To the Graduate Council:

I am submitting herewith a thesis written by Robert E. Moore entitled "Aural Harmonic Thresholds and Acoustic Stapedial Reflex Thresholds for Normals Using Air- and Bone-Conducted Stimuli." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Audiology.

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We have read this thesis
and recommend its acceptance:

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Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

AURAL HARMONIC THRESHOLDS AND ACOUSTIC STAPEDIAL REFLEX THRESHOLDS FOR NORMALS USING AIR- AND BONE-CONDUCTED STIMULI

A Thesis

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R.E.M.

ABSTRACT

The purpose of this study was to investigate if there is a difference in inner ear distortion for air- and bone-conducted pure tones in normal hearing subjects. Acoustic reflex thresholds (SL) and aural harmonic thresholds (SL) for both air- and bone-conducted stimuli were obtained at 500, 1000, and 2000 Hz.

The results of this study indicated that there was no significant difference between air- and bone-conducted aural harmonic thresholds (SL). The conclusion was made that the difference in acoustic reflex thresholds (SL) for air- and bone-conducted pure tones is not caused by a difference in inner ear distortion for air- and bone-conducted stimuli. It is possible, however, that there is a difference in harmonic growth at the inner ear for air- and bone-conducted pure tones.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION.	1
II.	PROCEDURES.	6
III.	RESULTS AND DISCUSSION.	16
IV.	SUMMARY AND CONCLUSION.	21
BIBLIOGRAPHY		23
APPENDICES		26
VITA		32

LIST OF TABLES

TABLE		PAGE
1.	Harmonic Distortion and Maximum Output Level of the TDH-39 Earphone and the B-70A Bone Vibrator	9
2.	Test-Retest Data for Three Subjects	15
3.	Acoustic Reflex Threshold and Aural Harmonic Threshold Means (dB SL) for Air- and Bone-Conducted Stimuli.	17
4.	Auditory Threshold Means (dB HTL) and Standard Deviations.	27
5.	Acoustic Reflex Threshold for Air Stimuli in dB (S.L.).	28
6.	Acoustic Reflex Thresholds for Bone Stimuli in dB (S.L.).	29
7.	Aural Harmonic Threshold for Air Stimuli in dB (S.L.).	30
8.	Aural Harmonic Threshold for Bone Stimuli in dB (S.L.).	31

LIST OF FIGURES

FIGURE		PAGE
1.	Test Apparatus. Acoustic reflex thresholds using air- and bone-conducted stimuli	7
2.	Test Apparatus. Aural harmonic thresholds using air- and bone-conducted stimuli	11

CHAPTER I

INTRODUCTION

When the human ear is stimulated by a sinusoidal acoustic signal, the electro-physiological response is sinusoidal until the stimulus is increased above a certain level. When the amplitude of the driving force surpasses this level, overloading occurs and nonlinear distortion with its concurrent harmonics of the fundamental frequency of the original signal results (v. Bekesy, 1934; Chapin and Firestone, 1934; Cotton, 1935; Lewis, 1940; Wever, 1941; Moe, 1942).

In the human ear the structures of the organ of Corti are the first to overload in this manner. The structures of the middle ear and the fluids of the inner ear have been found to respond in a linear fashion to amplitude levels of sound which would destroy the sensory structures of the inner ear (Wever and Lawrence, 1954). Also, animal experiments using electrical potentials measured at the cochlea have shown that these harmonics probably originate at the cochlea, although the middle ear was not excluded from the originating process (Wever and Bray, 1938; Wever, Bray, and Lawrence, 1940). This phenomenon was first termed "aural harmonics" by Stevens and Newman (1936). Clinically, the threshold of aural harmonics can be determined using the Flottorp-Opheim procedure (Opheim and Flottorp, 1955).

This test determines the nonlinearity of the ear using the second harmonic tone produced by the ear when stimulated by a pure tone. The existance of the harmonic is made perceivable to the individual by introducing a second tone which is approximately twice the frequency of the first signal. The frequency of the second tone is varied to produce a beat phenomenon to which the individual is asked to respond.

The threshold for aural overload has been investigated by several researchers for various reasons. Lawrence and Blanchard (1954) studied the relationship between the threshold of aural overload and susceptibility to noise induced acoustic trauma. They postulated that the lower the threshold at which the hearing mechanism was no longer linear the more susceptable the ear was to damage by noise. They found with normal hearing subjects the average threshold of aural overload above audiometric zero at the following fundamental frequencies to be: 250 Hz - 23 dB, 500 Hz - 48 dB, 1000 Hz - 65 dB, and 2000 Hz - 65 dB. These results are in good agreement with the findings of other researchers (Opheim and Flottorp, 1955; Lawrence and Yantis, 1956; Harbert and Young, 1964; Harbert, Young, and Menduke, 1966). All these investigators found the range of the aural overload thresholds for normal hearing subjects to be large. Djupesland and Flottorp (1970) also reported norms for aural overload

thresholds in sensation levels (SL) as follows: 250 Hz - 31 dB SL, 500 Hz - 42 dB SL, 1000 Hz - 48 dB SL, and 1500 Hz - 49 dB SL.

Thresholds for aural overload have also been examined in pathological ears. In subjects with inner ear pathologies the mean value above audiometric zero was not found to be significantly different from those of normal hearing subjects. However, the dynamic range between the hearing threshold level (HTL) and the aural overload threshold was significantly reduced in the pathological ears (Opheim and Flottorp, 1955; Lawrence and Yantis, 1956; Harbert and Young, 1964; Djupesland and Flottorp, 1970). In a series of cases with presbycusis, Harbert, Young, and Menduke (1966) found a significant increase in point of overload above audiometric zero compared with normal ears and those affected by other inner ear pathologies. In conductive hearing losses Lawrence and Yantis (1956) have shown that aural overload thresholds were elevated above audiometric zero in relationship to the degree of the hearing loss at the fundamental frequency.

The results found with the aural overload threshold test and the acoustic reflex threshold test are very comparable. Both tests have wide ranges for normal hearing subjects. Jerger, Jerger, and Mauldin (1972) reported that 95 % of all normal reflexes would occur in the range of 70 - 100 dB HTL. Other relationships between these

two tests were noted by Djupesland and Flottorp (1970). They found a correlation between the two tests for several hearing impairments. Most notably, when recruitment was present with the hearing loss, as determined by the Alternate Binaural Loudness Balance test (Fowler, 1936), both thresholds were found to be at lower than normal sensation levels.

Djupesland, Flottorp, Sundby, and Szalay (1973), have studied the relationship between acoustic reflex thresholds elicited through bone-conducted pure tones and air-conducted pure tones in normal hearing subjects. They found that at 250 Hz through 1000 Hz the bone-conducted reflex threshold was at a lower level than the air-conducted reflex threshold. This difference ranged between 5 and 25 dB. At frequencies above 1000 Hz bone-conduction reflex thresholds could not be elicited. At the levels where the reflexes were observed, a tingling sensation was produced in the area of the bone vibrator. Since control experiments excluded artifacts and a tactile stapedius reflex, it was felt that unusual overload of the inner ear started at the tingling sensation threshold. This led the authors to believe that the difference in reflex thresholds was due to differences in inner ear distortion for air- and bone-conducted pure tones. A follow-up investigation was begun to study this hypothesis by Sundby, Flottorp, and Djupesland (cited by Djupesland,

1975). In a correspondence dated March 15, 1976, Djupesland indicated that their study was still in preparation.

The purpose of this study was to investigate if the difference seen in air- and bone-conducted acoustic reflex thresholds was due to a difference in inner ear distortion for the two stimuli as postulated by Djupesland, Flottorp, Sundby, Szalay (1973). In order to investigate this difference the following question was asked:

Is there a significant difference between air- and bone-conducted aural harmonic thresholds (SL)?

To answer this question acoustic reflex thresholds and aural harmonic thresholds for air- and bone-conducted stimuli were obtained at 500 Hz, 1000 Hz, and 2000 Hz on fifteen subjects at both ears.

CHAPTER II

PROCEDURES

Fifteen subjects having normal hearing participated in the study. The right and left ear of each subject was used. The subjects ranged in age from 20 to 30 and the mean age was 23.7 years. There were 4 males and 11 females. All subjects were required to have pure tone air- and bone-conduction thresholds of 15 dB HTL or better (re 1969 ANSI Standard) at each ear used for the study at the following audiometric test frequencies: 250, 500, 1000, 2000, 4000, and 8000 Hz. 250, 4000, and 8000 Hz were required to be normal to avoid any contamination of test results because of irregularities at these frequencies. The presence of an air-bone gap of more than 10 dB precluded the use of the individual in the study. In addition, all subjects were required to have tympanograms within normal limits. Auditory threshold means and standard deviations are shown in Appendix A.

The apparatus used in the acoustic reflex portion of the study is shown in Figure 1. The signal source was a stimulus generator section of an impedance audiometer (American Electromedics Model 83). During air-conducted testing the output of the generator was delivered to an earphone (Telephonics Model TDH-39) mounted in an MX-41/AR

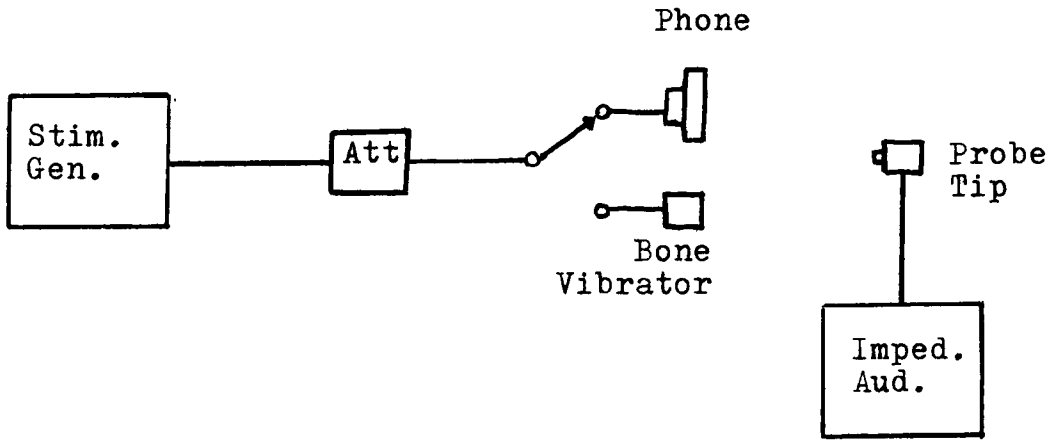


Figure 1. Test Apparatus. Acoustic reflex thresholds using air- and bone-conducted stimuli.

cushion and held in place by a standard headband. With bone-conducted testing the output was delivered to a bone vibrator (Radioear Model B-70A) held in place at the mastoid process by a standard headband. The occurance of the acostic reflex in the contralateral ear in response to the test stimulus was monitored by means of the impedance audiometer.

System calibration was performed prior to the beginning of the study. With the earphone the output of the stimulus generator was directed into an artificial ear (Bruel) and Kjaer Model 4152) as measured with an audiometer calibrator (Bruel and Kjaer Model 159). Using the bone vibrator the signal was directed to an artificial mastoid (Bruel and Kjaer Model 4930). Measurements were made using both transducers at the following test frequencies: 500, 1000, and 2000 Hz. The results of these measurements are shown in Table 1. The calibration of the probe tone in the probe tip was accomplished using a 2cc coupler modified to allow the tip to fit into it.

The point of reflex threshold was defined as the level at which a one-half unit deflection toward zero of the impedance audiometer intensity meter was seen. The descending method was used for determining the acoustic reflex thresholds for both air- and bone-conducted stimuli. It was found that it was more reliable to observe the gradual decline of the reflex and note its least noticeable threshold, than to gradually increase the stimulus and note the reflex's

Table 1

Harmonic Distortion and Maximum Output Level of the TDH-39 Earphone and the B-70A Bone Vibrator

TDH-39 Earphone		
Frequency (Hz)	Level of 2nd Harmonic component in %	Maximum output in dB (HTL)
500	2.6	123.0
1000	2.3	122.6
2000	6.9	123.5
B-70A Bone Vibrator		
Frequency (Hz)	Level of 2nd Harmonic component in %	Maximum output in dB (HTL)
500	5.5	79.0
1000	1.7	87.0
2000	1.0	90.0

onset.

The apparatus for the aural harmonic part of the study is shown in Figure 2. The two signal sources were the oscillator sections of a Grason-Stadler 1705 Audiometer and a Grason-Stadler E800-4 Audiometer. The signal from the Grason-Stadler E800-4 was passed through a filter (Allison Model AL-2ABR) to help insure that the second harmonic of the tone used as the fundamental was at least 60 dB below the fundamental frequency (Lawrence and Yantis, 1956). The amplitude and the frequency of this signal were monitored using a Heathkit VTVM and a frequency counter (General Radio Model 1192). The signal from the Grason-Stadler 1705 was passed through a phase shifter (Grason-Stadler Model E3520B) to insure correct phase relationship between the two signals. The amplitude and frequency of this signal were monitored using a VTVM (Hewett-Packard Model 4000) and a Heathkit frequency counter. Both signals were passed through 500 Ohm resistors and then combined at the common attenuator (Hewett-Packard Model 350C). From the common attenuator the signals were amplified by a locally constructed amplifier. For air-conducted testing the combined signals were delivered to an earphone (Telephonics Model TDH-50) mounted in an MX-41/AR cushion and held in place by a standard headband. With bone-conducted testing the same transducer was used as in the acoustic reflex threshold testing. The two signals from the oscillators

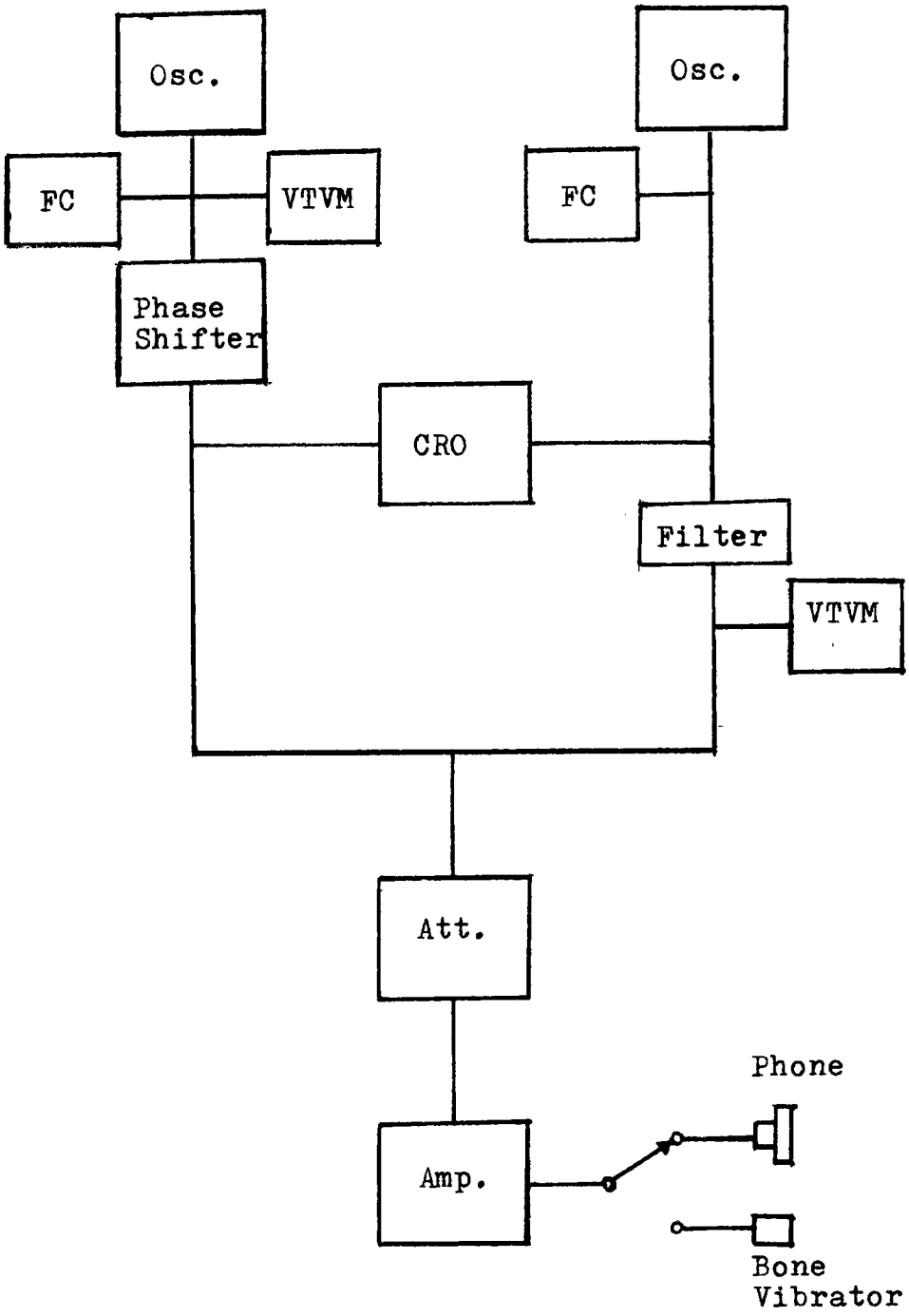


Figure 2. Test Apparatus. Aural harmonic thresholds using air- and bone-conducted stimuli.

were monitored using an oscilloscope (Tektronix Type 564). This system was calibrated using the same instrumentation as for the previously mentioned part of the study. The systems for acoustic reflex threshold measurements and aural harmonic threshold measurements were calibrated following the study to insure accuracy of the measurements.

To determine the threshold of aural harmonic a method based on the Flottorp-Opheim procedure (1955) was used. This procedure was a variation of the method of best beats. This method has been criticized by Trimmer and Firestone (1937) as a method to quantify aural harmonics. However, since the purpose of this study was to compare the perceptibility of the second harmonic and the occurance of the acoustic reflex, this method was regarded as adequate to reporduce a numerical expression of the phenomena.

Prior to the test each subject was given instructions and an opportunity to perform the task. The instructions were:

> During this test you will hear tones which will be steady and those which will be characterized by beats. Those signals that are characterized by beats may seem to alternate between loudness and softeness or may just appear to be distorted. When you hear a signal that you judge to be steady indicate this by a steady horizontal movement of the hand. When you hear a signal which you judge to be alternating or distorted indicate this by a vertical movement of the hand.

In order to practice the task a 500 Hz tone was presented through the headphone at 60 dB sensation level.

The subject was expected to indicate the perception of this signal by a horizontal movement of the hand. Then, a second tone was introduced, 4 Hz above the original signal, which produced beats. The subject was expected to indicate the perception of the beats by a vertical movement of the hand. When it was determined that the subject understood the instructions and could perform the task, the test was begun.

To determine the aural harmonic threshold a 496 Hz stimulus tone was introduced at 70 dB sensation level at the right ear. Then an exploring tone was introduced at 996 Hz at 60 dB above the subject's threshold for 1000 Hz. The intensities of the two tones were varied until the subject indicated by vertical movement of the hand that he had heard beats. To insure that the beats heard were produced by the interference between the second harmonic of the stimulus tone and the exploring tone, the two signals were countinuously monitored using the oscilloscope. After the subject had indicated that he had heard the beats, each signal was lowered in intensity using the common attenuator until the subject signalled that he no longer heard the beats. The exploring tone was then reduced slightly to determine if the beats would return. If they did return, the two signals were again reduced using the common attenuator. This procedure was followed until the beats had disappeared completely. The intensity

level of the stimulus tone was then recorded as the aural harmonic threshold.

The testing was continued at 998 and 2007 Hz as the fundamental frequencies and, then, at the left ear. The test was then repeated using the bone vibrator as the transducer. During the test session several frequencies were retested to insure the accuracy of the results. Also, three of the fifteen subjects were retested following the study. No significant differences were observed in the retest data. The test-retest dats is shown in Table 2.

During the course of the study two potential subjects were unable to perform the task involved with the aural harmonic threshold test. One individual could not hear the beats at one ear. At the ear where the beats were not heard, he reported a history of middle ear disorders. The other individual could not hear the beats at either ear and became confused during the testing. When it became apparent that the responses were unreliable through retesting, the test was terminated.

Table 2

Test-Retest Data for Three Subjects

Frequency (Hz)		AHT (AC) Test	AHT (AC) Retest	AHT (BC) Test	AHT (BC) Retest	ART (AC) Test	ART (AC) Retest	ART (BC) Test	ART (BC) Retest
				Subject 1					
500	R	49	44	61	61	85	85	76	72
	L	48	44	65	64	85	85	76	76
1000	R	50	55	66	64	90	90	77	77
	L	52	50	65	61	85	85	77	77
2000	R	60	61	55	53	90	90	74	74
	L	63	62	54	59	85	85	80	80
				Subject 9					
500	R	59	59	58	62	95	95	76	76
	L	60	60	58	59	95	95	76	76
1000	R	64	66	61	62	100	100	82	82
	L	66	63	64	59	95	95	82	82
2000	R	65	63	63	63	95	95	90	90
	L	61	60	59	60	90	90	84	84
				Subject 10					
500	R	47	52	54	55	80	80	67	67
	L	53	53	49	49	85	85	72	72
1000	R	60	59	63	58	90	90	72	72
	L	61	58	57	60	90	90	82	82
2000	R	66	60	65	61	90	90	84	84
	L	63	63	63	63	95	90	90	90

Key: AHT - aural harmonic threshold
ART - acoustic reflex threshold
AC - air-conducted
BC - bone-conducted
R - right ear
L - left ear

CHAPTER III

RESULTS AND DISCUSSION

The mean values for aural harmonic thresholds (SL) and acoustic reflex thresholds (SL) for both air- and bone-conduction are shown in Table 3. The actual test data in terms of sensation level are shown in Appendices B. C. D. and E.

As can be seen in Table 3 there was a 15.2 dB difference between air- and bone-conducted acoustic reflex thresholds (SL) at 500 Hz. At 1000 Hz the difference was 13.2 dB between the two measures. These differences were expected based on previous results reported by Djupesland, Flottorp, Sundby, and Szalay (1973). There was only a 2.2 dB difference at 2000 Hz between air- and bone-conducted acoustic reflex thresholds (SL).

The primary question of this study was:

Is there a statistically significant difference between air- and bone-conducted aural harmonic thresholds (SL)?

Aural harmonic threshold (SL) data for air-conduction and bone-conduction were compared by a t-test for related measures (Ferguson, 1971) at each frequency. An alpha level of .05 was selected for rejection or non-rejection of the question under test.

Table 3

Acoustic Reflex Threshold and Aural Harmonic Threshold Means (dB SL) for Air- and Bone-Conducted Stimuli

Stimulus	500 Hz	1000 Hz	2000 Hz
	Reflex Data		
AC	81.7	83.7	81.5
BC	66.5	70.5	79.3
	Aural Harmonic Data		
AC	42.8	53.9	58.3
BC	45.6	53.3	57.0

Key: AC - air-conduction
BC - bone-conduction

This resulted in "t" values of 1.15 at 500 Hz, 0.23 at 1000 Hz, and 1.16 at 2000 Hz. These values were not significant at the .05 alpha level (2.05 for 29 df). Based on these results it appears that the difference between air- and bone-conducted acoustic reflex thresholds cannot be attributed to a difference in inner ear distortion for air- and bone-conducted pure tones.

These results do not support the hypothesis proposed by Djupesland, Flottorp, Sundby, and Szalay (1973) that the difference in air- and bone-conducted acoustic reflex thresholds (SL) was due to a difference in inner distortion for the two stimuli. Since these results tend to exclude differences in inner ear distortion as the cause of differences in air- and bone-conducted acoustic reflex thresholds (SL), other possible causes must be considered. In the course of their study Djupesland, Flottorp, Sundby, and Szalay (1973) excluded a tactile stapedius reflex caused by the direct contact of the bone vibrator with the skin as a cause of the difference in acoustic reflex thresholds (SL). Also excluded were the effects of simultaneous stimulation of both cochlea by the bone vibrator and the occlusion effect, through the use of results with unilaterally deaf subjects compared to those of bilaterally normal hearing subjects. Another result of their study was that the rate of loudness increase as a function of sensation level was not significantly

different with air- and bone-conducted pure tones.

One factor which was not investigated in the present study was the possibility of a difference in the growth of harmonic distortion for air- and bone-conducted pure tones. The aural harmonic threshold test measured the point at which the individual could first detect the presence of the harmonic. These thresholds were at relatively low intensity levels compared to those of the acoustic reflex thresholds. It is possible that as the intensities of the two signals were increased above the aural harmonic threshold their individual effect on the cochlea was different. This change may have been in the form of a difference in inner ear distortion. If true, this would account for the results of this study in which no difference was found for inner ear distortion using air- and bone-conducted stimuli at the aural harmonic threshold level.

In Table 3 an approximate 15 dB difference is shown between acoustic reflex thresholds (SL) using air- and bone-conducted stimuli at 500 Hz and 1000 Hz. This difference could be useful in the clinical setting. Many individuals with sensorineural hearing losses have hearing thresholds too high to allow air-conducted acoustic reflex threshold testing. With the bone-conducted acoustic reflex threshold (SL) being approximately 15 dB lower than the air-conducted acoustic reflex threshold (SL)

at 500 Hz and 1000 Hz, this might provide an additional 15 dB to the test range.

If it is true that the difference in air- and bone-conducted acoustic reflex thresholds (SL) is due to a difference in inner ear distortion, it is possible that the difference can be used diagnostically by comparing the degree of cochlear distortion in normal and pathological ears. Djupesland (1964) has shown that in patient's with Meniere's disease the low-frequency bone-conducted acoustic reflex thresholds (SL) were lower than in normal ears.

CHAPTER IV

SUMMARY AND CONCLUSION

It was the purpose of this study to investigate the difference in inner ear distortion for air- and bone-conducted stimuli.

Fifteen adults, ranging in age from 20 to 30 years, were selected as subjects. Both ears of each subject were used in the study. The criteria for subject selection was that all subjects have normal hearing bilaterally as determined by pure tone audiometric testing and tympanometry.

Each of the subjects were tested utilizing the aural harmonic threshold test and the acoustic reflex threshold test. Both tests were administered using air- and bone-conducted pure tones.

As expected the acoustic reflex thresholds (SL) were found to be different at 500 Hz and 1000 Hz for air- and bone-conducted stimuli. The aural harmonic threshold (SL) test scores were compared statistically utilizing a t-test for related measures. The statistical analysis indicated that there was no significant difference between air- and bone-conducted aural harmonic thresholds (SL) at all test frequencies.

Based on these results, the conclusion must be

made that there is no significant difference in inner ear distortion for air- and bone-conducted stimuli. This questions the hypothesis that differences in air- and bone-conducted acoustic reflex thresholds (SL) are due to differences in inner ear distortion for the two stimuli. Since all other possible causes for the difference have been excluded in a previous study, the only possible alternate conclusion is that there is a difference in harmonic growth as the intensities of the two stimuli are increased.

The following topics are suggested for possible further research:

1. An investigation is recommended regarding the possibility of non-linear harmonic growth with air- and bone-conducted pure tones. This could be done by replicating Bekesy's (1932) study in which air- and bone-conducted stimuli were cancelled by adjustments in amplitude and phase. After cancellation is acheived, the intensities of the two stimuli would be increased in linear steps. If the harmonic growth of the two stimuli is linear the signals should remained cancelled.

2. The bone-conducted acoustic reflex thresholds (SL) of individuals with different types of sensorineural hearing losses should be investigated.

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APPENDICES

APPENDIX A

Table 4

Auditory Threshold Means (dB HTL)
and Standard Deviations

Stimulus		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Air	RE	3.6	3.2	4.9	4.0	5.0	3.9
		4.7	5.2	5.1	5.3	5.9	5.1
Air	LE	3.8	3.1	5.1	4.2	3.7	3.9
		4.5	5.2	6.1	4.7	5.3	4.9
Bone	RE	-	4.0	4.6	3.8	5.0	-
		-	3.2	3.9	4.3	4.1	-
Bone	LE	-	4.2	3.9	4.2	4.6	-
		-	4.7	4.5	5.2	4.7	-

APPENDIX B

Table 5

Acoustic Reflex Threshold for Air Stimuli in dB (S.L.)

Subject No.		500 Hz	1000 Hz	2000 Hz
1	R	90	95	90
	L	90	90	85
2	R	75	75	70
	L	85	70	80
3	R	90	85	75
	L	80	75	85
4	R	80	80	85
	L	80	85	80
5	R	85	90	85
	L	90	80	80
6	R	65	70	70
	L	70	75	70
7	R	85	90	95
	L	100	90	80
8	R	100	100	90
	L	85	90	80
9	R	85	100	100
	L	95	100	95
10	R	65	80	85
	L	70	80	80
11	R	65	85	85
	L	70	80	90
12	R	85	85	90
	L	80	85	85
13	R	75	75	65
	L	80	65	70
14	R	75	70	70
	L	80	70	70
15	R	90	90	95
	L	90	95	95
Mean		81.7	83.7	81.5
S. D.		9.68	9.82	9.93

Key: R = Right Ear
L = Left Ear
S. D. = Standard Deviation

APPENDIX C

Table 6

Acoustic Reflex Thresholds for Bone Stimuli in dB (S.L.)

Subject No.		500 Hz	1000 Hz	2000 Hz
1	R	71.5	77.5	84.7
	L	81.5	72.5	80.0
2	R	62.0	72.0	79.7
	L	62.5	77.5	80.0
3	R	71.5	72.0	79.7
	L	77.0	67.5	85.0
4	R	66.5	72.5	80.0
	L	62.5	67.5	90.0
5	R	62.5	67.5	74.7
	L	67.5	72.5	75.0
6	R	57.5	62.5	70.0
	L	52.5	72.5	75.0
7	R	71.5	82.0	75.0
	L	69.0	62.5	75.0
8	R	71.5	72.5	84.5
	L	69.0	77.0	90.0
9	R	71.5	77.0	85.0
	L	76.5	82.0	84.5
10	R	57.5	57.5	79.5
	L	62.5	82.0	85.0
11	R	52.5	62.5	69.7
	L	62.5	67.5	74.7
12	R	66.5	77.0	74.5
	L	72.0	67.5	75.0
13	R	57.0	52.5	80.0
	L	62.0	57.5	69.5
14	R	72.0	67.5	64.6
	L	62.0	62.5	75.1
15	R	71.5	82.0	95.0
	L	76.5	77.0	89.5
Mean		66.5	70.5	79.3
S. D.		7.34	10.44	7.019

Key: R = Right Ear
L = Left Ear
S. D. = Standard Deviation

APPENDIX D

Table 7

Aural Harmonic Threshold for Air Stimuli in dB (S.L.)

Subject No.		500 Hz	1000 Hz	2000 Hz
1	R	56	55	60
	L	53	57	63
2	R	47	50	57
	L	41	50	57
3	R	37	62	65
	L	44	58	76
4	R	42	37	52
	L	37	45	54
5	R	35	60	62
	L	47	49	65
6	R	37	46	55
	L	41	58	53
7	R	36	53	47
	L	28	45	48
8	R	68	69	60
	L	61	66	60
9	R	49	64	70
	L	60	71	66
10	R	22	50	60
	L	34	51	53
11	R	41	55	54
	L	38	45	62
12	R	53	56	58
	L	53	55	55
13	R	30	55	34
	L	30	27	44
14	R	29	60	64
	L	34	45	66
15	R	47	56	63
	L	48	60	65
Mean		42.8	53.9	58.3
S. D.		10.49	9.85	8.33

Key: R = Right Ear
L = Left Ear
S. D. = Standard Deviation

APPENDIX E

Table 8

Aural Harmonic Threshold for Bone Stimuli in dB (S.L.)

Subject No.		500 Hz	1000 Hz	2000 Hz
1	R	56	66	65
	L	60	60	54
2	R	17	47	60
	L	22	49	70
3	R	44	49	60
	L	57	49	65
4	R	52	59	52
	L	59	53	53
5	R	53	57	53
	L	47	57	58
6	R	43	50	51
	L	18	52	46
7	R	32	50	44
	L	47	37	45
8	R	61	60	60
	L	45	62	58
9	R	53	56	58
	L	58	64	59
10	R	44	48	60
	L	39	57	58
11	R	37	49	58
	L	47	54	60
12	R	43	54	50
	L	50	57	56
13	R	38	33	41
	L	43	46	51
14	R	54	50	66
	L	43	60	68
15	R	48	57	71
	L	34	57	64
Mean		45.6	53.3	57.0
S. D.		11.54	11.67	7.42

Key: R = Right Ear
L = Left Ear
S. D.= Standard Deviation

VITA

Robert E. Moore was born in Athens, Tennessee, on December 17, 1946. Early in his childhood his family moved to Maryville, Tennessee, where he attended elementary school and was graduated from Everett High School in June, 1964. The following September he entered the University of Tennessee at Knoxville.

In November, 1965, he entered the United States Army. After a four year tour of duty and two years of employment with the Federal Bureau of Investigation, he entered Hillsborough Community College in Tampa, Florida in September, 1971. In March, 1973, he received an Associate of Arts degree from that institution and entered the University of South Florida in Tampa. In the fall of 1974 he transferred to the University of Tennessee in Knoxville, and in June, 1975, he received a Bachelor of Arts degree in Liberal Arts. In that same month he began study toward a Master of Arts degree in Audiology, and this degree was awarded in June 1976.

The author is a member of Phi Theta Kappa, Tennessee Speech and Hearing Association, and National Student Speech and Hearing Association. Mr. Moore will join the staff of the Shea Clinic, Memphis Eye and Ear Hospital, and the Memphis Otologic Foundation in Memphis, Tennessee after graduation.

He is married to the former Jane Anne Burt of Lodi, Wisconsin.