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Effects of Monaural and Binaural Delayed Auditory Feedback on Reading Time of Stutterers and Non-Stutterers

Barry E. Guitar
Western Michigan University

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EFFECTS OF MONAURAL AND BINAURAL DELAYED AUDITORY FEEDBACK ON READING TIME OF STUTTERERS AND NON-STUTTERERS

by

Barry E. Guitar

A Thesis Submitted to the Faculty of the School of Graduate Studies in partial fulfillment of the Degree of Master of Arts

Western Michigan University Kalamazoo, Michigan August 1967
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Finally, for their enduring good cheer, he wishes to thank his roommates, Ed and Charley.

Barry E. Guitar
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CHAPTER I

INTRODUCTION

The concept of the speaking process as a closed-cycle system or servo-system has been an impetus to much research. In turn, the concept has been further developed and refined by research. Investigations of the auditory feedback component in the system, particularly studies dealing with delayed auditory feedback, have revealed that the auditory channels are an important and rather sensitive component. Recent experiments also have suggested the possibility that the two auditory feedback channels may not be identical, that one may predominate over the other. Literature relevant to these topics will be discussed in the next section.

Delayed Auditory Feedback

Tape recorders with a separate playback head at a variable distance from the recording head have enabled investigators to delay a person’s auditory feedback for a time generally ranging from 90 to 800 milliseconds (msec). Lee’s (1951) pioneer experiments demonstrated the now-familiar reaction to delayed auditory feedback: the subjects spoke very slowly with increased sound pressure or tried to maintain normal rate but had halting speech and syllable repetition. Discussing this reaction, Lee proposed a model of the speech mechanism made up of loops responsible for units of speech: phonemes, syllables, words, and thoughts; the length of each loop would be

1
proportional to the time required to perform the speech unit's activity. Lee further suggested that the units are monitored by kinesthetic, tactile, and auditory feedback. The syllable loop, the only one monitored by the auditory channel, was the one disturbed by delayed auditory feedback. Lee hypothesized that the delay kept the auditory monitor from being satisfied with production and resulted in halting speech and syllable repetition. (See Smith (1962).)

Black (1951) reported on the effects of auditory feedback delays ranging from 20 to 350 msec delivery at 85-90 dB re .0002 dyne/cm². He, too, found that speakers experiencing delayed feedback spoke with increased sound pressure and had long reading times. Longest reading times occurred with delays of 180 msec; this led Black to suggest that the duration of the syllable, rather than any longer unit of speech, was an important factor in the effects of delayed auditory feedback.

Since these early experiments, a number of other researchers have observed essentially similar effects, particularly the increase in reading time, under the condition of delayed auditory feedback (Atkinson (1953), Spilka (1954), Tiffany and Hanley (1956), and Davidson (1959)). A complex conceptual framework was needed to answer the many questions raised by these studies.

Fairbanks (1954) published his model of the speech mechanism as a servo-system. Fairbanks postulated motor, generator, and modulator units (representing the lungs and diaphragm, the vocal
folds, and the articulators) driven by signals from a storage unit which contained standard time and sound patterns of motor, generator, and modulator activities for a particular desired speech output. The feedback processes take place as the output of the motor, generator, and modulator units is detected by auditory, kinesthetic, and tactile sensors and is fed back to a comparator component. The comparator places the new information about output beside the pattern in the storage unit. Where a difference occurs, the comparator signals a mixer unit which adjusts the signal driving the motor, generator, and modulator units. The adjustment is meant to bring actual output in line with the pattern of desired output. The error signal, which is the result of the comparison between actual output and the standard pattern for desired output, notifies the storage unit to hold a pattern that hasn't been satisfactorily achieved by the actual output or to move ahead to the next pattern when the previous pattern is achieved. In practice, the flow of speech is maintained because the comparator is able to predict immediate future output and have a stored pattern ready for the effectors to work on when that output is realized.

This model attempted to describe many more of the complex and interrelated operations within the speech process than did the earlier mentioned model of Lee. It made use of both recent experimental information about the speaking process and cybernetic concepts of communication systems. Fairbanks suggested a division of labor in the speech mechanism which allows some localization in the interpretation of results of experiments on the speech mechanism. As
Fairbanks points out:

One evident feature of the model as well as of the live system, is that it contains many components in a complicated arrangement and readily becomes disordered. (The model) can be caused to repeat, prolong, and hesitate by several different manipulations, one of which is feedback delay.

In a careful study of the effects of delayed auditory feedback, Fairbanks (1955) observed that peak disturbances of articulation and duration occurred when the delay time reached 200 msec. This was generally in agreement with Black's findings. Two other effects of delayed auditory feedback, changes in mean sound pressure and mean fundamental frequency of connected speech, both appeared to increase sharply with the first delay time (100 msec) and maintain that level throughout the other delay times. Fairbanks interpreted these findings to indicate that the undifferentiated increases in sound pressure and fundamental frequency were caused by "increased muscular tension in the vocal mechanism" from attempts to resist interference and maintain control. These he called indirect effects. The disturbances of articulation and duration Fairbanks termed direct effects, determined by "the phase relationships of input and feedback." These direct effects, he suggested, are functions of the units of speech which are controlled by feedback. Articulation errors and increases in speaking time are manifest in proportion to the critical relationship between the time of feedback delay and the temporal length of controlling units of speech.

Fairbanks and Guttmann (1958) investigated the nature of the
articulatory errors induced by delayed auditory feedback. It was revealed that in the case of sixteen young men reading a passage five times under different delay times, certain types of articulation disturbance varied selectively with the specific interval of delay. At the peak of articulatory disturbance (200 msec delay), errors of addition were more prevalent than other types of disturbance, and seventy per cent of these additions were repetitions. Fairbanks and Guttmann pointed out that this error of double articulation may be the system's way of restoring the normal output-feedback relationship.

Studies of delayed auditory feedback have been in general agreement about its effects on reading time for normal speakers. Some work has also been done on the reactions of speech defectives to the delay. Ham (1967) tested stutterers, people with voice disorders, and people with articulation defects, as well as normal speakers, under delayed auditory feedback. He found that the effects of the delay on total speech time and words per minute did not vary significantly with groups; that is, the experimental groups, the stutterers, persons with voice problems, and those with articulation defects, had essentially similar reactions to delayed auditory feedback for measures of duration.

The disturbance of speech under delayed auditory feedback is widely documented with unusually widespread concordance among investigators. As Fairbanks (1955) has said, "Although individual differences are large, its universality is remarkable."
Central Auditory Processes

The disruption of speech under conditions of delayed auditory feedback has indicated a parameter of normal speech: dependence on a limited temporal pattern of auditory feedback. The attempts to explain this temporal limitation have used current and past research findings to construct theories of the entire speech process.

A theory of speech and hearing outlined by K. U. Smith (1962) in his book on delayed sensory feedback, accounts for the effects of delayed auditory feedback by first assuming that in the sensory feedback mechanisms of the speaking process are internuncial neurons which detect differences in stimulation at two dendrite points. This part of the system is sensitive to spatial and temporal differences in stimulation. Smith calls attention to recent studies of the auditory system which have shown that differential response takes place not only in the cochlear nucleus but also in the central auditory system. Galambos (1957) found that "internuncial cells in the medulla respond to minute phase or time differences between stimuli presented to the two ears or to two points on one organ of Corti." Patterns of spatial and temporal differences monitored by these neurons correspond to patterns in the postural, sound-generating, tone-generating, and articulatory movements of speech. Temporal distortions, affecting such a critical dimension of a speech control mechanism, disturb the highly integrated patterns of movement in speech. The result is the articulatory and durational disruption which Fairbanks terms the primary effects of delayed auditory feedback.
Other studies of the central auditory system have demonstrated differential responses to stimuli presented to different ears, despite the fact that each cochlea is represented bilaterally in higher centers. Rosenzweig's (1951) experimentation in which he administered clicks to a single ear of a cat and measured the resulting cortical potentials, led him to conclude that, "At the auditory cortex . . . the population of cortical units representing the contralateral ear is larger than the population representing the ipsilateral ear . . . . This interpretation is also consistent with data on human perception."

Research with neurological patients is generally in agreement with this finding of Rosenzweig's. The following studies may be support for the view that humans, as well as cats, have a more extensive representation of the contralateral, rather than the ipsilateral, ear on each side of the auditory cortex. Studies suggest that the peripheral auditory mechanism may be a good indicator of speech functions in higher centers (Boone, 1959; Kimura, 1961a, 1961b; Bocca and Calearo, 1963). There is evidence that speech sounds are recognized in only one hemisphere (Berry and Eisenson, 1956); the ear best represented in that hemisphere, then, may be the most efficient for recognizing sounds of speech. Patients with lesions between cerebral hemispheres have been studied to explore the connections between the ear and the speech centers in the brain.

Differences in communication ability between right and left hemiplegics were found by Boone (1959) to be quite marked. On
tasks of listening to speech, naming, writing, and conversation, right hemiplegics, with, obviously, left cortical lesions, gave significantly poorer performances than left hemiplegics, with right cortical lesions. Boone found, however, that the left hemiplegics made an unexpectedly large number of errors on the task of reauditoryization which included auditory retention for digits and listening to spoken directions. He concluded that this deficit was related to "an overall intellectual deficit and not to receptive aphasia."

Researchers have used a wide variety of tests to observe the differences between patients with impairments on the left side of the brain and those with impairments on the right side. Bocca and Calearo (1963), writing about central hearing processes, cite the tests of Calearo and Antonelli on subjects with lesions of the temporal cortex to contrast with tests on normal subjects. These tests of discrimination with distorted and interrupted voice show no significant differences on normal subjects, but show for pathological subjects a significantly depressed score on the ear contralateral to the lesion.

Newby (1964) has pointed out how this sort of a pathology cannot be detected with normal pure tone and speech discrimination tests, since sub-cortical ascending auditory pathways intersect to effect at least partial bilateral representation in the auditory cortex. In his text, Audiology, Newby says, "... as the auditory tasks increase in complexity, the presence of the central nervous system lesion is revealed by an inability of the contralateral ear to perform at the same level as the ipsilateral ear."
The effects on perception of speech sounds of temporal lobe lesions was also studied by Kimura (1961a). Patients with lesions of the right or left temporal lobe were administered two numbers simultaneously to right and left ears. Kimura found that patients with lesions of the left temporal lobe had much poorer digit spans than those with right lesions. To her it seemed likely that "the left temporal lobe is specialized for recognition of verbal material at least in the auditory modality. . . ."

Kimura's (1961b) further study of perception of verbal stimuli by neuropathological patients showed that there was no significant difference between two groups of patients with opposite handedness who had speech represented in the left hemisphere when they were given the test cited above (Kimura, 1961a). However, significant differences were shown for two left-handed groups with speech represented in opposite hemispheres. The uncrossed auditory pathways, from right cochlea to right temporal lobe and left cochlea to left temporal lobe, of subjects of these studies were apparently still intact. Kimura suggested that the crossed auditory pathways are the most efficient.

These findings with neuropathological patients are beginning to be substantiated in tests with normal human subjects. Effective tests to measure inter-ear differences in the normal person's central auditory system, if, indeed, such differences do exist, have been difficult to devise. Kimura notes that with normal subjects in whom both crossed and uncrossed auditory pathways are functioning,
test material must be unusually difficult to be able to detect a
difference between ears. Kimura (1963) tested normal children on
the task she had used with patients who had temporal lobe lesions.
She presented a different number simultaneously to each ear of 120
right-handed children, 4-9 years old; for each age group the right
ear was significantly more effective in recognizing the digits, with
no difference between the results of boys and girls. Kimura inter­
preted this data as suggesting that left cerebral dominance for
speech is established by the age of four, and probably earlier. She
also suggested that her results may be integrated with the reports
of children's recovery from aphasia in which the left side was
damaged. Speech representation, she says, in the left side may be
present in young children, but perhaps not so firmly established
as in adults.

The recent investigations of hemispheric dominance for speech
and hearing are additions to a large accumulation of literature on
this topic. Normal speech requires thorough organization in the
central nervous system. Coordination in the activities of speech
muscles appears to depend upon paired impulses sent from the brain;
one impulse may lead the other to synchronize the muscle pairs to
move the tongue, jaw and other articulators. Travis (1931) and Orton
(1937) developed a view of stuttering as a failure of timing and
integration in the central nervous system. In Jaspers' (1932)words,
the "cause . . . in most stuttering . . . is . . . (that) neither the
right nor left hemisphere is able to get control." Much of the
disparity of the published studies of handedness, cerebral dominance, and stuttering may reflect the fact that handedness is probably a poor index of dominance in higher functions. The interest in cerebral dominance has led investigators to try to find reliable measures of dominance in functions which can be tested peripherally. Visual perception, visual-motor coordination, and various auditory functions have succeeded handedness as hunting grounds for the elusive expression of cerebral dominance.

Peterson (1942) designed a test with which he intended to test ear preference. Each of 24 subjects was asked to listen to pure tones delivered over an earphone and to give a verbal signal when he heard the tone. Intensity control on the output was turned up very slowly and if the subject made no move to listen, he was told he could lean forward. The ear which the subject turned toward the earphone was taken to be the preferred ear. Subjects were given a total of nine tests. Peterson concluded that the test results may be interpreted to indicate that ear dominance existed in slightly less than 50% of thirty-nine sets of three trials.

Elkins (1956) followed Peterson's lead in testing normal subjects for ear preference. She administered auditory stimuli to elicit turning of the dominant ear and attempted to correlate the results with a more objective measure of ear dominance: differences in reading time during monaural delayed auditory feedback. Elkins' subjects experienced a delay time of 160 msec at a level of 16 dB less than the vocal input received by the microphone. They read three
series of phrases under three different conditions: delayed auditory feedback presented to one ear while the other was masked with white noise, the reverse of this, and binaural delayed auditory feedback. Elkins found that the duration of oral reading responses of her subjects did not vary significantly when delayed feedback was shifted from one ear to the other. She also found that duration didn't vary with shifting of delayed feedback from monaural to binaural delivery. Thus Elkins was not able to detect ear dominance using delayed auditory feedback. One explanation for Elkins' results may be that the level at which the subjects experienced the feedback was too low to cause a significant disturbance in higher centers of the brain to demonstrate a dominant ear. An experiment using delayed auditory feedback at a level near 100 dB would seem more likely to be an adequate test for ear dominance.

The concept of ear dominance has been related to speech defects. The French investigator Tomatis (1952) has developed a view that each normal speaker has a "directing ear" which transmits the critical feedback signals to the contralateral auditory cortex and then to the center for language function in the left side of the brain. A "physiological delayed feedback" effect, Tomatis says, occurs in persons whose dominant ear is not on the right side. This is apparently caused by feedback transmission to the language center being delayed by having to cross from the right auditory cortex to the center on the left side. In a later publication, Tomatis (1964) contends that stuttering results from the lack of a dominant ear.
and that stuttering is improved by therapy designed to establish a dominant ear.

Statement of the Problem

The literature on delayed auditory feedback and on central auditory processes indicates that a difficult task administered to the peripheral auditory mechanism, particularly one involving feedback-output operations, may be a good test of central auditory function. Furthermore, the literature reflects a lack of agreement in studies of the presence of a dominant ear. A dominant ear may or may not exist in normal speakers; if it does exist in normal speakers, the literature implies, the absence of a dominant ear in speech defectives, particularly in stutterers, may be a significant pathological feature of these persons.

An experiment was designed to 1) test for the presence of a dominant ear in groups of stutterers and non-stutterers, and 2) measure total reading time of a standard passage under conditions of normal, amplified normal, amplified and delayed binaural, and both left and right amplified and delayed monaural auditory feedback. The findings would then be related to the purpose of the study.

The purpose of the present study was to ask, and answer where possible, the following questions:

1. Is there any difference between groups of stutterers and groups of non-stutterers on total reading time under several conditions of auditory feedback?
2. If so, is a difference associated with the monaural conditions?

3. Is there a significant relationship between the indication of a dominant ear and total reading time under monaural delayed auditory feedback?
CHAPTER II

PROCEDURE

Subjects

The subjects were divided into two groups, stutterers and non-stutterers. The group of stutterers consisted of three females and seven males between the ages of nineteen and thirty-one with a median age of 22.5 years. In this group were persons currently or formerly in therapy for secondary stuttering in a speech clinic or school program. The group of non-stutterers was composed of fifteen females and six males, between the ages of eighteen and thirty-five with a median age of 24 years. In this group were persons who had no history of stuttering and who did not evidence stuttering behavior during control conditions of the experiment. All subjects had normal hearing sensitivity as demonstrated by pure tone test results across the speech frequencies of 500, 1000, and 2000 Hz.; furthermore all subjects had an inter-ear sensitivity difference of less than seven decibels. None of the subjects had had any neurological pathology, so far as judgment was possible without neurological workups on the subjects.

From this original composite of thirty-one subjects, two different groupings of subjects were arranged for statistical analysis. The first set consisted of all ten stutterers and ten of the non-stutterers matched with the stutterers for sex, handedness, and
ear preference. The second set included seven of the stutterers with right ear preference and seven non-stutterers with right ear preference.

Equipment

The apparatus and facilities used in the experimental session are listed below. A block diagram of the experimental apparatus is presented in Figure 1.

1. All-Tronics Delayed Feedback Apparatus (All-Tronics, Inc., Battle Creek, Michigan)
2. Grason-Stadler Speech Audiometer, Model 162
3. Electrovoice microphone, Model 664
4. Grason-Stadler earphones, D30 (matched)
5. Industrial Acoustics Company Sound Suite

The reading material was the first paragraph of the Rainbow Passage (Fairbanks, 1940). A copy is in the appendix. A.

The microphone was placed approximately six inches from the speaker's mouth; the material to be read was typed out on a sheet of stiff paper and placed on a stand at a comfortable distance from the speaker in line with the microphone. Delay time on the apparatus was set at 187 milliseconds (Spilka, 1954). A reference (normal) sound pressure level for the electronic feedback system was determined by having two listeners speak and adjust, in ascending and descending trials, the signals coming over the earphones to obtain a loudness match with the bone-conducted sidetone level. For the experimental task the level of feedback coming over the earphones
Figure 1. Block diagram of experimental apparatus
was set at 30 dB above the reference level determined previously (Fairbanks, 1955). This was about 105 dB SPL for most subjects as determined by calibration equipment (Bruel and Kjaer Audiometer Calibrator, Model 158) measuring signals at the earphone.

Experimental Task

Each subject was placed in the sound-treated room, separated from the experimenter's booth by a sound-treated wall with an observation window. Each subject completed the following three tasks:

1. Ear Preference Test

The subject was asked to listen to intermittent pure tones of decreasing sound pressure presented over a single earphone on a stand at ear level; the subject stood in front of the stand with his feet at a fixed distance from the stand. He was instructed to signal, by raising a hand, when he could no longer hear the tones. Furthermore, he was told "Several people have asked if they could lean forward or tilt their head to hear the tones better. If you want to do that it will be all right." The experimenter then presented five sets of intermittent tones of decreasing sound pressure; each set was at a different frequency: 500, 1000, 2000, 3000, and 4000 Hz. He observed for each set whether the subject turned one side of his head toward the earphones and which side was turned. If, after two sets, the subject had not turned his head, the experimenter told the subject "If you want to lean forward or tilt an ear to hear better that will be all right," and the testing continued. Three out of five directional responses determined a preference.
2. Hearing Test

The subject was then seated in a chair facing away from the observation window and administered a pure tone hearing test at speech frequencies (Beltone Pure Tone Audiometer, Model 14-A).

3. Reading

Following the hearing test, the subject was presented with the major experimental task; he remained in the chair where he had been placed for the hearing test and was requested to read, aloud and at a natural speed, the Rainbow Passage. The subject read under five different conditions of auditory feedback presented in random order. The five conditions were: a) normal (without earphones on) (NF); b) binaural amplified feedback (BAF); c) binaural amplified, delayed auditory feedback (BD); d) monaural, delayed auditory feedback, right ear (RD); and e) monaural delayed auditory feedback, left ear (LD). Feedback could be switched from direct to delayed by a manual switch on the delayed feedback apparatus; binaural or monaural delivery over the earphones was selected by a control on the speech audiometer. The subject was advised to resist stopping or laughing under the delayed feedback condition. He was also shown how to place the contralateral earphone behind and not touching the pinna of the contralateral ear when a monaural condition was called for. Instructions concerning the appropriate placement of earphones for each reading and the signal to start were given over the earphones and a wall-mounted speaker. After all readings were completed, the experimenter asked the subject whether he noticed anything irregular during the
session, such as a change in feedback condition during a reading. This information was sought to maintain proper equipment operation at all times.

Collection of Data

Each reading by each subject was timed by the experimenter. Readings were timed with a stopwatch (Meylan, type 202 A D) calibrated to three-fifths of a second and were recorded to the nearest three-tenths of a second. These data were recorded along with ear preference, right, left, or neither, and the thresholds of auditory sensitivity.

Statistical Procedures

Statistical treatment of the data was performed with an analysis of variance procedure (ANOV) appropriate to the experiment's two factor, two-by-five design with repeated measures on five levels of one factor. For this experiment the five percent level of significance was used in statistical analysis. Where significant F ratios were obtained, the data were further probed using the Newman Keuls test (Winer, 1962). Other statistical measures were employed to examine parts of the data relevant to the discussion.
CHAPTER III

RESULTS

The present experiment was designed to test subjects, groups of stutterers and non-stutterers, for the presence of a dominant ear and to measure subjects' total reading time of the Rainbow Passage under several conditions of auditory feedback. The results of the tests and measurements were then to be related to questions about dominance in the central auditory system.

The test for ear preference indicated that of 31 persons, 22 demonstrated a right ear preference, three a left preference, and six no preference. For the purpose of statistical analysis, the subjects were divided into two different groupings. The results of analysis of each grouping are presented below.

First Grouping

The first grouping consisted of ten stutterers and ten non-stutterers matched for sex, age, handedness, and ear preference. These matches are shown in Table 1. The mean total reading times across feedback conditions for these subject groups are listed in Table 2; raw scores are shown in Appendix C.

The average reading times of the first grouping of subjects were examined with an analysis of variance, which is summarized in Table 3. Inspection of the analysis reveals that the F ratio testing the group's difference was not significant, and that the F ratio
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<td>R</td>
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<td>R</td>
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<td>22</td>
<td>M</td>
<td>R</td>
<td>N</td>
</tr>
</tbody>
</table>

*The following abbreviations will be used to represent the data: M-Male, F-Female, R-Right, L-Left, and N-None.*
TABLE 2. SUMMARY OF MEANS AND STANDARD DEVIATIONS IN SECONDS FOR TOTAL READING TIME (N = 10/GROUP)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Conditions</th>
<th>N**</th>
<th>A</th>
<th>BD</th>
<th>RD</th>
<th>LD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stutterers</td>
<td>Mean</td>
<td>42.63</td>
<td>32.01</td>
<td>42.34</td>
<td>37.14</td>
<td>35.43</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>9.21</td>
<td>2.66</td>
<td>4.50</td>
<td>3.15</td>
<td>2.53</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>28.05</td>
<td>27.78</td>
<td>41.68</td>
<td>34.63</td>
<td>33.84</td>
</tr>
<tr>
<td>Non-stutterers</td>
<td>S.D.</td>
<td>5.38</td>
<td>4.02</td>
<td>14.60</td>
<td>8.25</td>
<td>8.45</td>
</tr>
</tbody>
</table>

The following abbreviations will be used to represent the experimental conditions: N-Normal Feedback; A-Binaural Amplified Feedback; BD-Binaural Delayed and Amplified Feedback; RD-Right Monaural Delayed and Amplified Feedback; LD-Left Monaural Delayed and Amplified Feedback.

TABLE 3. SUMMARY OF ANALYSIS OF VARIANCE FOR MEANS OF TOTAL READING TIME FOR TREATMENT CONDITIONS. FIRST GROUPING. N = 10. F RATIO IS FOR NEAREST TABLED df.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td>5875.36</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Groups)</td>
<td>555.55</td>
<td>1</td>
<td>555.55</td>
<td>1.879</td>
</tr>
<tr>
<td>Subj. within Group</td>
<td>5319.81</td>
<td>18</td>
<td>295.54</td>
<td></td>
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<tr>
<td>Within subjects</td>
<td>5103.11</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (Treatments)</td>
<td>1494.08</td>
<td>4</td>
<td>373.52</td>
<td>*9.06</td>
</tr>
<tr>
<td>AB</td>
<td>643.12</td>
<td>4</td>
<td>160.78</td>
<td>*3.90</td>
</tr>
<tr>
<td>B x Subj. w/ Group</td>
<td>2965.91</td>
<td>72</td>
<td>41.19</td>
<td></td>
</tr>
</tbody>
</table>

*F,.95 (1,18) = 4.41

*F,.95 (4,60) = 2.53
associated with treatments' differences was significant. Interaction between groups and treatments were significant, making it difficult to analyze the effects of treatments on groups. It was thought that the interaction could be accounted for by means of a geometric analysis of the data.

The geometric analysis of the interaction effect for total reading time, plotting groups across conditions, is shown in Figure 2. It is apparent that the groups exhibit closely similar profiles with the exception of the first treatment in which the stutterers showed unpredictably high reading time. In Figure 3 the plot of mean total reading times associated with treatment conditions for each group substantiates the evidence in the plot in Figure 2 that the extremely long reading time for the first group in the first treatment is responsible for the interaction effect.

Based on the geometric means analysis, a Newman-Keuls procedure was employed to compare means for total reading time within each group. It was determined that for the group of stutterers, all possible paired comparisons of treatment means showed no significant differences (see Appendix D). The Newman-Keuls test on the non-stutterers' results showed significant differences between several pairs of treatment conditions (see Appendix D). The two control conditions, normal (N) and amplified feedback (A), were significantly shorter in reading time than conditions of binaural delayed (BD), right monaural delayed (RD), and left monaural delayed (LD) feedback; however, the first two conditions, N and A, did not
Figure 2. Mean total reading times for groups across conditions. N = 10.
Figure 3. Mean total reading times associated with treatment conditions for each group. N = 10.
differ significantly from each other. The two monaural conditions, RD and LD, although not significantly different from each other, were significantly shorter than the binaural delay condition. Finally, BD was significantly longer than all other conditions.

Reading times associated with the monaural conditions, RD and LD, for the group of stuttersers (D1) were compared with the differences between the monaural conditions for the group of non-stutterers (D2), using a t-test. This comparison indicated that the differences, D1 and D2, were not significantly different from each other, as may have been expected from the overall analysis.

In an attempt to understand the non-significant differences between treatment conditions for the stuttering group it was noted that the standard error of the treatment conditions for stutterers which is used as an error term in the Newman-Keuls analysis (see Appendices C, D, and E) was approximately twice the value of the standard error of the non-stutterers. This state of affair is interpreted to mean that the within-group variability was of a magnitude to render the differences between treatment conditions for stutterers non-significant.

Summary

With the exception of the stutterers' long reading time under the normal feedback condition, stutterers and non-stutterers behaved essentially similarly across treatment conditions. It is probably that intra-group variability of the stutterers rendered their treatment conditions differences non-significant. The non-stutterers exhibited differences that were statistically significant. N and A
the two control conditions were significantly shorter in reading time than BD, RD, and LD, the three delay conditions. N and A did not differ from each other, significantly. RD and LD did not differ from each other, significantly, but were significantly shorter than BD.

Second Grouping

A second grouping of subjects consisted of seven stutterers and seven non-stutterers, all of whom had a right ear preference (see Appendix C). Mean total reading times for treatments with associated standard deviations are given in Table 4.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean</th>
<th>A</th>
<th>BD</th>
<th>RD</th>
<th>LD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stutterers</td>
<td>45.38</td>
<td>31.15</td>
<td>41.50</td>
<td>36.64</td>
<td>34.15</td>
</tr>
<tr>
<td>S.D.</td>
<td>23.63</td>
<td>5.76</td>
<td>11.35</td>
<td>8.14</td>
<td>6.25</td>
</tr>
<tr>
<td>Non-stutterers</td>
<td>26.82</td>
<td>29.52</td>
<td>42.22</td>
<td>36.90</td>
<td>35.31</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.37</td>
<td>2.57</td>
<td>8.36</td>
<td>7.94</td>
<td>4.56</td>
</tr>
</tbody>
</table>

An analysis of variance for this grouping of subjects is summarized in Table 5. The analysis indicates that the F ratio for the groups' difference was not significant, whereas the F ratio associated with the treatments' differences was significant. The interaction between groups and treatments was significant and it
TABLE 5. SUMMARY OF ANALYSIS OF VARIANCE FOR MEANS OF TOTAL READING TIME FOR TREATMENT CONDITIONS. SECOND GROUPING. N = 7. F RATIO IS FOR NEAREST TABLED df.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between subjects</strong></td>
<td>4650.93</td>
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<td></td>
</tr>
<tr>
<td>A (Groups)</td>
<td>227.88</td>
<td>1</td>
<td>227.88</td>
<td>0.62</td>
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<tr>
<td>Subj. within Group</td>
<td>4423.05</td>
<td>12</td>
<td>368.58</td>
<td></td>
</tr>
<tr>
<td><strong>Within subjects</strong></td>
<td>4487.99</td>
<td>56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (Treatments)</td>
<td>960.28</td>
<td>4</td>
<td>280.07</td>
<td>*5.5</td>
</tr>
<tr>
<td>AB</td>
<td>993.52</td>
<td>4</td>
<td>263.38</td>
<td>*5.2</td>
</tr>
<tr>
<td>B x Subj. w/ Group</td>
<td>2534.19</td>
<td>48</td>
<td>52.79</td>
<td></td>
</tr>
</tbody>
</table>

*F.95 (1,12) = 4.75

*F.95 (4,40) = 2.61

was, therefore, difficult to analyze the effects of treatments on groups. Geometric analysis of the mean reading times was carried out to account for the interaction.

Figure 4 shows the geometric analysis for the interaction effect for means of total reading time, plotting groups across conditions. Other than the first treatment, in which the stutterers show an unusually high mean reading time, the graphs show similar profiles for both groups. Figure 5 shows the plot of mean reading times associated with treatment conditions for each group. This plot substantiates the indication in Figure 4 that the extremely long reading time for the experimental group in the first treatment is responsible for the interaction effect.

The Newman-Keuls procedure (see Appendix E), based on the
Figure 4. Mean total reading time for groups across conditions. N = 7.

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Figure 5. Mean total reading times associated with treatment conditions for groups. N = 7.
geometric analysis, was used to compare means for reading time within each group. This analysis showed, as in the first grouping, that for the stuttersers all possible paired comparisons showed no significant differences, whereas for the non-stuttersers several paired treatment conditions showed a statistically significant difference. N and A, the control conditions, were significantly shorter in reading time than BD, RD, and LD, the three delay conditions. The first two conditions, N and A, did not significantly differ from each other. The two monaural conditions, RD and LD, were not significantly different from each other, but were significantly shorter than the binaural delay conditions. The binaural delay condition was significantly longer than all other conditions.

A t-test of the two monaural conditions of each group showed differences between the two conditions, RD and LD, of the stuttersers were not significantly different from the differences between the two monaural conditions of the non-stuttersers.

Summary

The second grouping included only experimental and control subjects who demonstrated a right ear preference. As in the first grouping of subjects, with the exception of the stuttersers' long reading time under the normal feedback condition (N), experimentals and controls behaved essentially similarly. Stuttersers as a group did not show significant differences among treatment conditions, probably because of intra-group variability. However, for the non-stuttersers, all paired comparisons except between the control
conditions, N and A, and between the two monaural conditions, RD and LD, showed a difference which was statistically different. The binaural delay condition, BD, was significantly longer than the two monaural conditions, which, in turn, were significantly longer than the two normal conditions.

The questions which led to this experiment were concerned with dominance in the central auditory system. A trend associated with this concern may be operating in the monaural feedback conditions, RD and LD. Figures 6 and 7 reflect this trend. In Figure 6 five out of seven stutterers with a right ear preference demonstrate a clearly longer reading time for the condition of right monaural delay. One shows a longer reading time for the left monaural delay condition; and one shows a very slightly longer reading time for the LD condition. In Figure 7, five non-stutterers with right ear preference show a definitely longer reading time under the RD condition whereas only two non-stutterers of the seven with right ear preference show a little longer reading time under the left delay condition. This trend will be discussed in the next section.
Figure 6. Total reading time associated with monaural delay conditions for stutterers. N = 7.
Figure 7. Total reading time associated with monaural delay conditions for non-stutterers. N = 7.
CHAPTER IV

DISCUSSION

This chapter will attempt to relate the major findings of the present study to previous research. Relevant findings of studies discussed in Chapter I will be considered. The increased reading time of subjects experiencing several conditions of delayed auditory feedback is consistent with previously published studies. Fairbanks (1955) found that all delay conditions brought about disturbances of duration, and that the disturbances were at a maximum when delay time was 200 msec. The present experiment employed a sound pressure level similar to that used by Fairbanks: 30 dB above the level at which amplified and unamplified feedback were matched by a listener. Ham (1967) reported increases in total speech time for subjects across delay times of 100, 200, 400, and 800 msec, with maximum increases at 100 msec. The results of this experiment also support the work of Lee (1951) and Black (1951) whose subjects' reading times increased under delayed feedback. Black reported that his subjects' maximum disturbance of duration occurred at a delay time of 180 msec. The present experiment used, as stated earlier, a delay time of 187 msec.

Total reading times across feedback conditions for stutterers versus non-stutterers were not significantly different as shown by the analysis of variance. This is also evident in the similar profiles for mean reading time across experimental conditions of both groups.
This finding seems to verify Ham's observation that total speech time disruption for stutterers and normals were not significantly different. The question asked prior to the experiment, concerning a statistically significant difference between the groups on these tasks must be answered negatively.

The groups did differ, however, in terms of the treatment conditions. It was indicated that the stutterers as a group did not show significant differences among treatments whereas the non-stutterers did demonstrate significant differences. The lack of a significant difference between paired comparisons of treatment conditions for the stutterers may be attributed to intra-group variability. This variability has been attested to by other researchers. As mentioned earlier, Fairbanks (1955) observed, "Although individual differences in the disturbances are large, its universality is remarkable." The interpretation can be made that, for the normals, the increased complexity of the task is reflected by their increased reading time. Under the disruption of delayed feedback, the subjects may have first slowed their reading rates trying to maintain correct articulation by listening closely to their output which was taking longer to come back. The subjects may then have found that by exaggerating their articulatory movements, a process which would take more speaking time, they could receive adequate tactile and kinesthetic feedback to maintain correct articulation. The increase in the complexity of the task reflecting increased reading time occurred when the delayed feedback was delivered first to one ear and then to both, cutting out
first one channel for normal feedback, then both.

The second question asked before the experiment, about a group difference associated with monaural reading time, must also be answered negatively. Since the groups were found to be not significantly different across the treatment conditions, no difference between groups for monaural conditions could occur. There did seem to be a trend, however, for longer total reading times under the right monaural delay condition. The subject grouping of seven stutterers and seven non-stutterers, all of whom had right ear preference, was plotted on total reading time for each ear. Inspection of these plots, shown in Figures 6 and 7, demonstrated this trend.

There is evidence to support the notion that cerebral function for communication is lateralized and that the contralateral ear is an indicator of such a state of affairs (Kimura, 1961a, 1961b; Boone, 1959; Bocca and Calearo, 1963). The trend of longer total reading times under right monaural delay, although not statistically significant, tends to find support from such information. Kimura (1961b) indicated that for patients with lesions of the temporal lobe, this behaviorally manifest dominance of the ear contralateral to the hemisphere dominant for speech can be easily demonstrated. However, she says, the difference between the ears of normal speakers may be detectable only with very difficult tasks.

The trend for longer reading times during the right delay condition may be interpreted in several ways. The feedback-output operations under these conditions, may be shunted so that the left ear is
carrying the major burden of receiving and transmitting feedback information. Were this a non-dominant ear it may be expected to perform this function less efficiently than the right ear. The lack of a statistically significant difference between monaural conditions might be expected if the present experimental task was not complex enough to demonstrate a clear cut dominance. On the other hand, the right ear, the ear contralateral to the hemisphere in which speech theoretically would be localized for subjects with a right ear preference may show more disturbance effect because it is more sensitive to feedback. That is, Kimura's (1963) study of normal subjects who perceived numbers more effectively through the right auditory mechanism, may be support for the possibility that delayed feedback is perceived more acutely by the right ear of most normal subjects, resulting in a greater disturbance during a monaural delay condition on that side and longer reading times.

The present study found that for non-stutterers total reading time under binaural delay is significantly different from the two monaural conditions. Elkins' (1956) research, however, demonstrated no significant difference between binaural and the two monaural conditions. Her study used a delayed feedback level 16 dB less than vocal output received by the microphone. In addition, the ear not receiving delayed feedback was masked by white noise. Either or both of these conditions may have mitigated against subjects demonstrating a difference between monaural and binaural delay effects. Such a low level of feedback may have resulted in a disturbance of small
magnitude such that when the number of auditory pathways carrying the monaural delayed feedback was halved, cortically, no effect was demonstrated. Furthermore, it is not impossible to imagine the masking signal causing such a commotion in the central auditory system that masking in one ear and delayed feedback in the other was as disturbing as binaural delayed feedback. The present experiment allowed normal feedback to reach the ear not receiving delayed feedback. Thus, monaural normal feedback may have reduced the effect of the relatively loud and, therefore, quite disturbing delayed feedback.

The present study found, in concurrence with Elkins, that the two monaural feedback conditions were not statistically different from each other. Elkins, however, does not observe a trend of one monaural condition being more disruptive than the other. The present study may have observed this trend where Elkins doesn't because, again, a much higher level of feedback was used as well as normal feedback to the non-test ear.

The trend of differences between the effects of right and left monaural delay, although not statistically significant, may be at least encouragement, if not serious evidence, for the possibility that a servosystem model of the speaking process must account for two distinct auditory feedback channels. Furthermore, a model revision would need to describe one monaural auditory pathway as dominant, in terms of transmission time and efficiency, over the other.

The third question asked in this experiment, of an association
between a behaviorally preferred ear and a greater disruption in
total reading time under a monaural condition will have to be
answered negatively. Both groups of subjects who had a right ear
preference did not show a significant difference between monaural
conditions. These subjects, however, did show an important trend of
greater reading time under the right monaural delay condition. Thus,
there is an indication that the association in question might be
shown to exist in future studies.

Limitations

The present study made use of only one feedback level and one
delay time. This may have limited the task complexity possibility
which may be required for normal speakers without neuropathology to
demonstrate a dominant ear. Other studies (Black, 1951; Fairbanks,
1955), however, have shown that delay times between 180 and 200 msec
are maximally disturbing. Studies using several levels of delayed
auditory feedback have found highest levels to be most disturbing
(Tiffany and Hanley, 1956). The single high feedback level of
105 dB used in this study provides a difficult task without causing
discomfort for subjects. Other and perhaps finer measures of a
subject's vocal disturbance under delayed feedback conditions might
have been employed. Fundamental frequency, sound pressure level,
phonation/time ratio, mean syllable duration, and speech power
variance have been measured by other experimenters probing the
effects of delayed auditory feedback. This study, despite the
relatively gross measure of total reading time, has raised some interesting possibilities.

The writer recognizes the risk of interpreting a trend in non-significant data. The trend of greater reading time associated with right monaural conditions, however, seemed to be worthy of discussion. It is not impossible that the slight inter-ear sensitivity differences that existed for these subjects could be influencing the trend. The level of feedback, however, was 80 dB above these thresholds. It is unlikely that the sensitivity differences could account for the reading time differences under these conditions.

Suggestions for Further Research

Future research efforts in this area should aim to reduce variables and increase complexity of the task. Larger groups would tend to alleviate the effects of intra-group variability which hampered this study. Attempts to determine a maximally disturbing delay time for each subject would increase the difficulty of the task. Other measures of disturbance such as fundamental frequency and mean syllable duration may produce more significant results.
CHAPTER V

SUMMARY

This study investigated certain effects of monaural and binaural delayed auditory feedback on the total reading time of stutterers and non-stutterers. Previous research has indicated the possibility that cerebral function for speech is localized in one hemisphere and that the ear contralateral to that hemisphere would, under proper conditions, respond differentially to designate that arrangement of cerebral function. Furthermore, oral reading responses under delayed auditory feedback was implicated by the literature as a potential test for such cerebral localization of speech function.

Each of thirty-one subjects was asked to demonstrate in a majority of trials a preference for one ear; he then read a standard passage under five randomly administered conditions: normal feedback, binaural amplified feedback, binaural amplified and delayed feedback, right monaural amplified and delayed feedback, and left monaural amplified and delayed feedback. Delay time was approximately 187 msec and feedback was delivered at about 105 dB SPL. The readings under these conditions were timed with a stopwatch and the data, total reading time in seconds, were subjected to statistical analysis.

Subject groupings for analysis consisted of, first, ten stutterers and ten non-stutterers matched for sex, handedness, and ear preference and, second, seven stutterers and seven non-stutterers, all of whom had a right ear preference.

43
The results were related to specific questions asked prior to
the experiment. These questions are answered below.

The groups of stutterers and non-stutterers did not differ in
their performance on the tasks. The groups, considered separately,
showed internal differences. Stutterers as a group did not show
significant differences in total reading time under the several
feedback conditions. High intra-group variability appears to have
brought about this lack of differences. The groups of non-stutterers,
also considered separately, did show differences among treatment
conditions. The reading times for the normal and the amplified feed­
back conditions, while not different, were shorter than the reading
time for the three delay conditions. The two monaural conditions
were not different from each other; the binaural delay condition gave
longer reading times than either the normal or monaural conditions.

No difference was observed between stutterers and non-stutterers
in terms of their performances on the monaural conditions. Although
the monaural conditions of both groups showed no difference, and,
thus, no ear response indicating speech function lateralization was
demonstrated, a trend favoring the right ear was seen. The trend of
longer reading times for subjects with right ear preferences experi­
cencing right rather than left monaural delay might be taken as an in­
dication that a difference between the cerebral hemispheres, a differ­
ence for speech function, could be revealed in tests using delayed
feedback if a sufficiently effective experimental design were evolved.

Within the limitations imposed by the design of the experiment
and treatment of the results, certain conclusions regarding the questions asked may be justified.

1. Stutterers and non-stutterers do not differ in their performances under delayed auditory feedback in terms of speaking rate.

2. Individual responses to delayed auditory feedback is widely variable and suggests that a large number of subjects should be used in tests of effects of delayed auditory feedback.

3. While differences which indicate higher neural functions may exist between ears and be detected by their responses, the tests must be extremely complex.
APPENDIX A

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 the pot of gold at the end of the rainbow.
APPENDIX B

INSTRUCTIONS TO SUBJECTS

Sit in this chair and place this microphone so that it is six inches from your mouth. Make yourself comfortable because you will have to stay six inches from the microphone when you read this passage.

Adjust this stand so that you can read the passage easily when you are six inches from the microphone.

I will ask you to read the passage when you are hearing yourself under several conditions: normal feedback without earphones, amplified feedback coming in both ears, and delayed feedback - when it will take longer than usual for your voice to come back. Sometimes I will ask you to read without the earphones, sometimes with the earphones on both ears and sometimes with the earphones on just one ear. When I ask you to put the earphones on one ear, put the other earphone behind and not touching the other ear.

When you are experiencing delayed feedback you may find it more difficult to read. Try to read at a normal rate, without stopping or laughing. I will be timing your readings. I will tell you over the speaker when to start and what way to wear the earphones.

Do you have any questions?

47.
## APPENDIX C

Summary of Newman-Keuls procedure used to probe the significance of difference between mean total reading time for treatments. N = 10.

### Group 1 - Stutterers

<table>
<thead>
<tr>
<th>Conditions</th>
<th>2A</th>
<th>5LD</th>
<th>4RD</th>
<th>3BD</th>
<th>1N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordered means</td>
<td>32.01</td>
<td>35.43</td>
<td>37.14</td>
<td>42.34</td>
<td>42.63</td>
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<tr>
<td>2</td>
<td>-</td>
<td>3.42</td>
<td>5.13</td>
<td>10.33</td>
<td>10.62</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>-</td>
<td>1.71</td>
<td>6.91</td>
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</table>

\[ S_{Ba_1} = 2.57 \]
\[ r = 2 \quad 3 \quad 4 \quad 5 \]

\[ q_{0.95}(r, 36) = 2.86 \quad 3.44 \quad 3.79 \quad 4.04 \]

\[ S_{(q_{0.95}(r, 36))} = 7.35 \quad 8.84 \quad 9.74 \quad 10.38 \]

### Group 2 - Non-stutterers

<table>
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<tr>
<th>Conditions</th>
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<th>1N</th>
<th>5LD</th>
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<td>7.05*</td>
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</table>

\[ S_{Ba_1} = 1.25 \]
\[ r = 2 \quad 3 \quad 4 \quad 5 \]

\[ q_{0.95}(r, 36) = 2.86 \quad 3.44 \quad 3.79 \quad 4.04 \]

\[ S_{(q_{0.95}(r, 36))} = 3.57 \quad 4.30 \quad 4.74 \quad 5.05 \]
Summary of Newman-Keuls procedure used to probe the significance of difference between mean total reading time for treatments. $N = 7$.

### Group 1 - Stutterers

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<td>3.9</td>
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</table>

$$s_{B_a1}^r = 3.53$$

$$q_{.95}(r,24)$$

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<td>2.92</td>
<td>3.53</td>
<td>3.90</td>
<td>4.17</td>
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</table>

$$s_{B_a1} (q_{.95}(r,24))$$

| 10.30 | 12.46 | 13.76 | 14.72 |
APPENDIX E

Summary of Newman-Keuls procedure used to probe the significance of difference between mean total reading time for treatments. \( N = 7 \).

Group 2 - Non-stutterers

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\[ S_2 = 1.61 \]

\[ \frac{B}{a_2} \]

\[ q_{.95}(r,24) \]

\[ 2.92 \quad 3.53 \quad 3.90 \quad 4.17 \]

\[ S_{Bq_{.95}(r,24)} \]

\[ 4.70 \quad 5.68 \quad 6.28 \quad 6.71 \]
## APPENDIX F

### TOTAL READING TIMES FOR STUTTERERS AND NON-STUTTERERS

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**Abbreviations:**
- s - stutterer
- n - non-stutterer
- r - right ear preference
- N - no ear preference
- l - left ear preference
- 2 - also in second grouping

(first twenty subjects were in first grouping)
BIBLIOGRAPHY


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