To the Graduate Council:

I am submitting herewith a thesis written by Larry N. Robinette entitled "Acoustic Reflex Threshold-Duration Functions for Normals and Noise-Induced Permanent Threshold Shift." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Audiology.

Samuel B. Burchfield,
Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

ACOUSTIC REFLEX THRESHOLD-DURATION FUNCTIONS FOR NORMALS AND NOISE-INDUCED PERMANENT THRESHOLD SHIFT

A Thesis

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Master of Arts

Degree

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ABSTRACT

The purpose of this investigation was to compare the effects of temporal auditory integration on the acoustic reflex thresholds for subjects with normal hearing and for subjects with noise-induced permanent threshold shift. Threshold-duration functions were determined for 1, 2, and 4 KHz pure tones and for broad-band noise.

Acoustic reflexes were monitored using an impedance technique. Stimulus durations employed were 20, 50, 100, 200, and 500 msec. A measurement technique was developed which included observation of the impedance bridge output deflections in conjunction with latency time to confirm the occurrence of reflex activity.

Results of the study indicated that there may be flattening of acoustic reflex threshold-duration functions for persons having noise-induced hearing losses. Flattened functions appeared to be frequency specific and corresponded to areas of hearing loss. The degree of flattening of the functions was related to the degree of the hearing loss, with flatter functions occurring for greater hearing losses.

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CHAPTER I

INTRODUCTION

Temporal auditory integration may be defined as the physiological process whereby the intensity required for auditory threshold of a stimulus increases as the duration of the stimulus decreases. The term summation has also been used in discussing this phenomenon, as the observed responses are considered to be due to temporal summation at the synaptic junctions in the neural pathways (Zwislocki, 1960). Temporal auditory integration is generally studied in terms of the change in stimulus intensity necessary for threshold response as stimulus duration is varied. The relationship between the amount of intensity and the duration required for threshold is referred to as a threshold-duration (T-D) function. Clinical determination of the T-D function has been called brief tone audiometry (BTA) (Harris, Haynes, and Myers, 1958 and Sanders and Honig, 1967).

Threshold-duration functions have been investigated by several researchers and for various types of stimuli. Normal-hearing subjects have been tested with pure-tone stimuli and with broad-band noise stimuli (Garner, 1947). Rate of threshold change as a function of stimulus duration was found to be dependent upon the bandwidth of the test

signal. Pure tones were found to summate at a rate of 10 dB/decade for stimulus durations less than 200 msec, while broad-band noise stimuli summated at a rate of 8 dB/decade. The summation value for pure tones was obtained, however, by averaging data across several test frequencies. It has subsequently been shown that the temporal summation rate varies with the frequency of the stimulus (Simon, 1963, Sheeley and Bilger, 1964, and Gengel and Watson, 1971) and is larger for a 1 KHz tone than for a 4 KHz tone.

Threshold-duration functions have also been examined in pathological ears, particularly those with cochlear hearing losses. Miskolczy-Fodor (1954) and Harris, Haines and Myers (1958) observed deviant T-D functions with pure-tone signals for various types of cochlear disorders. Wright (1968a) reported that measurements of T-D functions were more sensitive to physiologic disturbances at the level of the cochlea than were measures of loudness recruitment. In subsequent studies, Wright (1968b) indicated that T-D functions were not affected by conductive hearing losses and Wright and Cannella (1969) reported that in cases of mixed hearing loss only the sensorineural component of the loss contributed to deviant T-D functions. Nerbonne (1970) reported that brief-tone audiometry is quite sensitive in detecting cochlear lesions caused by exposure to broad-band noise.

Investigations of temporal auditory integration at suprathreshold levels have indicated a strong positive correlation between pulse duration and loudness for durations greater than click-pitch thresholds (Miskolczy-Fodor, 1960 and Small, Brandt, and Cox, 1962). With a possibly strong correlation between loudness and the activation of the acoustic reflex (Ross, 1968), this suggested the possibility of temporal summation effects on the threshold of the acoustic reflex. Djupesland and Zwislocki (1971) demonstrated an unexpectedly pronounced duration effect of temporal integration on the human acoustic reflex threshold. The sound intensity required for a criterion response had to be lowered by about 25 dB when the duration of the signal was increased from 10 to 100 msec. The reflex threshold elevation for 20 msec tones in reference to 500 msec tones may be as great as 35 dB with the greatest differences in the higher frequencies (Woodford, Henderson, and Hamernik, 1973; Djupesland, Sunby, and Flottorp, 1974; and Woodford, Henderson, Hamernik, and Feldman, 1975). The latter study investigated the acoustic reflex threshold-duration (ART-D) function in normal and hearing-impaired subjects at pure-tone frequencies of 0.5, 1, 2, 3, and 4 KHz. The difference in reflex threshold between 20 msec and 500 msec tones was found to be less for subjects with hearing loss of cochlear origin than for normal-hearing subjects at all test freq-

uencies. Yost and Parker (1973) attempted to differentiate among normal hearers and those with Meniere's Syndrome using ART-D functions at 0.5, 1, and 2 KHz but were unable to demonstrate a marked difference between the two groups.

The purpose of this study was to compare the ART-D functions of normal-hearing subjects and subjects having noise-induced permanent threshold shift (NIPTS). Acoustic reflex threshold-duration functions were obtained for both broad-band noise and pure-tone stimuli at 1, 2, and 4 KHz. Thus a comparison of the results for the NIPTS group could be made for frequencies were the hearing levels were essentially normal and those where hearing loss was present.

CHAPTER II

PROCEDURES

Twenty-four subjects, twelve having normal hearing and twelve having noise-induced permanent threshold shift, participated in the study. The subjects ranged in age from 20 to 33 and the mean age was 26.3 years. There were 18 males and 6 females. All subjects were required to have tympanograms within normal limits. Subjects for the normal-hearing group were required to have pure-tone air and bone conduction thresholds of 10 dB HTL or better (re 1969 ANSI standard) bilaterally at each of the following audiometric test frequencies: 0.25, 0.5, 1, 2, 4, 6, and 8 KHz. The presence of an air-bone gap of 5 dB or more at any of the test frequencies from 0.25 to 4 KHz or a history of prolonged exposure to high intensity noise levels eliminated persons from the normal-hearing group. In addition, evidence of a "notch" in the audiogram at 4 or 6 KHz, regardless of the hearing level, eliminated persons from the normal-hearing group.

Subjects for the NIPTS group were required to have no air-bone gaps greater than 5 dB and air and bone conduction thresholds of 10 dB or better (re 1969 ANSI standard) for the test ear at 0.25, 0.5, and 1 KHz. For the frequencies 2 through 6 KHz, subjects were required to exhibit at

least a 20 dB HTL "notch" of the type associated with NIPTS and to evidence at least 10 dB of recovery at 8 KHz. The only requirements for the nontest ear were that there be no air-bone gaps greater than 5 dB at any of the test frequencies from 0.25 to 4 KHz, and that there be no physiological anomaly present which would preclude the measurement of the acoustic reflex at that ear. Subjects in the NIPTS group were, in addition, required to have a history of prolonged exposure to high intensity noise levels. Auditory threshold means and standard deviations are shown in Appendix B.

Pure-tone pips of various durations at 1, 2, and 4 KHz and bursts of broad-band noise were used as the test stimuli. Rise and decay times were linear and were set to 5 msec to avoid audible clicks at relatively high sound pressure levels (Harris, 1947 and Wright, 1960). Rise-fall time is the time taken for the amplitude of the acoustic waveform represented by the voltage displayed on an oscilloscope to vary between 10 and 90 per cent of the peak amplitude. Stimuli were presented with an interstimulus interval of 3.0 seconds to avoid the possibility of attempting to re-elicit the reflex before full recovery had occurred following cessation of the previous stimulus. Ward (1962) concluded that the acoustic reflex was inactive within one second after the cessation of a tone pulse which e-

licited the reflex, but Kryter (1970) reported that there may be some residual reflex contraction for up to three seconds in some people.

The test stimuli had peak durations of 17, 47, 97, 197, and 497 msec. Peak duration was the time that the test stimulus was at peak amplitude, whereas total duration included both rise-decay and peak duration times. Equivalent durations of the stimuli were determined using the equation derived by Dallos and Olsen (1964):

$$t=2r/3 + P$$

where t is duration, r is the rise-fall time (for stimuli with equal rise and decay times) and P is the duration of the stimulus peak. The test stimuli used in the study thus had equivalent durations of 20, 50, 100, 200, and 500 msec. Durations longer than 500 msec were not used because changes in the reflex threshold as a function of duration are virtually completed for a 500 msec duration. A summary of the stimulus envelope parameters is presented in Table 1.

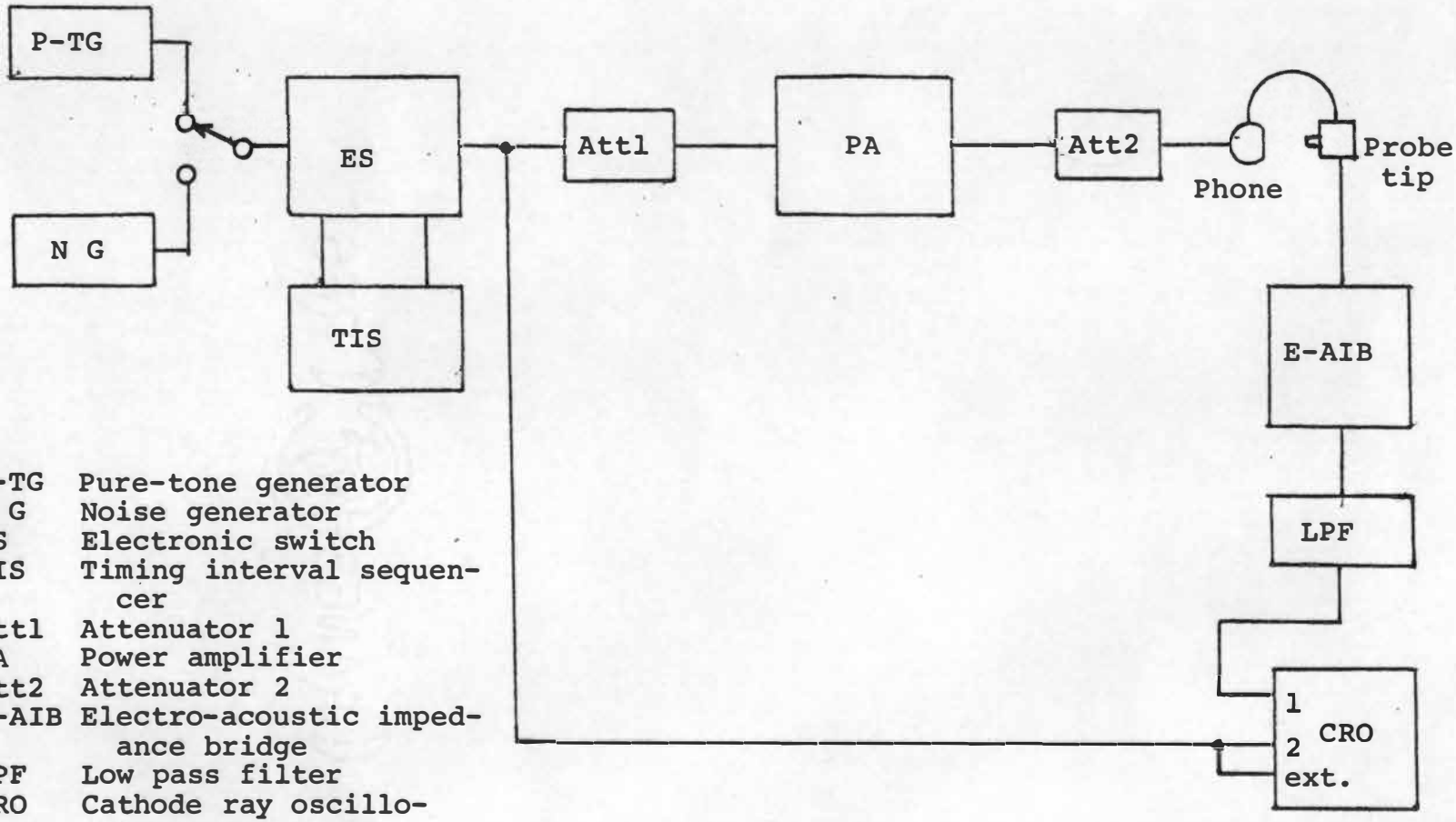
The apparatus used to produce the test stimuli and to monitor subject responses is shown in Figure 1. The two signal sources were a sinewave generator (Wavetek model 136) and a noise generator (Grason-Stadler model 455C). A double-pole/double-throw switch permitted selection of either pure tones or broad-band noise as the test signal. The continuous signals produced by the stimulus sources were inter-

Table 1

Stimulus Envelope Parameters

(All values are in milliseconds)

Rise/Fall Time	Peak Duration	Total Duration	Equivalent Duration
5.0	17	27	20
5.0	47	57	50
5.0	97	107	100
5.0	197	207	200
5.0	497	507	500



P-TG Pure-tone generator
N G Noise generator
ES Electronic switch
TIS Timing interval sequencer
Att1 Attenuator 1
PA Power amplifier
Att2 Attenuator 2
E-AIB Electro-acoustic impedance bridge
LPF Low pass filter
CRO Cathode ray oscilloscope

Figure 1. Test Apparatus.

rupted and shaped with 5 msec rise and fall times by an electronic switch (Grason-Stadler model 829E). The electronic switch was triggered by a timing interval sequencer (see Appendix A) which was preprogrammed to produce the five desired signal durations and the interstimulus interval automatically. Each stimulus duration was selectable by a rotary switch setting on the front of the unit.

After passing through the electronic switch, the stimuli passed through attenuator 1 (Hewlett Packard model 355C) and were delivered to a power amplifier (Dynaco model Mark IV). The output of the power amplifier was delivered through attenuator 2 (Grason-Stadler model 1293) to an earphone (Telephonics model TDH-49) mounted in an MX-41/AR cushion and held in place by a standard headband. The occurrence of the acoustic reflex in the contralateral ear in response to the test stimulus was monitored by means of an electro-acoustic impedance bridge (Grason-Stadler model 1720). Impedance matching was observed throughout the setup to insure system linearity. The output of the bridge was delivered through a low-pass filter (Allison model 2ABR) to one input of a dual channel oscilloscope (Tektronix model 5103N) with a slow phosphor cathode ray tube. The cutoff frequency of the filter was set at 75 Hz. The output of the electronic switch was fed to the second input of the oscilloscope as well as to the external trigger input so

that a trace sweep was initiated each time a stimulus was presented. This made it possible to simultaneously monitor the stimulus presentation and the output of the electro-acoustic bridge. The horizontal time base was set to 100 msec/cm and the vertical amplifier sensitivity was 50 mv/cm. The accuracy and stability of the stimulus durations and the intensity levels developed by the earphone were checked periodically throughout the experiment.

System calibration was performed prior to the beginning of each test session. With the electronic switch set to the "A ON" position, attenuator 1 set for minimum attenuation, and attenuator 2 set for 10 dB of attenuation, a 1 KHz sinusoid was fed into the input of the electronic switch. The output attenuator of the sinewave generator was then adjusted so that the earphone produced 130 dB SPL into an artificial ear (Bruel and Kjaer model 4152) as measured with a microphone amplifier (Bruel and Kjaer model 2603). This procedure was then repeated for the 2 and 4 KHz tones and for the broad-band noise stimulus. After calibration, attenuator 1 was set to provide 55 dB of attenuation, so that the initial level of the stimuli presented to the ear of a subject was 75 dB SPL.

During testing, the subjects and all equipment used for testing were located in an IAC commercial test suite. The ambient noise level of the room was measured with a

sound level meter (Bruel and Kjaer model 2203) and was found to conform to ANSI standard S3.1 1960 R-1971 for permissible noise levels in audiometric test rooms. The overall sound pressure level in the room was 45 dB measured on the linear scale.

The presentation order of the four stimulus types (1, 2, and 4 KHz pure tones and broad-band noise) was randomized for the twenty-four subjects. Similarly, the ordering of the five stimulus durations (20, 50, 100, 200, and 500 msec) was randomized for each of the four stimulus types for each subject. Two subjects from the normal-hearing group and two subjects from the NIPTS group were retested at least one week after the initial test session to be used for a reliability check of the measurement technique.

All of the acoustic reflex thresholds were obtained in a single test session lasting approximately one hour. Following audiometric testing, subjects were seated in the test room and the earphone was placed over the test ear. The probe tip from the impedance bridge was sealed in the contralateral ear and tympanometry was performed. The pressure in the ear canal was then adjusted to the point of maximum compliance as determined from the subject's tympanogram. Since a normal tympanogram was required for a subject to qualify for this study, the pressure was in all cases within ±50 mm H_2O. The first stimulus envelope was

then selected on the timing interval sequencer which automatically presented a series of stimuli of the selected duration with a delay of 3.0 seconds between each stimulus. The level of presentation was adjusted by means of attenuator 1 (and attenuator 2 in cases where more than 130 dB SPL was required) and the output of the electo-acoustic bridge was monitored on the oscilloscope until a definite deflection could be observed which coincided with the presentation of the stimulus. The level was then increased by 5 dB and a descending technique was employed to determine the point of threshold. This point was defined as the level at which a just-noticable deflection of the bridge output could be seen on the oscilloscope screen. The latency of this just-noticable deflection was checked to insure that it corresponded to the latency of the acoustic reflex at threshold (approximately 100 to 150 msec). At least three descending trials were made for each stimulus, and the level at which the above criteria were met two out of three times was recorded as threshold.

The descending technique was found to be necessary to help insure that random deflections of the oscilloscope trace due to movement of the subject or to facial muscle activity were not mistaken for acoustic reflex activity. It was, in general, much easier to observe the gradual decline of reflex activity as the stimulus intensity was de-

creased, than to determine its onset as the stimulus intensity was increased.

During the course of testing it was discovered that some subjects seemed to demonstrate some fatigue of reflex activity for the 4 KHz stimulus. In these cases, it was necessary to allow a few minutes of rest after each descending trial to insure that fatigue effects were minimized.

CHAPTER III

RESULTS AND DISCUSSION

The reflex test-retest data for four subjects is shown in Table 2. The Pearson product-moment correlation coefficient (Hays, 1973) for this data was 0.97, which was found to be significant at better than the 0.01 level using the t-ratio technique (Hays, 1973). This r-value indicates that 94% of the variability in the retest thresholds could be predicted by variability in the original test thresholds. The excellent repeatability of the acoustic reflex thresholds may have been due in part to the measurement technique employed. Use of the reflex latency at threshold as part of the measurement criterion made it possible to virtually eliminate movement artifacts and allowed differentiation of the reflex response for stimulus intensity changes as small as 2 or 3 dB.

Acoustic reflex threshold means and standard deviations for both groups and all test conditions are shown in Table 3. The mean thresholds for the 500 msec stimuli were similar to those reported by Jepsen (1951), Peterson and Liden (1972), and Woodford, et al. (1975) for pure tones and by Deutsch (1972) for both pure tones and broad-band noise. Examination of the standard deviations reveals that in general the greatest variability for reflex thresholds

Table 2

Reflex Test-Retest Data for Four Subjects

Duration (msec)	1 KHz Test	1 KHz Retest	2 KHz Test	2 KHz Retest	4 KHz Test	4 KHz Retest	BBN Test	BBN Retest
				Subject 8				
20	114	114	118	121	123	124	104	105
50	106	106	109	113	115	116	98	100
100	100	100	103	103	103	104	95	97
200	97	99	100	100	100	100	87	95
500	95	97	96	98	95	96	86	89
				Subject 9				
20	124	128	123	130	124	126	114	113
50	115	118	117	123	118	120	104	103
100	110	109	108	112	111	110	97	96
200	105	105	102	107	99	103	92	94
500	103	102	96	98	96	95	90	92
				Subject 23				
20	115	118	118	120	131	128	110	110
50	103	108	103	116	125	124	101	96
100	101	105	97	104	122	120	97	92
200	99	101	93	94	119	115	93	91
500	97	100	90	93	106	104	90	91
				Subject 13				
20	112	114	120	121	122	121	110	106
50	108	110	117	116	114	114	98	99
100	104	105	103	105	110	111	94	93
200	102	100	99	100	101	102	87	88
500	96	98	95	96	99	98	84	86

Table 3

Acoustic Reflex Threshold Means (dB SPL)
and Standard Deviations

Dur. (msec)	1 KHz		2 KHz		4 KHz		BBN	
	Normal	NIPTS	Normal	NIPTS	Normal	NIPTS	Normal	NIPTS
20	112.5	112.7	116.8	118.8	124.0	124.1	104.8	107.9
	8.8	5.9	10.4	7.7	6.1	7.5	13.5	8.6
50	104.2	105.2	107.2	105.8	115.0	115.2	95.0	99.2
	8.6	5.4	11.4	16.1	6.9	8.6	14.0	8.2
100	99.3	100.5	100.2	103.3	107.0	109.8	86.5	94.3
	7.9	4.0	9.3	7.1	6.4	9.4	13.7	7.8
200	95.8	96.9	96.2	97.9	99.1	104.1	81.5	89.3
	7.3	4.1	7.6	6.9	6.1	8.9	13.9	7.7
500	93.6	93.6	92.0	94.2	92.9	98.2	77.8	85.8
	7.9	3.9	7.1	6.7	5.3	7.4	13.8	8.6

was associated with the broad-band noise stimulus for the normal-hearing group. The opposite was reported by Deutsch (1972), who indicated that the standard deviations for pure tone stimuli were significantly larger than those associated with noise stimuli. Comparison of the differences between threshold means and the corresponding standard deviations for the normal-hearing group reveals that there is considerable overlap of data for the two groups. This is probably due in part to the relatively mild degree of hearing loss for the NIPTS group.

Acoustic reflex threshold-duration (ART-D) functions have previously been determined by computing changes in reflex threshold re the threshold at 200 or 500 msec duration (Parker and Yost, 1973; Woodford, et al., 1973; and Woodford, et al., 1975). Observation of the mean reflex thresholds for the present study, however, indicates that the reflex thresholds for the normal-hearing and NIPTS groups are similar for the 20 msec duration stimuli and digress as the stimulus duration is increased. It would therefore seem more appropriate to compute the ART-D functions using the 20 msec thresholds as the reference points. Mean ART-D functions constructed in this manner are shown in Figure 2 for the normal-hearing group and in Figure 3 for the NIPTS group. There is a definite frequency effect observable, with steeper threshold-duration functions for the higher

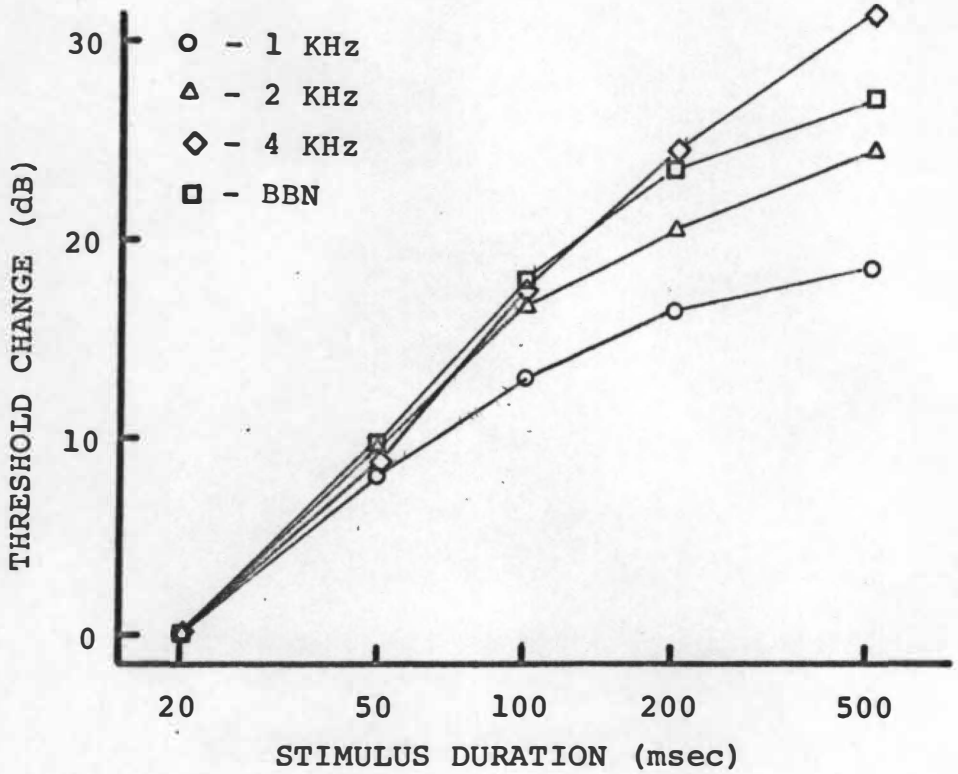


Figure 2. Mean ART-D functions for normal-hearing subjects (n=12).

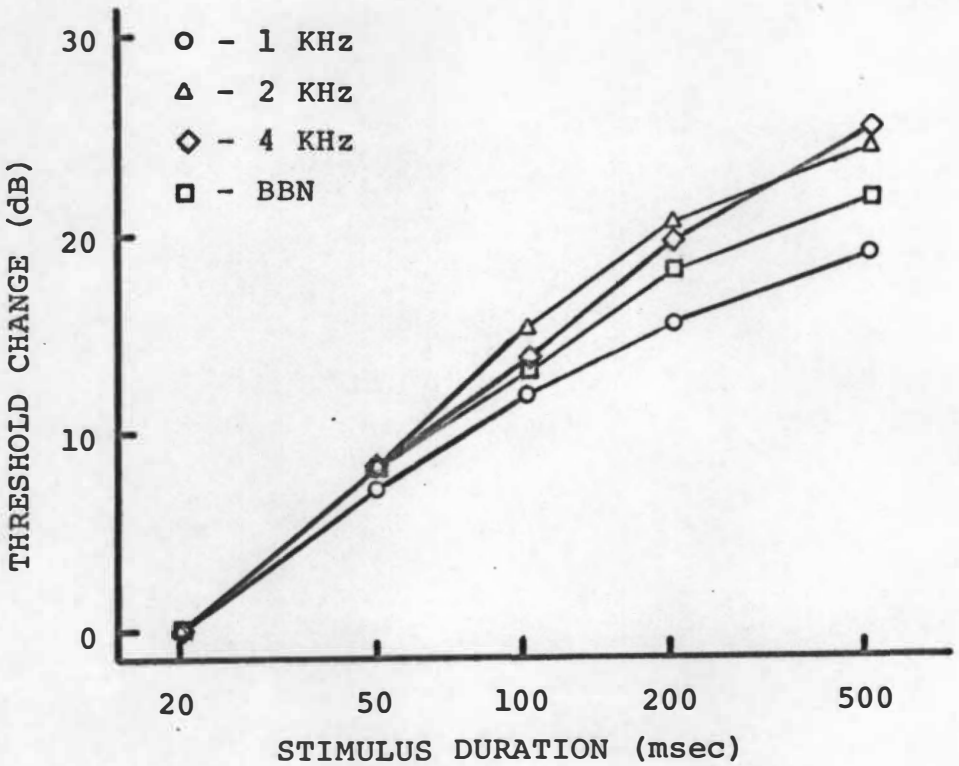


Figure 3. Mean ART-D functions for NIPTS subjects (n=12).

frequencies than for the lower frequencies for both groups. The ART-D functions are slightly steeper than those obtained by Woodford, et al. (1975), but differences were in general less than 5 dB.

Figure 4 shows a comparison of the ART-D functions averaged for the pure-tone stimuli and the broad-band noise ART-D function for the normal-hearing group. The function for the broad-band noise stimulus is somewhat steeper than that for the average pure-tone stimuli. This is opposite to the trend reported for the psychophysical threshold findings (Garner, 1947). For stimulus intensities near threshold, the threshold-duration functions are steeper for pure tones than for noise. It was Garner's contention that it is loudness, not intensity, that is integrated. The loudness growth functions for intensities near threshold are also steeper for pure tones than for noise. As the stimulus intensity is increased, however, the equal loudness contours (Fletcher and Munson, 1933) become flatter, and the loudness growth functions for pure tones and broad-band noise become similar. This could explain the similarity between the ART-D functions averaged for the pure-tone stimuli and the broad-band noise ART-D function, since activation of the acoustic reflex is believed to be directly related to loudness of the stimulus (Ross, 1968).

Direct comparisons between the mean ART-D functions

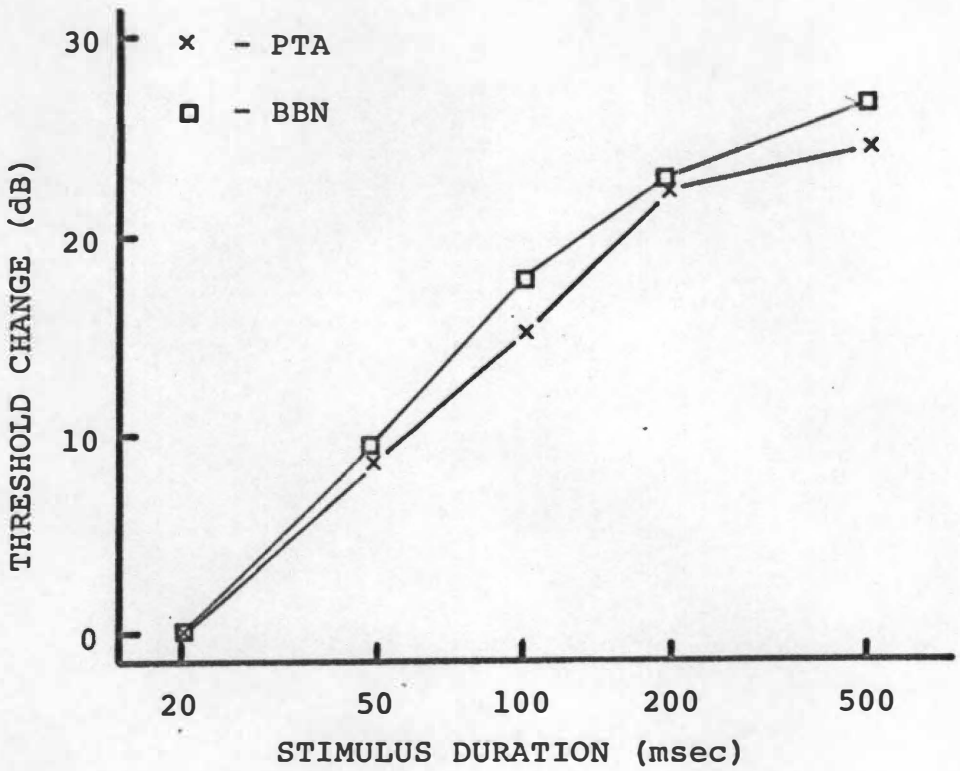


Figure 4. Comparison of average pure tone and broad-band noise ART-D functions for normal-hearing subjects.

for the normal and NIPTS groups are shown in Figure 5 for the 1 KHz stimulus, Figure 6 for the 2 KHz stimulus, Figure 7 for the 4 KHz stimulus, and Figure 8 for the broad-band noise stimulus. As can be seen from Figures 5 and 6, the mean ART-D functions for the 1 and 2 KHz stimuli are similar for both groups. This is consistent with the essentially similar hearing levels for the two groups at these frequencies. At 4 KHz, however, the NIPTS group had a mean hearing level of 34.6 dB HTL, and at this frequency the mean ART-D function for the NIPTS group was approximately 5 dB less steep than for the normal-hearing group. The implication would seem to be that flattening of the ART-D functions is frequency specific and corresponds to areas of hearing loss. The mean ART-D functions for the broad-band noise stimulus showed greater separation between the normal-hearing and NIPTS groups than did the 4 KHz stimulus. It would therefore appear that ART-D functions using broad-band noise as the test stimulus would be more sensitive to cochlear pathology than ART-D functions utilizing pure tones. It must be remembered, however, that the variability of the reflex thresholds for the normal-hearing group for broad-band noise was fairly large. It is therefore impossible to determine if the differences in the broad-band noise ART-D functions for the two groups are due to sensitivity of the measure or to random variability.

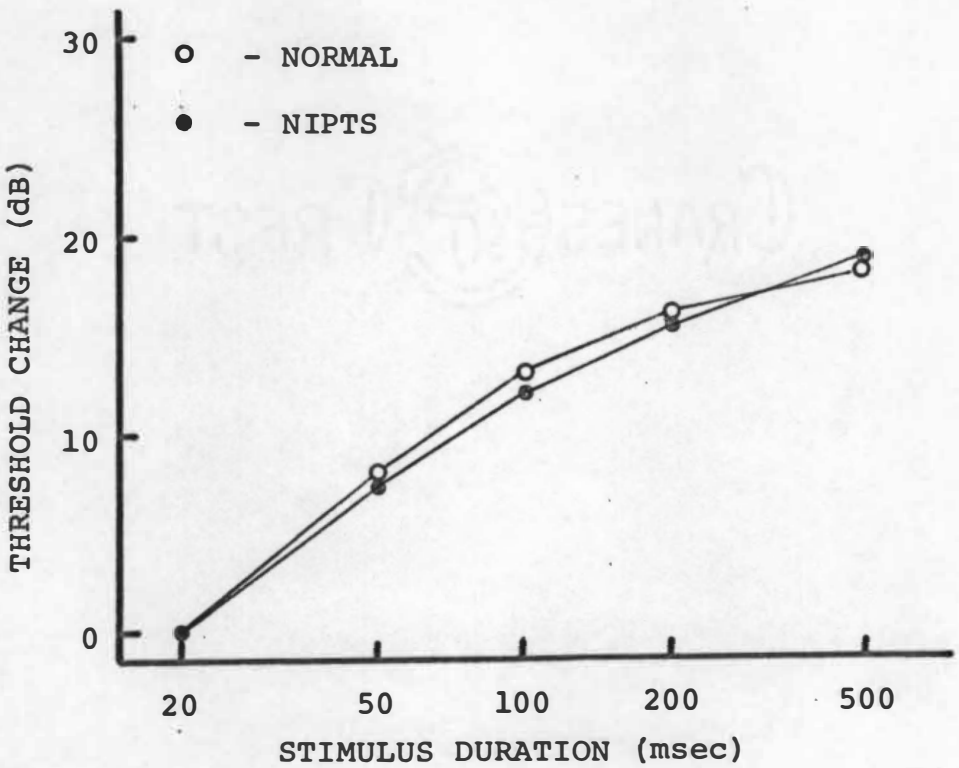


Figure 5. Mean ART-D functions for 1 KHz stimulus.

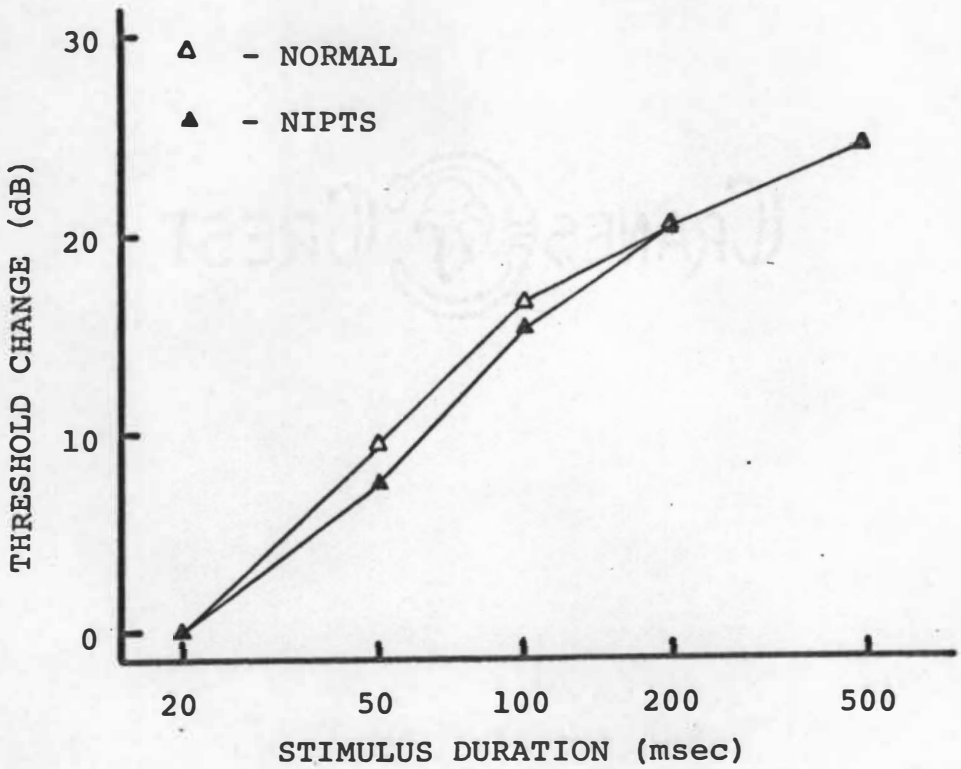


Figure 6. Mean ART-D functions for 2 KHz stimulus.

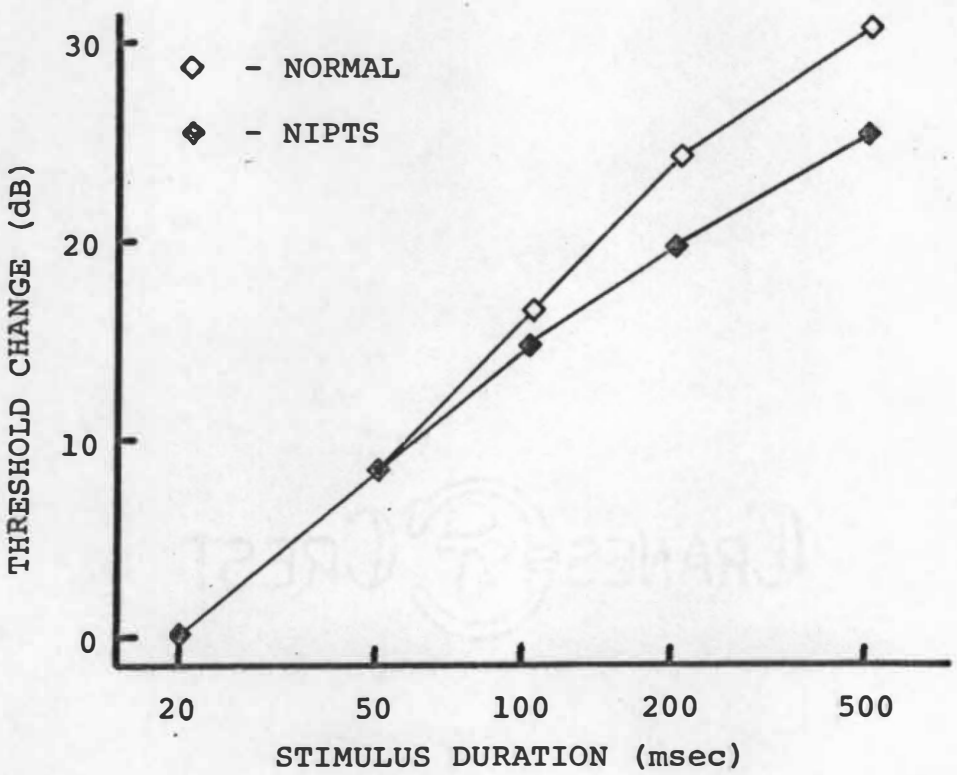


Figure 7. Mean ART-D functions for 4 KHz stimulus.

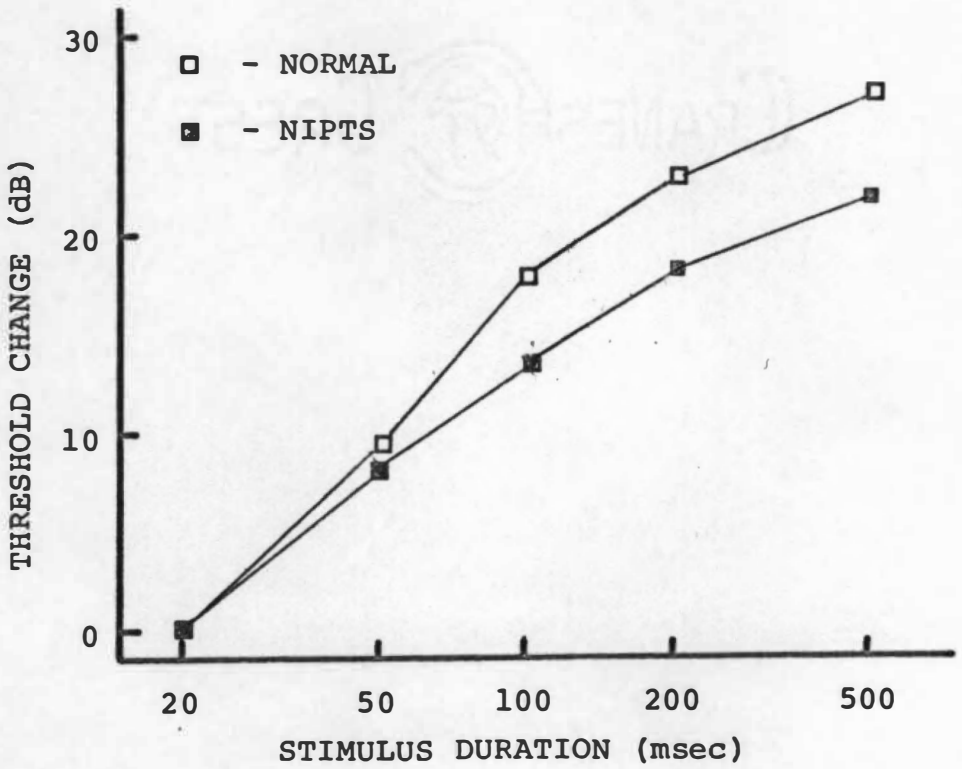


Figure 8. Mean ART-D functions for broad-band noise stimulus.

The relationship between steepness of the ART-D function and degree of hearing loss for the NIPTS group was investigated using the Spearman rank correlation technique (Seigel, 1956). The calculated correlation coefficient between hearing level and slope of the ART-D function was -0.4 which was significant at the 0.10 level, indicating that there is a correspondence between degree of hearing loss and slope of the ART-D function. This relationship, though not strong, indicated that in general greater hearing losses yielded less steep ART-D functions.

Woodford, et al. (1973) reported a rather pronounced difference between the ART-D functions for males and females, with females having functions with steeper slopes. He attributed this difference to the possibility of subclinical cochlear pathology in the males, since they had all been exposed at some time to high intensity level noise. In order to investigate the possible influences of such a sex difference on this study, the normal-hearing subjects were divided into two groups on the basis of sex, and mean threshold changes were calculated for each group. This was done for only the normal-hearing group, since there was only one female subject in the NIPTS group. The results are shown in Table 4. There appears to be no difference in the average threshold changes for males and females.

Table 4

Mean Changes in Acoustic Reflex Thresholds for Normal-Hearing Males (n=7) and Females (n=5)

Duration (msec)	1 KHz		2 KHz		4 KHz		BBN	
	Male	Female	Male	Female	Male	Female	Male	Female
20	18.9	19.0	25.9	23.4	30.6	31.8	27.1	27.0
50	10.3	11.2	15.6	14.6	22.0	22.2	17.3	17.2
100	5.3	6.4	8.3	8.2	13.7	14.6	9.4	7.8
200	2.1	2.4	4.4	4.0	5.7	6.8	4.3	3.0
500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CHAPTER IV

CONCLUSIONS

The results of this study indicate that the acoustic reflex threshold-duration functions for subjects with noise-induced permanent threshold shift tend to be flatter than the functions obtained for subjects with normal hearing. The slope of the ART-D function appears to be dependent upon the frequency of the test stimulus used and is steeper for high frequency than for low frequency stimuli. The ART-D function averaged for 1, 2, and 4 KHz pure tones is slightly less steep than the ART-D function for broad-band noise, possibly due to equality of the loudness growth functions for pure tones and broad-band noise at the intensity levels required for elicitation of the reflex.

The ART-D functions for the NIPTS group were similar to those for the normal-hearing group for 1 and 2 KHz stimuli and were flatter than those for the normal-hearing group for the 4 KHz stimulus, indicating that flattened ART-D functions may be frequency specific and may correspond to areas of hearing loss. The degree of flattening of the ART-D functions appears to be somewhat related to the degree of hearing loss, with less steep functions occurring with greater hearing losses.

The acoustic reflex thresholds for 20 msec duration

stimuli were found to be similar for both groups, and differences between the group thresholds increased as stimulus duration was increased. The hearing-impaired subjects seemed, therefore, to have a decreased ability to utilize additional stimulus energy provided by increased duration. Inefficient temporal auditory integration has been shown to be concurrent with enlarged critical ratios (Simon, 1963) and with loudness recruitment (Miskolczy-Fodor, 1954). Since both of these phenomena are attributed to cochlear pathology, it appears likely that flattened threshold-duration functions are yet another indicator of cochlear lesions.

If acoustic reflex threshold-duration functions are to be utilized as an aid in the detection of cochlear disorders, comprehensive information is required concerning the effects of test frequency and degree of hearing loss on the acoustic reflex threshold variability and on the slope of the ART-D functions. Since temporal integration rate seems to vary as a function of the frequency of the test stimulus, normative data should be established for each test frequency and should include variability of the reflex thresholds. The relationship between degree and type of hearing loss and slope of the ART-D functions must be better established.

Further investigation is warranted concerning the use of noise stimuli to determine the ART-D functions.

Differences were seen in the ART-D functions for the normal-hearing and NIPTS groups using broad-band noise as the test stimulus, but the variability of the reflex thresholds for the normal-hearing group for this stimulus was too large to allow conclusions to be drawn. It might be informative to obtain ART-D functions for subjects with sloping hearing losses using low- and high-pass filtered broad-band noise. This would allow comparison of the functions in individual subjects for frequency regions where lesser and greater degrees of hearing loss are present.

The use of acoustic reflex threshold-duration functions as an aid in the detection of cochlear hearing losses appears to be a promising area. Statements regarding the utility of this auditory measurement technique, however, must await further study in normal-hearing subjects and in subjects with a variety of hearing disorders.

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APPENDICES

APPENDIX A

The timing interval sequencer used in this study was constructed within the Department of Audiology. Two Signetics 555 integrated circuit timers were interconnected in a "flip-flop" arrangement, so that the end of the timing cycle of either timer was the beginning of the timing cycle of the other timer. Outputs from the timers were amplified and used to trigger an electronic switch (Grason-Stadler model 829E). One timer controlled the on time of the electronic switch, which determined the stimulus duration, and the other timer controlled the off time of the electronic switch, which determined the interstimulus interval.

The duty cycle of each timer was adjustable by means of potentiometers which were selectable by a rotary switch setting. Ten potentiometers were available in all, seven for setting stimulus duration and three for setting interstimulus interval. Before the beginning of the experiment, five of the stimulus duration control potentiometers were adjusted to provide the five required stimulus durations; one of the interstimulus interval control potentiometers was adjusted to provide the required interstimulus interval. Each of the required stimulus durations could then be selected by the proper rotary switch setting. No switch was required for the interstimulus interval, since only one value was used.

Pushbutton switches were available to start and stop the stimulus presentation sequence. The sequencer automatically caused a series of stimuli of the selected duration to be presented with a 3.0 second interstimulus interval.

APPENDIX B

Table 5

Auditory Threshold Means (dB HTL) and Standard Deviations

Group	0.25 KHz	0.5 KHz	1 KHz	2 KHz	4 KHz	6 KHz	8 KHz
Normal	3.3	3.3	5.0	3.8	3.3	3.8	3.8
	4.9	5.4	5.2	5.3	6.2	5.3	5.3
NIPTS	4.6	4.6	4.2	5.0	34.6	40.8	29.2
	4.5	4.5	4.7	6.7	22.3	24.1	19.8

Vita

Larry N. Robinette was born in Coeburn, Virginia on January 19, 1949. His family led a somewhat nomadic life and he attended elementary schools in Westport, Indiana and Center Grove, Tennessee. He graduated from Franklin County High School in Winchester, Tennessee in 1967 and entered the University of Tennessee. In June, 1972, he received a Bachelor of Science degree in Electrical Engineering. In the fall of 1972, he accepted a research assistantship at the University of Tennessee and began study toward a Master's degree in Audiology. He received this degree in March 1975.