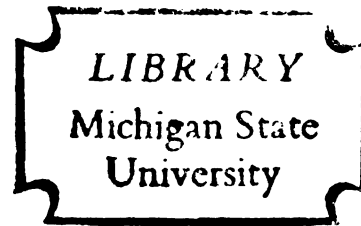


THE EFFECT OF CONTINUOUS VERSUS
INTERMITTENT EXPOSURE TO
ROCK AND ROLL MUSIC UPON
TEMPORARY THRESHOLD SHIFT

Thesis for the Degree of M. A.
MICHIGAN STATE UNIVERSITY
ELLEN K. SMITLEY
1969



ABSTRACT

THE EFFECT OF CONTINUOUS VERSUS INTERMITTENT EXPOSURE TO ROCK AND ROLL MUSIC UPON TEMPORARY THRESHOLD SHIFT

By

Ellen K. Smitley

In this study forty young normal hearing subjects, twenty males and twenty females, were exposed to sixty minutes of rock and roll music in a sound field at 110 dB sound pressure level.

The purpose of this experiment was to compare the average temporary threshold shifts (TTS) of young normal hearing subjects exposed to rock and roll music at a 110 dB SPL played continuously for a period of sixty minutes with the mean TTS of subjects exposed to the same stimuli and intensity level played intermittently for a period of sixty minutes.

Other purposes included the comparison of mean TTS of male and female subjects under each exposure condition and the comparison of TTS measured 2, 30, 60 and 90 minutes following exposure.

Ellen K. Smitley

Pure-tone air-conduction thresholds at 250, 500, 1000, 2000, 3000, 4000, and 8000 Hz were determined monaurally prior to and four times following the exposure.

The data were examined by means of a three-way analysis of variance. The means, ranges, and standard deviations for TTS were also reported.

Results showed that there is a significant TTS difference between continuous and intermittent exposure conditions with greater TTS resulting from continuous exposure at 250, 500, 2000 and 3000 Hz. Recovery at 3000 and 4000 Hz for TTS is slower for subjects exposed continuously than for those having brief rest periods.

There is a significant difference between TTS at 2, 30, 60, and 90 minutes following exposure with systematic improvement in threshold occurring as a function of time.

The mean TTS of males and females were not found to differ significantly. Large differences were found among subjects concerning the absolute amount of TTS. Also, a general trend was observed for the mean TTS to be progressively larger from 250 through 4000 Hz, under both conditions.

THE EFFECT OF CONTINUOUS VERSUS
INTERMITTENT EXPOSURE TO ROCK AND ROLL
MUSIC UPON TEMPORARY THRESHOLD SHIFT

By

Ellen K. Smitley

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Audiology and Speech Sciences

1969

659190
12/3/69

Accepted by the faculty of the Department of
Audiology and Speech Sciences, College of Communication
Arts, Michigan State University, in partial fulfillment
of the requirements for the Master of Arts degree.

William F. Rintelmann
Director of Thesis

Guidance Committee:

William F. Rintelmann Chairman
Edward J. Hardick
Leo V. Seal

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	v
 Chapter	
I. INTRODUCTION	1
Purpose of the Study	3
Definitions	4
II. REVIEW OF THE LITERATURE	6
III. EXPERIMENTAL PROCEDURES	29
Subjects	30
Equipment	31
Test Environment	34
Test Procedures and Experimental Groups	36
Statistical Analysis	39
IV. RESULTS AND DISCUSSION	40
Descriptive Statistics	41
Significance Tests	53
Discussion	57
V. SUMMARY AND CONCLUSIONS	61
Summary	61

Chapter	Page
Conclusions	62
Recommendations for Further Research	63
BIBLIOGRAPHY	65
Appendix	
A. ANALYSIS OF VARIANCE AT 250 Hz . .	71
B. ANALYSIS OF VARIANCE AT 500 Hz . .	72
C. ANALYSIS OF VARIANCE AT 1000 Hz .	73
D. ANALYSIS OF VARIANCE AT 2000 Hz .	74
E. ANALYSIS OF VARIANCE AT 3000 Hz .	75
F. ANALYSIS OF VARIANCE AT 4000 Hz .	76
G. ANALYSIS OF VARIANCE AT 8000 Hz .	77

LIST OF TABLES

Table	Page
1. Temporary threshold shift means, ranges and standard deviations in dB averaged for four post-exposure periods	41
2. Mean temporary threshold shift in decibels as a function of time	43
3. Mean temporary threshold shift in decibels as a function of condition .	43
4. Mean temporary threshold shift in decibels as a function of sex	44
5. Mean temporary threshold shift 2, 30, 60 and 90 minutes following exposure for the groups receiving continuous or intermittent exposure	54
6. Summary of F statistics and approximate significance of the F statistics for conditions, sex and time at seven frequencies (250-8000 Hz)	55

LIST OF FIGURES

Figure	Page
1. Recommended allowable exposure time for intermittent noise	25
2. A schematic diagram of test room and adjoining control room	35
3. Mean temporary threshold shift at 250 Hz resulting from continuous and intermittent exposure at 2, 30 60 and 90 minutes post-exposure	46
4. Mean temporary threshold shift at 500 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure	47
5. Mean temporary threshold shift at 1000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure	48
6. Mean temporary threshold shift at 2000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure	49
7. Mean temporary threshold shift at 3000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure	50

Figure	Page
8. Mean temporary threshold shift at 4000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure	51
9. Mean temporary threshold shift at 8000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure	52

CHAPTER I

INTRODUCTION

Recently, great concern has been expressed over loudly played rock and roll music. It has been estimated that in some establishments rock and roll music is played as loudly as 120-130 decibels (dB) sound pressure level.¹ Numerous newspaper articles and other lay publications have expressed concern over the effects of loudly played rock and roll music upon human hearing. Consumer's Reports stated that rock and roll musicians and their audiences may incur permanent hearing losses.² The State Journal published a statement by a Memphis State University researcher who felt that due to rock and roll music,

¹The State Journal, "Loud, Screaming Music Can Badly Damage Ear," June 16, 1968.

²"Not Exactly Music to Your Ears," Consumer's Reports, July 1968, p. 349.

we may be raising a nation of teenagers who will become hard of hearing.³ On the other hand, Rintlemann and Borus⁴ of Michigan State University reported that this concern is unwarranted.

Few studies have been undertaken to investigate the effects of loud music upon the hearing mechanism. However, many speculations have been made that loudly played rock and roll music causes a noise-induced hearing loss. Most of these statements have been generalizations based upon present damage risk criteria applied to industrial noise. Unlike most industrial noise that is "on" constantly for 8 hours, rock and roll music is commonly played for 3-5 minutes followed by a 1-2 minute break between selections. Combos generally take a 30 minute break following a 45-60 minute performance. The short "off" times between songs and the longer breaks between sets may provide relief for the ear. Exposure to continuously played rock and roll music may result in

³The State Journal, "Rock and Roll Music Assayed," December 12, 1968.

⁴William F. Rintelmenn and Judith F. Borus, "Noise-Induced Hearing Loss and Rock and Roll Music," Archives of Otolaryngology, 88 (October 1968), pp. 377-385.

a greater temporary threshold shift than exposure to intermittently played rock and roll music.

Purpose of the Study

The primary purpose of this study was to compare the average temporary threshold shifts (TTS) of young normal hearing subjects exposed to rock and roll music at a sound pressure level of 110 dB for a period of sixty minutes with no "off" times with the mean TTS of subjects exposed to the same stimuli and intensity level for a period of sixty minutes with 4-6 minute "on" times and 30 second "off" times.

Secondary purposes included: (1) comparison of mean TTS of male and female subjects under each condition and (2) comparison of TTS measured 2, 30, 60 and 90 minutes following exposure.

Briefly, the experiment consisted of exposing young normal hearing subjects to 60 minutes of either continuous (60 minutes with no "off" times) or intermittent (60 minutes with 4-6 minute "on" times and 30 second "off" times) rock and roll music in a sound field at 110 dB sound pressure level re 0.0002 dynes/cm². Pure-tone air-conduction threshold measurements consisted of one pre-exposure measurement

and four post-exposure measurements: 2, 30, 60 and 90 minutes following exposure.

Based upon the primary and secondary purposes of the study, the following null hypotheses were advanced:

- 1) There is no significant difference between the mean TTS of subjects exposed to 60 minutes of continuous rock and roll music and the mean TTS of subjects exposed to 60 minutes of intermittently played rock and roll music.
- 2) Under identical conditions there is no significant difference between the mean TTS of males and the mean TTS of females.
- 3) TTS 2, 30, 60 and 90 minutes following exposure to rock and roll music played at 110 dB sound pressure level will not differ significantly from each other.

Definitions

The following definitions of terms are used in this study:

Temporary Threshold Shift (TTS)--the difference in a subject's threshold for hearing measured before

and after exposure to sounds which is characterized by the subject's threshold for hearing returning to its pre-exposure level.

Noise Induced Hearing Loss--a permanent shift or depression in a person's threshold for hearing solely as a result of exposure to the sound environment under question. Aging or other factors affecting the hearing mechanism are presumably eliminated as causative factors.

Exposure--this refers to the length of time one is subjected to a noise.

Damage Risk Criteria--estimated safe sound pressure levels that can be tolerated for a given time without risk to the hearing mechanism.

Continuous Exposure--subjection to rock and roll music for 60 minutes with no "off" times. The noise stimulus is constantly present.

Intermittent Exposure--subjection to rock and roll music for 60 minutes with 4-6 minute "on" times followed by 30 second "off" times.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter includes: (1) a historical review of noise exposure and its possible effects upon the human ear; (2) evidence of current concern over a particular type of noise, rock and roll music; and (3) a summary of current research pertaining to the possible effects of rock and roll music upon the ear. Differing approaches toward this type of investigation are discussed.

As early as 1831 there was documented concern about the effects of noise upon the hearing mechanism. Fosbroke¹ reported a "mechanical" etiology of deafness found in blacksmiths as a result of their employment. Toynbee² wrote in 1860 that "deafness from concussion is of three modes: blows on the ear;

¹Lancet, 1, p. 645, cited by C. C. Bunch, "The Diagnosis of Occupational or Traumatic Deafness; a Historical and Audiometric Study," Laryngoscope, 67 (September 1937), p. 618.

²Diseases of the Ear, p. 348, cited by C. C. Bunch, Ibid., p. 619.

loud sounds; and falls." Dalby³ in 1872 speculated that hearing loss as a result of noise exposure was a function of long repeated shocks as in the case of boilermakers. It was observed by Roosa⁴ in 1887 that a large proportion of workmen employed in hammering large iron plates for long durations of time suffered a loss of hearing. Also, in 1887, Hartmann⁵ attempted to more specifically describe the type of hearing loss observed in boilermakers. He summarized his observations as follows: "Bone conduction is considerably diminished, the two highest tones not being heard at all (c⁴ and g⁴). This shows that injurious action of the noises in boiler shops is chiefly expended upon those portions of the sound perceiving apparatus, which serve for the perception of the higher tones."

In 1908 Bezold and Siebenmann⁶ recorded the most frequent injury to the inner ear to be that from

³Lancet, 2, p. 873, cited by C. C. Bunch, Ibid., p. 620.

⁴Trans. of Amer. Oto. Soc., 4, p. 34, cited by C. C. Bunch, Ibid.

⁵Diseases of the Ear, p. 32, cited by C. C. Bunch, Ibid.

⁶Textbook of Otology, p. 280, cited by C. C. Bunch, Ibid.

excessive noise and labeled the injury "acoustic trauma." They suggested a differentiation between trauma cases with an injury to the labyrinth caused by one short sound like an explosion or whistle of a locomotive and an injury caused by frequently repeated loud noises.

Ballenger⁷ in 1914 explained occupational deafness physiologically. He proposed that in the presence of loud noise the terminal nerve filaments of the labyrinth were continuously subjected to irritation and thus underwent a degenerative change often amounting to complete atrophy and subsequent deafness.

Turner⁸ in 1924 stated that "noise deafness" increases gradually as a function of the duration of continued exposures and reported the presence of the condition in boilermakers, coopers, factory workers, artillerymen and sailors in the Royal Navy. Bauer⁹

⁷W. L. Ballenger, Diseases of the Nose, Throat and Ear, (Philadelphia and New York: Lea and Febiger, 1914), p. 1010.

⁸Al Turner, Diseases of the Nose Throat and Ear, (New York: William Wood & Co., 1924), p. 364.

⁹L. H. Bauer, Aviation Medicine, (Baltimore: Williams & Wilkins Co., 1926), p. 157.

in 1926 found the constant roar of a high powered motor to cause a diminution of hearing. Syme¹⁰ also reported in 1927 marked nerve deafness in subjects who worked continuously in loud noises. In 1933 Swann¹¹ reported a large percentage of locomotive workers to be hard of hearing.

Today, approximately 140 years after the first report in the scientific literature, noise exposure remains a significant problem in our highly technological society. This potential hazard to hearing exists not only within the realm of employment but also within the context of everyday living. One current focus of this concern is upon the popular music of our times, specifically rock and roll music. Recently, the possible effects of rock and roll music upon the human ear has received attention in a variety of lay publications

¹⁰W. S. Syme, Diseases of the Nose, Throat and Ear, (New York: William Wood & Co., 1927), p. 356.

¹¹C. C. Swann, "The Effects of Noise on Hearing," International Journal of Medicine and Surgery, 46, (1933), p. 314.

and technical magazines.¹²⁻²³ Numerous speculations have been made about "harmful effects" of rock and roll music upon hearing. These statements concerning

¹²Hearing Progress, "Loud Rock and Roll Music May Cause Deafness," Maico Hearing Foundation (Fall-Winter), 1967.

¹³Winnepeg Free Press, "Rock and Roll Music Not Harmful: Report," Winnepeg, Canada, November 11, 1968.

¹⁴The State Journal, "Rock and Roll Music Assayed," by Joseph L. Meyer, Lansing, Michigan, December 12, 1968.

¹⁵Time, August 1968.

¹⁶Chicago Daily News, "Rock Band Noise Level Could Injure Your Child," by Phyllis Battelle, July 16, 1968.

¹⁷The State Journal, "Loud, Screaming Music Can Badly Damage Ear," June 16, 1968.

¹⁸The Medical Post, "Noise Level Causes Frustration Deafness," January 28, 1969, p. 21.

¹⁹Washington Daily News, "No Hearing Loss from Rock and Roll," by Fred Friske, November 1968, P. 32.

²⁰Consumer's Reports, "Not Exactly Music to Your Ears," July 1968, p. 349.

²¹Popular Mechanics, "Rock and Roll Music Can Be Hazardous to Hearing," by John R. Pearson, November 1968, p. 22.

²²Sound and Vibration, 1, No. 12, December 1967, (Front Page News), Acoustical Publications, Inc.

²³Detroit Free Press, "Action Line," April 21, 1969.

the possible effects of rock and roll music are predictions of a permanent hearing loss based upon temporary threshold shifts or generalizations from present damage risk criteria for industrial noise.

The issue is controversial among professionals as well as the lay population. In Michigan Hearing²⁴ two audiologists disagreed on the effects of loud music upon hearing. Rupp reported a "health danger to the hearing mechanism from prolonged exposure" and advocated legislation to establish allowable sound pressure levels for amplifiers in discotheques. In the same issue of this publication, Rintelmann reported that "insufficient evidence exists concerning the ultimate effects of rock and roll music on the hearing mechanism." Based upon data from a study conducted by Rintelmann and Borus in which they tested the hearing of young people exposed to rock and roll music for relatively long periods of time, they concluded there is only a minor risk to auditory damage.²⁵

²⁴Michigan Hearing, "Does Rock and Roll Music Harm Hearing?," (Summer 1969), pp. 5-13.

²⁵Ibid.

The controversial nature of the issue is further illustrated by Ralph Nader's urging Senate subcommittees to conduct hearings to reveal the scope of the problem. Nader advocates legislated noise level restrictions and ear protection for musicians and band hall workers.²⁶

The above references are just a few of the numerous statements that have appeared in newspapers and magazines concerning the "damage" of rock and roll music on the hearing mechanism. On the other hand, there have been very few studies reported to date in the scientific literature. A few studies have been conducted and are reported below.

Recent research has been undertaken to determine whether the concern over the loudness of rock and roll music is warranted. Two opinions are prevalent: (1) rock and roll music causes a hearing loss and (2) rock and roll music does not cause a hearing loss in the vast majority of the population. In general, five experimental approaches have been employed to substantiate these opinions. One is measuring the hearing of people who have been

²⁶Washington Post, "Nader Asks Hill Probe of Rock 'n' Roll Din," June 2, 1969.

exposed to rock and roll music over a period of time. Rintelmann and Borus²⁷ measured the hearing of 42 rock and roll musicians who were exposed to approximately 105 dB SPL of music for an average of 11.4 hours a week for 2.9 years. They found 95% of the musicians did not incur hearing losses.

A second approach is to examine laboratory animals histologically who have been exposed to rock and roll music. Lipscomb²⁸ exposed a guinea pig to 88 hours of rock and roll music with a peak intensity of 122 dB SPL over a two month period of time. He found marked sensory cell damage in the cochlea of the experimental animal.

A third approach is to measure very high frequency pure-tone thresholds. Downs, Hemenway and Doster²⁹ determined high frequency thresholds (4000 ~ 18000 Hz) for a group of 24 high school musicians and a control group of the same number.

²⁷William F. Rintelmann and Judith F. Borus, "Noise-Induced Hearing Loss and Rock and Roll Music," Archives of Otolaryngology, 88, (October 1968), pp. 377-385.

²⁸David M. Lipscomb, "High Intensity Sounds in the Recreational Environment," Clinical Pediatrics, 8, No. 2, (February 1969), pp. 63-68.

²⁹Marion Downs, W. Hemenway, and Mildred Doster, "Sensory Over-Load," Hearing and Speech News, (May-June 1969), pp. 10-11.

They found 75% of the musicians to have poorer high frequency pure-tone thresholds at one or more frequencies than the control group of non-musicians.

A fourth approach employed is attempting to predict hearing loss on the basis of temporary threshold shift (TTS). Jerger, Jerger, and Pollack³⁰ recorded sound pressure levels as high as 120 dB in close proximity to one group of performing musicians. These investigators found the four audience members to sustain TTS up to 35 dB following a four hour exposure and concluded that the performance of contemporary rock and roll music poses a serious threat to hearing.

Rupp and Koch³¹ measured TTS of five subjects after two and one-half hours exposure to rock and roll music where sound pressure levels peaked at 120 dB. They found an average of 30 dB TTS at 4000 Hz. On the basis of the maximum overall SPL

³⁰James Jerger, Susan Jerger, and Kenneth Pollack, "Temporary Hearing Loss in Rock and Roll Musicians," Houston Speech and Hearing Center, Unpublished Manuscript, 1968.

³¹Ralph R. Rupp and Larry J. Koch, "But, Mother Rock and Roll Music Has to be Loud! The Effect of Noise on Human Ears," Michigan Hearing, (Spring 1968), pp. 4-7.

of the music and the TTS, the authors concluded that long exposure to loud music is a possible health hazard.

A fifth approach is to predict hearing loss resulting from rock and roll music on the basis of damage risk criteria. Lebo, Oliphant and Garrett wrote: "One may predict that noises greater than 92 dB in sound pressure composed of frequencies primarily between 500 and 8000 Hz and sustained for a period of one hour will produce as much as 40 dB threshold shift in the area of 4000 Hz in approximately 10% of the ears exposed, no measurable shifts in the other 10% and 30 dB shift in the remaining 80% of the ears."³²

Based upon a thousand measurements, Flugrath³³ found rock and roll music to be played on the average at 104 dB SPL. Since 104 dB exceeds maximum permissible damage risk criteria, he feels it should be considered potentially damaging to hearing.

³²Charles P. Lebo, Kenward S. Oliphant and John Garrett, "Acoustic Trauma from Rock and Roll Music," California Medicine, 107, (November 1967), pp. 387-380.

³³James M. Flugrath, "Modern-Day Rock-and-Roll Music and Damage-Risk Criteria," Journal of the Acoustical Society of America, 45, No. 3, (1969), pp. 704-711.

Since most studies have used the experimental approach of predicting permanent hearing loss on the basis of TTS or damage risk criteria (DRC), it is important to review the foundations upon which this approach is based.

Damage risk criteria are statements of safe and unsafe noise conditions. Before proposing criteria for safe conditions, one must determine what is meant by damage to hearing. There is general agreement that inability to hear and understand every day speech constitutes the best measure of auditory impairment. It has been demonstrated that when the average hearing level, at 500 through 2000 Hz, is 15 dB (ASA 1951) or better, reception for speech is excellent.³⁴ Hearing impairment then can be said to exist when the average of hearing levels at 500, 1000 and 2000 Hz exceeds (or is poorer than) 15 dB. Based upon this rationale, noise exposure criteria have been proposed to prevent hearing "impairment." Several damage risk criteria have been developed.

³⁴R. R. Quiggle, Aram Glorig, J. H. Delk and A. B. Summerfield, "Predicting Hearing Loss for Speech from Pure Tone Audiograms," Laryngoscope, 959, No. 1, (January 1957), pp. 1-15.

Kryter proposed one of the early DRCs that took frequency into consideration. He estimated a maximum safe intensity level based upon the "critical band concept." Kryter wrote: "A fair, perhaps conservative evaluation of laboratory and industrial studies on stimulation deafness would seem to be that for long and intermittent exposures, any frequency of sound (or narrow band not exceeding the critical width) that is 85 dB or less above 0.0002 dyne/cm², will not cause any temporary or permanent deafness."³⁵

Hardy stated that the frequency-sensitivity curve of the ear and the manner in which the ear perceives loudness is extremely important in determining how sound will damage the ear.³⁶

Rosenblith and Stevens³⁷ published their DRC in 1953 which was largely based upon Kryter's

³⁵Karl D. Kryter, "Deafening Effects of Noise," Journal of Speech and Hearing Disorders, Monograph Supplement 1, (September 1950), p. 36.

³⁶Howard C. Hardy, "Tentative Estimate of a Hearing Damage Risk Criterion for Steady-State Noise," Journal of the Acoustical Society of America, 24, No. 6, (November 1952), pp. 756-761.

³⁷Walter A. Rosenblith and Kenneth N. Stevens, Handbook of Acoustic Noise Control, 2, (Noise and Man, WADC Technical Report 52-204, June 1953), pp. 1-262.

earlier DRC. They proposed that sounds above 85 dB may cause some deafness, either temporary or permanent, after long periods of exposure applied intermittently over months or years.

An exploratory committee (Z24-X-2) of the American Standards Association³⁸ investigated the possibility of establishing standards for undesirable and injurious noise levels. This committee surveyed all available data and concluded that data could not be sufficiently validated to warrant drawing up such standards. Although the Z24-X-2 group did not specify damage risk criteria per se, their findings and conclusions represent a basis for a DRC. This study provides suggestive evidence that a continuous spectrum noise that is 80 dB re 0.0002 dyne/cm² or less in any octave band higher in frequency than 300-600 Hz will cause negligible damage to persons exposed for 25 years for an 8 hour work day. Noise of greater intensity, according to this investigation, may cause some hearing loss.

³⁸Exploratory Subcommittee Z24-X-2 of the American Standards Association, Z 24 Sectional Committee on Acoustics, Vibration and Mechanical Shock, "The Relations of Hearing Loss to Noise Exposure," (1954), pp. 5-63.

Much of the information pertinent to the problem of noise exposure and the establishment of damage risk criteria has been obtained through studies of TTS. A temporary threshold shift is any threshold shift that is not permanent with time. It is generally true that an individual exposed to moderate or intense noise will experience a temporary loss of hearing at some portion of the frequency range. When the person remains away from the noise, the shift in threshold diminishes and returns to the preexposure threshold.

Ward, Glorig and Sklar³⁹ in 1954, conducted a study based upon the concept of TTS and its relation to permanent hearing loss. They assumed that if a noise fails to produce a TTS, it cannot produce a permanent loss and obtained results supportive of an 85 dB DRC for continuous noise.

³⁹W. Dixon Ward, Aram Glorig and Diane L. Sklar, "Temporary Threshold Shift from Octave-Band Noise: Applications to Damage Risk Criteria," Journal of the Acoustical Society of America, 31, No. 4, (April 1959), pp. 522-528.

In 1960 Kylin⁴⁰ published a study of temporary and permanent threshold shifts caused by exposure to steady state noise. His field studies showed that exposures to overall levels between 80 and 84 dB SPL did not result in any elevated thresholds. Exposures 95 - 99 dB SPL and 100 - 104 dB SPL affected the thresholds at all frequencies tested. Kylin was unable to demonstrate definitely, however, that a relation exists between the temporary and permanent loss of hearing.

Also in 1960, Kryter proposed a new set of damage risk criteria for different age groups based upon frequency of the noise and exposure duration.⁴¹

Glorig, Ward and Nixon conducted an intensive study relating Noise Induced Temporary Threshold Shift (NITTS) to Noise Induced Permanent Threshold Shift (NIPTS) and made the following conclusions:

⁴⁰Bengt Kylin, "Temporary Threshold Shift and Auditory Trauma Following Exposure to Steady-State Noise," Acta-Oto-Laryngologica, 51, No. 6, Supplement 152, (1960), pp. 1-89.

⁴¹K. D. Kryter, "Damage Risk Criteria for Hearing," ed. L. L. Beranek, Noise Reduction, (New York: McGraw-Hill, 1960), chap. 19, pp. 495-513.

- 1) If there is no NITTS there will be no NIPTS.
- 2) If the resting threshold is elevated, the magnitude of the NITTS will be proportionately less.
- 3) A specific noise exposure (Level and time Combination) will produce a corresponding specific amount of NIPTS.
- 4) The progression of NIPTS is similar to that of NITTS, but with a different time scale.⁴²

These authors also stated: "We have assumed on the basis of limited PTS evidence but considerable TTS data, that if no more than 12 dB TTS at 2000 Hz accumulates during a work day, no significant PTS will occur during a work life. We believe that when TTS is allowed to recover before further exposure, there will be no significant PTS over a usual work life."⁴³

Glorig proposed that there are four major factors of noise exposure important to the production of hearing loss. These four factors are:

⁴²Aram Glorig, W. Dixon Ward and James Nixon, "Damage Risk Criteria and Noise Induced Hearing Loss," Archives of Otolaryngology, 74, (October 1961), pp. 413-423.

⁴³Ibid.

- 1) The overall noise level
- 2) The frequency composition or spectrum of the noise
- 3) The duration and time distribution of the noise exposure during a typical day
- 4) The total duration of noise exposure during an expected work life⁴⁴

This author emphasized the importance of the distribution of exposure time and total time of exposure. He feels a statement of the time distribution must accompany the description of any noise exposure and that intermittency of exposure may be a method of ear protection. The ear that has had a chance to rest between exposures, according to Glorig, is probably more resistant to permanent loss than the ear that has been exposed continuously without rest periods.⁴⁵

In 1962 Ward⁴⁶ compared the TTS produced by intermittent noise with that produced by a steady

⁴⁴Aram Glorig, "The Effects of Noise on Hearing," Journal of Laryngology and Otology, 75, No. 5, (May 1961), p. 456.

⁴⁵Ibid., p. 457.

⁴⁶W. Dixon Ward, "Studies on the Aural Reflex II: Reduction of Temporary Threshold Shift from Intermittent Noise by Reflex Activity; Implications for Damage Risk Criteria," Journal of the Acoustical Society of America, 34, No. 2, (February 1962), pp. 234-241.

noise. It was found that an on-fraction of .50 (30 second bursts of noise alternating with 30 second intervals of quiet) resulted in a reduction of 50% in the TTS produced by 1200-2400 and 2400-4800 Hz octave bands of noise. However, in the case of 300-600 and 600-1200 Hz bands of noise, the same fraction reduced TTS to about one-third the value observed after continuous stimulation. Ward attributed this difference to the action of the middle-ear muscles, which attenuate low frequency sounds more than high frequency sounds.

The following year, 1963, Ward stated: "When noise exposure is intermittent or varies in level with time rather than being continuous or steady, the action of the middle ear muscles becomes even more important because even a short rest will at least partially restore their contractile strength."⁴⁷

The Subcommittee on Noise of the American Academy of Ophthalmology and Otolaryngology proposed guidelines for establishing standards for

⁴⁷W. Dixon Ward, "Auditory Fatigue and Masking," ed. James Jerger, Modern Developments in Audiology, (New York and London: Academic Press, 1963), pp. 240-284.

preventing significant noise-induced hearing loss in the majority of exposed persons. This subcommittee published the following:

- 1) When exposure to broad band noise is continuous during the working day (5 hours or more), the average of the levels at 300-600, 600-1200, 1200-2400 Hz should not exceed 85 dB.
- 2) When exposure to broad band noise is habitual and the noise is continuous for less than 5 hours per day, the following table should be consulted for recommended allowable exposures.

Average Level of 300-600, 600-1200, 1200-2400 Hz bands	On-time per day in minutes
85 dB	Less than 300
90 dB	Less than 120
95 dB	Less than 50
100 dB	Less than 25
105 dB	Less than 16
110 dB	Less than 12
115 dB	Less than 8
120 dB	Less than 5

- 3) When exposure to broad band noise is intermittently on during the work day, the recommended allowable exposure time may be determined by consulting Figure 1.⁴⁸

⁴⁸ Subcommittee on Noise of the Committee on Conservation of Hearing, "Guide for Conservation of Hearing in Noise," American Academy of Ophthalmology and Otolaryngology, revised 1964.

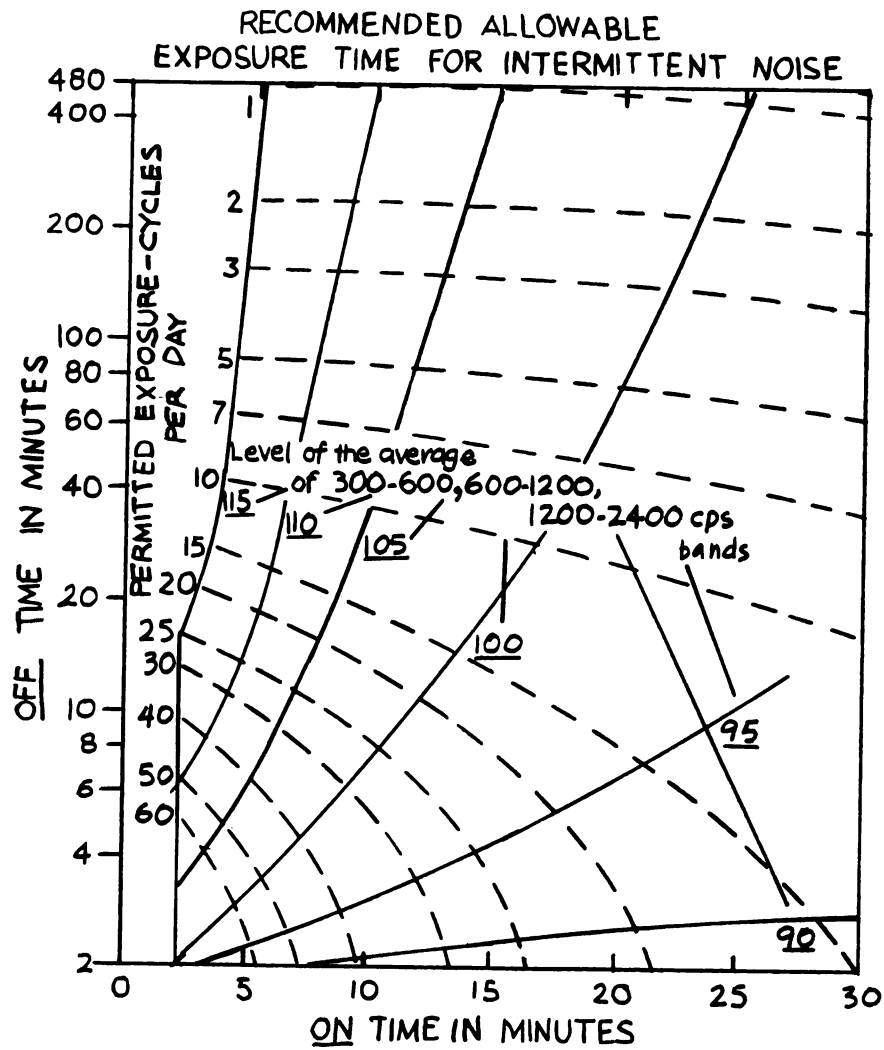


Figure 1.--Recommended Allowable Exposure Time for Intermittent Noise

This figure shows the relationship between the duration of the on-time between the noise burst (ordinate) and the allowable average level of the 300-600, 600-1200 and 1200-2400 Hz bands. The broken contours show the number of permitted exposure cycles (on-time off-time combinations per day), calculated for a working day of 480 minutes.⁴⁹

In 1965 Harris studied the effects of 105-110 dB SPL noise exposure on several hundred young men over a period of five years. Harris concluded: "It is certain that our population can work for at least up to five years, and probably to ten, in noise of 105-110 dB SPL with less than 15% of the ears receiving a permanent threshold shift of over 20 dB at any frequency."⁵⁰ This author also found permanent threshold shift predictions on the basis of temporary threshold shift to be vastly over-estimated.

Working group 46 of the National Academy of Science-National Research Council Committee on

⁴⁹Ibid.

⁵⁰J. D. Harris, "Hearing-Loss Trend Curves and the Damage Risk Criterion in Diesel-Engineeroom Personnel," Journal of the Acoustical Society of America, 37, No. 3, (March 1965), p. 452.

Hearing, Bioacoustics and Biomechanics⁵¹ published damage risk contours in an effort to show the maximum allowable durations for bands of noise of known frequency and sound pressure level to which a person can be safely exposed. The total duration of noise allowable per day was calculated for 39 different patterns of interrupted exposure. The basic criteria adopted by this group designates an environment safe if an average NIPTS in people after 10 years or more of near daily exposure is less than 10 dB at 1000 Hz and below, 15 dB at 2000 Hz and 20 dB at 3000 Hz and above.

In 1967 Ward wrote: "In all cases more energy can be tolerated in a fluctuating intermittent or interrupted noise than in one at a constant level."⁵² One year later Ward⁵³ stated that in a typical eight hour work day an 80 dB noise cannot

⁵¹Karl Kryter, "Hazardous Exposure to Intermittent and Steady State Noise," NAS-NRC Committee on Hearing, Bioacoustics, and Biomechanics, Working Group 46, (January 1965), pp. 1-34.

⁵²W. Dixon Ward, "The Use of Temporary Threshold Shift in the Derivation of Damage Risk Criteria for Noise Exposure," International Audiology, 5, (February 1967), pp. 309-313.

⁵³W. Dixon Ward, "The Identification and Treatment of Noise-Induced Hearing Loss," Preprint, (1968).

be responsible for a noise induced hearing loss, but in a noise around 104 dB everyone who works with ears unprotected in the noise shows a high frequency hearing loss after a few years exposure.

In summary, the hearing of a person can be damaged as a result of intense noise exposure. Studies of the relation between hearing and exposure to noise have resulted in a number of different damage risk criteria. No one has suggested that octave band levels below 70 dB are dangerous, nor has anyone judged as safe levels above 95 dB in the 1200-2400 and 2400-4800 Hz octave bands for persons who receive prolonged exposures over a period of several years. Further, when exposure to noise is intermittent or interrupted by short rest periods, the detrimental effects on auditory thresholds (either NITTS or NIPTS) appears to be of smaller magnitude than when exposure to noise is continuous.

CHAPTER III

EXPERIMENTAL PROCEDURE

This chapter contains five sections. The first section describes the subjects employed in this study. The equipment used is presented in the second section. The third section presents the test environment. The fourth section deals with a description of the test procedures and experimental groups. The final section discusses the method of data analysis.

Briefly, in this study forty young normal hearing subjects, 20 males and 20 females, were exposed to 60 minutes of rock and roll music in a sound field at 110 dB sound pressure level (SPL). The subjects were divided into two groups. One group of 20 subjects was exposed to the stimulus for 60 minutes continuously with no "off" times. The other group of 20 subjects was exposed to the same stimulus for 60 minutes intermittently with 4-6 minute "on times followed by 30 second "off"

times. Thus, the total time subjects in the intermittent group were in the test room was 65 minutes since the 30 second "off" periods were interspersed in the 60 minutes of exposure to the music. Bekesy audiometry was employed to obtain pre-exposure threshold measurements and four post-exposure measurements at 2, 30, 60 and 90 minutes following exposure.

Subjects

A total of forty subjects, twenty males and twenty females with an age range from 18 years and 6 months to 24 years and 9 months and a mean age of 21 years and 6 months, were used in this study. Most of the subjects were students at Michigan State University. All subjects had normal hearing as determined by pure-tone air-conduction screening audiometry conducted bilaterally at 20 dB hearing level (re ISO 1964) at octave intervals 250 through 8000 Hz plus the half octave at 3000 Hz. Subjects obtaining thresholds poorer than 20 dB ISO at any of the test frequencies were not used.

In addition, each subject used in this study met the following criteria:

- 1) There was no familial history of congenital hearing loss or a history of middle ear problems.
- 2) The subject had never been in the armed forces or discharged firearms frequently.
- 3) The subject had never worked in a noisy environment such as a factory with high noise levels.
- 4) The subject had not listened to loudly played rock and roll music 48 hours prior to participating in this study.

Precautions were taken to insure that no subject was aware of the type of stimulus to be employed prior to the actual exposure in order that individuals who disliked rock and roll music would be included in this study.

Equipment

The following equipment was utilized for the presentation of the auditory stimulus and the measurement of pre-exposure and post-exposure thresholds:

Speech Audiometer	(Grason-Stadler, Model 162)
Loudspeaker	(Altec, Model 612A "417B-12", 100 watt capacity)
Tape Recorder	(Ampex 601)
Bekesy Audiometer	(Grason-Stadler, Model E800)
Earphones	(Telephonics, Model TDH 39-10Z)
Earphone Cushion	(Model MX 41/AR)

In addition, the following equipment was employed for calibration:

Sound Level Meter	(Brue1 and Kjaer, Type 2203)
Octave Band Filter Network	(Brue1 and Kjaer, Type 1613)
Artificial ear	(Brue1 and Kjaer, Type 4152)
Condensor Microphone	(Brue1 and Kjaer, Type 4132 used in conjunction with the artificial ear)
Condensor Microphone	(Brue1 and Kjaer, Type 4131 used for sound field measurements)

To accomplish pure-tone testing a Bekesy, Model E800, sweep frequency audiometer was used to drive TDH-39 transducers housed in Mx 41/AR biscuit type cushions.

A commercially available speech audiometer (Grason-Stadler, Model 162)was employed in conjunction with the tape recorder (Ampex 601) to present the taped stimuli. The output of the speech audiometer was used to drive the loudspeaker.

The equipment was calibrated prior to and following the experiment. The Bekesy E800 Audiometer used for determining air conduction thresholds was calibrated by using the sound level meter and its associated octave band filter network. The TDH-39 earphone was connected to the 6cc coupler of

the artificial ear and this in turn was coupled to the sound level meter. The output of the audiometer was checked at a 60 dB attenuator setting.

The speech audiometer was calibrated so that audiometric zero was equivalent to 20 dB above 0.0002 dyne/cm^2 in the sound field at the position of the center of the subject's head where the subject would enter the sound field. Calibration of this system was accomplished by using speech spectrum noise which was fed into a loudspeaker in the sound field while the speech audiometer was set at 60 dB on the audiometer dial. This procedure was recommended by Tillman, Johnson and Olsen.¹ Thus, the loudspeaker was calibrated to 20 dB SPL re zero on the speech audiometer attenuator dial. All measurements were made with the experimenter observing the sound level meter readings from the control room.

¹Tom W. Tillman, Robert Johnson and Wayne O. Olsen, "Earphone verses Sound Field Threshold Sound-Pressure Levels for Spondee Words," Journal of the Acoustical Society of America, 39, (1966), pp. 125-133.

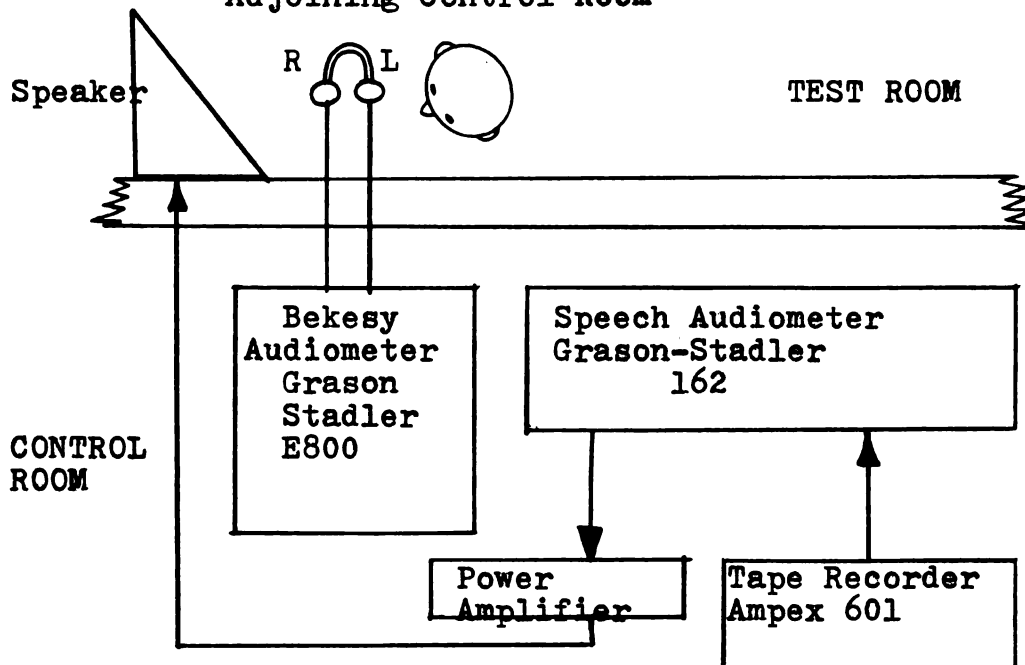
The intensity of the exposure stimulus (tape recorded rock and roll music) was checked daily to ascertain that the overall level averaged 110 dB SPL in the sound field. Since some investigators have reported sound pressure levels of rock and roll music greater than the average level of 105 dB SPL as reported in Chapter II, a sound pressure level of 110 dB was selected for the presentation of the rock and roll music employed in this study.

No systematic differences were found during the conduction of this study in the calibration of the speech audiometric system or the Bekesy audiometer, nor were there systematic differences in the signal level of the exposure stimulus (rock and roll music).

Test Environment

The test room (pre-fabricated double-walled IAC room with a pre-fabricated single wall IAC control chamber) and all audiometric equipment were located in the Audiology and Speech Sciences building at Michigan State University. Ambient noise level in the test chamber was found to be 45 dB on the C-Scale of the Bruel and Kjaer Sound

Figure 2.--A Schematic Diagram of Test Room and Adjoining Control Room



Level Meter. A schematic diagram of the test room and adjoining control room are shown in Figure 2.

During all audiometric testing and exposure periods, the subject was seated in the test room. All of the audiometric equipment was situated in the adjoining control room. The subjects were monitored by means of a window and a two-way electronic communication system.

Test Procedures and Experimental Groups

Pre-exposure thresholds were determined monaurally by means of discrete frequency Bekesy audiometry. Each subject was given the following instructions:

As soon as you hear the tone, press the button. When the tone is just no longer audible, release the button.

Each subject was given sufficient practice to insure that he or she could accomplish the threshold tracing task correctly.

Following the determination of pre-exposure thresholds at octave intervals 250-8000 Hz and the half octave 3000 Hz, the taped music was played in the sound field at 110 dB SPL for 60 minutes. The subject was oriented so that the test ear was at an azimuth of 45 degrees from the diaphragm of the loudspeaker. The exposure stimulus included two tape recordings of rock and roll music played by a nationally known rock and roll combo. One tape consisted of music recorded continuously with no breaks between selections and the other consisted of identical selections with 4-6 minute "on" times followed by 30 second "off" times. The variance

in the "on" times of intermittently recorded rock and roll music resulted from recording either one long selection or two short songs with no break in between, which lasted for a duration of 4-6 minutes.

During exposure the subject was required to sit quietly in the test room. No activity other than listening was allowed during exposure. In other words, subjects were not permitted to study, knit, sleep, etc. during the exposure period.

Post-exposure thresholds were determined monaurally in the same ear as the pre-exposure audiogram at the following frequencies: 250, 500, 1000, 2000, 3000, 4000 and 8000 Hz.

The first post-exposure thresholds were determined two minutes after exposure. The pre-exposure instructions mentioned earlier concerning threshold tracing were repeated for the subject. The second, third and fourth post-exposure thresholds were measured 30, 60 and 90 minutes, respectively, following the exposure.

The subjects were divided into two experimental groups according to the type of stimulus exposure they received--continuous or intermittent. Each group was further sub-divided

by sex into equal sub-groups with ten subjects in each group. Thus, there were a total of four sub-groups. Within each group of twenty (continuous and intermittent) and each sub-group of ten (male and female), the starting frequency for post-exposure thresholds was rotated in the following manner:

Group I--Intermittent Exposure				Group II--Continuous Exposure			
Subj#	Freq.	Subj#	Freq.	Subj#	Freq.	Subj#	Freq.
Male		Female		Male		Female	
1	250	2	250	3	250	4	250
5	500	6	500	7	500	8	500
9	1000	10	1000	11	1000	12	1000
13	2000	14	2000	15	2000	16	2000
17	3000	18	3000	19	3000	20	3000
21	4000	22	4000	23	4000	24	4000
25	8000	26	8000	27	8000	28	8000
29	250	30	250	31	250	32	250
33	500	34	500	35	500	36	500
37	1000	38	1000	39	1000	40	1000

For each subject the same test order concerning frequency was used for all post-exposure measurements.

During the time between post-exposure threshold measurements, all subjects were required to remain in the building housing the Auditory Research

Laboratory. They were free to study or engage in quiet activity while awaiting to be re-tested.

Statistical Analysis

Each of the subject's four post-exposure thresholds were compared with the pre-exposure thresholds. The threshold shifts of the two groups were compared as well as the shifts of the sub-groups, male and female.

A three way analysis of variance was employed to determine whether to accept or reject the null hypotheses proposed at the outset of this study. It was used to determine if the mean TTS of Group I (continuous) and Group II (intermittent) were significantly different at a .05 level of confidence. It was also employed to determine whether the TTS of females differed significantly from the TTS of males at the .05 level of confidence, and whether TTS 2, TTS 30, TTS 60 and TTS 90 differed significantly from one another at the .05 level of confidence.

Descriptive statistics included a measure of central tendency (the mean) and a measure of variance (the standard deviation).

CHAPTER IV

RESULTS AND DISCUSSION

In order to investigate the variables presented in the null hypotheses at the outset of this study, various statistical measures, including a three way analysis of variance are employed. In brief summary, the null hypotheses are as follows: (1) there are no significant differences between the mean TTS of subjects exposed to 60 minutes of continuously played rock and roll music and the mean TTS of subjects exposed to 60 minutes of intermittently played rock and roll music; (2) under identical exposure conditions, there are no significant differences between the mean TTS of males and the mean TTS of females; and (3) there are no significant differences between TTS 2, 30, 60 and 90. The results obtained are presented below.

Descriptive Statistics

A summary of the TTS obtained is shown in Table 1. The measure of central tendency employed to describe the data was the mean. The measure of variance employed was the standard deviation. The ranges are also reported. The means, standard deviations and ranges shown in Table 1 represent an average of all of the four post-exposure measurements for the total sample of 40 subjects.

Table 1.--TTS means, ranges and standard deviations in dB averaged for four post-exposure periods. (N=40)

Freq.	Mean	Range	Standard Deviation
250 Hz	- .71	-12 to 8 (20)	3.90
500 Hz	1.23	- 6 to 14 (20)	3.59
1000 Hz	3.23	- 7 to 22 (29)	5.16
2000 Hz	5.27	- 9 to 27 (36)	6.95
3000 Hz	10.57	-17 to 45 (62)	10.14
4000 Hz	17.09	- 4 to 62 (66)	12.95
8000 Hz	6.34	-10 to 49 (59)	10.49

Table 1 shows the mean TTS combined for 2, 30, 60 and 90 minutes. The subjects exhibiting the least and the most TTS at any of the four post-exposure times compose the range. The negative

numbers indicate that the subject's post-exposure threshold for that frequency at either TTS 2, 30, 60 or 90 was lower (better) than the pre-exposure measurement. The standard deviation is also combined for all four post-exposure periods.

It can be seen in Table 2 that the mean temporary threshold shifts become progressively larger through 4000 Hz. The standard deviation also increases as a function of frequency through 4000 Hz. The **range** too becomes progressively larger through 4000 Hz. The average TTS across all seven frequencies is 6.15 dB. The scores range from -17 dB to 62 dB of TTS. At 3000 and 4000 Hz, two minutes following exposure, individuals varied as much as 50 dB in the resulting TTS. These large differences in TTS suggest individuals vary in susceptibility to noise-exposure.

Mean TTSs were compiled across the variables of sex, condition (continuous and intermittent) and time (TTS 2, TTS 30, TTS 60 and TTS 90) at seven frequencies (250, 500, 1000, 2000, 3000, 4000 and 8000 Hz). These data are shown in Tables 2, 3, and 4.

Table 2.--Mean TTS in decibels as a function of time. (N=40)

		250	500	1000	2000	3000	4000	8000
TTS 2	-	.03	3.58	7.40	12.18	17.73	25.95	13.08
TTS 30	-	.43	1.43	2.65	4.63	10.13	16.15	6.00
TTS 60	-	.95	.28	1.85	2.53	7.80	13.88	3.70
TTS 90	-	1.45	.38	1.03	1.75	6.63	12.38	2.60

Table 2 reveals systematic differences in mean TTS between all the frequencies tested at all post-exposure intervals. This table shows that at each post-exposure time period (TTS 2, 30, 60 and 90) there is a systematic increase in the amount of TTS as a function of frequency from 250 through 4000 Hz. Further, there is also a systematic decrease in the amount of TTS for recovery times from 2 to 90 minutes at all frequencies tested.

Table 3.--Mean TTS in decibels as a function of condition. (N=40)

	250	500	1000	2000	3000	4000	8000
Continuous	.56	2.10	4.35	7.38	13.60	18.54	6.85
Intermittent	-1.99	.35	2.11	3.16	7.54	15.63	5.84

Table 3 shows differences in TTS between the continuous and intermittent exposure conditions. TTS resulting from the intermittent is less than for the constant exposure throughout the frequency range.

Table 4.--Mean TTS in decibels as a function of sex. (N=40)

	250	500	1000	2000	3000	4000	8000
Female	-.85	1.29	3.61	5.34	12.51	14.86	4.39
Male	-.56	1.16	2.85	5.20	8.63	19.31	8.30

Inconsistent differences between the TTS of males and females are shown in Table 4.

Inspection of Tables 2, 3, and 4 reveals differences among the TTS data. It is assumed that TTS 2 was a result of the noise stimulus, namely rock and roll music played at a 110 dB sound pressure level for a period of sixty minutes. It is clearly demonstrated that TTS results from exposure to high noise levels.

The mean TTS of subjects exposed to continuously and intermittently played rock and

roll music at each of seven frequencies is shown in Figures 3 through 9. In these figures TTS is plotted as a function of post-exposure measurements at 2, 30, 60 and 90 minutes following exposure. Thus, these figures graphically illustrate the relationship of TTS to two of the variables studied, namely, continuous versus intermittent exposure and post-exposure recovery time.

Figures 3 through 9 illustrate that, in general, at all frequencies and at all recovery times, the continuous exposure condition produced greater threshold shifts than did the intermittent exposure condition. The largest differences were found at 3000 and 4000 Hz at 90 minutes post-exposure. Thus, individuals who were exposed to rock and roll music with no rest periods (off-times) obtained slightly greater threshold shifts than those subjects receiving short (30 second) rest periods. More importantly, however, those exposed with no rest showed slower recovery at 3000 and 4000 Hz. This appears to be one of the most significant findings of this study.

Figure 3.--Mean temporary threshold shift at 250 Hz resulting from an intermittent exposure at 2, 30, 60 and 90 minutes post-exposure.

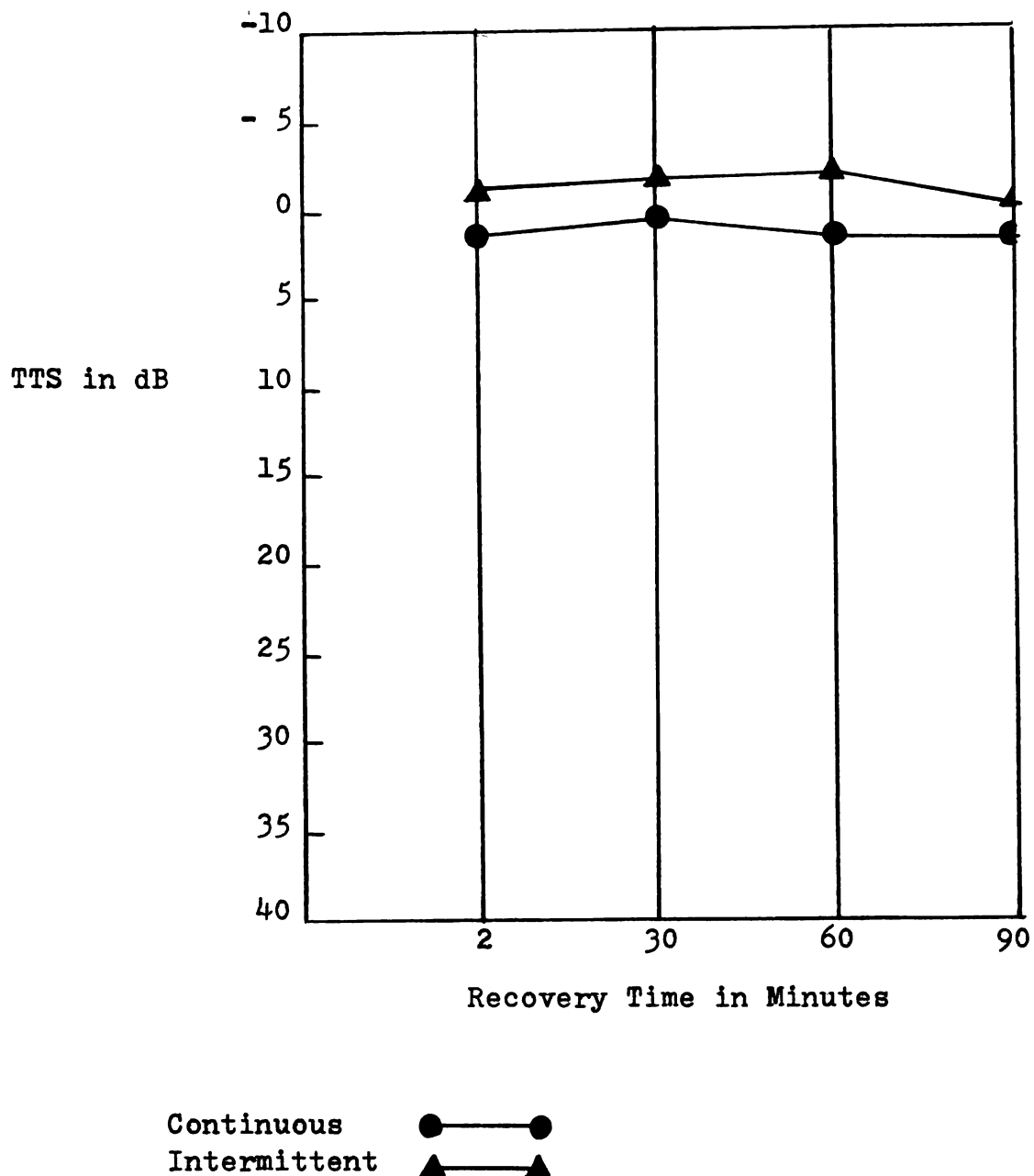


Figure 4.--Mean temporary threshold shift at 500 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure.

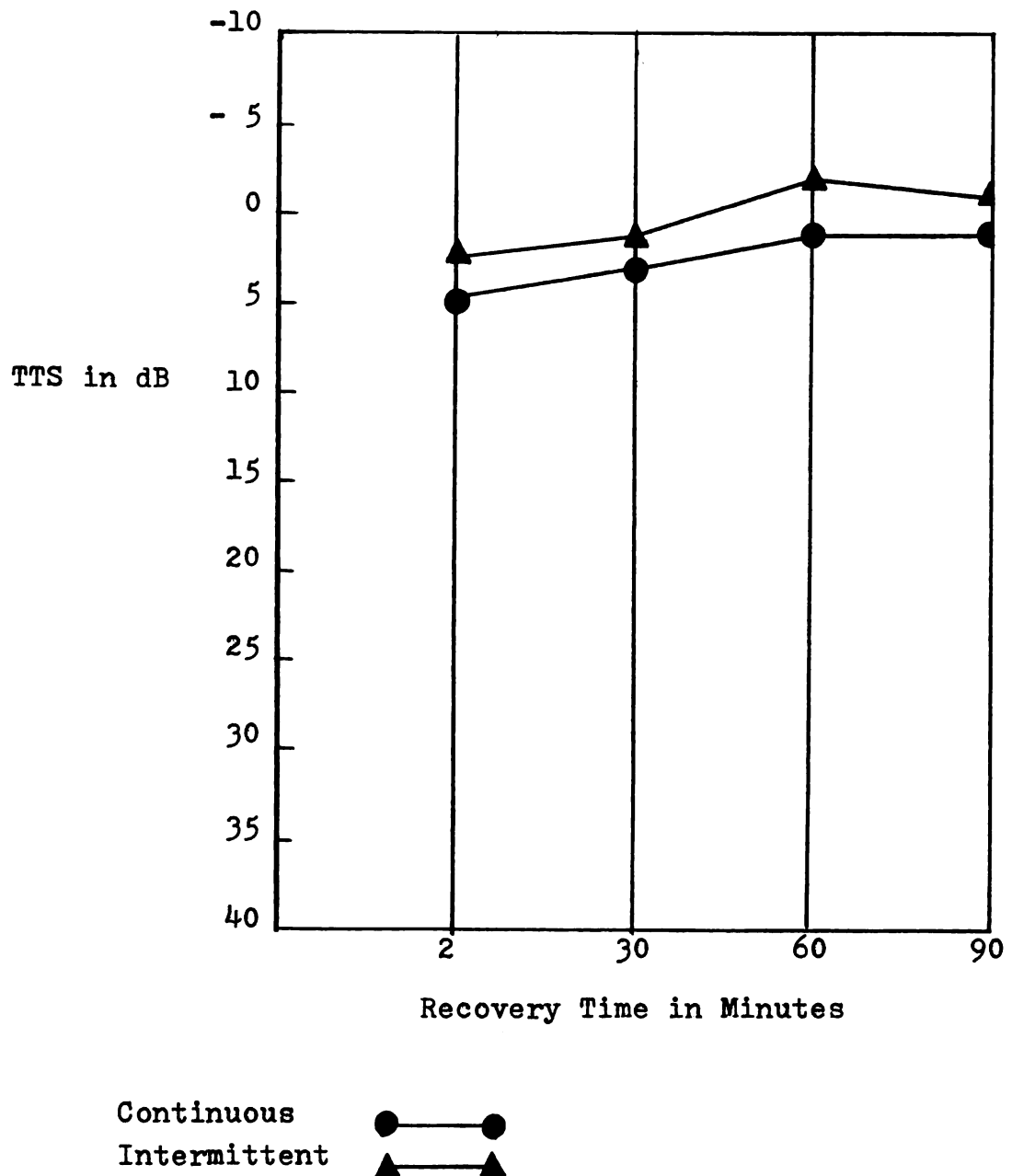


Figure 5.--Mean temporary threshold shift at 1000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure.

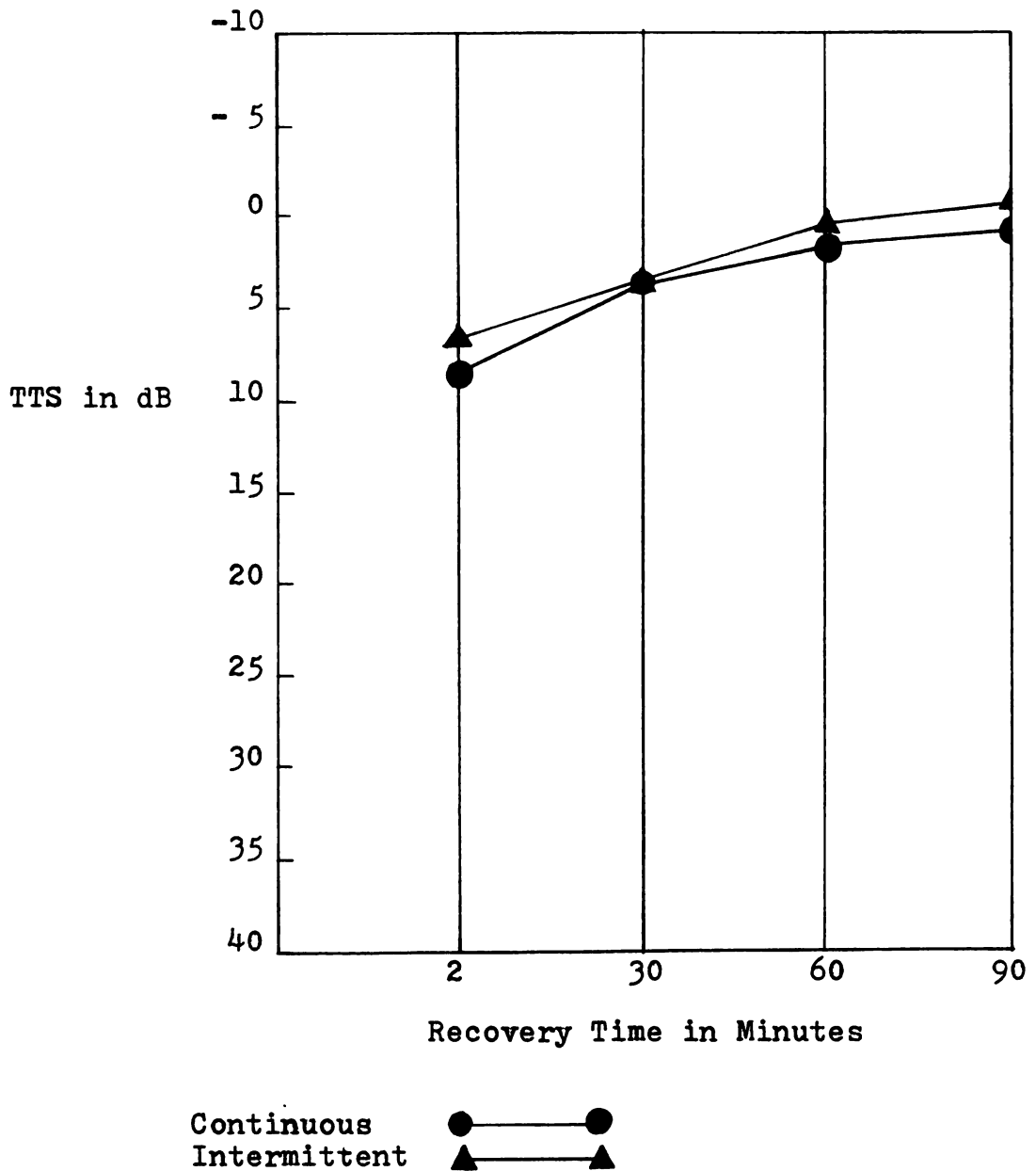


Figure 6.--Mean temporary threshold shift at 2000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure.

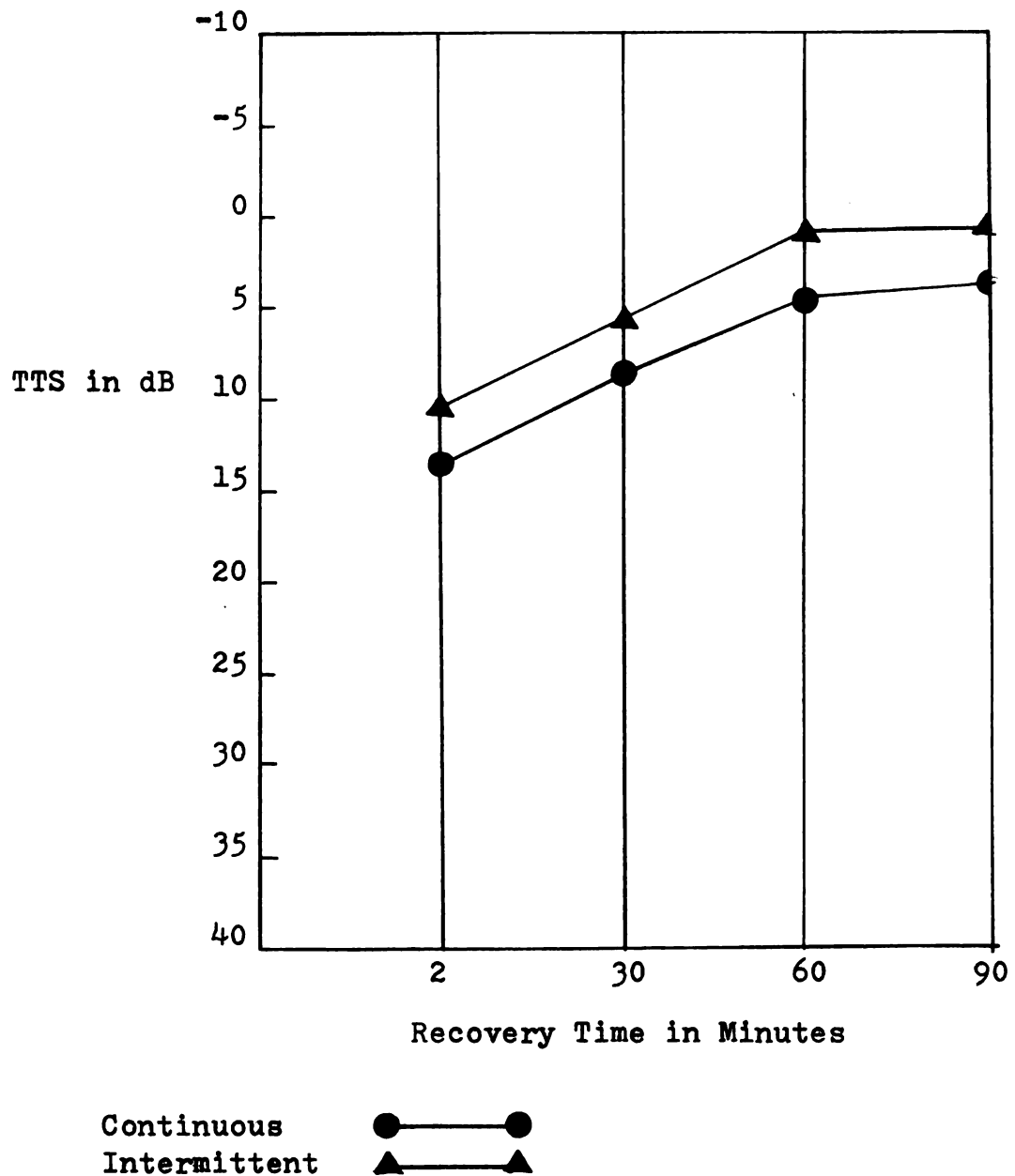
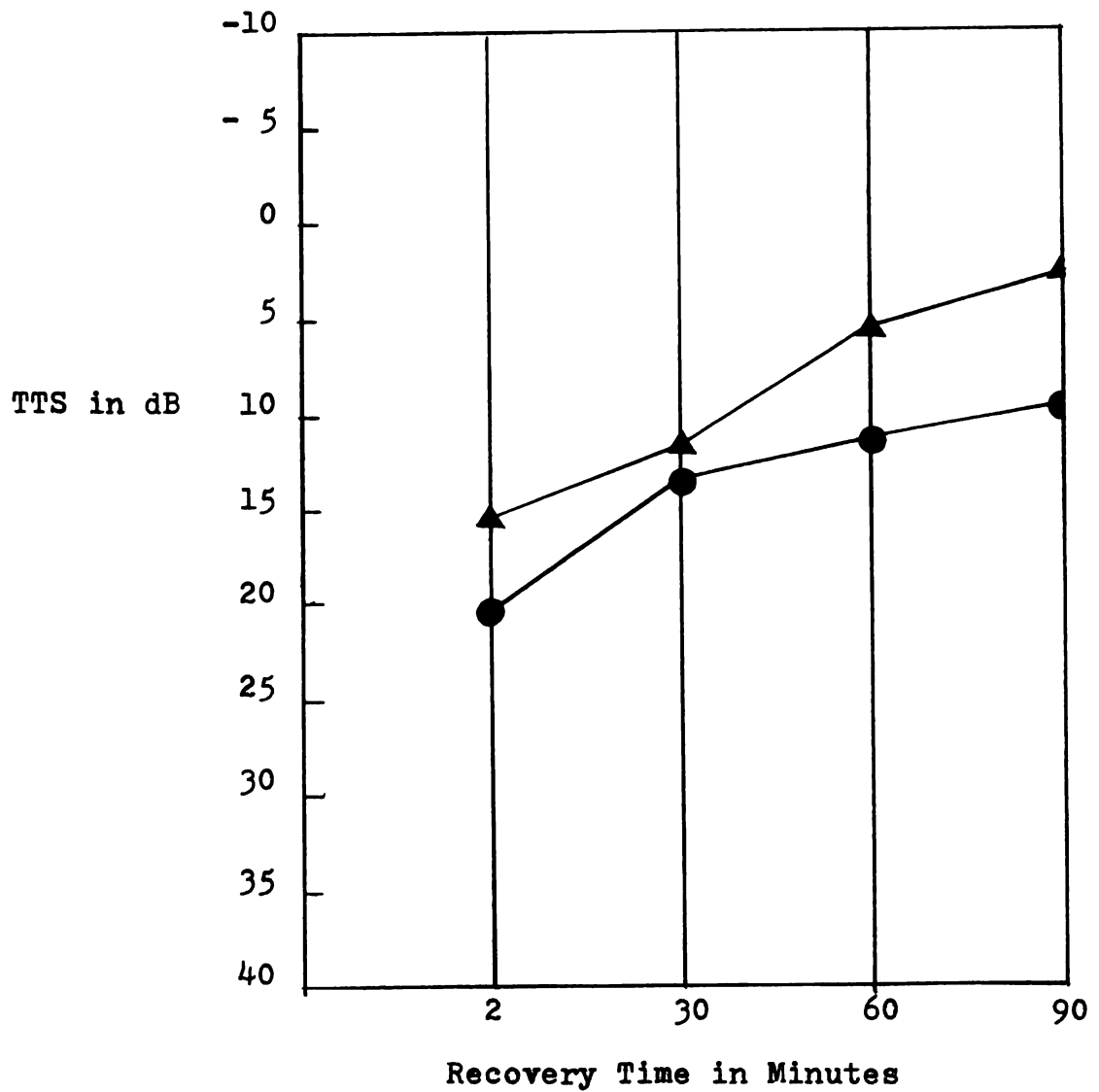
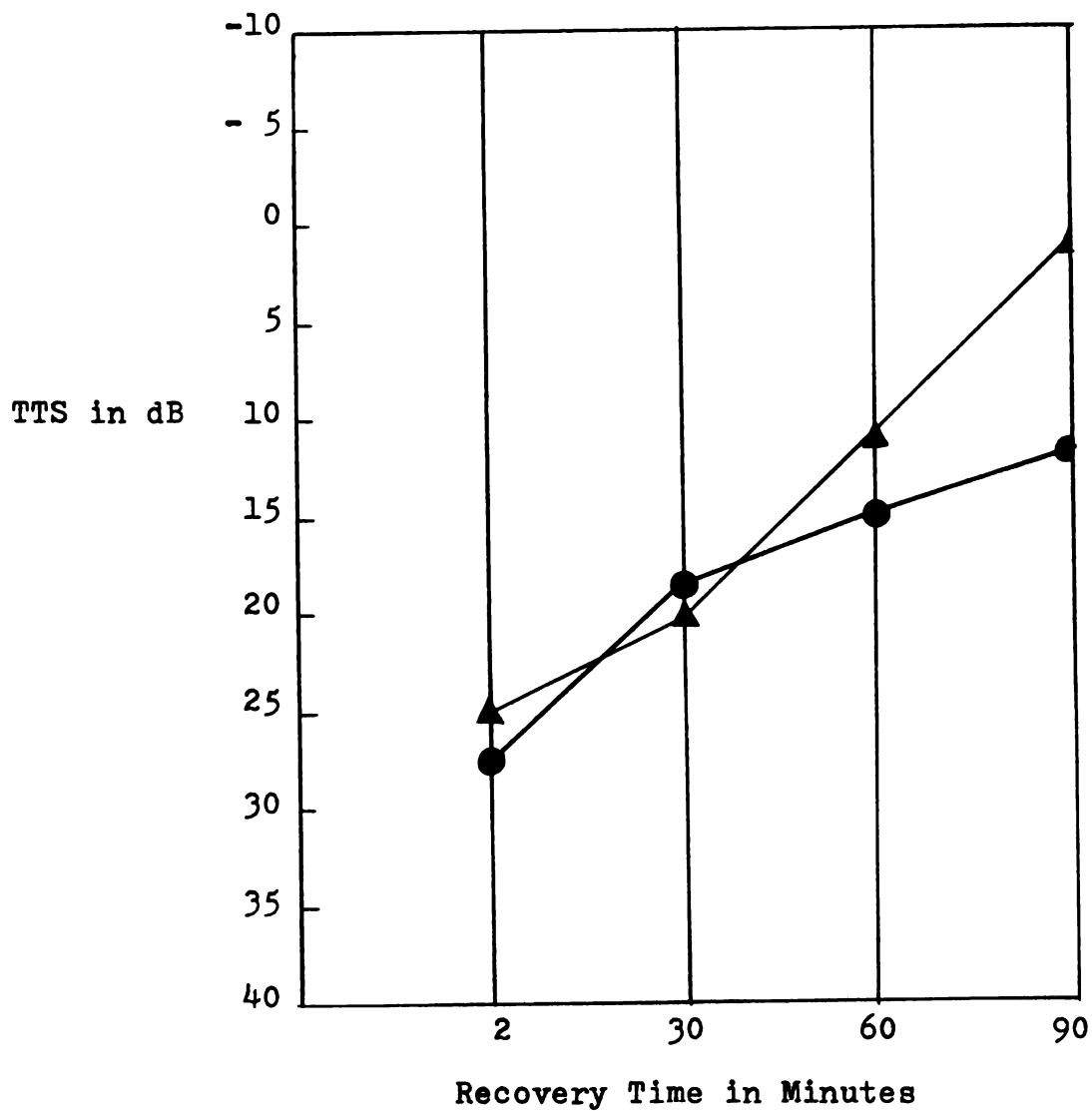


Figure 7.--Mean temporary threshold shift at 3000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure.



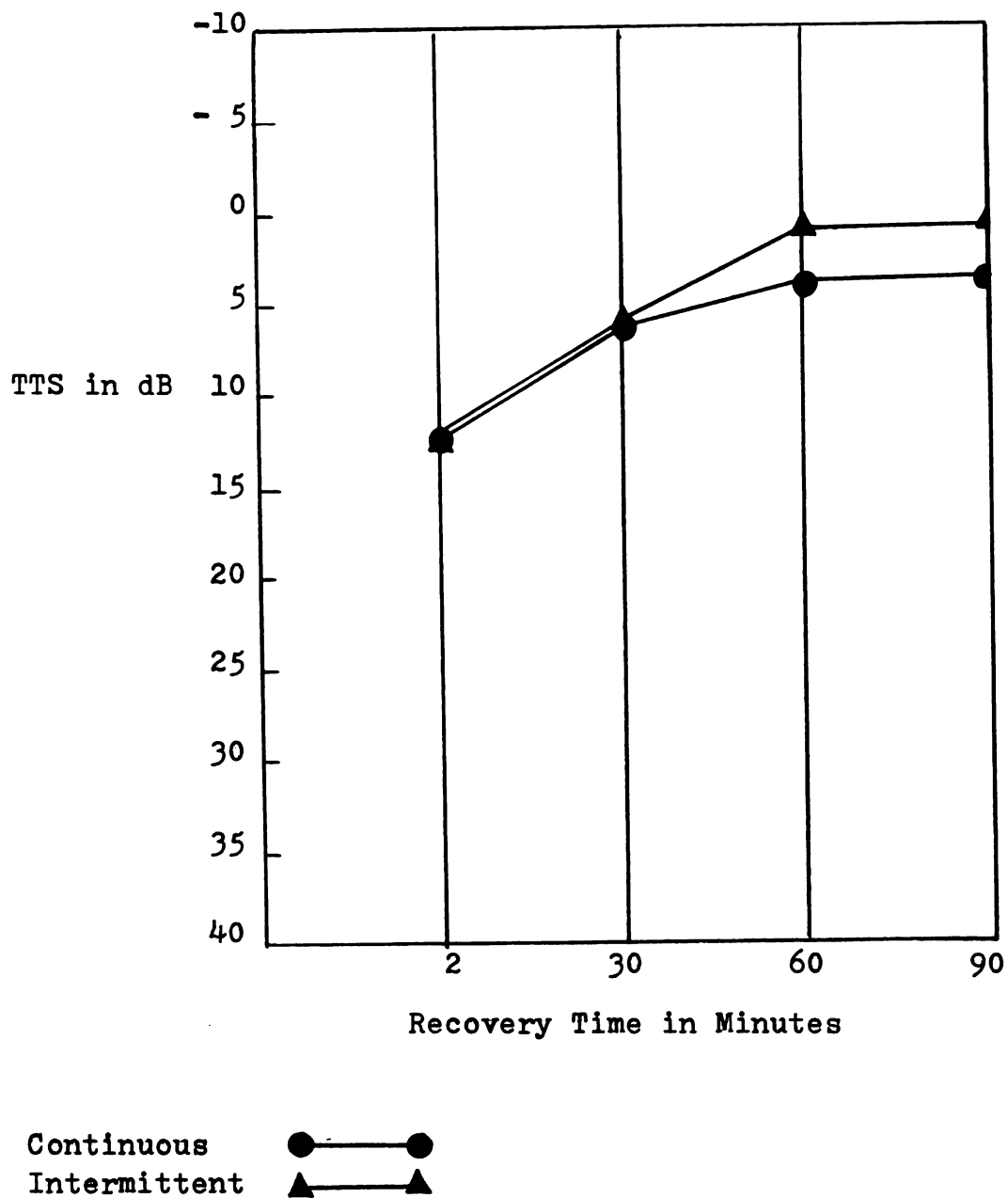
Continuous ● — ●
Intermittent ▲ — ▲

Figure 8.--Mean temporary threshold shift at 4000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure.



Continuous ● — ●
Intermittent ▲ — ▲

Figure 9.--Mean temporary threshold shift at 8000 Hz resulting from continuous and intermittent exposure at 2, 30, 60 and 90 minutes post-exposure.



The data shown in Figures 3 through 9 are summarized in Table 5.

Significance Tests

The null hypotheses were tested by calculating a three way analysis of variance¹ on the obtained results. A three way model was employed for the calculation of three variables at each of the seven frequencies employed.² The individual analysis of variance tables for each frequency are found in the Appendices A through G. Table 6 presents a summary of the analysis of variance at each of the seven frequencies tested.

Table 6 shows significant differences between conditions at 250, 500, 2000 and 3000 Hz at the .05 level of confidence. At 1000 Hz a significant difference between conditions is approached (at the .08 level of confidence.)

¹E. F. Lindquist, Design and Analysis of Experiments in Psychology and Education, (Boston: Houghton Mifflin Co., 1956), pp. 220-253.

²B. J. Winer, Statistical Principles in Experimental Design, (New York: McGraw-Hill Book Co., Inc., 1962), pp. 337-338.

Table 5.--Mean TTS 2, 30, 60 and 90 minutes following exposure
for the groups receiving continuous or intermittent exposure.

Minutes Post-exposure	Frequency in Hz						4000	8000
	250	500	1000	2000	3000			
2	Continuous	.95	4.55	8.75	14.40	19.90	27.40	13.20
	Intermittent	-1.00	2.6	6.05	9.95	15.50	24.50	12.35
30	Continuous	.45	2.75	3.85	7.05	13.45	17.75	5.90
	Intermittent	-1.50	1.50	3.95	6.25	11.95	20.45	6.40
60	Continuous	1.45	1.25	2.95	4.45	10.85	15.80	4.00
	Intermittent	-2.75	-2.75	1.00	.40	4.60	12.10	2.45
90	Continuous	1.00	.85	2.05	3.4	10.05	13.35	4.25
	Intermittent	-2.90	-.80	.00	.10	3.20	11.40	1.45

Table 6.--Summary of F statistics and approximate significance of the F statistic for conditions, sex and time at seven frequencies (250-8000 Hz).

Frequency in Hz	Source of Variance	F Statistic	p
250	Conditions (Cont. vs Intermittent)	7.92015	.008
	Sex	.09211	.763
	Time	2.15181	.098
500	Conditions	4.43194	.042
	Sex	.02261	.881
	Time	25.27667	.0005
1000	Conditions	3.20314	.082
	Sex	.37199	.546
	Time	50.36677	.0005
2000	Conditions	8.14926	.007
	Sex	.00868	.926
	Time	100.80477	.0005
3000	Conditions	6.56863	.015
	Sex	2.70092	.109
	Time	66.91529	.0005
4000	Conditions	.72018	.402
	Sex	1.69577	.201
	Time	142.17833	.0005
8000	Conditions	.13667	.714
	Sex	2.04069	.162
	Time	36.53055	.0005

Gross subject differences in the absolute amount of TTS at a given post-exposure period plus the large variability among subjects in recovery time is a possible explanation for the failure to reach the .05 level of confidence at 1000 Hz. At 4000 and 8000 Hz significant differences between conditions were not found. These high frequencies may be very susceptible to TTS whether the stimulus be continuous or intermittent. As indicated in Table 6, the first null hypothesis concerning continuous versus intermittent exposure is rejected at the .05 level of confidence for frequencies 250, 500, 2000 and 3000 Hz. In other words, at these frequencies continuous exposure to rock and roll music resulted in significantly greater TTS than did intermittent exposure. The first null hypothesis, however, cannot be rejected at 1000, 4000 and 8000 Hz.

According to the data shown in Table 6, no significant differences between the mean TTS of males and females was found. Therefore, results make it necessary to fail to reject the second null hypothesis.

The third null hypothesis regarding post-exposure time intervals is rejected at the .01 level of confidence at 500 to 8000 Hz. Thus, as recovery time increased there was a significant reduction in the amount of TTS from 2 to 90 minutes post-exposure.

Discussion

According to Table 6, the results of the present study do not show significant differences in mean TTS for male and female subjects. Further, no significant differences between male and female mean TTS were noted at any of the individual frequencies (see Appendices A-G). According to the literature, sex differences have been found in some TTS studies³⁻⁴ whereas, in others they have not been observed.⁵

³W. Dixon Ward, Aram Glorig and Diane L. Sklar, "Susceptibility and Sex," Journal of the Acoustical Society of America, 31, No. 8, (August 1959), p. 1138.

⁴Bengt Kylin, "Temporary Threshold Shift and Auditory Trauma Following Exposure to Steady State Noise," Acta-Oto-Laryngologica, Supplement 152, (1960).

⁵W. Dixon Ward, "Temporary Threshold Shift in Males and Females," Journal of the Acoustical Society of America, 40, (1966), pp. 478-485.

At 3000 and 4000 Hz an interaction effect between the variables sex and condition is present. (This can be seen in Appendices E and F.) At the .05 level of confidence, an interaction effect occurring twice out of 28 possibilities can be explained as resulting from chance.⁶

As shown in Table 6, the results of the present study indicate that the mean TTS obtained by exposure to a continuous stimulus is different at the .05 level of confidence from the mean TTS incurred by exposure to an intermittent stimulus at 250, 500, 2000 and 3000 Hz. The TTS at these frequencies resulting from the continuous exposure conditions is systematically greater than the TTS resulting from the intermittent exposure. This finding is in agreement with other reported

⁶David Bakan, On Method, Chap. I: "The Test of Significance in Psychological Research" (San Francisco: Jossey-Bass Inc., 1968), pp.1-30.

investigations.⁷⁻⁹ The largest differences occurred at 3000 Hz.

One investigator found that the TTS produced by intermittent steady-state noise with an on fraction of .50 (30 seconds of noise followed by 30 seconds of quiet) resulted in reduction of 50% in the TTS produced by 1200-2400 and 2400-4800 Hz octave bands of noise.¹⁰

TTS 2, 30, 60 and 90 minutes post-exposure differ significantly from one another at the .01 level of confidence. The mean temporary threshold shifts are greater at two minutes following exposure than at 30, 60 and 90 minutes following exposure. The mean TTS shown at the 30 minute post-exposure measurement is greater than the mean

⁷W. Dixon Ward, "The Use of Temporary Threshold Shifts in the Derivation of Damage Risk Criteria for Noise Exposure," International Audiology, 5, (February 1967), pp. 309-313.

⁸Aram Glorig, "The Effects of Noise on Man," Journal of the American Medical Association, 196, No. 10, (June 6, 1966), pp. 131-134.

⁹W. Dixon Ward, "Auditory Fatigue and Masking," Modern Developments in Audiology, ed. James Jerger, (New York and London: Academic Press, 1963), pp. 240-284.

¹⁰Ward, Journal of the Acoustical Society of America, 34, No. 2, (February 1962), pp. 234-241.

TTS found at the 60 minute measurement and the mean TTS found at the 60 minute post-exposure measurement is greater than the mean TTS shown at the 90 minute post-exposure measurement. Thus, there was a systematic recovery from TTS as a function of time. This finding is not unexpected and agrees with the results obtained in previous studies.¹²⁻¹³

¹¹W. Dixon Ward, "Recovery from High Values of Temporary Threshold Shift," Journal of the Acoustical Society of America, 32, No. 4, (April 1960), pp. 497-500.

¹²W. Dixon Ward, Aram Glorig and Diane L. Sklar, "Temporary Threshold Shift from Octave-Band Noise: Applications to Damage Risk Criteria," Journal of the Acoustical Society of America, 31, No. 4, (April 1959), pp. 522-528.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to compare the mean temporary threshold shift of subjects exposed to continuous and intermittent tape recordings of rock and roll music played at 110 dB SPL in a sound field for a duration of 60 minutes.

Secondary purposes included comparing the mean TTS of males with the mean TTS of females and observing the recovery curves as a function of time from 2 to 90 minutes.

Summary

Forty normal hearing young adults were subjects in this experiment. Twenty of these individuals were males and twenty were females. The age range for the total group was 18 years and 6 months to 24 years and 9 months with a mean age of 21 years and 6 months.

Pre-exposure thresholds were determined monaurally by discrete frequency Bekesy audiometry at 250, 500, 1000, 2000, 3000, 4000, and 8000 Hz.

The taped rock and roll music was played in a sound field for 60 minutes at 110 dB SPL. The exposure stimulus was continuous (no "off" times) for 20 subjects and intermittent (4-6 minute "on" times and 30 second "off" times) for 20 subjects.

Post-exposure thresholds were determined monaurally in the same ear as the pre-exposure audiogram. Thresholds were obtained 2, 30, 60 and 90 minutes following exposure.

Conclusions

Within the limitations of this study, the following conclusions appear warranted:

- 1) There is a significant TTS difference between continuous and intermittent exposure conditions with greater TTS resulting from continuous exposure at 250, 500, 2000 and 3000 Hz.
- 2) There is not a significant difference in TTS between continuous and intermittent exposure conditions at 1000, 4000 and 8000 Hz.
- 3) Recovery from TTS is slower for subjects exposed continuously than for those with brief (30 second) rest periods especially at 3000 and 4000 Hz.

- 4) There is a significant difference between TTS at 2, 30, 60 and 90 minutes following exposure with systematic improvement in threshold occurring as a function of time.
- 5) A general trend was observed for the mean TTS to be progressively larger from 250 through 4000 Hz, under both conditions (continuous and intermittent).
- 6) There is not a significant difference between the mean TTS of males and the mean TTS of females.
- 7) Large individual differences were found among subjects concerning the absolute amount of TTS. This range in amount of TTS among subjects became progressively larger from 250 through 4000 Hz. Of course, this would be expected since the higher frequencies exhibited the most TTS. Differences among individuals regarding susceptibility to noise-induced hearing loss could perhaps explain the variability found among subjects in the amount of temporary threshold shifts.

Recommendations for Further Research

- 1) The present study should be replicated with the following changes. First, a single group of subjects should receive exposure to both the continuous and intermittent conditions. Second, the intermittent condition should be modified so that the "on" time is 2-4 minutes and the "off" time is one minute.
- 2) Additional data needs to be obtained regarding overall SPL that music is played by rock and roll bands.

- 3) Prediction of permanent threshold shift from temporary threshold shift needs to be investigated further. This can probably best be accomplished by a longitudinal study comparing TTS over a period of years with the PTS sustained in that period of time within the same group of subjects.
- 4) Useful information would be provided by comparing thresholds for hearing among two groups of individuals: one group of nonmusicians who frequently listen to rock and roll music played at loud levels and another group of nonmusicians who never or infrequently listen to rock and roll music played at loud levels.
- 5) An interesting additional facet to this problem would be to discover if a relationship exists between an individual's attitude toward loudly played rock and roll music with that individual's TTS.

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

- Ballenger, W. L., Diseases of the Nose, Throat and Ear, Philadelphia and New York: Lea and Fibiger, 1914.
- Kryter, K. D., "Damage Risk Criteria for Hearing," in Noise Reduction, L. L. Beranek, Ed. New York: McGraw-Hill Company, 1960.
- Lindquist, E. F., Design and Analysis of Experiments in Psychology and Education, Boston: Houghton Mifflin Company, 1956.
- Syme, W. S., Diseases of the Nose, Throat and Ear, William Wood and Company, 1927.
- Turner, Al, Diseases of the Nose, Throat and Ear, New York: William Wood and Company, 1924.
- Ward, W. Dixon, "Auditory Fatigue and Masking," in Modern Developments in Audiology, James Jerger, Ed., New York and London: Academic Press, 1963.
- Winer, B. J., Statistical Principles in Experimental Design, New York: McGraw-Hill Company, 1962.

Periodicals

- "Principles for Evaluating Hearing Loss: Council on Physical Medicine and Rehabilitation," Journal of the American Medical Association, 157, (1955), 1408-1409.
- "Front Page News," Sound and Vibration, 1, No. 12, (1967).

"Not Exactly Music to your Ears," Consumer Reports,
(1968), 349.

Time, (August 1968).

"Loud Rock and Roll Music May Cause Deafness,"
Hearing Progress, (Fall-Winter 1967).

"Noise Level Causes Frustration Deafness," The Medical Post, (1969), 21.

Bauer, L. H., Aviation Medicine, (1926), p. 157.

Bunch, C. C., "The Diagnosis of Occupational or Traumatic Deafness; a Historical and Audiometric Study," Laryngoscope, 67, No. 9, (1937), 615-691.

Downs, Marion, Hemenway, W., and Doster, Mildred, "Sensory Overload," Hearing and Speech News, (May-June 1969), 10-11.

Flugrath, James M., "Modern Day Rock and Roll Music and Damage-Risk Criteria," Journal of the Acoustical Society of America, 45, No. 3, (1969), 704-711.

Glorig, Aram, Ward, W. Dixon, and Nixon, James, "Damage Risk Criteria and Noise-Induced Hearing Loss," Archives of Otolaryngology, 74, (October 1961), 413-423.

Glorig, Aram, "The Effects of Noise on Hearing," Journal of Laryngology and Otology, 75, No. 5, (May 1961), 447-478.

Hardy, Howard C., "Tentative Estimate of a Hearing Damage Risk Criterion for Steady-State Noise," Journal of the Acoustical Society of America, 24, No. 6, (November 1952), 756-761.

Harris, J. D., "Hearing-Loss Trend Curves and the Damage-Risk criterion in Deisel-Engineerroom Personnel," Journal of the Acoustical Society of America, 37, No. 3, (March 1965), 444-452.

- Hirsh, I. J. and Ward, W. Dixon, "Recovery of the Auditory Thresholds after Strong Acoustic Stimulation," Journal of the Acoustical Society of America, 24, No. 2, (March 1952), 131-141.
- Kylin, Bengt, "Temporary Threshold Shift and Auditory Trauma Following Exposure to Steady State Noise," Acto-Oto-Laryngologica, Supplement 152, (1960), 1-89.
- Lebo, Charles P., Oliphant, Kenward S., and Garrett, John, "Acoustic Trauma from Rock and Roll Music," California Medicine, 107, (November 1967), 378-380.
- Lipscomb, David M., "High Intensity Sounds in the Recreational Environment," Clinical Pediatrics, 8, No. 2, (February 1969), 63-68.
- Pearson, John F., "Rock and Roll Music Can Be Hazardous to Hearing," Popular Mechanics, (November 1968), 22.
- Quiggle, R. R., Glorig, Aram, Delk, J. H., and Summerfield, A. B., "Predicting Hearing Loss for Speech and from Pure Tone Audiograms," Laryngoscope, 67, No. 1, (1957), 1-15.
- Rintelmann, William F., "Does Rock and Roll Music Harm Hearing," Michigan Hearing, "Summer 1969), 5-13.
- Rintelmann, William F., and Borus, Judith, "Noise-Induced Hearing Loss and Rock and Roll Music," Archives of Otolaryngology, 88, (1968), 377-385.
- Rupp, Ralph R., "Does Rock and Roll Music Harm Hearing," Michigan Hearing, (Summer 1969), 5-13.
- Rupp, Ralph R., and Koch, Larry J., "But, Mother Rock and Roll Music Has to be Loud," The Effect of Noise on Human Ears," Michigan Hearing, (1968), 4-7.

- Swann, C. C., "Effects of Noise on Hearing," International Journal of Medicine and Surgery, 46, (1933), 314.
- Tillman, Tom W., Johnson, Robert and Olsen, Wayne O., "Earphone verses Sound-Field Threshold Sound Pressure Levels for Spondee Words," Journal of the Acoustical Society of America, 39, (1966), 125-133.
- Ward, W. Dixon, Glorig, Aram, and Sklar, Diane L., "Temporary Threshold Shift from Octave-Band Noise: Applications to Damage Risk Criteria," Journal of the Acoustical Society of America, 31, No. 4, (1959), 522-528.
- Ward, W. Dixon, Glorig, Aram, and Sklar, Diane L., "Susceptibility and Sex," Journal of the Acoustical Society of America, 31, No. 8, (1959), 1138.
- Ward, W. Dixon, "Studies on the Aural Reflex II: Reduction of Temporary Threshold Shift from Intermittent Noise by Reflex Activity; Implications for Damage-Risk Criteria," Journal of the Acoustical Society of America, 34, No. 2, (1962) 234-241.
- Ward, W. Dixon, "Temporary Threshold Shift in Males and Females," Journal of the Acoustical Society of America, 40, (1966), 478-485.
- Ward, W. Dixon, "The Use of Temporary Threshold Shift in the Derivation of Damage Risk Criteria for Noise Exposure," International Audiology, 5, (1967), 309-313.

Newspapers

- "Rock and Roll Loudness Not Harmful: Report," Winnipeg Free Press, Winnipeg, Canada, (November 11, 1968).

"Loud, Screaming Music Can Badly Damage Ear," The State Journal, Lansing, Michigan, (June 16, 1968).

Battelle, Phyllis, "Rock Band Noise Level Could Injure Your Child," Chicago Daily News, (July 16, 1968).

Friske, Fred, "No Hearing Loss from Rock and Roll," Washington Daily News, (November 1968), 32.

Myler, Joseph L., "Rock and Roll Music Assayed," The State Journal, (December 12, 1968).

Unpublished Material

Jerger, James, Jerger, Susan, and Pollack, Kenneth, "Temporary Hearing Loss in Rock and Roll Musicians," Unpublished Study, Houston Speech and Hearing Center, 1968.

Ward, W. Dixon, "The Identification and Treatment of Noise-Induced Hearing Loss," Preprint, 1968.

Other Sources

Exploratory Subcommittee Z24-X2 of the American Standards Association Z24 Sectional Committee on Acoustics, Vibration, and Mechanical Shock, "The Relations of Hearing Loss to Noise Exposure," (1954), 5-63.

Kryter, Karl D., "Deafening Effects of Noise," Journal of Speech and Hearing Disorders, Monograph Supplement 1, (September 1950), 27-56.

Kryter, Karl D., "Hazardous Exposure to Intermittent and Steady-State Noise," NAS-NRC Committee on Hearing, Bioacoustics, and Biomechanics, Working Group 46, (January 1965), 1-34.

Kylin, B., "Temporary Threshold Shift and Auditory Trauma Following Exposure to Steady-State Noise," Acta-Oto-Laryngologica, 51, No. 6, Supplement 152, (1960).

Rosenblith, Walter A, and Stevens, Kenneth N., Handbook of Acoustic Noise Control, Volume II Noise and Man, WADC Technical Report 52-204, (June 1953), 1-262.

Subcommittee on Noise of the Committee on Conservation of Hearing: "Guide for Conservation of Hearing in Noise," American Academy of Ophthalmology and Otolarvngology, Revised in 1964.

APPENDICES

APPENDIX A

Analysis of Variance at 250 Hz

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic	Approx. Sig. of F Stat.
A	3.025	1	3.03	.09211	.763
B	260.100	1	260.10	7.92015	.008
AB	72.900	1	72.90	2.21984	.145
C	46.225	3	15.41	2.15181	.098
AC	45.725	3	15.24	2.12853	.101
BC	22.250	3	7.42	1.03575	.380
ABC	8.950	3	2.98	.41663	.741

A is Sex

B is Treatment

C is Time

APPENDIX B

Analysis of Variance at 500 Hz

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic	Approx. Sig. of F Stat.
A	.625	1	.625	.02261	.881
B	122.500	1	122.500	4.43194	.042
AB	1.225	1	1.225	.04432	.834
C	361.000	3	120.333	25.27667	.0005
AC	12.275	3	4.092	.85948	.465
BC	17.00	3	5.667	.19031	.317
ABC	24.075	3	8.025	1.68569	.174

A is Sex

B is Treatment

C is Time

APPENDIX C

Analysis of Variance at 1000 Hz

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic	Approx. Sig. of F Stat.
A	23.256	1	23.26	.37199	.546
B	200.256	1	200.26	3.20314	.082
AB	39.006	1	39.01	.62391	.435
C	979.669	3	326.56	50.36677	.0005
AC	23.369	3	7.79	1.20144	.313
BC	4.669	3	1.56	.24003	.868
ABC	19.319	3	6.44	.99322	.399

A is Sex

B is Treatment

C is Time

APPENDIX D

Analysis of Variance at 2000 Hz

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic	Approx. Sig. of F Stat.
A	.756	1	.76	.00868	.926
B	709.806	1	709.81	8.14926	.007
AB	49.506	1	49.51	.56838	.456
C	2720.819	3	906.94	100.80477	.0005
AC	8.719	3	2.91	.32302	.809
BC	12.969	3	4.32	.48048	.697
ABC	65.569	3	21.86	2.42928	.069

A is Sex

B is Treatment

C is Time

APPENDIX E

Analysis of Variance at 3000 Hz

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic	Approx. Sig. of F Stat.
A	604.506	1	604.51	2.70092	.109
B	1470.156	1	1470.16	6.56863	.015
AB	1494.506	1	1494.51	6.67743	.014
C	2985.119	3	995.04	66.91529	.0005
AC	13.469	3	4.49	.30192	.824
BC	40.119	3	13.37	.89931	.444
ABC	60.069	3	20.02	1.34652	.263

A is Sex

B is Treatment

C is Time

APPENDIX F

Analysis of Variance at 4000 Hz

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic	Approx. Sig. of F Stat.
A	792.100	1	792.10	1.69577	.201
B	336.400	1	336.40	.72018	.402
AB	3080.025	1	3080.02	6.59387	.015
C	4478.025	3	1492.67	142.17833	.0005
AC	2.650	3	.88	.08414	.969
BC	14.150	3	4.72	.44927	.718
ABC	9.825	3	3.28	.31195	.817

A is Sex

B is Treatment

C is Time

APPENDIX G

Analysis of Variance at 8000 Hz

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Statistic	Approx. Sig. of F Stat.
A	612.306	1	612.31	2.04069	.162
B	41.006	1	41.01	.13667	.714
AB	596.756	1	596.76	1.98886	.167
C	2657.319	3	885.77	36.53055	.0005
AC	80.519	3	26.84	1.10690	.350
BC	77.819	3	25.94	1.06979	.365
ABC	25.869	3	8.62	.35562	.785

A is Sex

B is Treatment

C is Time

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03175 0502