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A STUDY OF THE EFFECTS OF DELAYED SIDE-TONE UPON VOICED AND WHISPERED READING TIME

by

Bruce Preston Ryan

A Thesis Submitted to the Graduate Faculty in
Partial Fulfillment of the Requirements of the
Master of Arts Degree

School of Graduate Studies
Western Michigan University
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CHAPTER I

INTRODUCTION

Definition of Delayed Side-Tone

The term delayed side-tone feedback refers to the delaying of one's hearing of himself by a fraction of a second, so that instead of hearing himself as he normally does, he hears himself or his own speech a fraction of a second later.

> . . . in order to produce delayed speech feedback it is necessary to return the speaker's speech to his own ears approximately one-quarter second after he has spoken. This is best accomplished by means of a magnetic tape recording and reproducing machine which has independent circuits and magnets. A pair of earphones should be used to experience the effect prominently since they deliver delayed speech and exclude the normal air-borne undelayed speech sound which provides the normal monitory signal.[1]

Lee found that this effect produced an artificial stutter and other abnormalities.[2]

Fairbanks discusses the speech mechanism as a servosystem in which there are many feedbacks and control centers, hearing being one of the most important to the production of speech. He describes it as follows:

> . . . servosystem . . . employs feedback of the output to the place of control, comparison of the output to the input, and such manipulation of the output-producing device as will cause the output

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[1] Bernard Lee, "Artificial Stutter," Journal of Speech and Hearing Disorders, 16:53, 1951.

[2] Ibid., pp. 53-55.

to have the same functional form as the input. The system performs its task when, by these means, it produces an output that is equal to the input times a constant. Examples of such systems are the heating plants of our homes and the homeostatic mechanisms of our bodies. It seems evident that the speaking system has at least the rudiments of a servosystem.[3]

Essentially it is thought that the delayed feedback causes confusion in the speaker due to this abnormal feedback and he in turn reacts by speaking abnormally.

It has been demonstrated by Black that people talk louder when the side-tone is louder, that people talk louder in certain rooms and, more to the point, that the delayed side-tone acts as a brake on speaking, an attenuator to the precision of articulation, and an estimator of voice pitch.[4]

The purpose of this present study was to explore the differences in duration of reading time between voiced and whispered reading under conditions of normal side-tone and side-tone delay.

Hearing and Delayed Side-Tone

In general one may say that sound waves reach the cochlea through two routes. One route is through the outer ear (air conduction), and

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[3]Grant Fairbanks, "Systematic Research in Experimental Phonetics: 1. A Theory of the Speech Mechanism as a Servosystem," Journal of Speech and Hearing Disorders, 19:133, 1954.

[4]John Black, "Systematic Research in Experimental Phonetics: 2. Signal Reception; Intelligibility and Side-tone," Journal of Speech and Hearing Disorders, 19:144, 1954.

external auditory meatus. The second route is through the bones in the skull (bone conduction).

According to Stevens and Davis

> Sound waves entering the external canal may reach the inner ear by three main routes. The most important is by means of the ossicular chain across the middle ear from the tympanic membrane to the oval window. The second of these routes also involves the tympanic membrane, but transmission across the middle ear is by means of air waves . . . sound energy is taken up by the walls of the canal and transmitted through the bones of the skull around the middle to the inner ear. In this case of "bone conduction" the sound need never enter the external ear, but may be picked up directly by the skull.[5]

Though there is much still to be discovered about the phenomenon of hearing and many theories concerning it, especially with regards to the relation of bone and air conduction, certain experimental studies have been done. Stevens and Davis state

> Experimental evidence appears to indicate that both air-conduction and bone-conduction ultimately cause similar movements of the endolymphatic fluid and of the basilar membrane in the cochlea. The airborne vibrations arrive by way of the ossicles, whereas vibrations of the skull result in compression of the canals of the inner ear, including the labyrinth.[6]

Bekesy believes that the impact upon the cochlea is equal from both bone and air conduction.[7]

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[5]Stanley Stevens and Hallowell Davis, Hearing: Its Psychology and Physiology (New York: John Wiley and Sons, Inc., 1938), p. 252.

[6]Ibid., p. 293.

[7]G. V. Bekesy, "Structure of the Middle Ear and Hearing One's Own Voice by Bone Conduction," Journal of the Acoustical Society of America, 21:225, 1949.

Stromstra found the minimum transit time from the vocal folds to the cochlea by bone and air to be: bone -- 0.0003 seconds and air -- 0.00055 seconds.[8]

Fry maintains that one hears oneself mostly by bone conduction.

> . . . sing or speak . . . most sounds which we hear ourselves is conveyed through bone conduction.[9]

Saltzman's thinking on the subject of bone and air conduction is that

> In the normal ear, hearing by bone conduction is inferior to that of air conduction. The high frequency sounds are not transmitted through bone and speech hearing by air conduction is generally the preferred route.[10]

Anyone may perform the simple experiment of closing off the outer ear and speaking. By doing this one will find that one's voice sounds different. About this Saltzman states,

> When the external auditory meatus is closed, a sounding body over the mastoid process causes a compression of air in the auditory canal and the sound waves enter the inner ear by way of the ossicular chain.[11]

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[8]Courtney Stromstra, "A First Approximation of the Distance from the Vocal Chords to the Cochlea and the Transit Time of Bone Conduction from the Region of the Vocal Chords to the Region of the Cochlea" (unpublished Master's thesis, Ohio State University, 1951).

[9]D. B. Fry, "The Experimental Study of Speech," Nature, 173:845, 1954.

[10]Maurice Saltzman, Clinical Audiology (New York: Grune and Stratton, 1949), p. 27.

[11]Ibid., p. 24.

Earlier Saltzman observed that

> . . . many hear better by bone conduction if the outer meatus is closed.[12]

Lee, possibly the first experimenter in delayed feedback, mentioned that the feedback through the earphones had to be loud enough to overcome bone conduction.[13]

Tiffany and Hanley repeating Lee's experiment and attempting to check his statement about bone conduction found that a greater duration in reading time was related to higher intensity.[14]

Peters, in one of his experiments, observed and reported that he thought at certain levels of intensity bone conduction was still active and not overcome by the intensity in the outer ear.[15]

Spilka noted that some changes in length of syllable duration, phonation time, increase in voice intensity, and vocal variations were related to certain combinations of pressure, intensity and delay.[16]

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[12] Ibid., p. 21.

[13] Lee, op. cit., pp. 53-55.

[14] William Tiffany and Clair Hanley, "Delayed Speech Feedback as a Test for Auditory Malingering," Science, 115:59-60, 1952.

[15] Robert Peters, "The Effect of Changes in Side-tone Delay and Level Upon the Oral Reading of Normal Speakers," Journal of Speech and Hearing Disorders, 19:483-490, 1954.

[16] Bernard Spilka, "Some Vocal Effects of Different Reading Passages and Time Delays in Speech Feedback," Journal of Speech and Hearing Disorders, 19:37-47, 1954.

Butler and Galloway found the delay effect to be the best at 80 db with a delay of 0.17 seconds which according to various authorities is the average length of the English syllable.[17] They did not agree with Black[18] or Fairbanks[19] concerning an optimal delay time, but averred that pressure/intensity was a more important factor.

Whispering

In the present study whispering was chosen as the independent variable because it is believed that whispered speech is not transmitted as well by bone conduction as is voiced speech.

Judson and Weaver in discussing whispering say,

> English . . . is based on whispered speech; phonation is but an auxiliary . . . Within anatomical and physiological limitations the acoustic effects produced by whispering are constant and variable; there is the same articulatory mold to the articulators . . . It (whispering) may be produced with variations in emphasis and rate . . . such a waste of air that the efficiency of whispering is low.[20]

In whispering the surds (unvoiced phonemes) are more like the sonants (voiced phonemes) sounds. One may say that whispering is made

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[17] Robert Butler and Thomas Galloway, "Factoral Analysis of the Delayed Speech Feedback Phenomena," Journal of the Acoustical Society of America, 29:632-635, 1957.

[18] John Black, "Effect of Delayed Side-tone Upon Vocal Rate and Intensity," Journal of Speech and Hearing Disorders, 16:56-60, 1951.

[19] Grant Fairbanks, "Delayed Auditory Feedback," Journal of Speech and Hearing Disorders, 20:333-346, 1955.

[20] Lyman Judson and Andrew Weaver, Voice Science (New York: Appleton, 1942), p. 62.

up of surds. According to Kantner and West in their discussion of whispering,

> . . . it should be noted that the reduction of power is in the low-frequency range. The high frequency sounds are not reduced in power; in fact they may actually be increased in power to compensate for low frequency losses. Thus in whispered speech the pattern of energy is greatly modified. The sounds that are most intense are least intense in whispered speech . . . The surd and sonant analogues (ex: s, z) among the fricative sounds cannot usually be distinguished in whispered speech.[21]

All sounds vary in loudness, power, and frequency from person to person, but generally speaking the unvoiced sounds as in whispering would tend to be of higher frequency and less easily transmitted by bone conduction.[22]

Selection of Problem

Black,[23] Ewertson,[24] Fairbanks,[25] Lee,[26] Spilka,[27] Spuehler,[28] and Tiffany[29] all observed a rate or duration disturbance under

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[21]Claude Kantner and Robert West, Phonetics (New York: Harper and Brothers, 1941), p. 191.

[22]Saltzman, op. cit., pp. 12-15. [23]Black, loc. cit.

[24]H. W. Ewertson, "Delayed Speech Test," Acta Otalaryngology, 45:383-387, 1955.

[25]Fairbanks, loc. cit. [26]Lee, op. cit., pp. 53-55.

[27]Spilka, loc. cit.

[28]Henry E. Spuehler, "Effects and Interactions of Delayed Side-tone and Auditory Flutter" (abstract of unpublished Ph. D. dissertation, Purdue University, 1956).

[29]Tiffany, loc. cit.

conditions of delayed feedback, even though they had used varied procedures, delay times, and intensity levels as well.

Some of these investigators questioned the relative roles of delay and intensity, stating that one is able to monitor one's speech by bone conduction if the side-tone, air-conducted message was not loud enough. Our present knowledge of the physiology of hearing tends to support this thinking.

In view of the previous studies in side-tone delay and the present information about whispering, it was felt advisable to explore to what extent delayed feedback would affect whispered reading if it is hypothesized that whispered speech is not well transmitted by bone conduction. Would reading duration be the same, longer, shorter when one is whispering than when one is reading aloud? If other experimenters had difficulty in getting response to the delay feedback mechanism due to action of bone conducted sounds, then by eliminating bone conduction action or at least modifying it, would there be a significant difference between voiced and whispered reading duration under conditions of delayed side-tone?

CHAPTER II

RELATED STUDIES

According to available literature, Lee was one of the first to experiment with delayed feedback. He used a tape recorder and reproducer to get the effects. He observed that the subjects slowed down and had haltings, repetitions of syllables and continuant sounds. Also it was noted that professional typists, telegraphers, and musicians also experienced difficulty with their respective skills under conditions of delayed side-tone.[1]

Black using a recorder-producer tested 22 men who read lists of phrases with 10 periods of delayed side-tone and 1 condition of no delay. Periods of delay were 0.00, 0.03, 0.06, 0.09, 0.12, 0.15, 0.18, 0.21, 0.24, 0.27, and 0.30 seconds. The longer delays caused surprise, blockings, and facial distortions. The intensity of the readings increased progressively as the delay of side-tone was introduced and extended from 0.00 to 0.27 seconds. The rate was extremely retarded. Changes due to intervals greater than those of 0.09 seconds of delay were not statistically different.[2]

Tiffany and Hanley tested Lee's[3] idea of having to overcome bone conduction by using 30 subjects, splitting them up into 3 groups of 10

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[1]Lee, *loc. cit.* [2]Black, *loc. cit.* [3]Lee, *loc. cit.*

with each group of 10 reading under the same delay time but with intensity levels of 35 db, 55 db, and 75 db respectively. A 100-word passage from Robinson Crusoe was used and the subjects had a five-minute practice period to look over the material. A stop watch and head phones were employed. The subjects were instructed to "beat" the sound in their ears on their second reading. Their first reading was made with no delay, the second reading with delay, and the third with no delay. The subjects were instructed to read at a normal rate in all three readings. Readings one and three were compared and showed no statistical difference. Reading number two differed statistically from readings one and three. A greater duration in reading time was noted under conditions of higher intensity.[4]

Peters accelerated the side-tone to 0.001, 0.003 and 0.0015 seconds. Eighteen college age males with normal hearing read a total of 36 five-syllable phrases and a prose passage under each of 13 experimental side-tone conditions at their natural reading rate and maximum reading rate. The oral speech was recorded and graphic tracings of the recorded speech measured. The data were treated by double and triple classification analysis of variance. The results were: 1) speakers read faster under accelerated side-tone delay, and 2) speakers read progressively faster as the sound pressure level of side-tone is decreased.[5]

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[4]Tiffany and Hanley, loc. cit. [5]Peters, loc. cit.

Spilka's study was similar to others such as Lee's and Black's except for two differences: 1) he used reading passages of greater length, and 2) presented only one condition of delay to each subject. The delayed times employed were .094, .125, .156, .187, .219, .250, .312, and .375 seconds. There were 128 subjects ranging in age from 18 to 27. The testing procedures and equipment were highly technical in an attempt to reduce the variables. The results were treated statistically. Each of two subjects read the same material eight times under one condition of delay. Reading material was varied. The findings were that: 1) delayed feedback caused a) a lengthening of syllable duration, b) increase in phonation time, c) increase in mean vocal intensity, and d) a tendency for vocal variations to become greater; 2) some changes appeared to be related to pressure/intensity and delay; 3) no relationship between effects of feedback and length of delay; 4) significant interaction between reading passages and delay condition employed. Spilka also stated that there is a need for more basic information about the phenomenon of delayed feedback before any valid and reliable experimental work can be carried out. There are as yet too many variables which are not known or understood and therefore cannot be controlled.[6]

That same year Spilka attempted to demonstrate a relationship between certain personality aspects and reactions to delayed feedback. One hundred fifty college age males were studied under synchronous and delayed feedback. An attempt was made to relate the amount and direction

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[6]Spilka, loc. cit.

of change in rate/duration and intensity of voice variables to certain personality variables. The tentative conclusions were: 1) intensity variation due to delayed feedback appears most closely related to personality functioning, 2) increases in vocal intensity variation under conditions of delayed feedback appear to be positively related to negative self-attitudes, paranoid tendencies, and poor personality development.[7]

Kalmus, Denes, and Fry desired to observe the effect of delayed feedback upon such non-vocal activities as whistling, hand clapping, and playing a musical instrument. The delay used was .25 seconds. A pen recorder recorded movements of the hands in clapping. A tape recorder took down all responses. In the one set of results discussed it was noted that the subjects who attempted to clap rhythmically were all affected in some way or another by the aural delayed feedback. Also observed was a great deal of individual differences. The authors were surprised to find that certain abilities which heretofore had been accepted as being controlled or monitored by the visual, proprioceptive, and kinesthetic patterns would be so disturbed when the aural feedback was distorted.[8]

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[7]Bernard Spilka, "Relationships Between Certain Aspects of Personality and Some Vocal Effects of Delayed Speech Feedback," <u>Journal of Speech and Hearing Disorders</u>, 19:491-503, 1954.

[8]H. Kalmus, P. Denes, and D. B. Fry, "Effect of Delayed Acoustic Feedback on Some Non-vocal Activities," <u>Nature</u>, London, 175:1075, 1955.

Ewertson employed the delayed feedback to see if it could be used as a hearing test. Subjects recited memorized material at a delay of .25 seconds with a variance of intensity from 50-100 db. Of 100 normal hearing subjects tested all but 1 showed the effects of delayed feedback. Ewertson thus concluded that hearing loss may be determined from the point where subjects began to show the effects of delay.[9]

Black explored the possibility of the continued effect of delay persisting after the delay condition had been removed. He used 56 cadets, half of which performed as a control group with no delay in side-tone. Each subject read 10 lists of words, some under delay and some not. The effect of the side-tone continued some 150 seconds after the delay ceased being used, however, the subjects were not aware that the delay would not occur. He found

> . . . that readers recover from the effects of delayed side-tone in terms of reading rate and sound pressure within 150 seconds after exposure to delayed feedback during the reading of 50 syllables.[10]

Fairbanks had six subjects read the Rainbow Passage at a normal rate under various conditions of delay and no delay. They practiced for five minutes with the head set, the delayed feedback, etc. They made 7 straight readings with 15 seconds delay in between. One sentence was picked from the passage to be analyzed. The findings were: 1) greater

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[9]Ewertson, loc. cit.

[10]John Black, "The Persistence of the Effects of Delayed Side-tone," Journal of Speech and Hearing Disorders, 20:68, 1955.

number of articulation errors, longer duration, greater sound pressure, and higher fundamental frequency, 2) curves for articulation and duration were skewed with prominent peaks at .2 seconds, and 3) delayed feedback had the greatest effect on articulation.[11]

Tiffany and Hanley explored the possibility of adaptation. Twenty normal hearing subjects were subjected to 80 db of delayed side-tone during 24 readings of a 45-word prose passage primarily to determine the degree of speech distortion. Twelve successive readings were given the first week, and 12 the next. Measures of reading time, fluency, and related speaking abilities showed the following: 1) no significant adaptation rate; 2) significant adaptation in fluency from first to second week, in that the speakers "learned" to avoid repetitions, omissions of words, syllables, and sounds, but could not overcome the effect of delay upon rate; 3) adaptation trends were marred by individual differences; 4) "better" (faster) readers were not able to overcome the rate disturbance as quickly as "poorer" (slower) readers; and 5) tendency to relate amount of disturbance to later reading as those who had had trouble tended to read more slowly in later readings.[12]

Spuehler combined auditory flutter (short interruptions in feedback) with delayed feedback and found results which differed from other

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[11]Fairbanks, loc. cit.

[12]Tiffany and Hanley, "Adaptation to Delayed Side-tone," Journal of Speech and Hearing Disorders, 21:164-172, 1956.

feedback findings in only one respect. (Subjects read standard passage under 31 combinations of 6 levels of delay and 5 auditory flutter). He submits that it was possibly due to the combination of factors and offers no other explanation as to why the difference occurred. The tentative finding was that under conditions of auditory flutter and delay, normal reading rate is most affected at .15 seconds delay and more delay only results in a more normal reading rate. Running from 3 to 3,000 interruptions per second, the rate in reading time is at first increased and then decreased. Female groups showed a difference from male groups in that male groups tended to be less affected. Also noted was a carry-over to normal speech for a short period. Flutter was demonstrated to have similar effects upon speech as delayed side-tone, though not as potent. The combination of flutter and delay was more effective than flutter alone.[13]

> Feedback delay again has been demonstrated to have marked effect on speech output. Also auditory flutter, which serves to reduce by one half the amount of information fed back to the signal source, has been shown to have similar effects.[14]

Butler and Galloway repeated previous delayed feedback experiments with the two variations of having the subjects respond to blinking lighted numbers and words, similar to the tachistoscope, and they heard their pre-recorded voices played back. The results tend to disagree with Black and Fairbanks as to optimum delay time, but do agree with Spilka as to the relationship of pressure/intensity to delay feedback.

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[13]Spuehler, loc. cit. [14]Spuehler, op. cit., p. 5.

They used 388 subjects in 2 experiments. A linear relationship was found between performance on feedback tasks and intensity of signal. There was an interaction between intensity and delay time of speech feedback having various delays to be differentially effective only at high intensities. The best delay effect was at 80 db with the delay of 0.17 seconds, which according to various authorities, is the average length of the English syllable. The final conclusion was that intensity is more important than delay time, and that it is not necessary to use the subject's own live voice to demonstrate the effects of delayed feedback.[15]

STATEMENT OF THE PROBLEM

It is noted that bone conduction plays an important role in hearing. As we have stated earlier, Fry contends that we hear ourselves mostly by bone conduction.[16] Previous experimenters (see Hearing and Delayed Side-tone, page 2) have discussed the influence of bone conduction upon the effectiveness of delayed side-tone. In essence, they have said that one tends to monitor one's speech under conditions of delayed side-tone by bone conduction and for the delayed side-tone to be effective, the air-borne message must be of a high enough intensity to overcome bone conduction.

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[15]Butler, _loc. cit._

[16]Fry, _op. cit._, pp. 844-846.

It is thought (see Whispering, page 6) that whispered or unvoiced sounds are of such high frequency that they are not transmitted well by bone conduction.

The purpose of this experiment was to study the differences in reading duration between whispered and voiced speech under conditions of normal side-tone and side-tone delay.

Essentially this will be a reproduction of some previous studies with whispering being the only uniquely different variable studied. Since duration of utterance seemed to be the most consistently affected part of speech under conditions of side-tone delay, it served as the basis of measurement.

The subjects read aloud under conditions of no delay and delay. They read in a whisper under conditions of delay and no delay.

Expressed in terms of the null hypothesis, the study may be stated as follows:

Hypothesis I. THERE IS NO DIFFERENCE IN THE READING TIME OF NORMAL HEARING SUBJECTS IN THE AGE GROUP, 20-30, BETWEEN WHISPERED AND VOICED READING UNDER CONDITIONS OF NO SIDE-TONE DELAY.

So far as can be determined there has been little or no experimental demonstration to compare the time taken to read a passage in a whisper and aloud. This hypothesis is devised to determine if there is a difference.

Hypothesis II. THERE IS NO DIFFERENCE IN THE READING TIME OF NORMAL HEARING SUBJECTS IN THE AGE GROUP, 20-30, BETWEEN WHISPERED AND VOICED READING UNDER CONDITIONS OF SIDE-TONE DELAY.

As far as can be determined, little or no experimental demonstration has been made of the time taken to read a passage in a whisper under conditions of side-tone delay with reading the same passage aloud under conditions of side-tone delay. This hypothesis was devised to determine if there is a difference.

Hypothesis III. THERE IS NO DIFFERENCE BETWEEN THE EFFECT OF SIDE-TONE DELAY ON VOICED READING TIME AND WHISPERED READING TIME.

Is there any difference? Is it a significant difference? Will side-tone delay have a greater effect upon one or the other of these two speech conditions? As far as can be determined there has been little or no experimental demonstration of the effect of side-tone delay on voiced reading time as compared to whispered reading time when reading the same passage. This hypothesis was devised to determine if there would be a significant difference between the effect of side-tone delay on voiced reading time and whispered reading time.

CHAPTER III

PROCEDURE

Selection of Subjects

There were 20 subjects, 5 female and 15 male, selected from the Western Michigan University summer session of 1957. They were between the ages of 20 and 30 with a mean age of 24. (See appendix for complete listing.) They had no previous experience with the delay feedback mechanism. All were normal hearing subjects (i.e., no loss of acuity exceeding 15 db in either ear at more than one of the frequencies 125; 250; 500; 1000; 2000; 4000; and 8000 cycles per second.)

Equipment

Permo-Flux PDR-10 ear phones were used in all the experimental conditions and were equated by use of a voltmeter.

An Electro-Voice 915 "Century" crystal microphone was used and each subject placed so that his face was 6 to 8 inches from the microphone.

An Echo-Vox 720-B delay feedback mechanism with a Stromberg-Carlson Au-62 amplifier was used.

A Bell Tape Recorder RT 65 was employed to record the subjects' responses.

An Allison 21 B pure tone audiometer was used in all the testing for hearing acuity.

And finally, a Breno, 60-second, 30-minute stop watch was used in starting the subjects and in timing readings. (See Figure 1, page 21, for schematic outline of apparatus.)

The Reading Material

The reading material used in this study was the "Rainbow Passage".[1] (See appendix.) It was typewritten in capital letters and attached to a clipboard. During the testing it was placed on a stand slightly to the right and in front of the microphone. This passage was selected because it had been used in other studies of side-tone delay, it would be unfamiliar to the subjects, it contained all of the sounds of the English language, it was not overly long and yet long enough to yield measurable results, and it could easily be located if the experiment were to be repeated.

Instructions

General instructions as to the sweep hearing test and preliminary practice period were appropriate to get the desired response of the subject.

For the experimental conditions proper, the subjects all received the following standardized instructions:

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[1]Grant Fairbanks, Voice and Articulation Drillbook (New York: Harper Bros., 1940), p. 168.

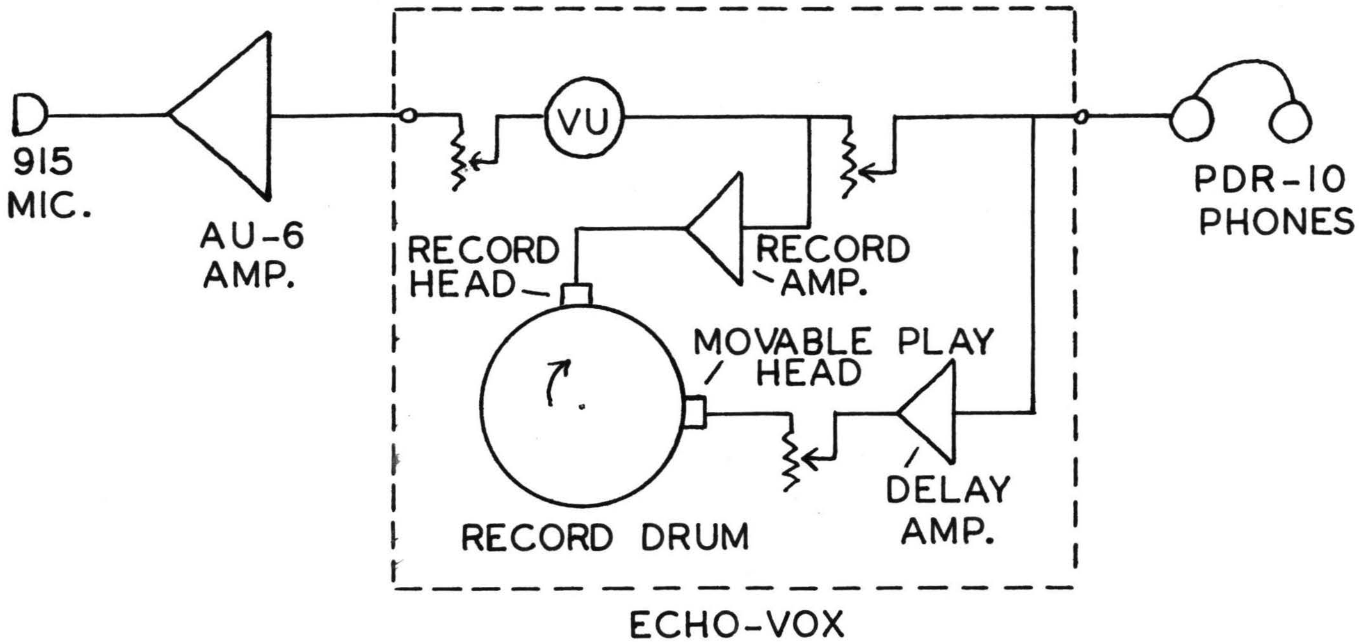

FIGURE 1

BLOCK DIAGRAM OF EQUIPMENT

Your part in this experiment will be to read the "Rainbow Passage" at your normal reading rate four times with a rest period of 30 seconds between each reading. You will read in a whisper for two of the readings. I will tell you which two to read in a whisper. You will hear your voice in the earphones. Do not stop reading until you have completed the passage. Don't move around anymore than you have to. Don't take off the earphones once we have started. Keep your eyes on the reading material and start when you hear a click like this (the tester clicked the stop watch.) I will say, "Ready," you will hear the click, then begin. (Preceding each of the readings, the tester reminded the subject that this particular test was to be read in a voice or a whisper.)

The Tests Proper

The four test conditions which followed the two practice readings, one practice in reading in a whisper and one practice in reading the passage aloud under normal side-tone delay with the earphones on, were as follows:

1. Reading aloud, earphones on, intensity of 77 db $\pm$.5 db, normal side-tone.
2. Reading aloud, earphones on, intensity of 76 db $\pm$.5 db and a side-tone delay of .17 seconds.
3. Reading the passage in a whisper, earphones on, intensity of 71 db $\pm$1.0 db, normal side-tone.
4. Reading the passage in a whisper, earphones on, intensity of 72 db $\pm$1.0 db and a side-tone delay of .17 seconds.

It should be mentioned that noise (i.e., hum of tubes, hiss static) was at least 20 db below the voiced reading level, but only 7 db below the level of the whispered reading.

The use of the delay time of .17 seconds and an intensity level of approximately 80 db was suggested by the recent findings of Butler and Galloway.[2]

There was a 30-second rest period between each of the readings. The test conditions were presented in a random order (see Appendix). The randomization was achieved through the use of the Tables of Random Permutation found in Cochran and Cox.[3]

Timing

All of the subjects' responses were tape recorded and timed with a stop watch. Each performance under each test condition was timed (see Appendix).

Statistical Analysis

The raw scores, or reading times for each of the four conditions for each of the subjects were then compared and statistically treated to determine if the differences between voiced and whispered times were statistically different. The following procedure was employed:

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[2]Butler, loc. cit.

[3]William G. Cochran and Gertrude M. Cox, Experimental Designs (New York: John Wiley & Sons, Inc., 1950), p. 454.

The means were computed using the formula:

$$M = \frac{\Sigma}{N}$$

The mean differences were first computed with the following formula:[4]

$$M_D = \frac{\Sigma D}{N}$$

Next the standard deviations were computed using the following formula:[5]

$$\sigma = \sqrt{\frac{\Sigma D^2}{N} - \left(\frac{\Sigma D}{N}\right)^2}$$

After the mean difference and standard deviations had been determined, the next step was to calculate the standard error of the mean of the difference with the following formula:[6]

$$\sigma_{M_D} = \frac{\sigma_D}{\sqrt{N-1}}$$

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[4]G. Milton Smith, A Simplified Guide to Statistics: For Psychology and Education (New York: Rinehart and Company, Inc., 1946), p. 67.

[5]Ibid., p. 66. [6]Ibid., p. 67.

Finally, the differences were subjected to a test of significance. The following formula was employed for this:[7]

$$t = \frac{M_D}{\sigma_{M_D}}$$

Summary of Procedure

1. Twenty subjects, between the ages of 20 and 30, 5 female, 15 male, were selected and tests indicated that they had normal aural acuity.

2. Subjects wore earphones in which they could hear themselves with normal side-tone as they read the "Rainbow Passage" once aloud and once in a whisper.

3. Instructions were then read to the subject.

4. The four test conditions were presented in a random order to the subject as he read the passage four times with a 30-second rest period between each reading. Two of these conditions required voiced reading and two conditions required whispered reading. One of each of the voiced and whispered readings was sent back to the subject at a delay of .17 seconds. The intensity varied from 72 to 77 db.

5. All responses were tape recorded and timed.

6. The data were analyzed to determine whether the differences between the comparative scores of whispered and voiced side-tone delay were statistically significant.

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[7] Ibid., p. 67.

CHAPTER IV

RESULTS

This chapter is concerned with the data procured and the statistical analysis to determine whether or not there were differences in reading rate between voiced and whispered reading of the same passage under conditions of side-tone delay. Raw scores will be found for all tests and subjects in the appendix. The time taken to read the passage under each condition and differences between them are expressed in means, standard deviations and mean differences as presented in Tables I, II, and III, pages 31-33. The *t* values of these differences are shown in Tables II and III.

1. Hypothesis I: THERE IS NO DIFFERENCE IN THE READING TIME OF NORMAL HEARING SUBJECTS IN THE AGE GROUP, 20-30, BETWEEN WHISPERED AND VOICED READING UNDER CONDITIONS OF NO DELAY IN SIDE-TONE.

The mean and standard deviation of the voiced reading time with no delay in side-tone were compared with those of the whispered reading time with no delay in side-tone. As shown in Table I, page 31, the means of the distributions were 31.85 for the voiced and 33.35 for the whispered. The standard deviations were 4.27 and 4.24 respectively. The mean difference was 1.51 and the standard deviation of the mean difference was 1.73. A comparison of these variables according to the formulae cited in Chapter III gave a *t* value of 3.79 with 19 degrees of freedom, as shown in Table II, page 32. A *t* of 3.79 is significant at the one per cent level of confidence. The chances are one in a hundred that this large a t value could have occurred by chance alone.

Thus the null hypothesis is rejected and there is a significant difference between whispered reading time and voiced reading time under conditions of no delay in side-tone. Whispered reading time was greater than voiced. Though individual differences were apparent, there was relatively small standard deviation of the mean of the differences. This finding tends to support the literature discussed in Chapter I, namely, that whispering is less efficient than voiced speech. We normally take longer to read while whispering.

2. Hypothesis II: THERE IS NO DIFFERENCE BETWEEN THE READING TIME OF NORMAL HEARING SUBJECTS IN THE AGE GROUP, 20-30, BETWEEN WHISPERED AND VOICED READING UNDER CONDITIONS OF SIDE-TONE DELAY.

The means and standard deviations of voiced reading time under conditions of side-tone delay and whispered reading time under conditions of side-tone delay were compared. It can be seen in Table I, page 31, that the means of the distributions were 43.64 for the delayed voiced and 49.67 for the delayed whispered reading. The standard deviations were 7.26 and 11.04 respectively. The mean difference was 6.04 and the standard deviation of the mean difference was 6.37. A comparison of these variables employing the pre-stated formulae yielded a t value of 4.16 with 19 degrees of freedom, as shown in Table II, page 32. A t of 4.16 is significant at the one per cent level of confidence. Thus indicating that the odds were 100 to 1 that this large a t value could have occurred by chance alone.

The null hypothesis is rejected and there is a significant difference between whispered reading time and voiced reading time under conditions of side-tone delay. Though this was the greatest difference demonstrated and had the largest t value, it should be noted that other inherent differences discussed in Chapter I may have had an effect upon the results. Whispered reading time is significantly greater than voiced reading time under conditions of side-tone delay.

3. Hypothesis III: THERE IS NO DIFFERENCE BETWEEN THE EFFECT OF SIDE-TONE DELAY ON VOICED READING TIME AND WHISPERED READING TIME.

This is the most important comparison and equally difficult to explain. As whispered reading time is inherently different from voiced reading time, it was felt that another kind of comparison was needed to demonstrate this hypothesis. Perhaps a referral to Figure 2, page 34, will aid in understanding what was attempted here. Figure 2 shows the the mean reading times for voiced reading under normal side-tone as 31.85, under delayed side-tone as 43.64, and the mean difference between them as 11.79. This mean difference of 11.79 is treated as a score which represents the effect of side-tone delay on voiced reading time.

We may repeat this procedure with whispered reading time. The mean of normal delay whispered reading time is 33.35, the mean of whispered reading time under conditions of side-tone delay is 49.67, and their mean difference is 16.37 as presented graphically in Figure 2, page 34. The mean difference of 16.37 is treated as a score which represents the effect of side-tone delay on whispered reading time.

Now we possess two scores to indicate the relative effects of delayed feedback on voiced versus whispered speech: 11.79 for voiced reading time and 16.37 for whispered reading time. Following the same statistical procedure as for the two previous statistical treatments of data, a mean difference of 4.59 is found (see Figure 2, page 34, for graphic presentation and Table I, page 31, for the means, mean differences, and standard deviations). Using the pre-mentioned formulae this difference of 4.59 was subjected to a _t_ test. The resulting _t_ value is 3.14 (see Table II, page 32). This _t_ value is significant at the one per cent level of confidence, thus indicating that the odds were 100 to 1 that this large a _t_ value could have occurred by chance alone.

The null hypothesis is rejected and there is a significant difference between these two scores. On the basis of this difference, we may say that delayed side-tone has an even greater effect on whispered reading time than it has on voiced reading time. This appears to lend some support to certain theories expressed in Chapter I. Whispering, poorly transmitted by bone conduction, creates a situation where it becomes difficult for one to monitor one's speech with the result being a greater effect of side-tone delay on one's speech performance, in this particular study, the reading rate.

4. No hypothesis was formulated for the results shown in Table III, p. 33, but they were reported to give full scope to this study.

Voiced reading time with no delay had a mean of 31.85 and a standard deviation of 5.72. A comparison of the variables yielded a <u>t</u> value of 9.53 as shown in Table III, page 33, which is significant at the one per cent level of confidence. This finding supports previous findings by other experimenters, that delayed side-tone retards voiced reading rate or lengthens reading duration.

5. Table III, page 33, shows whispered reading time without delay and with delay. The means were 33.35 and 49.67 respectively. The standard deviations were 4.24 and 11.04 respectively. The mean difference was 16.37 with a standard deviation of 8.38. The comparison of variables yielded a <u>t</u> value of 8.43 which is significant at the one per cent level of confidence.

In summary, we can tentatively conclude that whispered reading time is retarded by the use of delayed side-tone. Whispered reading time under conditions of side-tone delay is greater. It takes longer to read a passage while whispering under conditions of side-tone delay than it does to read the same passage while whispering with no delay in side-tone.

TABLE I

THE MEANS, STANDARD DEVIATIONS, AND MEAN DIFFERENCES OF THE READING TIMES IN SECONDS FOR TWENTY SUBJECTS IN AGE GROUP, 20-30

Conditions	Mean	Standard Deviation
Normal Voice	31.85	4.27
Normal Whisper	33.35	4.24
Difference	1.51*	1.73
Delay Voice	43.64	7.26
Delay Whisper	49.67	11.04
Difference	6.04*	6.37
Voice Difference	11.79	5.72
Whisper Difference	16.37	8.38
Difference	4.59*	5.76

* mean difference (M_D)

TABLE II

$\underline{t}$ VALUES FOR THE COMPARISON OF DIFFERENCES OF READING TIMES FOR TWENTY NORMAL HEARING SUBJECTS IN THE AGE GROUP, 20-30

19 d.f.	
Difference Between Normal Voice and Normal Whisper	3.79*
Difference Between Delay Voice and Whisper Voice	4.16*
Difference Between Effect of Delay on Voice and on Whisper	3.14*

* significant at the 1 per cent level of confidence

TABLE III

THE MEANS, STANDARD DEVIATIONS, MEAN DIFFERENCES AND t VALUES OF THE READING TIMES IN SECONDS FOR TWENTY SUBJECTS IN THE AGE GROUP, 20-30

Conditions	Mean	Standard Deviation	t Value
Normal Voice	31.85	4.27	
Delay Voice	43.64	7.26	
Difference	11.79*	5.72	9.53**
Normal Whisper	33.35	4.24	
Delay Whisper	49.67	11.04	
Difference	16.37*	8.38	8.43**

* mean difference (M_D)

** significant at the 1 per cent level of confidence

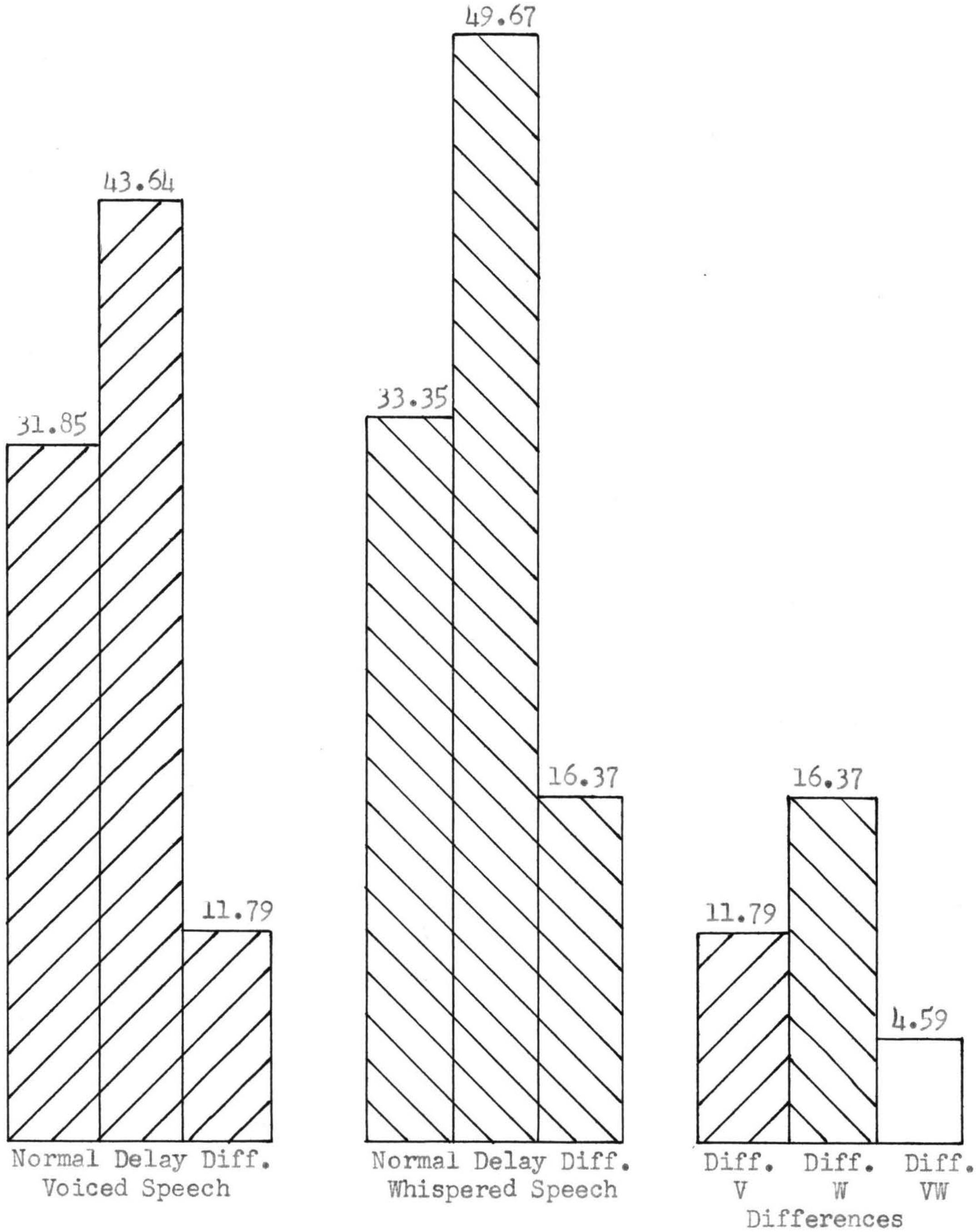

FIGURE 2

MEAN READING TIMES AND THEIR DIFFERENCES

CHAPTER V

CONCLUSIONS

Previous experimenters have noted that the factor of bone conduction, during conditions of side-tone delay, has played an important role in determining the effect of that delay. Recent studies (see Related Studies, page 9) tend to indicate that the intensity of the side-tone delay is as important as the interval itself. This need to amplify the delayed side-tone to produce the usual disruption of speech is felt to be due to the subject's ability to monitor his speech through bone conduction.

If we may assume that whispering is not well conducted by the bones in the skull, then it follows that the whispering itself should reduce the effectiveness of one's ability to monitor oneself by bone conduction under conditions of side-tone delay. Theoretically then there should be greater effects of side-tone delay on whispered reading as compared to voiced reading, since the factor of bone conduction monitoring has been reduced or modified.

It would appear that the results of this study tend to substantiate this hypothesis. There was a statistically significant difference between the effect of side-tone delay upon voiced and whispered reading time. Whispered reading time was longer. It would appear that side-tone delay produced greater reading rate/duration disturbances when one was reading in a whisper than when one was reading in a normal voice.

The results of this study contribute another bit of evidence to demonstrate that one does hear oneself and monitor one's speech by bone conduction.

Qualitative Evaluation

A survey of the raw scores will reveal great individual differences. The basis of these differences would appear to be due to some of the following: the subjects were not told ahead of time of the delay in side-tone entering in, and even though they had been instructed to continue reading, several were not able to restrain a laugh or an outburst of some kind; some of the subjects attempted to "beat" the voice in their ears by slurring their reading; after having once been exposed to the delay several subjects showed hesitancy in their next "no-delay" reading; it also appeared, immediately following a condition of delay, that the subject "lost" judgement of what was his normal reading time and hurried along.

Several of the subjects said they were able to overcome the voice in the ear, but objective observation did not reveal this to be true. Perhaps this is a question of semantics or one of relative values. There seem to be those who can resist the side-tone completely, but usually only after having some experience with it.

Limitations of the Present Study

It was thought that the elimination of any practice period under conditions of delay would remove the variable of the subject's learning to adapt to the effects. It is possible, however, that the surprise reactions of certain subjects could have affected their scores significantly.

It was extremely difficult to establish a whisper "level". It was necessary to increase the intensity during the whispering period, and even then it fell below that of the voiced reading. It should be realized that few people spend much time whispering, thus we have the factor of lack of practice. The timing could have been handled more efficiently by using better timing equipment. Finally, more subjects would have increased the validity of the findings.

Recommendations for Further Research

This study could certainly bear repeating with an improved experimental design and equipment. We are just now beginning to use the side-tone delay as an effective tool in testing hearing, and there are many studies to be done to standardize certain procedures, intensity levels, optimum delay times, etc.

It would be worthwhile to explore the facet of how we hear ourselves. Would it be possible to measure the amount that we hear by bone and the amount by air conduction?

Individual differences should be explored further. Are there any emotional patterns for those people who are able to resist the side-tone and visa versa? Is there any relation between normal loudness or intensity of voice and one's ability to monitor oneself?

Most of the previous studies, this one included, measure the effect of side-tone delay on a reading situation. It would be interesting to examine the effect of delayed side-tone on "free" speech.

SUMMARY

Twenty normal hearing subjects, 15 male and 5 female, read the "Rainbow Passage" aloud and in a whisper under 4 conditions of normal side-tone and delayed side-tone of 0.17 seconds intensity of 75 db. They were given a practice period to read the material both aloud and in a whisper. The difference in reading times under each condition were compared statistically.

The findings were:

1. There was a significant difference between voiced reading time without delay and voiced reading time with delay. The mean difference was 11.79 seconds. Voiced reading time was significantly longer under conditions of delay.

2. There was a significant difference between whispered reading time with no delay and whispered reading time with delay. The mean difference was 16.37 seconds. Whispered reading time under conditions of delay was longer.

3. There was a significant difference between voiced reading time and whispered reading time under conditions of no delay. The mean difference was 1.51 seconds. Whispered reading time under conditions of no delay was longer.

4. There was a significant difference between voiced reading time and whispered reading time under conditions of delay. The mean difference was 6.04 seconds. Whispered reading time under conditions of delay was longer.

5. There was a significant difference between the mean difference of 11.79 seconds for voiced reading time under conditions of delay and no delay, and the mean difference of 16.37 seconds for whispered reading time under conditions of delay and no delay. The difference between the two mean differences was 4.46 seconds. Whispered reading time is longer than voiced reading time under conditions of side-tone delay. Delayed side-tone seems to have more of an effect on whispered speech than on voiced speech.

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APPENDIX

ORDER, RANDOM ORDER OF TESTS, SEX, AND AGES OF SUBJECTS

Initials	Random Order	Sex	Age
1. A. F.	2413	M	29
2. M. V.	3412	F	20
3. A. L.	1234	F	21
4. G. M.	3142	M	23
5. J. W.	2341	M	26
6. H. B.	3421	M	27
7. J. L.	3412	M	23
8. G. M.	3412	M	25
9. M. C.	1324	M	28
10. P. N.	3142	M	24
11. J. L.	4123	M	26
12. C. W.	1423	F	23
13. C. W.	2134	M	23
14. B. M.	2431	M	25
15. J. C.	1423	M	22
16. K. G.	2134	M	23
17. S. S.	2413	M	25
18. S. K.	2413	F	22
19. O. M.	4132	F	21
20. D. M.	2134	M	24
			24 Mean Age

RAINBOW PASSAGE

WHEN THE SUNLIGHT STRIKES RAINDROPS IN THE AIR, THEY ACT LIKE A PRISM AND FORM A RAINBOW. THE RAINBOW IS A DIVISION OF WHITE LIGHT INTO MANY BEAUTIFUL COLORS. THESE TAKE THE SHAPE OF A LONG ROUND ARCH, WITH ITS PATH HIGH ABOVE, AND ITS TWO ENDS APPARENTLY BEYOND THE HORIZON. THERE IS, ACCORDING TO LEGEND, A BOILING POT OF GOLD AT ONE END. PEOPLE LOOK, BUT NO ONE EVER FINDS IT. WHEN A MAN LOOKS FOR SOMETHING BEYOND HIS REACH, HIS FRIENDS SAY HE IS LOOKING FOR A POT OF GOLD AT THE END OF THE RAINBOW.

SUMMARY OF RESULTS

Initials	Age	NV	DV	NW	DW	Diff V	Diff W	Diff T
1. A.F.	27	35.0	45.8	36.0	43.4	10.8	7.4	− 1.8
2. M.V.(F)	20	35.0	53.0	34.2	66.0	18.0	31.8	+13.8
3. A.L.(F)	21	27.8	40.0	29.0	39.0	12.2	10.0	+ 2.2
4. G.M.	23	31.0	39.0	31.5	35.0	8.0	3.5	− 4.5
5. J.W.	26	30.5	43.5	33.5	56.0	13.0	22.5	+ 9.5
6. H.B.	27	29.1	50.2	32.5	61.5	21.1	29.0	+ 7.9
7. J.L.	23	28.9	38.8	32.2	42.0	9.9	9.8	− .1
8. G.M.	25	27.0	33.2	29.0	38.9	6.2	9.9	+ 3.9
9. M.C.	28	27.1	35.5	30.0	38.8	8.4	8.8	+ .4
10. P.N.	24	45.0	50.8	46.0	58.0	5.8	12.0	+ 6.2
11. J.P.	26	36.5	51.0	38.1	69.8	14.5	31.7	+17.2
12. C.W.(F)	23	36.1	41.0	34.5	50.5	4.9	16.0	+11.1
13. C.W.	23	31.5	43.5	31.2	47.2	12.0	15.0	+ 3.0
14. B.M.	25	28.8	38.0	30.2	41.0	9.2	10.8	+ 1.6
15. J.C.	22	30.5	39.0	35.0	55.5	8.5	19.5	+11.0
16. K.G.	23	29.8	38.0	31.2	40.2	8.2	9.0	+ .8
17. S.S.	25	34.8	54.8	39.5	68.1	20.0	28.6	+ 8.6
18. S.K.(F)	22	31.8	59.0	34.0	60.0	27.2	26.0	− 1.2
19. O.M.(F)	21	27.0	32.6	26.0	38.5	5.6	12.5	+ 6.9
20. D.M.	24	33.8	46.0	33.5	44.0	12.2	11.5	− .7
	24	637.0	872.7	667.1	993.4	235.7	325.3	+91.8