consistent with the purpose of this study, the following hypotheses were tested in this study:

I. The subjects in the Low Subvocalizing (LV) group will have a significantly greater gain in reading comprehension as measured by the Nelson-Denny Reading Test than will the subjects in the Low Subvocalizing Control (LVC) group at the close of training. (Training procedures are outlined in Chapter III.)

II. The subjects in the High Subvocalizing (HV) group will have a significantly greater loss in reading comprehension as measured by the Nelson-Denny Reading Test than will subjects in the High Subvocalizing Control
(HVC) group at the close of training.

III. The subjects in the LV group will have significantly greater gain in reading comprehension as measured by the Nelson-Denny Reading Test than the HV group at the end of training.

IV. Subjects in the LV group will have a significant increase in EMG activity over the LVC group at the end of training.

V. Subjects in the HV group will have a significant decrease in EMG activity over the HVC group at the end of training.

VI. Subjects in the LV group will demonstrate a significant increase in EMG activity over the HV group at the close of training.

Limitations of Study

This study was limited to community college students within the Dallas County Community College District enrolled in Developmental Reading courses on the Richland College campus. Given the developmental nature of the reading process, assumptions about the results were limited to those concerning adult readers. Subjects for this study were volunteers, and may differ for that reason from the general population. While it is assumed for purposes of this study that the EMG is measuring subvocalization, it should be noted that the EMG may also
be measuring muscular tension. Laryngeal muscular activity may be influenced by such factors as stress and drug usage.

Basic Assumptions

It was assumed that subjects did not have physical abnormalities that precluded normal EMG activity of the larynx. It was further assumed that English was the primary language for the subjects and that they had no handicapping conditions, such as deafness or blindness, that affected their methods of processing visually presented stimuli.

Definition of Terms

For the purposes of this study, the following operational definitions were formulated:

1. **Subvocalization.** Subvocal behavior has been given numerous labels in the literature. Silent speech, covert oral behavior and inner speech all refer to the behavior that is termed subvocalization in this study. For purposes of this study, subvocalization is defined as the minute movements in speech musculature which occur during silent reading.

2. **Biofeedback.** This is a technique of controlling internal body processes through knowledge of bodily changes as they occur. This knowledge generally is made available through the use of some device that provides auditory or visual representation of the bodily process.
3. **Electromyography (EMG).** This is a technique of recording electrical activity of muscles. Either surface or needle electrodes may be used.

4. **Reading Comprehension.** Reading comprehension is the ability to recall information and generalize that knowledge to other situations in a manner measurable by a standard reading comprehension test.

5. **Low Subvocalization.** Muscular activity of the voice box, as measured by an electromyograph, at or below a mean of eight microvolts during silent reading.

6. **High Subvocalization.** Muscular activity of the voice box, as measured by an electromyograph, at or above a mean of thirteen microvolts during silent reading.
CHAPTER BIBLIOGRAPHY


CHAPTER II

BACKGROUND AND SIGNIFICANCE

The role of subvocalization in reading has been a question that researchers in the field of reading have been attempting to clarify since before the turn of the century. Several early researchers studied subvocalization, although their conclusions were severely limited by a lack of sophisticated technology and sometimes by inadequate experimental controls. Nevertheless, as early as 1880, S. S. Strincker (42), using introspection, found that when he tried to recite a poem he had memorized while silently reading a newspaper article, the speech movements which accompanied the reading broke through between the words of the poem. Strincker and his subjects claimed that they could not think of letters or words without experiencing the corresponding speech-motor phenomena.

Other early studies utilized some crude apparatus in an attempt to prove the existence of subvocal speech. Several of these studies were primarily concerned with the muscular activity connected with thinking, but some studied reading as a part of the thinking process. Curtis (10) placed a tambour on the larynx then asked his subjects to rest, read silently, silently recite and to whisper. The
laryngeal activity was recorded with a kymograph for these conditions. He found increased laryngeal activity from baseline in both the silent reading and silent recitation conditions in 75 per cent of his subjects. His findings were confirmed in a later study which studied tongue movements (9). Reed (39) attempted to record subvocalization by means of an apparatus that was made of very thin rubber stretched over a wire frame which was connected to a wood block. The block was held between the teeth and the membrane was suspended within the mouth cavity. A rubber tube was connected to the membrane, running through the block and then to a kymograph which recorded any changes in air pressure within the mouth. Breathing curves were also recorded from the nose, chest, and abdomen. The following tasks were required of his thirteen subjects: (1) not think of anything, (2) read silently, (3) write silently, (4) whisper, (5) read aloud, (6) count silently, and (7) solve arithmetic problems. Reed compared the breathing curves with his oral measures in an effort to separate subvocalization from breathing. He found that from one-fourth to three-fourths of his subjects exhibited subvocalization during the various thinking tasks, and these were independent of the breathing curves.

In a study using three subjects, Perky (37) recorded laryngeal movements by means of a Verdin Laryngograph. The subjects responded to a word by attempting to obtain
an "auditory image," that is, imagine they were hearing the word. It appears that she found an increase in subvocalization from baseline during the presentation of words and that the amplitude of that activity varied according to the degree of concreteness of the word.

In a study of rapid reading, Abell (1) concluded that subvocalization was a cause of slow reading and should be eliminated. She reported:

A characteristic correlate, in the case of our subjects, of slow reading, is the actual pronunciation or the vivid articulatory imagination of the words read. This device, which may assist in the comprehension of a strange word or obscure meaning, is certainly a hindrance when it becomes habitual. The discouragement of a child's tendency to accompany reading by articulation is an evident pedagogical requirement (1, p. 285).

This idea that subvocalization is detrimental to reading was adopted by numerous researchers (6, 38, 39). McDode (29) developed a reading method designed to circumvent the problems of subvocalization by teaching children to first read silently. His hypothesis, also later put forth by F. Smith (40), was that subvocalization develops as a side effect of first learning to read aloud, and that the reader retains the habit of actually saying the words even when reading silently. Even though he claimed good results, McDode failed to prove his basic hypothesis that subvocalization is detrimental to good reading, and his methods are very seldom used today (29). Nevertheless,
a later reading expert echoed McDode's concerns about subvocalization and warned reading teachers that it would hinder silent reading speed (16).

This view was by no means universally accepted, however, since E. B. Huey (25), in his early research aimed at interfering with subvocalization by distraction, adopted the view that "to the extent that it occurs, it aids the reader in keeping in mind the various elements of meaning until he receives a clear grasp of the idea intended by the author" (p. 238). Several later researchers also hold to this view. Conrad (8), in his review of reading and short-term memory research, stresses the significance of short-term memory in the reading process. He points out its necessity in understanding material by holding onto certain items while the implication of subsequent words is considered. He concludes that speech is the most efficient possible code for remembering words.

In their book on reading, Gibson and Levin (19) surmise that "it is by no means clear that dropping out subvocalization aids the comprehension of poor readers or even good readers when the material is difficult." Also, McGuigan (30) concludes from his review of the literature that subvocalization can serve a "unique language function" in providing proprioceptive feedback to the central nervous system.

At this point it seems necessary to briefly touch on
an issue that involves the whole class of covert behaviors, generally referred to as thinking, of which silent reading is a part. This issue deals with the question of whether thinking is exclusively a central nervous system function or whether thinking also necessarily involves muscular movements. These two positions are known respectively as the centralist and peripheralist theories of thinking.

The centralist position maintains that when a language stimulus, such as a mathematics problem, impinges on the body's receptors, an afferent neural impulse results, which in turn triggers certain brain events. It is these central events that are necessary for solution of the problem (24). Centralists do not deny that certain responses are by-products of thinking, but they would maintain that those by-products are not a necessary part of the process (24). However, given the same set of circumstances, the peripheralist would maintain that the occurrence of the efferent neural impulse resulting from the brain event, the covert response, and then the proprioceptive feedback are all necessary for the solution of the problem. In summary, the peripheralist believes that responses are necessary conditions for thinking, while the centralist says they are not (31).

Although such a far-reaching experimental question is beyond the scope of this work, it has obvious implications for a study of subvocalization. If a centralist
position is assumed, then it follows that subvocalization is but an artifact of learning to read and is essentially nonfunctional. If, on the other hand, one takes a peripheralist stance, then one would assume that subvocalization plays a useful role in the reading process (30, 34). This debate is far from over; its solution is dependent on much more research and the technological advances that will make a study of the physiological aspects of thinking possible. Thus far, subvocalization has been studied within this context because it appears to provide measurable evidence of a portion of the thinking process.

The whole area of reading has had a resurgence of popularity, with psychological researchers focusing on various minute areas of the complex reading process (12). However, much basic reading research involves such specialized and select areas that they create an intellectual distance between current research and a comprehensive understanding of the reading process (7, 12), and caution must be taken in aligning basic research with the applied aspects of reading. Studies involving subvocalization in the reading processes are much more closely aligned to a general and pragmatic view of the reading process (29).

Jacobson, in 1932, was one of the earliest users of electromyography. His data were used to support his belief that muscles are minutely active even when the body is seemingly at rest. In his studies of the effect
of imagination on the body, he had his subjects imagine only such activities as lifting a weight, watching a tennis game, or reading silently. His electromyogram (EMG) data showed that whatever muscle group would have been involved in the real activity responded with bursts of electrical activity when the subject imagined that activity (26).

Another classic work was done in 1937 by Max (35). He hypothesized that the activity of the fingers of deaf users of sign language would increase during the solution of thought problems. He found that abstract problems elicited action current responses more frequently and to a greater extent in the arm than in the legs. He concluded that these responses have a connection with the thinking process itself. In a review of the literature on biofeedback, Blanchard and Young (5) conclude that only in areas of elimination of subvocal speech, muscle retraining and elimination of tension headaches does the evidence support strong conclusions on the efficacy of biofeedback training.

An electromyographic study on the functioning of the intrinsic laryngeal muscles in humans is also historically important. Using needle electrodes, Foaborg-Andersen (13) had his subjects think about the phonation of the vowel "e" without audible phonation. He found that electrical activity in the crico-thyroid and the vocal muscles increased under this condition, although less than in the use in which phonation was actually expressed. Shortly
after this research, Foaborg-Andersen (14) conducted a second study that is apparently the first attempt to measure subvocalization during silent reading. He inserted needle electrodes in three locations of the laryngeal musculature. He recorded EMGs and sound records when the subjects rested, read silently, and read aloud. The subjects read their native prose (Danish) and foreign prose (Swedish). The researcher's conclusions were as follows: (a) vocal and mylohyoid EMG was increased in silent and overt reading of both Danish and Swedish prose; (b) EMG was substantially greater for subjects who were unaccustomed to reading foreign prose rather than reading their native language, but this effect was not present for subjects accustomed to reading the foreign text; (c) the EMG activity started .3 to .5 seconds before onset of an audible signal during overt reading. Edfeldt (11) extended this research still further. He classified 84 subjects as good, medium, or poor readers based on a battery of tests. He varied the difficulty of the text (easy vs. difficult) and the clarity of the text (clear vs. blurred). Using laryngeal EMG (needle electrodes) during reading and resting, he found that

. . . good readers engage in significantly less subvocalization during silent reading than do poor readers; that easy text results in significantly less subvocalization than does difficult text; and reading the clear text produced less silent reading than the blurred text (11, p. 129).
He concluded, "silent speech cannot be a habit which is, in itself, detrimental to the reading performance . . . it appears likely that . . . silent speech actually serves as an aid toward better reading comprehension" (11, p. 196).

McGuigan, Keller, and Stanton (32) measured surface lip and chin EMG in children and college students. They found that these EMG data increased significantly during silent reading for both groups of subjects over data taken at rest. Sokolov (41) reported increased speech muscle activity for linguistic tasks, including silent reading. McGuigan (30) found that college students increased their amplitude of EMG from resting during silent reading. Additionally, respiration and preferred arm EMG also significantly increased during silent reading over control data taken from non-preferred arm and from legs. In a study of information processing, McGuigan and Winstead (34) found that covert oral activity increased during silently performed tasks. They suggested from their findings that speech and other musculature may participate in central-peripheral circuits. They hypothesized that this occurred by generating afferently carried phonetic codes that retrieve phonemes from a central store.

Subvocalization was found to increase when the text is difficult to see (4, 11), as well as when it occurs simultaneously with competing verbal stimuli (33) and as the task becomes more difficult (8).
The biofeedback technique is based on the idea that individuals learn to make a certain response based on the feedback or information about the consequences of the response, thereby making compensatory behavioral adjustments (15). Electromyographic feedback has been used successfully for a number of rehabilitative applications concerned with the speech musculature. It has been used for the treatment of stuttering (21, 27), as well as the interfering muscle activity of subvocalization (2, 3).

Hardyck, Petrinovich, and Ellsworth (23) found that auditory feedback from speech muscles via an EMG produced long-lasting cessation of subvocalization that occurs during silent reading. Hardyck and Petrinovich (22), using auditory feedback to reduce subvocalization, found their feedback group (instructed to keep the tone off) did significantly less well on comprehension of difficult material than groups that did not have feedback. They also found that activity of speech muscles increased with difficulty of material. A recent study (36) found significant increases in reading rate while maintaining comprehension when subvocalization was eliminated. This experiment utilized many biofeedback sessions, and the experimenter reported initial drops in reading comprehension that were later regained. A study by Wells (43) revealed trends toward comprehension loss when subvocalization was suppressed. She concluded that subvocalization
may be an ancillary device employed by the reader during stress when stress is defined as conceptual or perceptual difficulty, distractions, or speed controls.

In addition to its possible role in comprehension, subvocalization has also been implicated in the process of recall. Relatively early studies that utilized EMG feedback (20, 28) failed to find a significant relationship between subvocalization and recall; however, these studies may have been hampered by a lack of technological sophistication in that they measured highest pen deflections on a polygraph reader (18). In a study that utilized a more elaborate data gathering procedure, Garrity (17) found that subvocalization was significantly related to recall. Her conclusion and that of McGuigan (30) was that subvocalization represents covert verbal rehearsal of items to be remembered.


35. Max, L. W., "An Experimental Study of the Motor Theory of Consciousness, IV, Action-current Response in the Deaf During Awakening,


CHAPTER III

PROCEDURES FOR COLLECTION OF DATA

Subjects

Subjects for this study were selected from the developmental reading classes of Richland College in Dallas, Texas. Students enrolled in developmental reading are typically trying to improve their reading skills so they will be able to successfully read and comprehend college-level material. Although concerned with reading improvement, these classes are not strictly remedial in nature. Many students in these classes read at or above their grade level. The average age of students was 22, with a range from 17 to 34. All students in the three developmental reading classes were told the following:

"Good morning. My name is Mary Ann Korioth. You have been asked to participate in an experiment designed to examine how changes inside your body affect reading. You will be asked to read a section in a book while we measure changes going on inside your body. This will be done by attaching these scalp electrodes to locations on your neck. They are designed to pick up minor changes inside your body. You will not feel any discomfort of any kind during the experiment."
"I would like to thank you for your assistance in this experiment."

The laboratory assistant then proceeded to screen all students, a process which enabled her to select out the high and low subvocalizers according to the Hardyck and Petrinovich (3) method outlined later in the Procedures section of this chapter. All subjects signed a Waiver of Liability, as is required by the Dallas Community College District for all experimental subjects.

Instruments

Electrode placement was accomplished by utilizing the procedure employed by Hardyck et al. (3). One electrode was placed on either side of the thyroid cartilage. The electrode placement using Beckman 16mm bioelectrodes allowed a large portion of the larynx to be recorded. An Autogenic Systems Autogen 1700 electromyograph was utilized to detect and measure myographic activity. This system utilizes shielded electrode cables, input connectors and preamplifiers, thereby negating the need for shielded room to preclude common-mode interference and other environmental electrical artifact. This particular model also has a bondpass filter designed to reject cardiac artifact. Feedback selected for study was analog tone feedback delivered via headphones worn by the subject. EMG data were provided by an integrator that
provided visually presented time-averaged readouts. The laboratory assistant noted these data on record forms created for this purpose. The EMG was set to pick up electrical activity at or above .5 microvolts. The equipment monitored this activity continuously, and the integrator provided an average activity level at one-minute intervals.

The laboratory assistant who collected the data was a senior in the Department of Psychology at the University of Texas at Dallas, in Richardson, Texas. She is a certified Biofeedback Technician and a member of the Biofeedback Society. In order to achieve these credentials she was engaged in an extensive one-semester training course involving both theoretical and practical applications of biofeedback. During her training she was supervised in the use of these procedures by a psychological associate and a licensed psychologist.

The Nelson-Denny Reading Test was recommended as the standardized reading test of choice (6). This test was standardized on a college population as well as high school population and the college population included a representative sample of junior (senior college preparatory students) and community college students (which included students in one- or two-year technical and vocational programs) (2).

Split-half reliability coefficients (corrected by the Spearman-Brown Formula) for the comprehension section
for grades 13 and 14 are .83 and .81 respectively and standard deviations of 11.46 and 11.30 respectively. A standard error of measurement was not reported for the split-half approach. The authors also report reliability by the equivalent forms method using forms card D for grades 9-12 but not grades 13-16. The standard error of measurement for Form C for grade 12 is 6.5 and 6.1 for Form D with a reliability coefficient of .74 for both forms. Validity coefficients are not formally reported by the authors. They suggest perusal of the reliability coefficients for evidence as well as examination of the test itself for validity (2).

Procedures

This study involved four groups—two experimental groups and a control group for each experimental group with 15 per group. The subjects were divided as high subvocalizers and low or non-subvocalizers, as defined in Chapter I, then randomly assigned to an experimental or control condition using a table of random numbers. Data were taken in an office. The subjects were seated at a desk in a comfortable desk chair. To minimize extraneous movement subjects were asked to rest the book on the desk. The data were taken by a research assistant who monitored the session by sitting to one side and slightly behind the subject. All equipment was turned away from
the subject to minimize the distractions of the visual readouts. EMG data were recorded on a standard form designed for this study (see Appendix A).

Determining the presence or absence of subvocalization was based on a procedure used by Hardyck and Petrinovich (4), and was as follows: The subjects were asked to read a chapter from a college text. They were then allowed to read for thirty minutes, during which time the EMG record was monitored and artifacts of swallows, head movements, and coughs (which produce strong EMG activity) were noted. These artifacts were removed from the records. The text used for this purpose was *The American Pageant: A History of the Republic*, Chapter 40, "Calvin Coolidge and the Jazz Age," by Bailey and Kennedy (1). This text was chosen because of its relatively low reading level—eighth grade—as measured by the Dale-Chall Readability Formula.

To establish the presence or absence of subvocalization, the subject was asked to stop reading while staying in the exact same position for five minutes, then start reading for five minutes, then stop reading for five minutes. Once the presence or absence of subvocalization had been established, the subject was asked to return in one week for the treatment phase.

The instrument used to measure reading comprehension, the Nelson-Denny Reading Test (2), was administered three times to all groups. The test was administered before
the experimental phase of the EMG training (pretest) and then again after the EMG training (posttest) of subjects in the experimental groups. The final reading comprehension testing (post-posttest) came one month after the posttest. Each subject was told individually that test results were not used in any way to determine his/her class grade.

**HV Training Procedure**

The training procedure for the high subvocalization (HV) group was as follows: Using analog-type feedback (the frequency of the tone varies according to the degree of muscle activity), the relationship between the tone and speech muscle activity was explained to the subject. This was done by first asking the subject to relax and then to swallow. The result of the swallow could immediately be heard by a change in the tone frequency. The subject was allowed to continue experimenting with the tone until the subject was satisfied he controlled the tone. The subject was then asked to read to himself with the feedback on. The instructions were to continue to read silently but to keep the tone off as much as possible (see Appendix B).

**LV Training Procedure**

There appear to be no prior studies in which subvocalization has been a training aim. A brief pilot
study was undertaken to determine the most useful instructions for the LV group. Five subjects who had been screened utilizing the Hardyck and Petrinovich method described earlier and identified as Low Subvocalizers were used for the pilot study. Since it seemed possible to mimic subvocal activity in order to achieve enough muscular tension to turn the tone on, a procedure was developed to encourage subvocalization. The subjects were individually introduced to a shaping procedure of first whispering while reading (an activity that obviously activated the EMG). After two minutes of this the subjects were told to stop whispering but to continue mouthing the words while reading. The subjects were then instructed to cease that activity but to continue to keep the tone on while reading. An auditory imagery component of subvocalization has been proposed (5); that is, some subvocalizers report that it is as though they can hear their own or someone else's voice while reading silently. Three of the five pilot study subjects were additionally instructed to imagine that they could hear someone reading as they read the material. A review of the pilot study data without statistical analysis suggested that those subjects who used auditory imagery (imagined they could hear themselves reading) increased their subvocalization more than did those who did not use the imagery. Based on this observation, the imagery was added to the shaping procedure.
Based on this informal pilot study, the training procedure for the LV group was as follows: initial exposure and introduction to the feedback equipment was the same as for the HV group. However, their instructions consisted of a five-minute instructional period in which they were told to turn the tone on first by whispering the words while reading for two minutes, and then to keep the tone on without other overt movement. They were asked to imagine they could hear a voice reading as they read silently (see Appendix C). After the five-minute initiation, they were instructed to keep the tone on while reading. Data were then taken as for the HV group. Training for all subjects consisted of one thirty-minute session.

The control groups for both experimental conditions were brought in, hooked up to the equipment and asked to read silently for thirty minutes. EMG data were taken, but no auditory feedback was provided.

The training was carried out by the Richland College psychology student assistant who was a senior psychology major at the University of Texas at Dallas and whose training has been discussed previously.

Treatment of Data

EMG data were analyzed with a 2x2 analysis of covariance with the pretest as the covariate measure. Pretest and posttest reading comprehension data were also analyzed by a 2x2 analysis of covariance with the pretest as the covariate measure.
CHAPTER BIBLIOGRAPHY


CHAPTER IV

RESULTS

The purpose of this chapter is to present and analyze the data yielded by this study. The purpose of this study was to investigate possible changes in reading comprehension after biofeedback intervention in the subvocalization process. Data were analyzed by computing analysis of covariance in order to control statistically for possible differences among the groups under study.

The results section is organized according to the two criterion measures: reading comprehension and electromyograph data. Tests of Hypotheses 1 through 3 are based on the reading comprehension data and Hypotheses 4 through 6 are tested by means of the electromyograph data. The .05 level of significance was used in all statistical tests.

Reading Comprehension Data

Hypothesis 1 predicted that subjects in the Low Subvocalizing (LV) group would have a significantly greater gain in reading comprehension as measured by the Nelson-Denny Reading Test than would the subjects in the Low Subvocalizing Control (LVC) group at the close of training. Hypothesis 2 predicted that the subjects in the High Subvocalizing (HV) group would have a significantly
greater loss in reading comprehension as measured by the Nelson-Denny Reading Test than would subjects in the High Subvocalizing Control (HVC) group at the close of training. Hypothesis 3 predicted that the subjects in the LV group would have a significantly greater gain in reading comprehension as measured by the Nelson-Denny Reading Test than the HV group at the end of training. These three hypotheses were first tested by subjecting the reading comprehension data to a 2 (low and high subvocalization) by 2 (control and experimental) analysis of covariance in which the pre-test reading comprehension scores were used as the covariate to adjust the posttest reading comprehension scores for initial differences. Table 1 contains the resulting adjusted means utilized in the analysis.

**TABLE 1**

**ADJUSTED MEANS OF READING COMPREHENSION POSTTEST SCORES FOR CONTROL AND EXPERIMENTAL TREATMENTS**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Statistic</th>
<th>Level of Subvocalization</th>
<th>Main Effect*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Control</td>
<td>N</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>9.4025</td>
<td>9.0709</td>
</tr>
<tr>
<td>Experimental</td>
<td>N</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Main Effect (Level of Sub-</td>
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<td>30</td>
<td>30</td>
</tr>
<tr>
<td>vocalization)</td>
<td>M</td>
<td>9.3556</td>
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</tbody>
</table>

* Treatment
The relevant tests of significance involving the means are shown in the summary of the analysis of covariance statistics presented in Table 2.

**TABLE 2**

**SUMMARY OF ANALYSIS OF COVARIANCE OF POSTTEST READING COMPREHENSION SCORES**

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (A)</td>
<td>.0201</td>
<td>1</td>
<td>.0201</td>
<td>.0399</td>
<td>.8424</td>
</tr>
<tr>
<td>Level of Subvocalization (B)</td>
<td>1.4310</td>
<td>1</td>
<td>1.4310</td>
<td>1.8280</td>
<td>.0977</td>
</tr>
<tr>
<td>A X B</td>
<td>.0077</td>
<td>1</td>
<td>.0077</td>
<td>.0153</td>
<td>.9022</td>
</tr>
<tr>
<td>Error</td>
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<td>55</td>
<td>.5042</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>29.1907</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Inspection of Table 2 reveals no interaction effect, $F(1, 55) = .0153$, which in turn, leads to consideration of the overall significance of the two main effects. Neither the main treatment effect, $F(1, 55) = .0399$ nor the main level of subvocalization effect, $F(1, 55) = 1.8280$ are significant. Therefore, Hypotheses 1 through 3, concerning changes in reading comprehension as a result of the biofeedback treatments, are not supported by these data. Further inspection of the probability column indicates that the effects did not approach significance.

An additional measure of reading comprehension
(post-posttest) was collected one month after the posttest. Thus, Hypotheses 1 through 3 were also tested by subjecting the reading comprehension post-posttest data to a 2 (low and high subvocalization) by 2 (control and experimental) analysis of covariance in which the pretest reading comprehension scores were used as the covariate to adjust the post-posttest reading comprehension scores for initial differences. Table 3 contains the resulting adjusted means utilized in the analysis.

**TABLE 3**

ADJUSTED MEANS OF READING COMPREHENSION POST-POSTTEST SCORES FOR CONTROL AND EXPERIMENTAL TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Statistic</th>
<th>Level of Subvocalization</th>
<th>Main Effect*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Control</td>
<td>N</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>9.1655</td>
<td>8.8310</td>
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<tr>
<td>Experimental</td>
<td>N</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>9.1812</td>
<td>8.9289</td>
</tr>
<tr>
<td>Main Effect</td>
<td>N</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>(Level of Sub-</td>
<td>M</td>
<td>9.1568</td>
<td>8.8966</td>
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</tbody>
</table>

* Treatment

The relevant tests of significance involving the means are shown in the summary of the analysis of covariance statistics presented in Table 4.
TABLE 4

SUMMARY OF ANALYSIS OF COVARIANCE OF POST-POSTTEST READING COMPREHENSION SCORES

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (A)</td>
<td>.0482</td>
<td>1</td>
<td>.0482</td>
<td>.1081</td>
<td>.7435</td>
</tr>
<tr>
<td>Level of Subvocalization (B)</td>
<td>1.2908</td>
<td>1</td>
<td>1.2908</td>
<td>2.8943</td>
<td>.0945</td>
</tr>
<tr>
<td>A X B</td>
<td>.0253</td>
<td>1</td>
<td>.0253</td>
<td>.0568</td>
<td>.8125</td>
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<tr>
<td>Error</td>
<td>24.5293</td>
<td>55</td>
<td>.4460</td>
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<td>Total</td>
<td>25.8937</td>
<td>58</td>
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</table>

Results of the covariance analysis of the post-posttest data, contained in Table 4, reveal no significant interaction effect, F (1, 55) = .0568. The lack of significant interaction effect leads to consideration of the two main effect tests. The main treatment and level of subvocalization effects, relating to Hypotheses 1 through 3, respectively, were not significant, F (1, 55) = .1081; F (1, 55) = 2.8943. Therefore, Hypotheses 1 through 3 were not confirmed by this post-posttest reading comprehension data, nor by the posttest reading comprehension data. Inspection of the probability column reveals that none of the effects closely approached significant levels.
Electromyograph Data

Hypothesis 4 predicted that subjects in the Low Subvocalizing (LV) group would have a significant increase in EMG activity over the Low Subvocalizing Control (LVC) group at the end of training. Hypothesis 5 predicted that subjects in the High Subvocalizing (HV) group would have a significant decrease in EMG activity over the High Subvocalizing Control (HVC) group at the end of training. Hypothesis 6 predicted that subjects in the High Subvocalizing (HV) group would demonstrate a significant decrease in EMG activity over the Low Subvocalizing (LV) group at the close of training. These three hypotheses were tested by subjecting the EMG data to a 2 (low and high subvocalization) by 2 (control and experimental) analysis of covariance in which the pretest EMG scores were used in the covariate to adjust the posttest EMG scores for initial differences. Table 5 contains the resulting adjusted means utilized in the analysis.
TABLE 5
ADJUSTED MEANS OF EMG POSTTEST SCORES FOR CONTROL AND EXPERIMENTAL TREATMENTS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Statistic</th>
<th>Level of Subvocalization</th>
<th>Main Effect*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Control</td>
<td>N</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>2.1732</td>
<td>4.4330</td>
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<tr>
<td>Experimental</td>
<td>N</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>2.7080</td>
<td>1.2836</td>
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<tr>
<td>Main Effect</td>
<td>N</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>(Level of Subvocalization)</td>
<td>M</td>
<td>2.4913</td>
<td>2.8075</td>
</tr>
</tbody>
</table>

* Treatment

The relevant tests of significance involving the means are shown in the summary of the analysis of covariance statistics presented in Table 6.

TABLE 6
SUMMARY OF ANALYSIS OF COVARIANCE OF EMG POSTTEST SCORES

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
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</thead>
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<tr>
<td>Treatment (A)</td>
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<td>2.9249</td>
<td>5.8834</td>
<td>.0106</td>
</tr>
<tr>
<td>Level of Subvocalization (B)</td>
<td>2.5689</td>
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<td>2.5689</td>
<td>5.1674</td>
<td>.0269</td>
</tr>
<tr>
<td>A X B</td>
<td>50.2276</td>
<td>1</td>
<td>50.2276</td>
<td>101.0322</td>
<td>.0000</td>
</tr>
<tr>
<td>Error</td>
<td>27.3430</td>
<td>55</td>
<td>.4971</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>83.0644</td>
<td>58</td>
<td></td>
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</tbody>
</table>
Inspection of Table 6 reveals a significant interaction effect, $F(1, 55) = 101.0322, P < .0001$. Therefore, the significant main effects of treatment and level of subvocalization will not be considered. The nature of this interaction is graphically presented in figure 1.

Figure 1. Mean EMG adjusted scores as a function of level of subvocalization.

Figure 1 illustrates the differences in subvocalization after treatment between the two experimental groups and between each experimental group and its control group. The LV and LVC groups are at the low end of the X axis while the HV and HVC groups are represented at the high end of the X axis. As can be seen by this visual explanation, the LV group did have an increase in subvocalization over the LVC group though not significantly so. The difference in the HV and HVC is more dramatic. This graph also displays the difference in subvocalization between
the LV and HV group following treatment. The level of subvocalization for the HV group was significantly lower than that of the LV group. However, given the failure to prove Hypothesis 4 (LV < LVC at close of treatment), it might be assumed that it was the significant suppression of subvocalization in the HV group rather than the increase in subvocalization in the LV group that led to the acceptance of Hypothesis 6 (HV < LV at close of treatment).

Subsequent tests among the four individual adjusted means followed the Newman-Keuls procedure. The Newman-Keuls results are presented in Table 7. These statistics indicate that all treatment-subvocalization combinations are significantly different from each other, with the exception of the comparison of the LVC with the LV groups.

**TABLE 7**

**NEWMAN-KEULS TEST OF EMG ADJUSTED MEANS**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>LVC</th>
<th>HVC</th>
<th>LV</th>
<th>HV</th>
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</thead>
<tbody>
<tr>
<td>LVC</td>
<td>---</td>
<td>2.2598*</td>
<td>.5348</td>
<td>.8896*</td>
</tr>
<tr>
<td>HVC</td>
<td></td>
<td>---</td>
<td>1.7250*</td>
<td>3.1494*</td>
</tr>
<tr>
<td>LV</td>
<td></td>
<td></td>
<td>---</td>
<td>1.4244*</td>
</tr>
<tr>
<td>HV</td>
<td></td>
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</tr>
</tbody>
</table>

*p < .01
Therefore, Hypothesis 4, that subjects in the Low Subvocalization (LV) group would have a significant increase in EMG activity over the Low Subvocalization Control (LVC) group, was not confirmed. Hypothesis 5, that subjects in the High Subvocalization (HV) group would have a significant decrease in EMG activity over the High Subvocalization Control (HVC) group at the end of training, was confirmed. Hypothesis 6, that the subjects in the High Subvocalizing (HV) group would demonstrate a significant decrease in EMG activity over the Low Subvocalizing (LV) group at the close of training, was also confirmed.

Discussion

The ability to suppress subvocalization is well documented in the literature. Consequently, it was hypothesized that this would occur in the HV group as a result of biofeedback training. A review of available literature on subvocalization did not reveal any prior attempts to train subvocalization in subjects where it was absent or existing at a very low rate. If, in fact, researchers who postulated that subvocalization is an aid to comprehension were correct, then it would seem reasonable to assume that adding it to a subject's repertoire of reading aids would increase his reading comprehension. It was therefore hypothesized that at the close of training the LV group would demonstrate significantly more
subvocalization than the LVC groups. It was also hypothe-
sized that the HV group and the LV group's reading
comprehension scores would be significantly higher than
either of these groups. The hypothesis was also made
that the HV group would suffer a loss in comprehension
after elimination of subvocalization. This would constitu-
tute a significant difference between the HV group and
the HVC group at the close of training as well as a
difference between the HV and the LV groups at the close
of training.

The hypotheses concerning the biofeedback training
for high subvocalization were confirmed. By the end of
the biofeedback training, subvocalization in the HV group
had decreased significantly in comparison to the HVC
group and the LV group. This finding is in keeping with
the vast majority of subvocalization studies such as
those reviewed extensively in McGuigan (5) and Gibson
and Lewis (3). In contrast, the LV group's rate of sub-
vocalization had not significantly increased over the
LVC group. It does not appear, therefore, that subvocali-
zation is a trainable response for silent readers at
least within the training time available for this study.

The hypotheses concerning reading comprehension
were not confirmed. Neither suppressing subvocalization
nor instilling subvocalization significantly affected
reading comprehension scores in the LV or HV group.
This finding is in contrast to that of Hardyck and Petrinovich (4), who found that eliminating subvocalization in their experimental group led to a loss of comprehension. This study is similar to the present study in terms of the subjects employed. Hardyck and Petrinovich (4) used college freshmen from a remedial English class. The present study utilized college freshmen and sophomores enrolled in a developmental reading class (a class designed to improve and enhance reading skills). Despite this subject similarity, the earlier researchers' findings were not supported. It appears from perusal of the earlier study that the experimenters provided their subjects with the expectation that subvocalization would enhance their comprehension. It may have been this expectation rather than subvocalization suppression, per se, that led to the subsequent loss in comprehension after subvocalization was diminished. The present finding supports, however, a study by Wells (7), who also failed to find a loss in comprehension as a result of subvocalization suppression. That study found that only increasing the level of textual difficulty produced a statistically significant loss in reading comprehension. The findings of the present study are also in keeping with another study using post secondary subjects, the author of which concluded that the presence of EMG activity is not a reliable correlate of poor reading performance at the college level (1).
The finding of the present study tends to support the contention that subvocalization may be an attentional strategy that is available to readers to increase the redundancy of the reading process when necessary. However, it probably does not contribute directly to the normal comprehension process of most competent readers. Another possibility is related to the findings of Conrad (2), who in studying a population of nonarticulating, profoundly deaf subjects found their comprehension dropped when they were forced to articulate the text as they read. In contrast, a group of articulating, profoundly deaf subjects gained in comprehension when they articulated as they read. Subvocalization may be a similar phenomenon in a hearing population. It is useful to some but not to all readers and not in all types of reading situations.

Another possibility for the lack of comprehension drop in the HV subjects may be related to the auditory imagery component suggested by other researchers (6, 7). Even though subvocalization may have been suppressed, the auditory imagery may still be operable.


CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Subvocalization has been the subject of study for reading researchers since before the turn of the century (1). However, despite numerous early attempts to study this phenomenon (3, 11, 12, 1), it was not until the advent of the electromyograph that direct study and modification of subvocalization became possible. The EMG is able to detect minute muscular activity not discernible using any other observational technique. Just as importantly, however, the EMG is capable of providing auditory or visual feedback to the individual about the duration and intensity of that muscular activity (5).

The role of subvocalization in silent reading is still being debated. That it slows silent reading speed is well documented (1, 2, 6, 7); however, whether it aids in reading comprehension is less well defined (7, 9, 10). Some researchers have concluded on the basis of their studies that subvocalization is an integral part of the reading process and its suppression should be discouraged (4). Others have concluded that such suppression leads to a drop in comprehension, especially when reading difficult material (7). As frequently occurs in science, such
simplistic conclusions with their broad implications for reading remediation have not been categorically supported by other studies. Wells (13) found no drop in reading comprehension when subvocalization was suppressed for either easy or difficult reading text. This unresolved issue of the role of subvocalization in reading comprehension is in turn related to the broader question of whether all cognition occurs within the central nervous system or whether the peripheral nervous system also provides necessary input for the most effective decoding of incoming visual stimuli (10). If one assumes the former, then subvocalization must be unnecessary in the reading comprehension process; however, assuming the latter, one accepts the premise that subvocalization provides feedback to the central nervous system necessary for the most efficient process of incoming stimuli.

The present study attempted to define the role of subvocalization in silent reading comprehension by eliminating subvocalization in a group of high subvocalizers and training subvocalization in a group of low subvocalizers.

Subjects were selected from students in developmental reading classes at Richland College. Students were screened for subvocalization using the Hardyck and Petrinovich method described in Chapter III. Those who reached the previously defined criteria for high subvocalization (above a mean of 13 microvolts) were randomly assigned
to experimental or control groups. Those who demonstrated the prerequisites for low subvocalization (below a mean of 8 microvolts) were also randomly assigned to experimental or control groups. There was a total of four groups with fifteen subjects in each group. All subjects were pre-tested for reading comprehension using the Nelson-Denny Reading Test. The high subvocalizers (HV) were exposed to auditory biofeedback training designed to lower their subvocalization activity. The control group (HVC) was exposed to the same procedure but without any biofeedback. The low subvocalizing experimental group (LV) was treated with an auditory biofeedback procedure designed to train or increase subvocalization. The control group (LVC) was exposed to the same procedure minus the auditory biofeedback. All groups were posttested for reading comprehension immediately after the training and again one month later (post-posttesting).

Hypotheses 1, 2, and 3, which were concerned with the effect of suppression or increase of subvocalization on reading comprehension, were not confirmed. Neither increasing subvocalization nor decreasing it seemed to have a statistically significant effect on reading comprehension scores as measured by the Nelson-Denny Reading Test. Hypothesis 4, that the LV group would have a significant increase in subvocalization over the LVC group, was not confirmed. The training procedure using biofeedback
was not successful in increasing subvocalization activity.

Hypotheses 5 and 6 were confirmed. These hypotheses were concerned with whether biofeedback training could lead to a statistically significant reduction in subvocalization in the HV group when compared to the HVC and LV groups. The results of this study indicate that biofeedback training can be used successfully for this purpose.

Conclusions

The following conclusions were drawn from this study. Formulation of these conclusions was based on results that were statistically significant at the .05 level.

1. EMG feedback can be utilized successfully in suppressing subvocalization during silent reading.

2. Low subvocalizers cannot be trained successfully to increase significantly their subvocal activity during silent reading using the EMG biofeedback.

3. Neither suppression of subvocalization in a HV group nor attempts to introduce subvocalization in a LV group can significantly affect either group's reading comprehension as measured by the Nelson-Denny Reading Test.

Recommendations

1. Future research on subvocalization and reading comprehension might include an attempt to control for
auditory imagery, perhaps by disrupting the process through white noise fed through head phones with the biofeedback presented visually. White noise is like static without discernible patterns or rhythms that might distract the reader. It might nevertheless disrupt covert auditory mediation.

2. Subvocalization training and suppression training were both of brief duration in the present study. A more lengthy training program, particularly for the subvocalization training, might produce more marked results in comprehension change.

3. There is some evidence to suggest that subvocalization is a tool for recall rather than comprehension. Future studies might focus on its contribution to the recall process.

4. Comparison of biofeedback studies in general are hampered by a lack of standardization in equipment used and how data are rendered (i.e., measuring spikes on a polygraph readout versus time-averaged readouts on an integrator). Attempts at replication of studies should utilize the same equipment and data collection procedures.

5. The majority of studies concerned with subvocalization do not take into consideration possible sex related differences in subvocalization. Future studies might include analysis of data according to sex for possible differential effects.
CHAPTER BIBLIOGRAPHY


### APPENDIX A

<table>
<thead>
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APPENDIX B

INSTRUCTIONS TO HV GROUP

The EMG picks up very small movements of your voice box muscles. The more muscle activity you have, the higher the tone. Relax (pause). Now swallow (pause). You see how it picks up that movement of your voice box.

Experiment with the tone so that you can see that you control the tone and whether it is on or off (pause).

Now I want you to read silently and try to keep the tone off as much as possible.
APPENDIX C

INSTRUCTIONS FOR THE LV GROUP

The EMG picks up very small movements of your voice box muscles. The more muscle activity you have, the higher the tone. Relax (pause). Now swallow (pause). You see how it picks up that movement of your voice box.

Experiment with the tone so that you can see that you control the tone and whether it is on or off (pause).

Now I want to show you how to keep the tone on while you read silently. Read this passage by whispering the words as you read (wait 2 minutes while S practices).

Now read this passage and mouth the words, but don't whisper (wait 2 minutes while S practices).

Read this passage without moving your lips or making sounds and imagine you can hear your voice reading (pause for practice).

I want you to read silently and try to keep the tone on as much as possible.
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Personal Communications


Unpublished Materials

