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A methodological comparison of tone decay in audiometrically normal ears

Margaret Jean Town
The University of Montana

A METHODOLOGICAL COMPARISON OF TONE DECAY

IN AUDIOMETRICALLY NORMAL EARS

by

Margaret J. Town

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Dean, Graduate School

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CHAPTER I

INTRODUCTION

A phenomenon called tone decay has been described as a continuous tone presented at or near threshold fading into inaudibility. Sorensen (11) described tone decay as being a process different from any other type of adaptation. He found that

> . . . after interruption of the tone the patient regains his original threshold within a few seconds, consequently the measured tone decay cannot be due to fatigue, which is defined by a decline in excitability caused by previous activity. Likewise, threshold tone decay can hardly be perstimulatory adaptation, which has a recovery period nearer one minute. (11)

Clinical interest in tone decay has increased from investigations [Sorensen (11), Green (3), and Owens (8)] which demonstrate excessive tone decay in persons having retrocochlear lesions. At present, determination of tone decay is being used in many clinics in the screening for retrocochlear lesions.

I. THE PROBLEM AND PURPOSE

Among aspects of tone decay which are at present not clearly defined are: (1) the effect of procedure on degree of tone decay and (2) the presence of decay, if any, in ears with "normal" thresholds. It was the concern of this study to investigate the phenomenon of tone decay in normal-hearing individuals and, if tone decay does in fact exist in these individuals to determine if the instructions and procedures utilized would affect the results.

One method that has been applied for the measurement of tone decay has been described by Carhart (1). The Carhart Threshold Tone Decay Test requires the use of a conventional pure tone audiometer. The procedure for this test is to present a sustained pure tone at threshold for 60 seconds unless the patient signals that the tone has become inaudible before that time. If the patient so signals, the level of the tone is increased 5 dB without interruption and the 60 second timing is started again. This procedure continues until the patient can hear the tone for a full minute. The amount of tone decay is numerically equal to the difference between the starting level and the level at which the test was terminated.

Another procedure frequently employed has been described by Rosenberg (9). A pure tone is presented at threshold for 60 seconds unless the patient signals that the tone has become inaudible before the time is up. The intensity is increased by 5 dB steps as the patient signals inaudibility. When exactly 60 seconds has elapsed the exploration for tone decay is stopped. The amount of tone decay is numerically equal to the difference between the starting intensity and the intensity at which the test was terminated.

In 1963, Green (3) modified Rosenberg's (9) procedure. He demonstrated that the type of instruction given the patient may affect the results obtained.

> In some patients who exhibit tone decay, the tonal quality of the test frequency disappears before the sound becomes inaudible. The tone may be replaced by a "buzz" or by a sound that is somehow different from the one heard during the so-called "on-effect" which occurs on initial presentation. In other individuals, the original tone may fade into inaudibility without passing through a noticeable intermediate stage. It has frequently been noted that after the patient signals that the tone has become inaudible, he nevertheless is still able to tell the tester when the tone is withdrawn (3).

In Green's Modified Tone Decay Test (MTDT) he specifically instructed the patient to respond to the test frequency only as long as it is subjectively pure in tonal quality. He also recommended that the patient be cautioned against shifting his earphones or chewing while he is being tested. In three cases of confirmed acoustic tumors Green found that the conventional Carhart Tone Decay Test revealed no alarming degree of tone decay, while the MTDT revealed clinically significant findings. Green (3) made little mention of what he considered to be "clinically significant" other than "if there is no more than 15 dB of tone decay, there is probably no need to continue the exploration in that ear" and that there is an "ill-defined border between clinically significant and clinically insignificant tone decay." He also pointed out that the presence of decay in ears with "normal" thresholds is not clearly understood; 75 dB of tone decay was demonstrated at 4000 Hz in an ear recording a 5 dB threshold at that frequency (3).

A review of the literature reveals limited information regarding tone decay in normal ears. One of the more thorough studies was presented by Sorensen (11); however, he used his own modification of Carhart's Tone Decay Test, and the study was limited to one frequency, 2000 Hz. He administered a tone decay test to a total of 75 male and female subjects with normal hearing and various auditory pathologies. All age groups up to 80 were equally represented. In the normal subjects little tone decay was found. In addition, little tone decay was found in patients having cochlear and conductive deafness. However, patients having confirmed retrocochlear pathology showed "excessive"tone decay.

Owens (8) found that in 20 persons having normal hearing there was little tone decay in any frequency, with the exception of 4000 Hz where tone decay was found frequently. The same tone decay test was given to 18 subjects with eighth nerve lesions, 53 with Meniere's disease, and 28 subjects with cochlear lesions other than Meniere's disease. The test incorporated a 20-second rest between 5 dB increments in tone presentation level. The rest period of 20 seconds was chosen on the basis of Hood's (4) diagram charting recovery from perstimulatory fatigue, in which the most rapid rise occured within 10 seconds, and the flattening of the curve began at about 20 seconds. It should be noted that Owens' procedure is based on the assumption that it is perstimulatory fatigue which Sorensen denies; and thus constitutes a major departure from other procedures in respect to the 20-second rest period. Therefore comparisons should be made with caution. He found that the subjects with eighth nerve lesions demonstrated tone decay at all frequencies showing a hearing loss; and rapidity of decay did not change much with increasing intensity. About 60% of the Meniere's group showed tone decay at one or two frequencies; and typically decay was slower as the intensity increased. Likewise, other types of cochlear deafness showed tone decay at only one or two frequencies.

Hopkinson and Thomas (5) conducted a comparison study of the Rosenberg and Owen test. Based on Rosenberg's classification of tone decay Hopkinson and Thomas superimposed the following classification for their study:

1.	0 to 10 dB	normal or conductive
2.	15 dB	borderline cochlear
3.	20 dB and 25 dB	cochlear
4.	30 dB or more	retrocochlear

In the total of 10 patients Hopkinson and Thomas classified as normal the Rosenberg procedure correctly identified all 10. The Owens procedure correctly identified 8 normal hearing patients but falsely identified two normal hearing patients as having cochlear pathology.

The above studies have used directions from Carhart's (1) Threshold Tone Decay Test or directions similar to them. Green demonstrated that the Modified Tone Decay Test using a variation in instruction revealed clinically significant tone decay in three cases of confirmed eighth nerve lesions while the standard Carhart method did not. It would appear that instruction is a crucial detail in this test, yet at present there is no standardization for directions.

The lack of standardization in instructions is only one of the many limitations in our knowledge of this test. An apparent question of the tone decay test is what constitutes a clinically significant result. Hopkinson and Thomas indicate that anything over 15 dB is clinically significant; yet Green cites an audiometrically normal ear having 75 dB of tone decay at 4000 Hz, and Sorensen (11) notes that 6 out of 35 patients with normal hearing showed pronounced tone decay.

It was the purpose of this study to investigate the following questions:

1. How much will a variation in method affect the degree of tone decay?
2. Is there tone decay existing in audiometrically normal ears?

The hypotheses in this study were:

1. that different procedures would produce a variation of tone decay in the same frequency, of the same ear, and
2. that varying amounts of tone decay could be demonstrated in an audiometrically normal ear under varying conditions.

The procedures under investigation were those listed in Table I. The methods were coded for convenience of the experimenter.

TABLE I

CODE FOR TONE DECAY METHODS

Method	Code Title
Carhart's	TDT
Rosenberg's	R-TDT
Green's Modified Rosenberg	MTDT
Green's Modified Carhart	MTDT-C

II. DEFINITIONS OF TERMS

For the purposes of this study "normal hearing" has been defined as passing a pure-tone screening test at 500, 1000, 2000 and 4000 Hz at 15 dB in both ears using

(ISO-1964) reference levels.

"Threshold" was defined as the lowest level at which the subject could detect the presence of the test tone at least 50% of the time using a method described by Newby (7). (See Appendix A)

It should be noted that this investigation was designed purely for clinical application and was restricted by limitations of clinical instrumentation. For example, the clinical audiometer used in this study was not calibrated to establish threshold better than 0 dB (ISO-1964) reference level. Therefore it was impossible to obtain the threshold of some of the "normal hearing" individuals that were used in this study.

"Tone decay," then, based on Rosenberg's classification, was considered to exist if it was recorded as 15 dB or more above threshold (9) or 0 dB when threshold was better than that, and thus unmeasurable.

CHAPTER II

EXPERIMENTAL PROCEDURE

In this investigation 24 individuals whose hearing was within normal limits were given tone decay tests at 4 frequencies under the following conditions:

1. Procedure and instructions as described by Carhart (TDT).
2. Procedure and instructions as described by Rosenberg (R-TDT).
3. Carhart's procedure with a modification and instruction as described by Green (MTDT-C).
4. Rosenberg's procedure with a modification and instruction as described by Green (MTDT)

Table II shows the procedure and instruction for each test.

I. SUBJECTS

The subjects were college students selected from Psychology 110 at the University of Montana, during Spring Quarter, 1967. They were in the age range of 18 to 22 years. The subjects used for this study all passed a screening test in both ears at 15 dB at 500, 1000, 2000 and 4000 Hz, (ISO-1964).

II. EQUIPMENT

All subjects were tested in a sound-treated room at the University of Montana Speech and Hearing Clinic. A

TABLE II

PROCEDURES AND INSTRUCTIONS FOR TONE DECAY TESTS

PROCEDURES	INSTRUCTIONS
TDT	
A continuous tone is presented at threshold for 60 seconds unless the patient signals that the tone has become inaudible before that time. If the patient so signals, the level of the tone is increased 5 dB without interruption and the 60 second timing is started again. This procedure continues until the patient can hear the tone for a full minute. The amount of tone decay is numerically equal to the difference between the starting level and the level at which the test was terminated.	A continuous tone will be presented to you. Keep your finger raised for as long as you hear the tone. If the tone disappears, lower your finger. If and when the tone comes back, raise your finger again and then lower your finger again if and when the tone disappears.
R-TDT	
A continuous pure tone is presented at threshold for 60 seconds unless the patient signals that the tone has become inaudible before the time is up. The intensity is increased by 5 dB steps as the patient signals inaudibility. When exactly 60 seconds have elapsed the exploration for tone decay is stopped. The amount of tone decay is numerically equal to the difference between the starting intensity and the intensity at which the test was terminated.	A continuous tone will be presented to you. Keep your finger raised for as long as you hear the tone. If the tone disappears, lower your finger. If and when the tone comes back, raise your finger again and then lower your finger again if and when the tone disappears.

TABLE II (continued)

PROCEDURES	INSTRUCTIONS
MTDT	
A continuous tone is presented at threshold for 60 seconds unless the patient signals that the tone changed before the time is up. The intensity is increased by 5 dB steps as the patient signals tonal change. When exactly 60 seconds have elapsed, the exploration for tone decay is stopped. The amount of tone decay is numerically equal to the difference between the starting intensity and the intensity at which the test was terminated.	A continuous tone will be presented to you. Keep your finger raised for as long as the tone remains constant or is very clear. As soon as the quality of the tone changes in any way, (for example, if it begins to buzz or begins to fade or becomes squeaky, or whatever), lower your finger immediately. When a clear tone comes back again raise your finger and again lowering if and when a clear tone changes. In addition please refrain from shifting your earphones or chewing during the time of testing.
MTDT-C	
A continuous tone is presented at threshold for 60 seconds unless the patient signals that the tone has changed before that time. If the patient so signals, the level of the tone is increased 5 dB without interruption and the 60 second timing is started again. This procedure continues until the patient can hear a constant tone for a full minute. The amount of tone decay is numerically equal to the difference between the starting level and the level at which the test was terminated.	A continuous tone will be presented to you. Keep your finger raised for as long as the tone remains constant or is very clear. As soon as the quality of the tone changes in any way, (for example, if it begins to buzz or begins to fade or becomes squeaky, or whatever), lower your finger immediately. When a clear tone comes back again raise your finger and again lowering if and when a clear tone changes. In addition please refrain from shifting your earphones or chewing during the time of testing.

Beltone audiometer MOdel 15-C calibrated to ISO-1964 reference levels was employed for all tests. Tones were presented to the subject through TDH-39 earphones. The examiner was in an adjoining room to the sound-treated room; the two rooms were joined by a two-way mirror and a talk-back system.

III. TASK

Each subject was seen at one appointed time. After the subject had passed the screening test, thresholds were determined in the right ear at 500, 1000, 2000 and 4000 Hz. (See Appendix A for procedure and instructions for obtaining threshold.)

Following the threshold test each subject was given the four tone decay tests: (1) TDT, (2) R-TDT, (3) MTDT, and (4) MTDT-C, and presented to the right ear in the following frequencies: 500, 1000, 2000 and 4000 Hz. The tone decay tests were counterbalanced for order effects (See Table III). It should be recognized that since threshold could not be measured below 0 dB some amount of tone decay may have been lost if thresholds were actually better than 0 dB. This would indicate, however, that whatever amounts of decay were obtained would only have been larger and hence more significant if the base level could have been more precise.

TABLE III

GROUPING FOR TONE DECAY TESTS

SUBJECT	ORDER OF PRESENTATION	SUBJECT	ORDER OF PRESENTATION	SUBJECT	ORDER OF PRESENTATION
1	TDT R-TDT MTDT MTDT-C	9	R-TDT MTDT TDT MTDT-C	17	MTDT MTDT-C TDT R-TDT
2	TDT R-TDT MTDT-C MTDT	10	R-TDT MTDT MTDT-C TDT	18	MTDT MTDT-C R-TDT TDT
3	TDT MTDT R-TDT MTDT-C	11	R-TDT MTDT-C TDT MTDT	19	MTDT-C TDT R-TDT MTDT
4	TDT MTDT-C MTDT R-TDT	12	R-TDT MTDT-C MTDT TDT	20	MTDT-C TDT MTDT R-TDT
5	TDT MTDT-C R-TDT MTDT	13	MTDT TDT R-TDT MTDT-C	21	MTDT-C R-TDT MTDT TDT
6	TDT MTDT MTDT-C R-TDT	14	MTDT TDT MTDT-C R-TDT	22	MTDT-C R-TDT TDT MTDT
7	R-TDT TDT MTDT MTDT-C	15	MTDT R-TDT TDT MTDT-C	23	MTDT-C MTDT TDT R-TDT
8	R-TDT TDT MTDT-C MTDT	16	MTDT R-TDT MTDT-C TDT	24	MTDT-C MTDT R-TDT TDT

IV. INSTRUCTIONS

Instructions for the screening and threshold audiometric tests were given orally through the earphones. Each set of instructions for the tone decay tests were typewritten and handed to the subject to read once before each test.

In order to evaluate examiner reliability ten subjects were called in for retest. Five of these were tested by the same examiner, five of them tested by another graduate student in Speech Pathology and Audiology. The subjects who were retested were given the screening test, the threshold test, and the tone decay tests in the same order as their first test. Results of this reliability check are given in Table IX.

CHAPTER III

RESULTS AND DISCUSSION

It was hypothesized in this study that (1) different procedures would produce a variation of tone decay in the same ear and (2) varying amounts of tone decay could be demonstrated in an audiometrically normal ear under varying conditions.

A test of the first hypothesis was as follows:

1. Null hypothesis: H_o: the probability of tone decay is the same for all four procedures. H_1: the probability of tone decay occurring differs according to the procedure. Tone decay is recorded if it occurs at 15 dB above threshold or more.

2. Statistical Test. The Cochran Q Test was chosen because the data was for four related groups, TDT, R-TDT, MTDT, and MTDT-C, and were dichotomized as having tone decay or not having tone decay. (10)

3. Significance Level. Let $\alpha = .01$. N = 24 = the number of cases in each of the k matched sets.

4. Rejection Region. The region of rejection consists of all values of Q which are so large that the probability associated with their occurrence under H_o is equal to or less than $\alpha = .01$.

An analysis was made for four frequencies: 500, 1000, 2000, and 4000 Hz.

I. TONE DECAY UNDER DIFFERENT PROCEDURES

For three of the four frequencies, 500, 1000, and 4000 Hz, the probability of tone decay being affected by the procedure was statistically significant at the .01 level. At the fourth frequency, 2000 Hz, the probability of tone decay varying under different procedures was rejected at the $\alpha = .01$ level. (See Appendix B for complete analysis of data).

It may be observed in Table IV that the MTDT and MTDT-C produced more tone decay responses than the TDT or the R-TDT. That is, tone decay was recorded more frequently with procedures using Green's instructions, as shown in Table IV.

TABLE IV

SUBJECTS DEMONSTRATING TONE DECAY AS A FUNCTION OF METHOD

Hz	TDT	R-TDT	MTDT	MTDT-C	Q	df	s
500	0	0	7	10	21.4	3	.001
1000	0	1	6	6	12.7	3	.01
2000	1	2	6	6	8.0	3	.05
4000	2	2	6	9	12.6	3	.01

N = 24

II. TONE DECAY IN NORMAL EARS

Results for the second hypothesis showed that 16 out of the 24 subjects evidenced tone decay in one or more of the frequencies under one or more conditions.

Grouped frequency distributions of persons demonstrating tone decay under 4 conditions are shown in Table V for 500 Hz, Table VI for 1000 Hz, Table VII for 2000 Hz, and Table VIII for 4000 Hz.

The Carhart TDT produced no tone decay for any of the 24 normal hearing subjects at 500 Hz, and 4000 Hz. One subject recorded tone decay between 15 and 25 dB above his threshold at 2000 Hz, and two subjects recorded tone decay 15 to 25 dB above threshold at 1000 Hz.

The Rosenberg Test (R-TDT) produced similar results as the Carhart Test. At 500 Hz and 4000 Hz all 24 subjects recorded no tone decay; however, at 2000 Hz two subjects recorded tone decay 15 to 25 dB above their threshold. At 1000 Hz one subject recorded tone decay 15 to 25 dB above threshold and one subject recorded 30 to 40 dB of tone decay above threshold.

The MTDT and the MTDT-C appeared to have no particular pattern to the recording of tone decay (see Tables V, VI, VII, and VIII), except that the majority of responses indicated no tone decay with some unusual recordings of tone decay 60 to 110 dB above threshold.

TABLE V

GROUPED FREQUENCY DISTRIBUTION OF TONE DECAY IN NORMAL EARS UNDER 4 DIFFERENT CONDITIONS WHERE 1=10 dB AT 500 Hz

CLASS INTERVAL	FREQUENCY			
	MTDT	TDT	R-TDT	MTDT-C
0 - 10	17	24	24	14
15 - 25	6			6
30 - 40				1
45 - 55				
60 - 80				2
85 - 95				
100 - 110	1			1
	N=24	N=24	N=24	N=24

TABLE VI

GROUPED FREQUENCY DISTRIBUTION OF TONE DECAY IN NORMAL EARS UNDER 4 DIFFERENT CONDITIONS WHERE i=10 dB AT 1000 Hz

CLASS INTERVAL	FREQUENCY			
	MTDT	TDT	R-TDT	MTDT-C
0 - 10	18	22	22	16
15 - 25	4	2	1	2
30 - 40	2		1	1
45 - 55				2
60 - 80				1
85 - 95				
100 - 110				2
	N=24	N=24	N=24	N=24

TABLE VII

GROUPED FREQUENCY DISTRIBUTION OF TONE DECAY IN NORMAL EARS UNDER 4 DIFFERENT CONDITIONS WHERE i=10 dB AT 2000 Hz

CLASS INTERVAL	FREQUENCY			
	MTDT	TDT	R-TDT	MTDT-C
0 - 10	18	23	22	18
15 - 25	5	1	2	2
30 - 40	1			
45 - 55				1
60 - 80				3
85 - 95				
100 - 110				
	N=24	N=24	N=24	N=24

TABLE VIII

GROUPED FREQUENCY DISTRIBUTION OF TONE DECAY IN NORMAL EARS UNDER 4 DIFFERENT CONDITIONS WHERE i=10 dB AT 4000 Hz

CLASS INTERVAL	FREQUENCY			
	MTDT	TDT	R-TDT	MTDT-C
0 - 10	18	24	24	18
15 - 25	6			3
30 - 40				1
45 - 55				1
60 - 80				1
85 - 95				
100 - 110				
	N=24	N=24	N=24	N=24

III. RELIABILITY

Observation of the individual tone decay recordings of test-retest scores indicates very little consistency of tone decay in the same person tested under the same conditions from one time to the next. (See Table IX). It was noted that while repeat threshold test results remained fairly constant, tone decay results did not. In addition, there were more instances of unusual amounts of tone decay occurring during the first testing than the second. Tone decay results appeared to be as inconsistent for the assistant examiner as for the experimenter.

It is not known at this time whether the phenomenon of tone decay is an inconsistent variable in an individual listener or if the tone decay tests themselves are not validly measuring decay. Some individuals stated after the tests that during the listening task they were not sure whether the tone was changing or fading.

IV. DISCUSSION

According to the results of this study, as was hypothesized, tone decay is demonstratable in normal ears and the amount of decay measured varies according to the method used. Tone decay recordings also vary in the same person when retested under the same conditions.

TABLE IX

INDIVIDUAL TONE DECAY RECORDINGS FIRST AND SECOND TESTING

(ASSISTANT)

	FIRST TESTING				SECOND TESTING			
	500	1000	2000	4000	500	1000	2000	4000
Threshold	10	5	0	5	10	5	5	5
TDT	5	5	5	0	0	5	5	0
R-TDT	5	5	5	0	0	5	5	0
MTDT	5	0	5	0	0	0	5	5
MTDT-C	5	5	5	0	0	0	5	5
Threshold	5	0	0	5	5	0	0	5
TDT	10	5	0	5	0	5	5	20
MTDT-C	15	5	55	105	0	5	5	10
MTDT	10	10	15	15	5	5	5	15
R-TDT	10	5	15	10	10	10	15	10
Threshold	5	10	5	5	5	10	10	5
TDT	10	10	10	5	10	5	0	0
MTDT-C	25	35	20	15	20	15	10	5
R-TDT	5	5	5	5	5	5	5	0
MTDT	10	20	5	10	10	20	15	5
Threshold	5	5	5	5	5	10	5	5
MTDT-C	5	10	0	15	5	10	0	0
R-TDT	0	5	15	0	0	5	0	0
MTDT	10	10	5	10	10	0	0	10
TDT	0	5	5	5	5	0	0	10
Threshold	5	5	5	5	5	10	5	5
R-TDT	0	0	0	0	10	5	5	0
MTDT-C	5	10	10	75	5	10	15	15
TDT	0	5	0	0	0	5	5	0
MTDT	20	10	20	40	5	5	5	10

TABLE IX (continued)

(EXPERIMENTER)

	FIRST TESTING				SECOND TESTING			
	500	1000	2000	4000	500	1000	2000	4000
Threshold	10	15	5	5	10	15	5	5
MTDT	10	10	25	25	20	30	25	25
R-TDT	5	15	10	30	5	5	5	10
MTDT-C	35	55	65	55	20	35	30	30
TDT	10	10	15	15	5	10	10	10
Threshold	15	5	5	0	10	5	5	0
TDT	0	0	0	0	0	0	0	0
R-TDT	0	0	0	0	0	0	0	5
MTDT-C	100	0	0	0	0	5	10	15
MTDT	100	25	0	0	0	10	5	0
Threshold	10	10	5	0	10	10	5	0
MTDT	0	5	0	0	5	0	0	0
TDT	0	0	0	0	0	0	0	0
R-TDT	0	0	0	0	0	0	0	0
MTDT-C	0	5	0	0	0	0	0	10
Threshold	10	5	5	10	10	5	5	10
TDT	0	0	0	0	0	0	0	0
MTDT	5	5	5	5	20	15	15	30
R-TDT	0	0	0	0	0	5	0	0
MTDT-C	10	10	5	10	25	20	10	35
Threshold	15	5	5	5	15	5	5	5
MTDT	10	10	5	0	0	0	0	5
MTDT-C	0	0	0	0	0	0	0	5
TDT	0	5	0	0	0	0	0	5
R-TDT	0	5	0	5	0	0	0	5

Due to the small number of subjects used in this study no statement can be made about general tendencies of tone decay occurring in normal hearing subjects; nor can this study indicate a base line for what is clinically significant.

Rather, this study was designed to contribute more information concerning usefulness of a tone decay test.

The results of this study seem to raise real question as to the diagnostic significance of the tone decay testing. For example, with tone decay recordings of 105 dB in an audiometrically normal ear of what significance would the same recording be in a pathological ear? Another question is one of variability. It was noted in this study that when Green's instructions were used more variability was found in amounts of tone decay from one test to the next than when using the standard Carhart instructions.

These kinds of questions point to a real need for additional research in the area of tone decay testing, particularly along the following lines:

1. reliability studies
2. standardization of instructions and procedures, and
3. quantitative data on tone decay in normal hearing, conductive, cochlear, and retrocochlear pathology for determination of the limits of clinical significance.

SUMMARY

This study was designed to determine whether tone decay is demonstratable in normal ears and if it is, to determine if the procedure used would influence the amount of tone decay recorded.

Twenty-four normal ears were given tone decay tests at four frequencies under the following conditions:

1. Procedure and instructions as described by Carhart (TDT),
2. Procedure and instructions as described by Rosenberg (R-TDT),
3. Carhart's procedure with a modification in instruction as described by Green (MTDT-C), and
4. Rosenberg's procedure with a modification in instruction as described by Green (MTDT).

It was found that 16 out of 24 normal-hearing subjects demonstrated tone decay at one or more frequencies under one or more conditions. The standard Carhart and Rosenberg methods recorded findings more similar to previous studies (less tone decay) while both methods using Green's instructions showed a number of subjects recording tone decay, even such extreme amounts as 105 dB above threshold. A statistically significant difference was found in amounts of tone decay occurring in the same person using different procedures.

It should be noted that this study has not been designed to make tone decay tests appear as a useless tool, merely that more information is needed. It would appear that some past generalizations have been contradicted in this

study in that tone decay as presently measured does occur in normal ears. This study indicates a need for more research in the area of tone decay testing.

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APPENDICES

APPENDIX A

INSTRUCTIONS AND PROCEDURE FOR TESTING AUDIOMETRIC THRESHOLD

INSTRUCTIONS

I am going to test your hearing. Raise your finger whenever you hear a tone and for as long as you hear the tone. The object of this test is to find the point where you can just barely detect the presence of the tone. At first the tone will be very soft; it will then get louder and then get softer again. After I am satisfied that we have the point where you can just detect the presence of the tone we will shift to a different tone and start the process all over. Again signal by raising your finger whenever you hear a tone, keeping your finger raised for as long as you hear the tone.

The first two underlined sentences will be read to the subject just prior to the screening test. If he passes the screening test the rest of the instruction will be read to him when thresholds are determined.

PROCEDURE FOR ESTABLISHING THRESHOLD

1. Only the right ear was tested.

2. The test began at the frequency of 1000. The procedure was the same for all frequencies tested.

3. Starting with the hearing-level control at 0 dB, the interrupter switch was depressed, and the intensity of

the tone was gradually increased until the patient signaled that he heard the tone. The intensity of the tone was increased beyond this point by about 20 dB, in order to give the patient an opportunity to hear the tone well.

4. The intensity of the tone was decreased in a steady counter-clockwise movement of the hearing-level control until the subject signaled that he could no longer hear the tone. A mental note was made on what the reading of the hearing-level dial was at this point.

5. The direction of rotation of the hearing-level control was reversed, increasing intensity of the tone until the patient signaled that he heard it again. At this point a mental note was made on the dial. The subject's threshold was now "bracketed" within 10 to 15 dB, and in this case was 0 to 15 dB.

6. At this point, the tone was completely cut off by releasing the interrupter switch.

7. The reading of the hearing-level dial was adjusted to 0 dB. If the subject heard this tone at least 50% of the time then this was regarded as his threshold.

8. If the subject did not hear the tone at 0 dB, the intensity was increased by 5 dB, and then the tone was presented. If the patient did not hear the tone, this step was repeated until he did signal that he heard the tone.

9. When the subject signaled that he heard the tone,

the interrupter switch was released briefly and the intensity decreased by 5 dB. The subject should have signaled that he did not hear the tone. If the subject signaled that he heard the tone, this step was repeated until he no longer heard it.

10. The intensity was increased by 5 dB, and the interrupter switch was depressed briefly. If the patient did not respond, the intensity was increased by 5 dB again, and the interrupter switch was depressed. This manner was continued until the patient responded. As soon as he responded, the intensity was dropped by 5 dB, and the procedure of presenting brief bursts of tone at 5 dB steps of increasing intensity was repeated until the patient responded. Each time he responded the intensity was decreased, and this procedure was repeated until the patient had responded at least 4 times.

APPENDIX B

TABLE I

RESPONSES TO TONE DECAY TESTS IN NORMAL EARS UNDER 4 CONDITIONS AT 500 Hz

Set	TDT	R-TDT	MTDT	MTDT-C	L_i	L_i^2
1	0	0	0	0	0	0
2	0	0	1	1	2	4
3	0	0	1	1	2	4
4	0	0	0	1	1	1
5	0	0	0	1	1	1
6	0	0	0	0	0	0
7	0	0	1	1	2	4
8	0	0	0	0	0	0
9	0	0	0	1	1	1
10	0	0	0	1	1	1
11	0	0	1	0	1	1
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	1	0	1	1
15	0	0	0	0	0	0
16	0	0	0	1	1	1
17	0	0	0	0	0	0
18	0	0	1	1	2	4
19	0	0	0	0	0	0
20	0	0	0	1	1	1
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	1	0	1	1
	$G_1=0$	$G_2=0$	$G_3=7$	$G_4=10$	$\sum_{L=1}^{24} L_i=17$	$\sum_{L=1}^{24} L_i^2=25$

$$Q = \frac{(k-1)[k\sum_{j=1}^{k} G_j^2 - (\sum_{j=1}^{k} G_j)^2]}{k\sum_{i=1}^{N} L_i - \sum_{i=1}^{N} L_i^2}$$

$= 21.4$ $df=K-1=4-1=3$

.001

Null Hypothesis

H_o: the probability of a tone decay response is the same for all conditions.

H_1: the probabilities of no tone decay response differs according to procedure.

Reject H_o — Accept H_1

TABLE II

RESPONSES TO TONE DECAY TESTS IN NORMAL EARS UNDER 4 CONDITIONS AT 1000 Hz

Set	TDT	R-TDT	MTDT	MTDT--C	L_i	L_i^2
1	0	0	0	0	0	0
2	0	0	1	0	1	1
3	0	0	1	1	2	4
4	0	0	0	0	0	0
5	0	0	1	1	2	4
6	0	0	0	0	0	0
7	0	0	1	1	2	4
8	0	0	0	0	0	0
9	0	0	0	1	1	1
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	1	0	1	1
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	1	0	1	2	4
17	0	0	0	0	0	0
18	0	0	1	1	2	4
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
	$G_1=0$	$G_2=1$	$G_3=6$	$G_4=6$	$\sum_{L=1}^{24} L_i=13$	$\sum_{L=1}^{24} L_i^2=23$

$$Q = \frac{(k-1)\left[k\sum_{j=1}^{k} G_j^2 - \left(\sum_{j=1}^{k} G_j\right)^2\right]}{k\sum_{i=1}^{N} L_i - \sum_{i=1}^{N} L_i^2}$$

$= 12.7 \qquad df=K-1=4-1=3$

.01

Null Hypothesis

H_o: the probability of a tone decay response is the same for all conditions.

H_1: the probabilities of no tone decay response differs according to procedure.

Reject H_o — Accept H_1

TABLE III

RESPONSES TO TONE DECAY TESTS IN NORMAL EARS UNDER 4 CONDITIONS AT 2000 Hz

Set	TDT	R-TDT	MTDT	MTDT-C	L_i	L_i^2
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	1	0	1	1
4	0	1	1	1	3	9
5	0	0	0	1	1	1
6	0	0	0	0	0	0
7	0	0	1	0	1	1
8	0	0	0	0	0	0
9	0	0	1	1	2	4
10	0	0	0	0	0	0
11	0	0	1	0	1	1
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	1	1	1
15	0	0	0	0	0	0
16	1	0	1	1	3	9
17	0	0	0	0	0	0
18	0	0	0	1	1	1
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	1	0	0	1	1
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
	$G_1=1$	$G_2=2$	$G_3=6$	$G_4=6$	$\sum_{i=1}^{24} L_i=15$	$\sum_{i=1}^{24} L_i^2=29$

$$Q = \frac{(k-1)\left[k\sum_{j=1}^{k} G_j^2 - \left(\sum_{j=1}^{k} G_j\right)^2\right]}{k\sum_{i=1}^{N} L_i - \sum_{i=1}^{N} L_i^2}$$

$= 8.0 \qquad df=K-1=4-1=3$

.05

Null Hypothesis

H_o: the probability of a tone decay response is the same for all conditions.

H_1: the probabilities of no tone decay response differs according to procedure.

Accept H_o — Reject H_1 at .01

TABLE IV

RESPONSES TO TONE DECAY TESTS IN NORMAL EARS UNDER 4 CONDITIONS AT 4000 Hz

Set	TDT	R-TDT	MTDT	MTDT-C	L_i	L_i^2
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	1	1	2	4
4	0	0	1	1	2	4
5	0	0	0	1	1	1
6	0	0	0	0	0	0
7	0	0	0	1	1	1
8	0	1	0	0	1	1
9	0	0	1	1	2	4
10	0	0	0	0	0	0
11	0	0	1	0	1	1
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	1	1	1
15	0	0	0	0	0	0
16	1	1	1	1	4	16
17	0	0	0	0	0	0
18	1	0	1	1	3	9
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	1	1	1
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
	$G_1=2$	$G_2=2$	$G_3=6$	$G_4=9$	$\sum_{i=1}^{24} L_i=19$	$\sum_{i=1}^{24} L_i^2=43$

$$Q = \frac{(k-1)\left[k\sum_{j=1}^{k} G_j^2 - \left(\sum_{j=1}^{k} G_j\right)^2\right]}{k\sum_{i=1}^{N} L_i - \sum_{i=1}^{N} L_i^2}$$

$= 12.6$ $\quad df=K-1=4-1=3$

.01

Null Hypothesis

H_o: the probability of a tone decay response is the same for all conditions.

H_1: the probabilities of no tone decay response differs according to procedure

Reject H_o — Accept H_1 at .01