ROCK AND ROLL MUSIC AND ITS EFFECTS UPON HUMAN HEARING

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WILLIAM MICHAEL JOHNSON

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ABSTRACT

ROCK AND ROLL MUSIC AND ITS
EFFECTS UPON HUMAN HEARING

By

William Michael Johnson

This study consisted of four parts: (1) an acoustical analysis of ten rock and roll groups and four marching bands; (2) threshold measurements on six musicians exposed to rock and roll music for a period of approximately seven years; (3) temporary threshold shift (TTS) measurements of five musicians after playing rock and roll music for an entire evening; and (4) an evaluation of attitudes of two groups of 25 young adults towards loudly played rock and roll music.

Results from the first part of this study showed that the mean SPL of the rock and roll music was 104.6 dB Linear, 103.5 dBC, and 98.1 dBA. The spectral distribution was fairly flat from the low to mid frequency region, 2000 Hz, with a reduction in the higher frequencies. The marching bands produced a mean SPL of 92.7 dB Linear, 91.9 dBC, and 84.8 dBA.

Pure-tone air-conduction thresholds at 125, 250, 500, 1000, 2000, 3000, 4000, and 8000 Hz were determined for the six rock and roll musicians. Measurements revealed no substantial changes in the auditory thresholds in five

out of six musicians from thresholds measured approximately seven years earlier.

Pure-tone air-conduction thresholds at octave intervals from 250 through 8000 Hz with the half octave of 3000 Hz demonstrated no greater than 10 dB of TTS in the group of five rock and roll musicians after completing an evening of performance.

Results from the fourth part of this study revealed group differences concerning opinions on the loudness of rock and roll music. The majority of group one, consisting of musicians and young adults attending a rock concert, felt rock music to be just right in loudness while the majority of the second group, which consisted of students attending a college lecture, stated rock and roll music was too loud. The remaining questions given showed no substantial differences between the two groups.

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

Linda L. Smith

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A THESIS

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INTRODUCTION

There have been many suppositions that rock and roll music performed at high intensity levels produces a noise-induced hearing loss. Yet, relatively few studies have been accomplished to determine the effects of loud music on the human hearing mechanism. The majority of these speculations have been based upon damage risk criteria applied to steady state noise[1] in an industrial setting.

Though many of these speculations were made in recent years, Lebo et al. (1967), Lebo and Oliphant (1968), Downs et al. (1969), Lipscomb (1969), Flugrath (1969), Rupp and Koch (1969), Dey (1970), and Jerger and Jerger (1970), there is still a considerable amount of interest concerning rock and roll music played at high intensity levels.

Considerable attention has been focused on rock and roll music performed at high intensity levels and its effects on the human hearing mechanism when performed at high intensity levels. Numerous newspaper and magazine articles have been published regarding these effects. One such

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[1]Kryter defined steady state noise as follows: the spectrum of sound is complex (i.e., does not consist of merely a single or even solely several pure tones) and that in the time domain its over-all intensity, measured by a typical sound-level meter, is steady within a few decibels for at least one minute (1963, p. 1516).

article was published in The State Journal (1968) where a researcher from Memphis State University stated that we may be raising a nation of teenagers who will become hard of hearing due to rock and roll music. Contrary to this, Rintelmann and Borus (1968) noted that the concern over the harmful effects of rock and roll music on the hearing of young people appears to be unwarranted.

Since the Rintelmann and Borus investigation, it has been speculated that hearing loss might occur from loudly played music but such a loss might not be manifested until several years have lapsed. To determine the long-term effects of loud music, pure-tone thresholds were measured on a small sample of musicians over an approximate seven year period. Short term effects of rock and roll music were also assessed by obtaining thresholds of musicians prior to and immediately following a performance of a rock and roll group. Finally, an effort was made to obtain current opinions from rock and roll musicians and listeners regarding their attitudes toward rock and roll music.

PURPOSE OF THE STUDY

The primary purpose of this study was to investigate the acoustic aspects of rock and roll music and music played by marching bands.

Secondary purposes were to evaluate the effects of rock and roll music on long-term pure-tone thresholds among musicians, temporary threshold shifts among musicians, and finally attitudes of young adults toward loudly played rock and roll music.

With reference to the purposes stated, answers were sought to the following specific questions:

1.) Are there differences in the acoustic analysis obtained in the present study from those obtained in previous studies?

2.) Is there a substantial difference between rock and roll music and marching band music when analyzed acoustically?

3.) Is there a change in auditory thresholds of musicians who have been in contact with rock and roll music over a period of several years?

4.) How much temporary threshold shift (TTS) results from playing in a rock and roll group for an entire evening?

5.) What are the attitudes of individuals attending a rock concert towards loudly played music, and further, do these attitudes differ from individuals who are not attending the concert?

REVIEW OF THE LITERATURE

Encompassed within this section is a review of the literature focusing upon three primary factors: (1) a historical account of noise and its possible effects upon the hearing mechanism; (2) a description of some proposed damage risk criteria; and (3) a review of research regarding rock and roll music and its possible effects upon the hearing mechanism.

Historical Summary of Noise Effects:

A historical survey of studies dealing with occupational deafness was presented by Bunch (1937). Results of histological and audiometric studies were also given. Several studies demonstrated that hearing losses concentrated in the high frequency region occurred when workers were exposed to various types of noise. Interest in noise and its effects on hearing was demonstrated as far back as the early 1800's. Fosbroke, cited by Bunch (1937, p. 618) was the first to disclose the problems of hearing as they related to noises within the working environment with the description of "blacksmith's deafness", in 1831. The working environment of boilermakers was examined in 1872 by Dalby, (Bunch, 1937, p. 619) who theorized that hearing losses resulted from working under these conditions. Hartman in 1887 (Bunch, 1937, p. 619) looked into this even further by attempting to characterize the type of hearing loss common among boilermakers. He stated that bone conduction is substantially reduced with the two highest tones not being heard at all. Thus, he deducted that injurious action of the noises in boiler shops is primarily focused upon those portions of the hearing mechanism which serve for the perception of the higher tones.

Larsen (1939) examined the hearing losses among workers in the Danish shipyard and machine factories. His findings disclosed that the degree of hearing loss was enhanced substantially with increasing duration of work and progressing age. He also found that the most extensive hearing loss was established around 4000, 6000, and 8000 Hz in boilermakers who had been unprotected from these intense low-frequency noises for more than fifteen years.

Another study dealing with occupational deafness considered employees of a metal working plant. McCoy (1944) found that after workers were exposed to the noise for twelve months the hearing loss was somewhat greater than when exposed for only one month.

Cox, Mansur, and Williams (1953) investigated weaving room employees of a cotton textile plant in regards to the pattern of hearing loss. They found that losses occurred at 2000 and 4000 Hz and that when these employees were removed from these noisy conditions for at least 40 hours there was partial recovery of hearing loss. Goldner (1953), also concerned with the pattern of hearing losses, studied 600 employees of a shipyard. He found that hearing losses primarily occurred at 4000 and 8000 Hz. He also found that the degree of deafness increased considerably with advancing age and increasing duration of work.

A report concerning the effects of noise exposure on hearing was published by a sub-committee of the American Standards Association in 1954. This report signified that intermittent and continuous exposure to noise yielded losses of hearing that centered primarily at 4000 Hz with slightly less hearing loss at 2000 and 8000 Hz. It was also noted that for those individuals exposed to continuous noise, there appeared to be a greater loss in hearing sensitivity.

Webster (1954) conducted a study involving aviation overhaul and repair shop personnel. He tested the hearing of these workers and found that hearing losses occurred primarily in the higher frequencies and that the amount of hearing loss increased with the advancing age of the worker.

Rosenwinkel and Stewart (1957) directed a study where they related the audiograms of two types of workers to the amount of time they worked on the job. The two types of workers used were 290 office workers and 270 workers in a large machine shop. To control the age factor they used workers with the same distribution of ages. They found that differences between the hearing losses of the machine shop workers and the office workers at 4000 Hz illustrated that exposure to steady-state noise exceeding 80 dB can bring about a measureable reduction in hearing sensitivity over a normal working life span.

A study conducted concerning exposure to noise in prison industries was reported by Yaffe and Jones (1961). This study demonstrated that a pronounced hearing loss at 3000, 4000, and 6000 Hz could result from noise exposure within the prison industry.

In general, the preceeding studies concerned with both configuration of hearing loss and the age factor have demonstrated that hearing losses were found primarily in the higher frequencies and the amount of loss increased with advancing age.

Noise Induced Permanent Threshold Shifts and Noise Induced Temporary Threshold Shifts were correlated in a study by Glorig, Ward, and Nixon (1961a). They submitted: "We have assumed, on the basis of limited PTS evidence but considerable TTS data, that if no more than 12 dB TTS at 2000 cps accumulates during a work day, no significant PTS will occur during a work life" (1961a, p. 423). They further stated that, "We believe that when TTS is allowed to recover before further exposure, there will be no significant PTS over a usual work life" (1961a, p. 422). Glorig, Ward, and Nixon (1961b) examined the problem of noise exposure and its effects upon TTS. They noted that when continually exposed to octave bands of noise of 75 to 78 dBA for a period of eight hours, no significant TTS in hearing was present at 4000 Hz, the frequency most prone to noise-induced hearing loss.

The Committee on the Problem of Noise (1963) examined noise within social or domestic locations. This committee concluded that noise within these situations did not produce any measureable effects other than occasional aggravation from the average person or continuous complaining from exceptional individuals. These exceptional individuals who continuously complain about noise are according to Borsky "hypersensitive cranks who represent at most 1 - 2% of the population" (1969, p. 190). These individuals complain about a variety of things such as the "state of city sewers". In other words, for some people little can be done to rectify the situation.

Rosen, Plester, El-Mofty and Rosen (1964) compared the hearing of individuals making-up "modern society" to the hearing of those in a primitive society. They demonstrated that members of a primitive culture who were free of significant noise sources had superior hearing sensitivity compared to the so called "normal" hearing members of the modern culture.

Taylor and Williams (1966) compared the hearing status of sport hunters who had used assorted shot guns, rifles, and handguns to the hearing status of a control group who had limited exposure to intense noise. They found that the sport hunters revealed poorer hearing, as averaged across all ages, than the control group.

Passchier-Vermeer (1968) examined a vast amount of data that was taken from a large number of noise and hearing surveys in the industrial environment. He found that 75% of the workers exposed to 75 dBA of noise eight hours per day for ten years or more, showed less than six dB change in hearing sensitivity for the frequencies from 3000 to 8000 Hz.

A study comparing the effects of brief noise versus continuous noise was completed by Sataloff, Vassallo, and Menduke (1969). They demonstrated that when brief noises occurred 40 times per day in otherwise quiet conditions there would be the same type of hearing impairment as that caused by a continuous noise that was 15 to 20 dBA lower in intensity.

Through the previous historical account of noise and its possible effects upon the hearing mechanism, it can be stated that, in general, when an individual is exposed to intense levels of noise for a relatively prolonged period of time he will eventually incur a loss in hearing sensitivity. This loss will primarily involve the higher frequencies, and will be greater if the noise is continuous as opposed to intermittent.

Some Proposed Damage Risk Criteria:

Since numerous studies have used damage risk criteria in an attempt to predict permanent hearing loss, it is appropriate to review some of the proposed criteria.

Kryter (1950) investigated problems of safe and unsafe noise conditions, or damage risk criteria, (intensity limits of noise that can be tolerated without serious risk of permanent hearing loss). He suggested a maximum sound pressure level that would be considered a safe noise condition. Kryter stated:

> A fair, perhaps conservative, evaluation of the 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/cm^2 will not cause any temporary or permanent deafness (1950, p. 36).

The United States Air Force (1956) published a regulation delimiting the allowable limits of noise exposure. The permissible lifetime limit (25 years) for an eight hour day exposure to broad band noise with the ears unprotected was defined as a maximum sound pressure level of 85 dB at each of four octave bands: 300 to 600, 600 to 1200, 1200 to 2400, and 2400 to 4800 Hz. Recommendations were established in which the Air Force suggested that ear protectors should be worn when the band pressure level in any of the bands exceeded 85 dB. The Air Force report further stated that whenever the band pressure levels in any of the bands reach 95 dB, then it will be mandatory that ear protectors be worn.

With the intent of deterring noise-induced hearing losses, the Sub-Committee on Noise of the American Academy of Ophthalmology and Otolaryngology proposed 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, Table (1) should be consulted for recommended allowable exposures.

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. This shows the relationship between the duration of the on-time between the noise burst (ordinate) and the allowable average 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 (AAOO 1964, p. 13-14).

Recently, a damage risk criterion was put into effect by the Occupational Safety and Health Administration (OSHA, 1971) of the United States Department of Labor. The OSHA noise regulations consist of basically two categories: (1) the maximum levels of industrial noise to which an employee may be exposed, and (2) what action the employer must take if these noise levels are exceeded.

The fundamental section of the OSHA standard is a table giving permissible noise exposures. This table has been reproduced as Table 2 which shows the recommended length of time that an individual may be exposed to various levels of sound. These exposures are considered to be the upper limits of daily doses that will not produce disabling hearing losses in more than 20% of a population exposed through a lifetime of work consisting of 35 years.

Table 1. Recommended allowable exposure to broad band noise according to the Sub-Committee on Noise of the American Academy of Opthalmology and Otolaryngology (1964).

Average Levels of 300-600, 600-1200, 1200-2400 Hz Bands	On-Time Per Day In Minutes
1.) 85 dB	1.) less than 300
2.) 90 dB	2.) less than 120
3.) 95 dB	3.) less than 50
4.) 100 dB	4.) less than 25
5.) 105 dB	5.) less than 16
6.) 110 dB	6.) less than 12
7.) 115 dB	7.) less than 8
8.) 120 dB	8.) less than 5

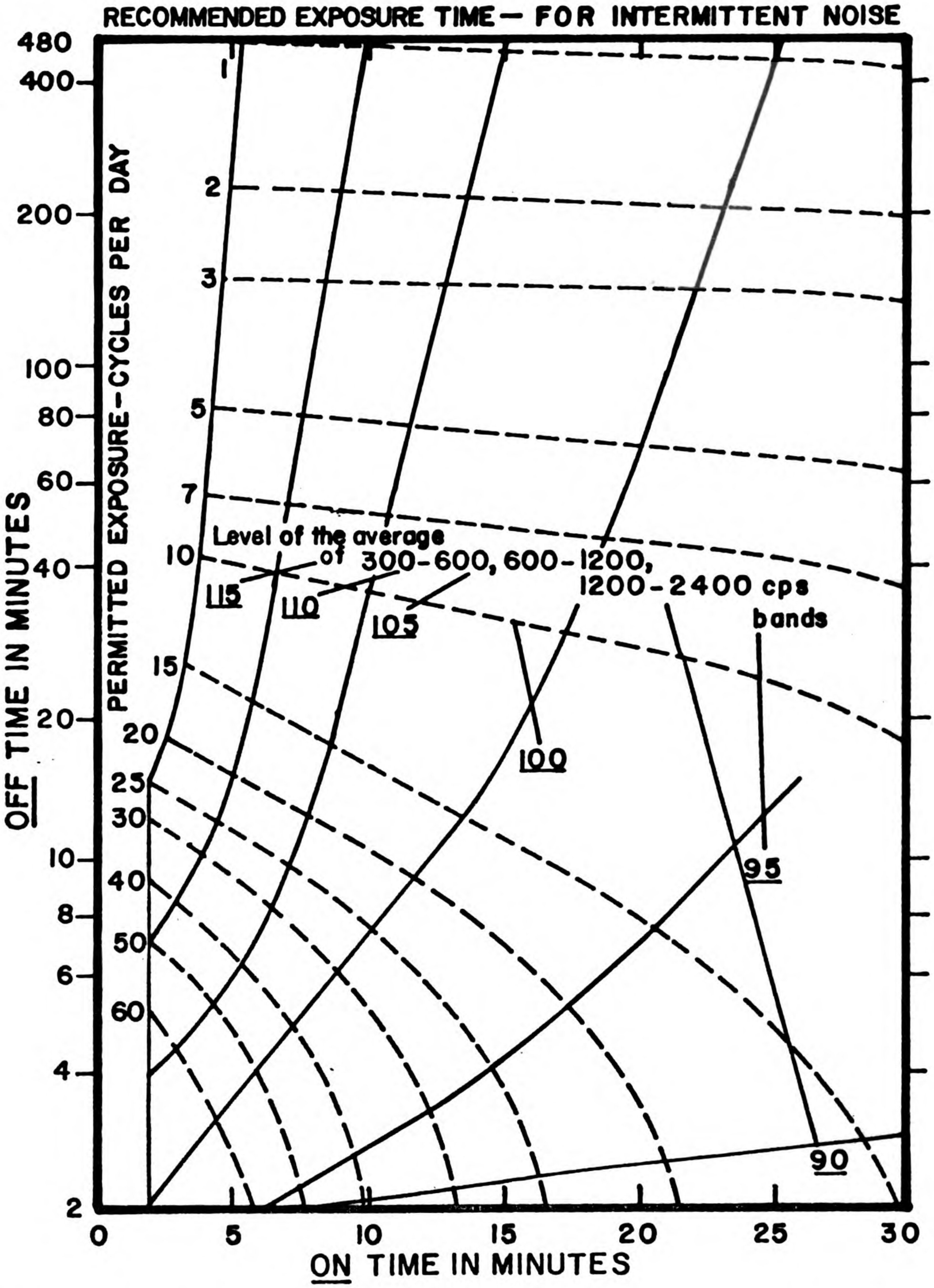

Figure 1. Recommended allowable exposure time for intermittent noise. (AAOO, 1964, p. 15)

Table 2. Recommended allowable exposure to noise (dBA) according to the Occupational Safety and Health Administration, United States Department of Labor (1971).

DURATION PER DAY: HOURS	SOUND LEVEL dBA, SLOW
8	90
6	92
4	95
3	97
2	100
$1\frac{1}{2}$	102
1	105
$\frac{1}{2}$	110
$\frac{1}{4}$ or less	115

(Federal Register 1971, p.10518)

Since many of the industries exceed the sound levels set by OSHA, the regulation states what must be done in three basic steps: (1) Reducing the noise at its source through engineering controls. The standard states that when employees are subjected to sound levels exceeding those listed, feasible administrative or engineering controls shall be utilized; (2) Providing hearing protection. Where engineering controls fail to reduce sound levels within the specified limits, the standard states that personal protective equipment shall be provided and used; and (3) Carrying out a program of hearing conservation. The OSHA act recommends that in all cases where the sound levels exceed the specified limits, a continuing, effective hearing conservation program shall be administered. (OSHA, 1971)

Studies Concerning Rock and Roll Music:

Prior to the 1960's, concern over noise exposure was primarily focused on occupational noise. This included noise encountered while working on the job such as the type machine shop laborers and drop forge operators would experience. Interest concerning these types of noise brought about some alterations in these hazardous environments in an effort to make them safe for the hearing of exposed workers. After the 1960's, interest in noise exposure began to expand and encompass recreational noise. Noises of this nature include sounds experienced by individuals during some sort of amusement or pasttime such as hunting, snowmobiling, and rock and roll music.

The remainder of this section will concentrate on this particular type of high-level acoustic stimulus. Studies that have focused upon rock and roll music and its possible effects upon the hearing mechanism are reviewed.

One of the first studies involving rock and roll music was conducted by Lebo, Oliphant, and Garret (1967). After making recordings of 50 to 100 seconds in length, at various locations within two different dance halls, they found that the octave band levels surpassed the Damage Risk Criterion established by the State of California in 1962. They stated: "We believe that we have demonstrated that the noise levels produced by some live rock and roll bands with the aid of high amplification unmistakably exceed those considered safe for prolonged exposure" (1967, p. 380).

In 1968 a three-part study concerning rock and roll music was conducted by Rintelmann and Borus: (1) They obtained acoustic analyses of the music played by six rock and roll groups; (2) They determined whether 42 musicians suffered a noise-induced hearing loss as a result of this music; and (3) They procured listeners' reactions to rock and roll music. In the first part of this study, they found the mean sound pressure level of rock and roll music to be 105 dB overall SPL with the acoustic spectrum being fairly flat from the low to middle-frequency region with a progressive reduction in the higher frequencies beyond 2000 Hz. In the second part of the study, they measured the pure-tone thresholds of 42 rock and roll musicians who were exposed to approximately 105 dB SPL of music for an average 11.4 hours per week for 2.9 years. They found that 95% of them did not have hearing losses as measured by conventional pure-tone air- and bone-conduction audiometry. In the final part of the study, they asked college students whether or not rock and roll music was "too loud". They found that the majority of the students felt that the music was too loud, but felt it was a necessary part of the music. In conclusion, Rintelmann and Borus stated: "Taking into account the limitations of this study, concern over the harmful effects of rock and roll music on the hearing of young people appears to be unwarranted" (1968, p. 65).

A study that compared octave band spectral measurements of rock and roll music to the measurements of fortissimo symphonic music was conducted by Lebo and Oliphant (1968). They found the measurements to be quite different between the two and concluded that fortissimo symphonic music was below the damage risk level, whereas rock and roll music was not.

Speaks and Nelson (1968) investigated the effects of TTS following an evening of exposure to rock and roll music. By measuring pure-tone thresholds of 25 musicians before and after an evening of exposure, with approximately 30 minutes between measurements and exposure, they found less than five dB of TTS in most cases. However, there were a few subjects with greater than 15 dB of TTS recorded. There were no musicians that manifested a shift of more than 25 dB.

Downs et al., (1969) compared the hearing sensitivity of 24 high school age rock and roll musicians to a control group. After obtaining threshold measurements of these individuals they found that 75% of the rock and roll musicians had high frequency hearing thresholds that were poorer at one or more frequencies than the control group subjects who were not exposed to the music. Differences between these groups, however, were not remarkable since most of the musicians were able to pass a pure-tone screening test at a level of 25 dB (ISO 1964) that ranged in frequencies from 500 to 8000 Hz.

Lipscomb (1969) studied histologically the structural changes of a guinea pig cochlea resulting from rock music exposure. He exposed a guinea pig to rock and roll music for a period of 88 hours over a two month period. This music was played at a level of 122 dB SPL average peak. During the first 65 hours of exposure one ear was protected through the use of a plug. Upon observation of this ear there was no apparent cytologic alteration. However, there was observable sensory cell damage to the unprotected ear. He concluded that since rock music resulted in marked sensory cell damage in the cochlea of the guinea pig, a program of hearing conservation should be initiated so that the dangers of excessive exposure to these sounds will be made clear to those participating in such activities.

Flugrath (1969) did an acoustical analysis of the sound levels recorded from rock and roll music and found the average sound pressure level to be 104 dB. Based on his findings, Flugrath felt that rock and roll music should be considered potentially damaging to the hearing mechanism.

Another acoustical analysis was performed in a rock and roll bands' rehearsal room by Rupp and Koch (1969). Overall sound pressure levels of 120 to 130 dBC were reported by these investigators. Individuals that were exposed to these levels of music were tested for TTS. They found threshold shifts to vary as a function of frequency. For 250, 500, and 1000 Hz, they reported minimal mean threshold shifts of 5 dB. Larger shifts were noted as the frequency increased with a 15 dB shift at 2000 Hz, a 25 dB shift at 4000 Hz, and a 20 dB threshold shift at 6000 Hz. As a result of this investigation, the authors stated that long exposure to rock and roll music is a possible health hazard.

Dey (1970) studied the effects of rock and roll music on the hearing of young adults. In this study, exposure did not take place at a discotheque but rather within the laboratory where Dey produced the acoustic conditions of rock and roll music. He exposed young adults to this type of music at sound pressure levels of 100 and 110 SPL for five to 120 minutes. He found that two out of 100 people would recover more slowly than typically expected when exposed to 100 dB for 120 minutes. Further he suggested that as much as 16% of the population could be permanently affected when exposed for 120 minutes to levels of 110 dB.

Jerger and Jerger (1970) reported on two groups of rock and roll musicians. They found these bands to be playing for an entire evening in an acoustic environment of 108 dB to

116 dB SPL. Eight of nine musicians demonstrated threshold shifts greater than 15 dB for at least one frequency in the range of 2000 to 8000 Hz.

Under controlled laboratory conditions Smitley and Rintelmann (1971) compared intermittent exposures of rock and roll music to continuous exposures with regards to TTS. The continuous presentation consisted of music recorded without any pauses or interruptions between selections while the intermittent presentation consisted of identical selections with four to six minute on-times followed by 30 second off-times. Two groups of subjects were exposed for 60 minutes at an average peak intensity of 110 dB SPL. One group received the intermittent exposure while the other group received the continuous exposure. They found significant differences in the TTS between continuous and intermittent exposures at each of the following frequencies: 250, 500, 2000, and 3000 Hz. The largest threshold shift under both conditions was found at 4000 Hz. There were no significant differences, however, between male and female threshold shifts.

Rintelmann, Lindberg, and Smitley (1972) conducted another laboratory study comparing exposure to intermittent versus continuous music. However, this time the use of discotheque ambient noise provided the "break times" instead of silence as in the previous study and the off-time (break time) was changed from 30 seconds to one minute between musical selections. They found that again temporary threshold shift was significantly less in the intermittent condition than in the continuous condition at frequencies of 2000, 3000, 4000, and 8000 Hz. They also found that whether subjects were exposed to the intermittent or the continuous conditions, the recovery times were similar.

Reddell and Lebo (1972) tested 43 rock and roll musicians and two listeners. They found the average pure-tone thresholds of the musicians to be normal from 250 to 8000 Hz, but with a characteristic "notch" at 4000 and 6000 Hz. They also presented the range of pure-tone thresholds for their sample of musicians with the poorest thresholds exceeding normal hearing especially in the high-frequency region. Unfortunately, these authors did not indicate how many musicians had thresholds which exceeded the normal limits. Further, the notch at 6000 Hz, which they interpreted as a noise-induced hearing loss, can probably be attributed to two other factors. First, some of the subjects were tested shortly after performing, hence, their thresholds undoubtedly contained some high-frequency TTS. Secondly, according to the findings of Harris (1971) a high-frequency notch can be attributed to the earphone enclosure (aural domes). Therefore, the significance of this high-frequency "notch", which was within the normal hearing range, can be questioned. In this same investigation Reddell and Lebo tested seven of the 43 musicians for TTS. They found that the greatest shift (20 dB) occurred at 6000 Hz. Also, ten subjects were administered the Short Increment Sensitivity Index test resulting in a mean score of 82%, suggesting cochlear pathology. Based on this study they suggested that the amplification should be attenuated to a safe level that would substantially reduce the risk of hearing damage to the audience and performers.

One of the most recent articles concerning rock and roll music and its possible effects upon the hearing mechanism was by Rupp, Banchowski, and Kiselwich (1974). They made measurements of four rock and roll groups and found the mean sound pressure level to be 105.2 dBA, and the range from 90 to 115 dBA. They also reported that these mean levels exceeded the "safe levels" proposed by Cohen, Anticaglia, and Jones (1970) by 25 dB when the guideline of 80 dBA for a four hour exposure was employed. From these results they proposed that "...protective guidelines be employed to regulate music levels and to protect the hearing of listeners" (1974, p. 24).

From this review of the effects of noise on the hearing mechanism it is apparent that concern over noise had begun more than 140 years ago. Moreover, this problem has increased substantially in recent years. There have been numerous studies resulting in various conclusions and sometimes contradicting results. In summary, the following conclusions appear warranted: (1) Exposure to extremely loud noise will result in damage to the hearing mechanism. Exactly what the levels of this noise have to be to cause damage, however, is not agreed upon by all experts; (2) Exposure to noise for brief periods of time is less damaging than exposure to noise for longer periods of time; (3) Also, exposure to noise intermittently is less damaging to hearing than exposure to noise continuously.

EXPERIMENTAL PROCEDURE

This section is concerned with the following:

1.) Acoustically analyze the music of rock groups and high school marching bands.

2.) Determine the existence of noise-induced hearing loss present in rock musicians.

3.) Acquire threshold measurements of a group of rock musicians to determine the existence of TTS.

4.) And determine attitudes towards loudly played music.

Procedures for the above four investigations will be discussed in the order listed above.

Acoustic Analysis of Rock Groups and High School Marching Bands:

Ten rock and roll groups and four high school marching bands were analyzed and comparisons were made between these two types of music. The marching bands consisted of approximately 80 to 110 instruments in each band. Five overall SPL measurements were made for each marching band and ten measurements were obtained for each rock group with the exception of one group in which 20 measurements were made. Each of these measurements were obtained utilizing the linear scale, A-weighted, and C-weighted scales at each of three distances (ranging 5 - 10 feet, 11 - 20 feet, 40 - 60 feet) from the sound source. Measurements were made on randomly chosen musical selections. The A scale was used since the damage risk criterion utilized in the United States Department of Labor's Occupational Safety and Health Act is based on this scale. Also, five octave band measurements from each marching band and ten octave band measurements from each rock group were obtained with the exception of one group in which eight measurements were made. Measurements were obtained for each of the center frequencies including 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16000 Hz. These octave band measurements were recorded in all instances where overall SPL measurements were made utilizing the A, C, and linear scales.

To obtain the sound pressure level readings a Bruel and Kjaer sound level meter (type 2204) using a Bruel and Kjaer one-inch sound field condensor microphone (type 4145) with a Bruel and Kjaer random incidence corrector was employed. For analysis of the octave bands a Bruel and Kjaer octave band filter (type 1613) was attached to the sound level meter. The entire system was calibrated before and after each measurement session on the rock groups and marching bands through the use of a Bruel and Kjaer pistonphone (type 4220) which emits a 250 Hz tone at 124 dB SPL re 0.0002 microbar. The condition of the batteries for the sound level meter were checked throughout the measurements. The K-factor of the microphone was also periodically checked so that accurate readings could be obtained.

Measurements of Possible Noise-Induced Hearing Losses Present in Musicians:

Subjects

Six musicians who received audiological tests were taken from a group of musicians who took part in the Rintelmann and Borus study in 1968. However, due to problems of changing their places of residence, different interests, etc., only six of the musicians out of the original 42 could be contacted. These six male subjects ranged in age from 25 to 28 years with a mean age of 26 years. In order to participate in the study each of these musicians were required to meet the following criteria originally established by Rintelmann and Borus: (1) no history of a hearing loss or chronic middle ear pathology, (2) never worked in a noisy environment such as a factory where high intensity levels existed, (3) never shot guns frequently such as in the armed forces or while hunting, (4) no familial history of a hearing loss, and (5) not listened to or played loud music for a period of at least 24 hours prior to being tested.

Regarding their exposure to rock music as musicians, these six individuals had performed with rock and roll groups for periods ranging from 5.4 to 9.9 years. The mean length of affiliation with rock and roll groups was 7.3 years and the median was 7.5 years. In regards to the amount of time these musicians spent playing per week, the time was divided between performing with the group and performing alone. It should be noted, however, that regardless of whether performing with the group or alone, an amplifier associated with the instrument was typically used. The average time spent playing rock and roll music was 18.5 hours per week performing with the group, and four hours per week performing alone, for an average total of 22.5 hours per week. The total amount of playing time for the six musicians ranged from 10 to 34 hours per week.

Test Administration and Instrumentation Employed

Pure-tone air- and bone-conduction thresholds were obtained using a Grason Stadler 1701 audiometer. Air-conduction thresholds were obtained via TDH-49 earphones mounted in MX-41/AR cushions. Bone-conduction thresholds were measured using a Radioear B-70-A white dot bone-conduction oscillator. Masking of the non-test ear took place on all bone-conduction threshold measurements with the use of narrow band white noise generated by the Grason Stadler audiometer. The minimum effective masking level used was 30 dB. Air-conduction thresholds were obtained at octave frequencies from 125 through 8000 Hz with the half octave of 3000 Hz. Bone-conduction thresholds were measured at octave intervals from 250 through 4000 Hz plus the half octave of 3000 Hz. Both air-conduction and bone-conduction thresholds were measured using the Hughson-Westlake ascending technique as described by Carhart and Jerger (1959).

Calibration of the air-conduction system was made daily prior to and following threshold measurements using a Bruel and Kjaer artificial ear assembly (type 4152) and a Bruel and Kjaer condensor microphone (type 4144) with the associated sound level meter (type 2204) and a Bruel and Kjaer octave band filter network (type 1613). The bone-conduction system was also calibrated during the course of the investigation. The calibration equipment utilized consisted of a Beltone artificial mastoid (M5A), a Beltone mastoid amplifier (M5A), and a Bruel and Kjaer microphone amplifier (Model 2603).

Testing took place in a two-room testing suite with the tester in a pre-fabricated single-walled IAC control chamber and the subject in a pre-fabricated double-walled IAC room. The ambient noise level within the test room was measured with a Bruel and Kjaer sound level meter (type 2204) using a Bruel and Kjaer one-inch sound field condensor microphone (type 4145) with a Bruel and Kjaer random incidence corrector to determine whether the ambient noise would interfere with the measuring of thresholds. The ambient noise level within this room was 43 dB on the C scale of a Bruel and Kjaer sound level meter.

The thresholds obtained from each of the subjects tested were analyzed and compared to the thresholds from data on the same subjects gathered in the Rintelmann and Borus (1968) study, and also with a second set of thresholds obtained by Rintelmann and Smitley (1971). These three sets of measurements covered a span of seven years. Since the thresholds gathered in 1968 were measured prior to the publication of the ANSI (1969) standards, the appropriate adjustment was made for the TDH-39 earphones. (see Melnick, 1971)

Threshold Measurements to Determine Amount of Temporary Threshold Shift:

Subjects

A group of five rock and roll musicians that were performing at a local discotheque received pure-tone threshold tests prior to and immediately upon the completion of their performance. This group consisted of one female and four males ranging in age from 22 to 26 years with a mean age of 24.8 years. A comparison of pre- and post-performance thresholds revealed the amount of temporary threshold shift present after an evening of exposure to rock and roll music.

Test Administration and Instrumentation Employed

Pure-tone air-conduction thresholds were obtained using a Beltone (10D) and a Maico (2B) portable audiometer with TDH-39 earphones mounted in MX-41/AR cushions. Bone-conduction thresholds were measured using Radioear B-70-A white dot bone-conduction oscillators. Air-conduction thresholds were obtained at octave intervals 250 through 8000 Hz with the half octave of 3000 Hz. Bone-conduction thresholds were measured at octave intervals from 250 through 4000 Hz plus the half octave of 3000 Hz. Both air- and bone-conduction thresholds were measured utilizing the Hughson-Westlake ascending technique as described by Carhart and Jerger (1959).

Calibration of the air- and bone-conduction systems was made prior to and following threshold measurements using the same calibration systems described earlier.

The test room was located on the second floor directly above the discotheque. This room was approximately 1800 square feet in size and consisted of plaster walls, tile ceiling and a hard-wood floor. The ambient noise level within this room was measured to determine if the ambient noise would interfere with the measuring of thresholds. The results of these measurements, presented in Appendix B, revealed that ambient noise levels for the audiometric frequencies used, except 250 Hz, were sufficiently low so as not to interfere with threshold measurements. (ANSI 1960)

The thresholds of these five musicians were obtained within a time period of seven to 25 minutes upon the completion of their performance. The order of presentation of the test frequencies was as follows: 1000, 2000, 3000, 4000, 8000, 500, and 250 Hz.

Attitudes Towards Loudly Played Music:

Five questions were presented to 50 young adults who were divided into two groups of 25 each. Group one consisted of musicians and audience members at a local discotheque. Within this group there were 19 males and six females ranging in age from 17 to 37 years with a mean age of 23.2 years. Group two was made up of students attending a college lecture. Within this group there were six males and 19 females ranging in age from 19 to 34 years with a mean age of 22.2 years.

Since group one consisted of 19 males and six females and group two consisted of 19 females and six males it is possible that group differences could simply be attributed to a sex difference. Thus, the two groups were equated for sex by merely drawing at random six from the 19 in each group so that both groups one and two were composed of six males and six females. These revised groups (N=12) were then compared to determine their attitude consistency with the larger groups (N=25).

The five questions, shown in Table 3, were given to group one at a location where rock and roll music was being played. To rule out the possible biasing effect of environment these questions were also given to group two in an environment where rock and roll music was not being played. Hence, this group served as a control. The answers to the five questions were recorded and analyzed to determine the responses most frequently given.

Table 3. Questions employed to elicit attitudes regarding rock and roll music.

1a.) Estimate the percentage of time, out of your total music listening experience, you listen to <u>live</u> rock music.

b.) Estimate the percentage of time,out of your total music listening experience, you listen to <u>recorded</u> rock music.

2.) Do you feel that rock music needs to be loud in order to enjoy it? If so, why?

3.) Do you think your hearing is being damaged from exposure to this type of music?

4.) Do you feel that rock music is typically too loud, too soft, or just about right?

5.) If it were a known fact that rock and roll music was damaging to your hearing, would you continue to voluntarily expose your hearing to this type of hazard?

RESULTS AND DISCUSSION

PART ONE: ACOUSTICAL ANALYSIS

The first part of this study consisted of acoustically analyzing various musical selections played by ten different rock groups and four different marching bands. A portion of this analysis is presented in Table 4 revealing A-weighted sound levels, reported in dB, of ten rock and roll groups at distances ranging from five to 60 feet from the source of the music. All ten groups were local groups from the Mid-Michigan area and the measurements were obtained in discotheques except groups nine and ten. Measurements for these two groups were gathered at outdoor concerts. The mean sound level of the ten rock groups for 330 measurements, regardless of distance from the source, was 98.1 dBA. The range was 75 to 111 dBA. Table 5 summarizes the C-weighted sound levels of the same rock groups reported in dB. The mean sound level of the same ten groups for 330 measurements, regardless of the distances from the source, was 103.5 dBC. The range was 84 to 115 dBC. Table 6 shows the mean Linear reading of all ten groups for 330 observations, regardless of distance from the source, to be 104.6 dB SPL. The range of observations varied from 88 to 115 dB SPL. Also presented

Table 4. Sound pressure levels (dBA) of rock and roll music at distances ranging from five to 60 feet from the sound source. (N=10 rock and roll groups).

	DISTANCE								
	5 - 10 feet			11 - 20 feet			40 - 60 feet		
GROUP	MEAN	RANGE	OBSERVATIONS	MEAN	RANGE	OBSERVATIONS	MEAN	RANGE	OBSERVATIONS
1.	104.4	101-108	10	103.4	101-106	10	98.3	96-100	10
2.	104.1	102-106	10	98.7	96-101	10	95.6	93- 97	10
3.	109.6	105-111	10	98.8	96-101	10	93.9	82- 96	10
4.	104.7	102-108	10	99.0	96-103	10	95.9	90- 99	10
5.	105.5	102-108	10	97.5	91-100	10	92.0	82- 97	10
6.	102.7	100-107	10	99.6	98-102	10	94.7	93- 96	10
7.	103.8	102-106	10	99.3	95-102	10	98.3	95-102	10
8.	102.2	96-106	20	95.9	87- 99	20	89.8	79- 97	20
9.	103.1	94-107	10	98.3	90-109	10	96.9	87-101	10
10.	91.6	84- 94	10	88.7	86- 91	10	83.1	75- 86	10
MEAN:	103.0 dBA			97.7 dBA			93.4 dBA		
RANGE:	84-111 dBA			86-109 dBA			75-102 dBA		

*GRAND MEAN: 98.1 dBA; RANGE: 75 - 111 dBA

*Grand Mean represents averages across all distances

Table 5. Sound pressure levels (dBC) of rock and roll music at distances ranging from five to 60 feet from the sound source. (N=10 rock and roll groups).

	DISTANCE								
	5 - 10 feet			11 - 20 feet			40 - 60 feet		
GROUP	MEAN	RANGE	OBSERVATIONS	MEAN	RANGE	OBSERVATIONS	MEAN	RANGE	OBSERVATIONS
1.	107.8	104-110	10	107.2	104-111	10	103.6	100-105	10
2.	109.2	107-111	10	103.3	101-105	10	99.8	96-102	10
3.	112.3	108-115	10	103.5	102-106	10	100.8	99-102	10
4.	109.6	106-113	10	103.6	100-109	10	100.1	92-104	10
5.	111.4	106-114	10	105.3	94-109	10	98.9	87-103	10
6.	110.5	107-113	10	104.5	103-108	10	98.7	96-100	10
7.	110.6	104-114	10	106.9	101-109	10	104.0	102-106	10
8.	107.1	100-110	20	103.0	95-106	20	97.2	89-103	20
9.	107.0	103-110	10	104.7	100-112	10	102.2	96-105	10
10.	95.7	94- 97	10	93.7	91- 96	10	88.4	84- 91	10
MEAN:	108.0	dBC		103.5	dBC		99.1	dBC	
RANGE:	94 - 115 dBC			91 - 112 dBC			84-106 dBC		

*GRAND MEAN: 103.5 dBC; RANGE: 84 - 115 dBC
*Grand Mean represents averages across all distances.

Table 6. Sound pressure levels (dB Linear) of rock and roll music at distances ranging from five to 60 feet from the sound source. (N=10 rock and roll groups).

	DISTANCE								
	5 - 10 feet			11 - 20 feet			40 - 60 feet		
GROUP	MEAN	RANGE	OBSERVATIONS	MEAN	RANGE	OBSERVATIONS	MEAN	RANGE	OBSERVATIONS
1.	108.6	106-110	10	108.1	105-111	10	104.2	100-106	10
2.	110.3	109-111	10	104.2	102-106	10	102.2	100-104	10
3.	112.9	109-115	10	104.6	103-106	10	101.5	100-102	10
4.	110.6	108-112	10	104.4	102-110	10	102.3	98-106	10
5.	112.1	108-114	10	106.7	100-109	10	101.2	90-104	10
6.	111.3	108-114	10	105.6	104-109	10	99.5	98-101	10
7.	111.6	106-115	10	107.5	101-110	10	105.1	103-107	10
8.	108.0	101-111	20	104.4	95-108	20	98.3	89-102	20
9.	107.8	104-110	10	105.9	101-113	10	103.1	97-106	10
10.	96.8	95- 98	10	94.2	91- 96	10	90.6	88- 92	10
MEAN:	108.9 dB Linear			104.5 dB Linear			100.5 dB Linear		
RANGE:	95 - 115 dB Linear			91 - 113 dB Linear			88 - 107 dB Linear		

*GRAND MEAN: 104.6 dB Linear; RANGE: 88 - 115 dB Linear
*Grand Mean represents averages across all distances.

in Tables 4, 5, and 6 are the means for each range of distance measured (5 - 10 feet, 11 - 20 feet, and 40 - 60 feet). It can be seen with each weighting scale that the sound pressure level decreases as the distance increases.

In addition to obtaining A-, C-, and Linear- weighted sound levels, octave band measurements were also gathered. The center frequencies of these bands were: 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16000 Hz. The results of these measurements made at a distance of five to 10 feet from the sound source are shown in Figure 2. This figure presents the average peak readings of the ten octave bands for the ten rock and roll groups. Figure 3 presents the measurements made at a distance of 11 to 20 feet from the sound source and Figure 4 shows the readings made at a distance of 40 to 60 feet from the sound source. All measurements, regardless of distance from the source, are shown as average peak readings. Each of the three figures show that, for the most part, the greatest amount of acoustical energy lies within the range of 63 to 2000 Hz and that the spectral distribution within this range is relatively flat. Also presented in Figures 2, 3, and 4 are the spectral distributions of ambient noise levels. These measurements were obtained at the same locations and distances that the sound level measurements were gathered for the music. By comparing the octave band levels for the music with the ambient noise levels it can be seen that the ambient noise was well below the sound levels of the music. It should be noted in Figures 2, 3, and to a lesser extent

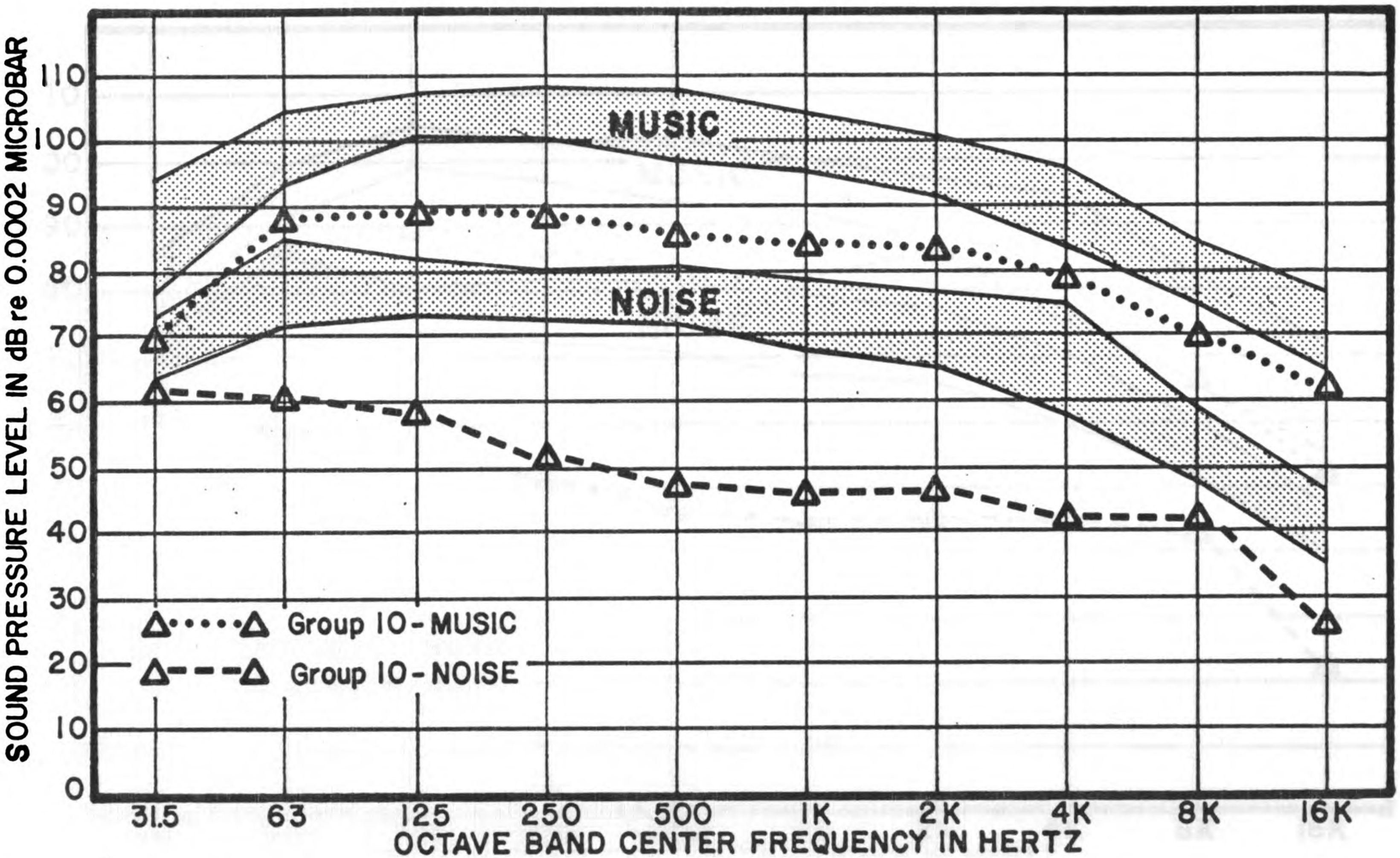

Figure 2. Octave band analysis in dB SPL (re 0.0002 microbar) of music played by ten rock and roll groups at a distance of five to 10 feet from the sound source. Also shown are the spectra of ambient noise at a distance of five to 10 feet from the stage. The shaded areas represent data for nine of the ten analyses (music and noise). The tenth group and associated ambient noise were considerably below the range and were plotted separately.

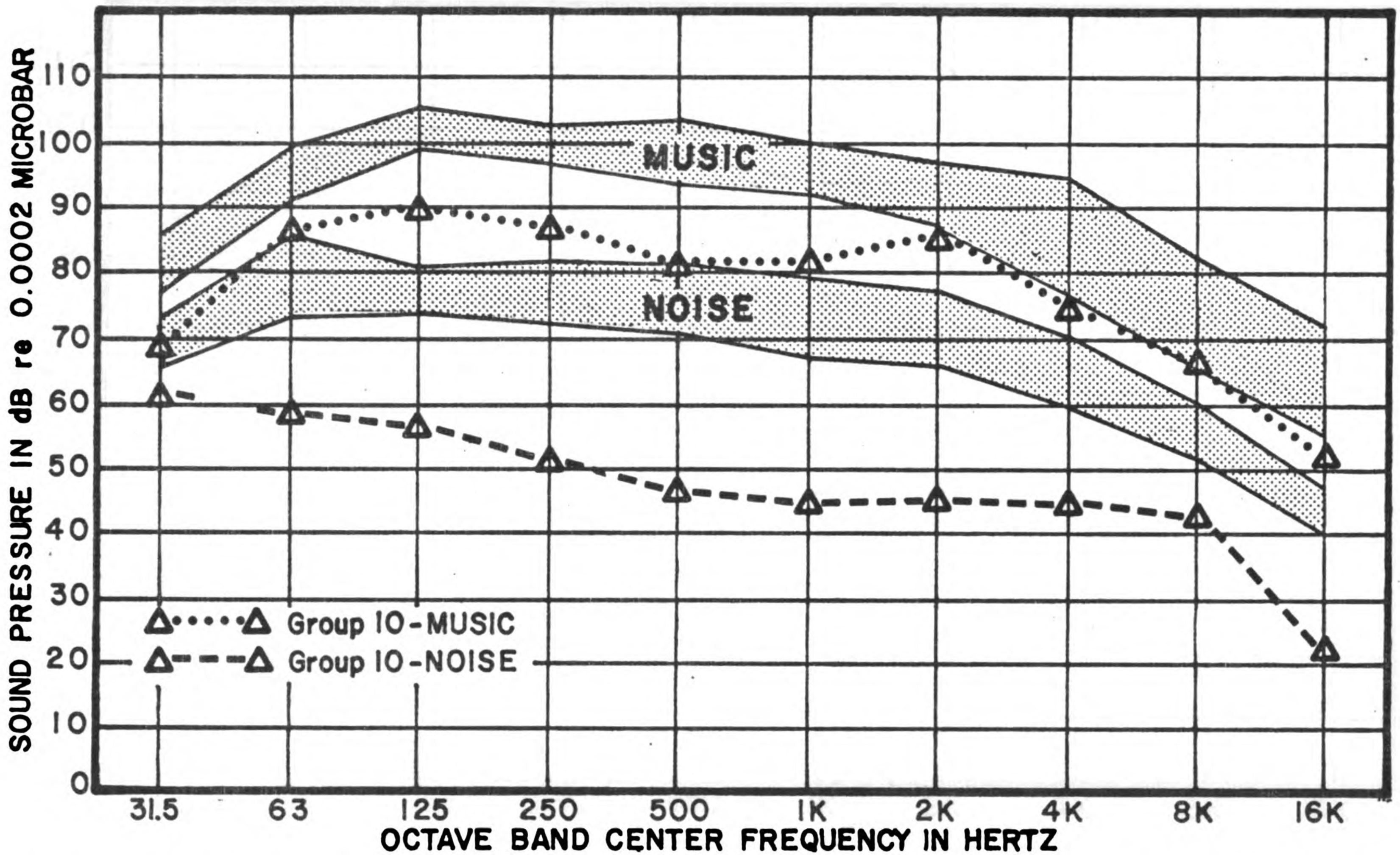

Figure 3. Octave band analysis in dB SPL (re 0.0002 microbar) of music played by ten rock and roll groups at a distance of 11 to 20 feet from the sound source. Also shown are the spectra of ambient noise at a distance of 11 to 20 feet from the stage. The shaded areas represent data for nine of the ten analyses (music and noise). The tenth group and associated ambient noise were considerably below the range and were plotted separately.

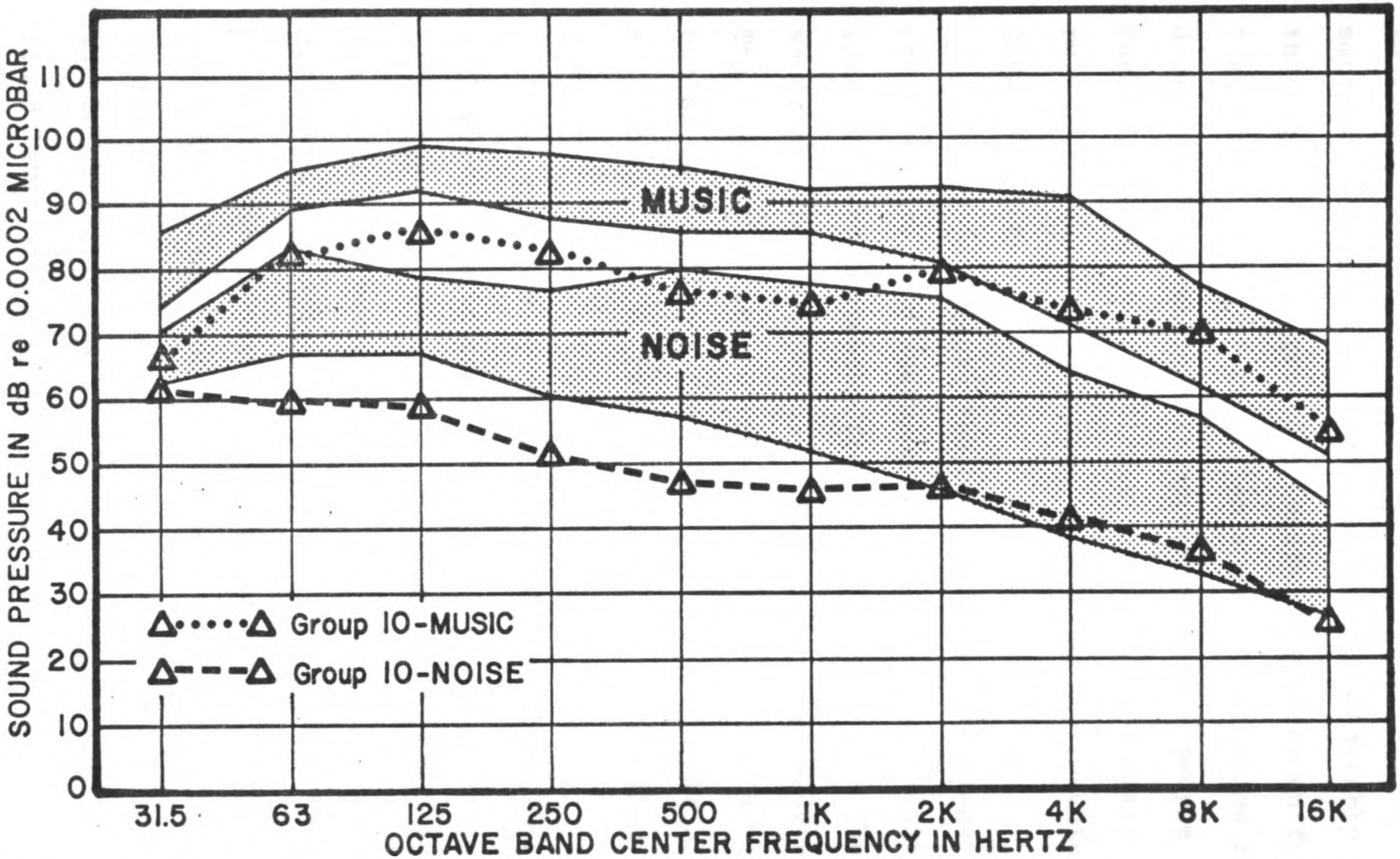

Figure 4. Octave band analysis in dB SPL (re 0.0002 microbar) of music played by ten rock and roll groups at a distance of 40 to 60 feet from the sound source. Also shown are the spectra of ambient noise at a distance of 40 to 60 feet from the stage. The shaded areas represent data for nine of the ten analyses (music and noise). The tenth group and associated ambient noise were considerably below the range and were plotted separately.

in Figure 4, the spectral distributions of the music and ambient noise levels of group ten are considerably lower than for the other groups presented. The reason for this is that the analysis of group ten's music took place at an outdoor concert in which only approximately 25 people attended. Because of the small audience size, they performed at a relatively quiet level, thus, producing the results shown in these figures.

Figure 5 presents the combined mean and range for all of the octave band measurements obtained at the various locations and distances from the sound source. The mean shows the greatest amount of energy to be 98.9 dB at 125 Hz. The figure also demonstrates that the mean spectral distribution is relatively flat over a broad frequency range, 63 to 2000 Hz, with a gradual drop-off for the higher frequencies.

The findings of these acoustical analyses were compared with previous studies and will be discussed later.

Also included within the first part of this study is the acoustical analysis of musical selections played by four different high school marching bands. Table 7 shows the A-, C-, and Linear-weighted sound levels of the four marching bands at distances ranging from five to 60 feet from the source of the music. The music of all four marching bands was acoustically analyzed outdoors. The mean A-weighted sound level of the marching bands for 60 measurements, averaged across distances from the source, was 84.8 dBA.

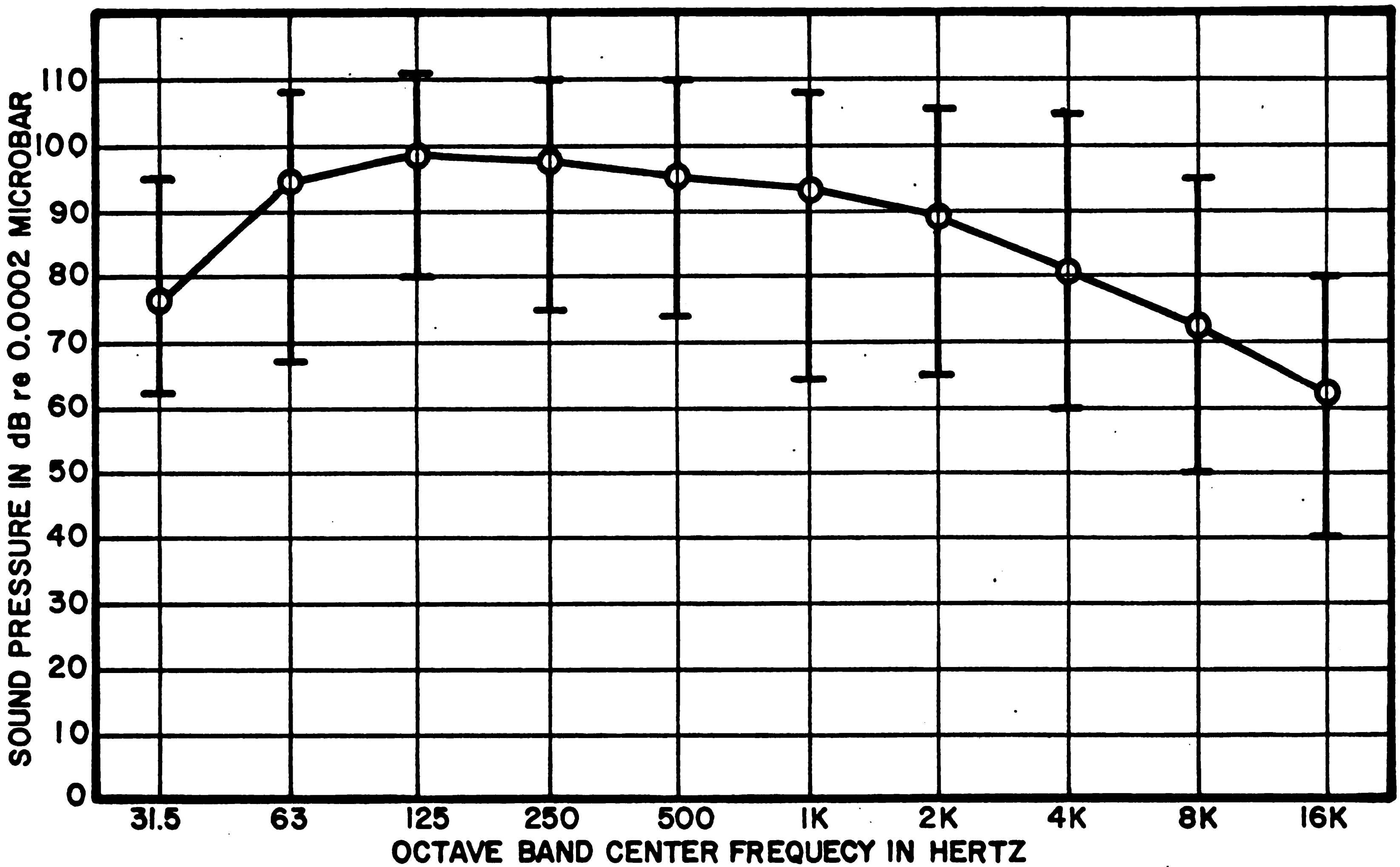

Figure 5. The mean and range of the octave band analysis in dB SPL (re 0.0002 microbar) of rock and roll music played by ten rock groups. The number of measurements for each octave band is 294.

Table 7. Sound pressure levels (dBA, C, and Linear) of marching band music at distances ranging from five to 60 feet from the sound source.

	DISTANCE								
	5 - 10 feet			11 - 20 feet			40 - 60 feet		
GROUP	MEAN	RANGE	OBSERVATIONS	MEAN	RANGE	OBSERVATIONS	MEAN	RANGE	OBSERVATIONS
1. dBA	84.8	84-86	5	80.6	78-84	5	80.8	80-82	5
dBC	94.6	91-97	5	89.8	85-92	5	87.4	87-89	5
Linear	96.0	94-97	5	91.2	89-93	5	88.2	87-89	5
2. dBA	88.0	87-90	5	83.4	79-88	5	78.4	77-79	5
dBC	95.2	94-96	5	89.6	88-91	5	87.6	84-90	5
Linear	95.2	95-96	5	90.4	88-92	5	89.0	87-90	5
3. dBA	92.0	90-93	5	84.0	82-85	5	82.0	80-86	5
dBC	97.0	94-101	5	92.2	91-94	5	90.4	88-93	5
Linear	98.0	96-103	5	92.4	91-94	5	90.4	88-93	5
4. dBA	92.4	91-93	5	86.4	85-88	5	84.0	83-86	5
dBC	96.6	95-101	5	93.0	93-93	5	90.6	90-92	5
Linear	96.8	95-101	5	93.8	93-95	5	91.2	91-92	5
MEAN: (Groups 1 - 4) dBA	89.3			83.6			81.3		
dBC	95.8			91.1			89.0		
Linear	96.5			91.9			89.7		
RANGES:	77 - 93 dBA			84 - 101 dBC			87 - 103 dB Linear		
*GRAND MEANS:	84.8 dBA			91.9 dBC			92.7 dB Linear		

*Grand mean represents averages across all distances.

The range was 77 to 93 dBA. The mean C-weighted sound level of all four bands for 60 measurements, regardless of the distance from the source, was 91.9 dBC. The range of the observations were 84 to 101 dBC. Also presented in Table 7 is the mean linear reading of all four bands which was 92.7 dB SPL (re 0.0002 microbar). Again, this level is taken from 60 readings, regardless of the distance from the source. The range was 87 to 103 dB SPL. The means for each range of distance (5 - 10 feet, 11 - 20 feet, and 40 - 60 feet) are also presented in Table 7. It can be seen with the A, C, and Linear weightings that the sound pressure level decreases as the distance increases.

In addition to gathering A-, C-, and Linear-weighted sound levels, octave band measurements were also obtained. The center frequencies of these bands were identical to the center frequencies used in the measurements of the rock and roll bands. The measurements made at a distance of five to 10 feet from the sound source are presented in Figure 6. Figure 7 presents the measurements made at a distance of 11 to 20 feet from the sound source and Figure 8 shows the measurements made at a distance of 40 to 60 feet from the sound source. These measurements are presented as average peak readings for each of the four marching bands. Each of these figures reveals that the greatest amount of acoustical energy lies within the range of 125 to 500 Hz. Beyond this range there is a gradual sloping into the higher frequencies.

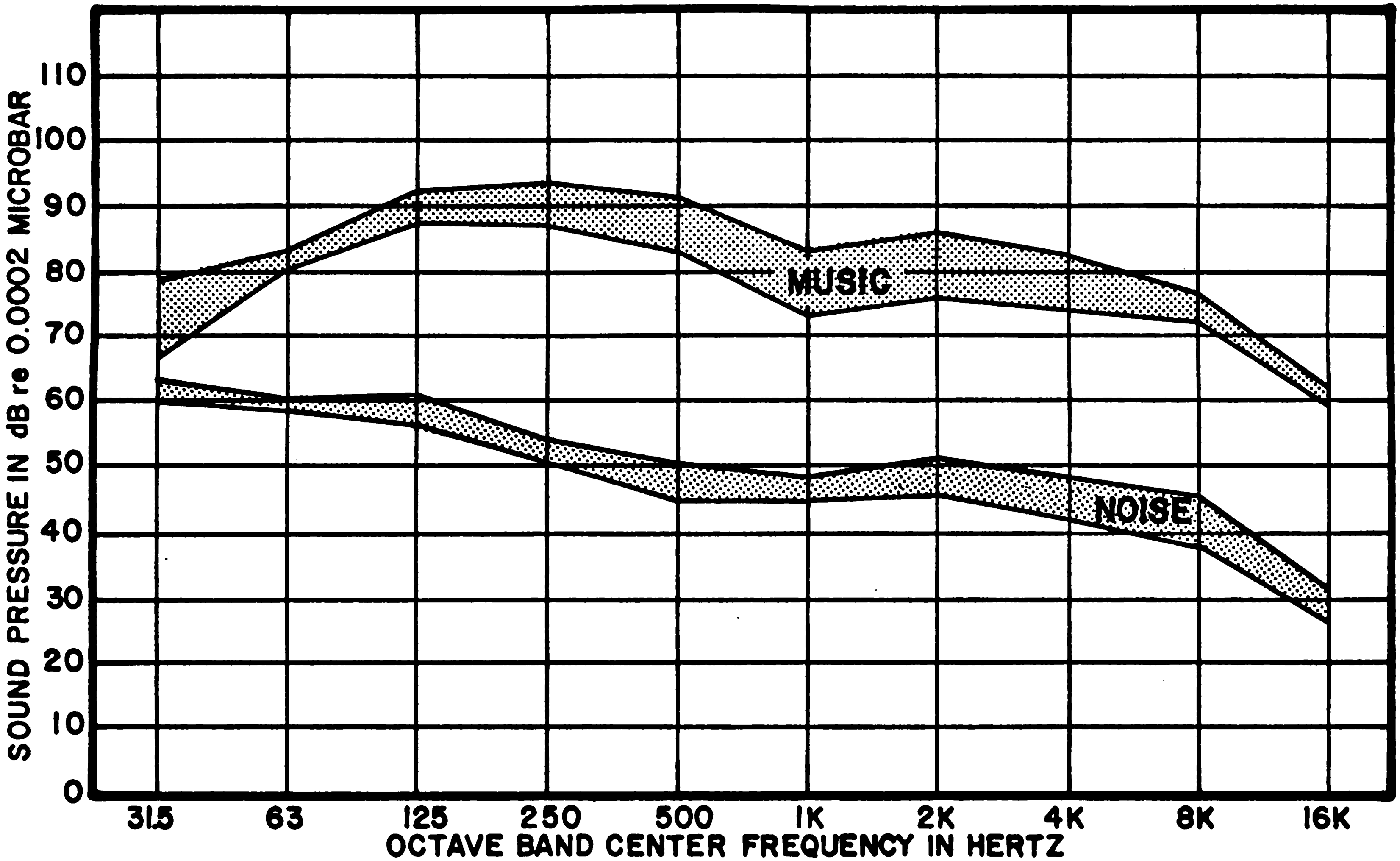

Figure 6. Octave band analysis in dB SPL (re 0.0002 microbar) of music played by four marching bands at a distance of five to 10 feet from the sound source. Also shown are the spectra of ambient noise at a distance of five to 10 feet from the band. The shaded areas represent data from the four bands analyses (music and noise).

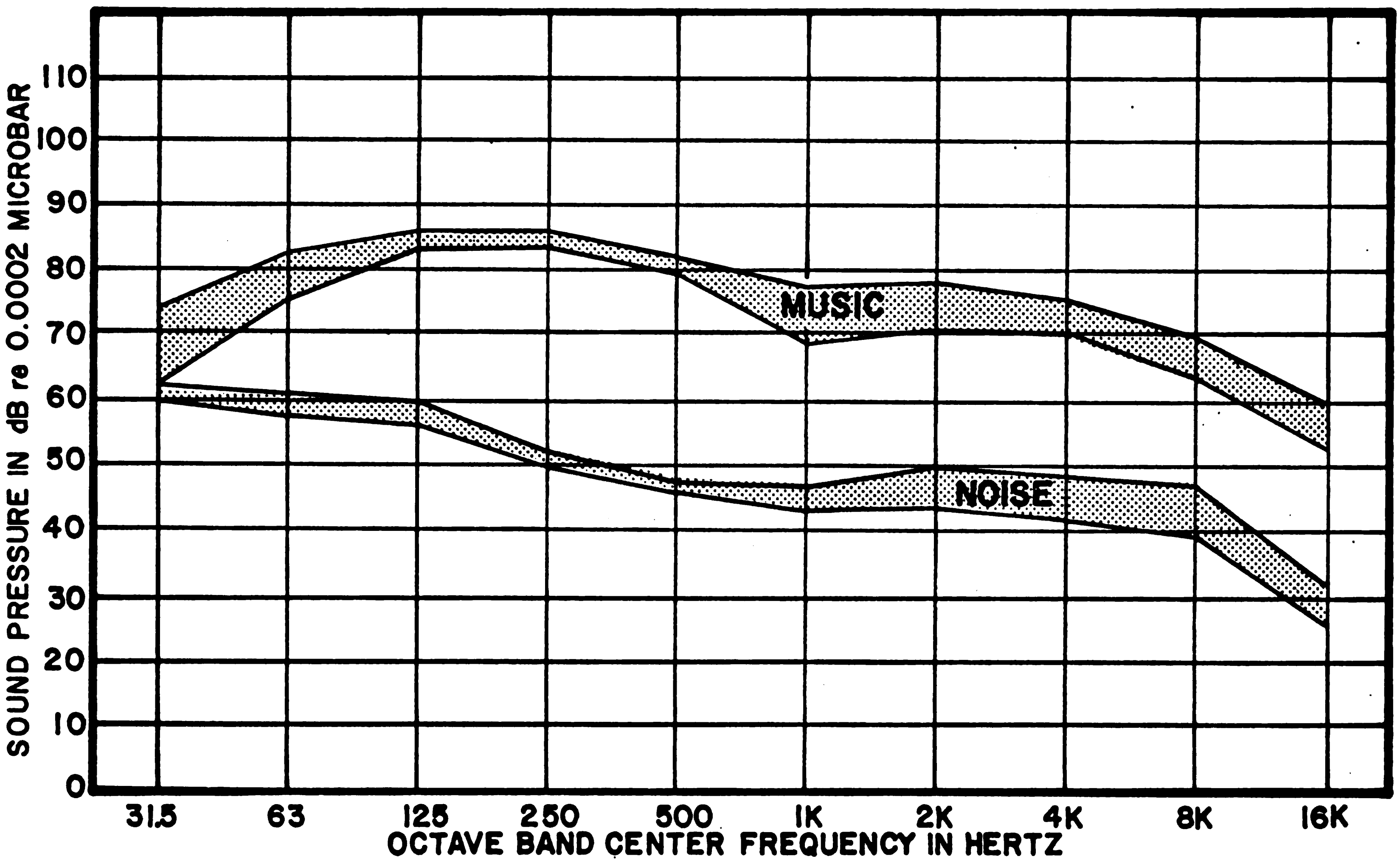

Figure 7. Octave band analysis in dB SPL (re 0.0002 microbar) of music played by four marching bands at a distance of 11 to 20 feet from the sound source. Also shown are the spectra of ambient noise at a distance of 11 to 20 feet from the band. The shaded areas represent data from the four bands analyses (music and noise).

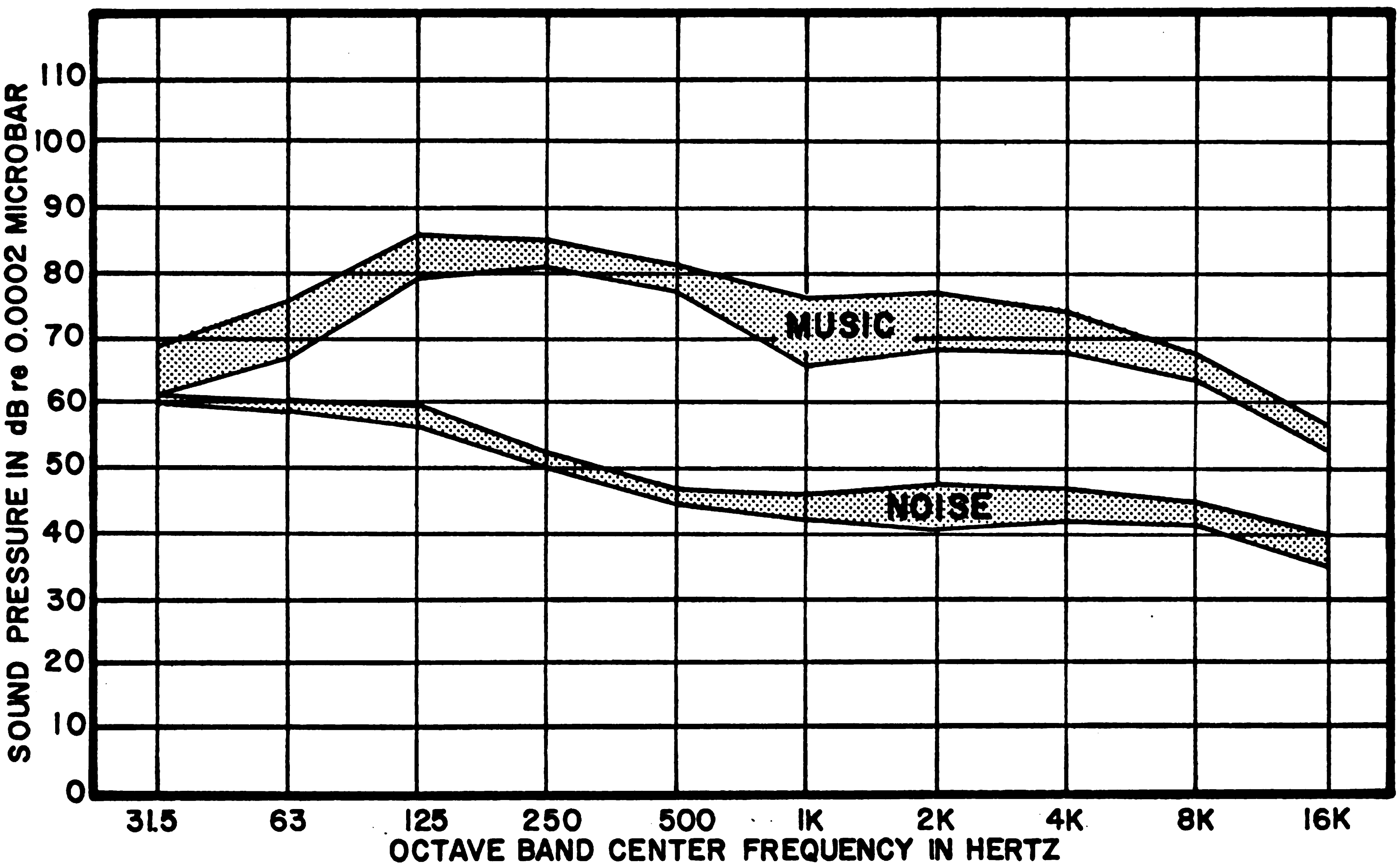

Figure 8. Octave band analysis in dB SPL (re 0.0002 microbar) of music played by four marching bands at a distance of 40 to 60 feet from the sound source. Also shown are the spectra of ambient noise at a distance of 40 to 60 feet from the band. The shaded areas represent data from the four bands analyses (music and noise).

Also presented in Figures 6, 7, and 8 are the spectral distributions for the ambient noise levels. The levels were obtained at the same location and distance that the sound levels of the music were measured. It can be seen that again the ambient noise levels were well below the music sound level.

Figure 9 shows the combined mean and range for all of the octave band measurements obtained at the various distances from the sound source. The mean shows the greatest amount of energy to be about 86 dB SPL at 250 Hz. It is also apparent that the greater energy lies within a frequency range of 125 to 500 Hz with a gradual reduction of acoustic energy for the higher frequencies.

Regarding differences between the music produced by rock and roll groups and marching bands, these distinctions were examined and will be discussed later.

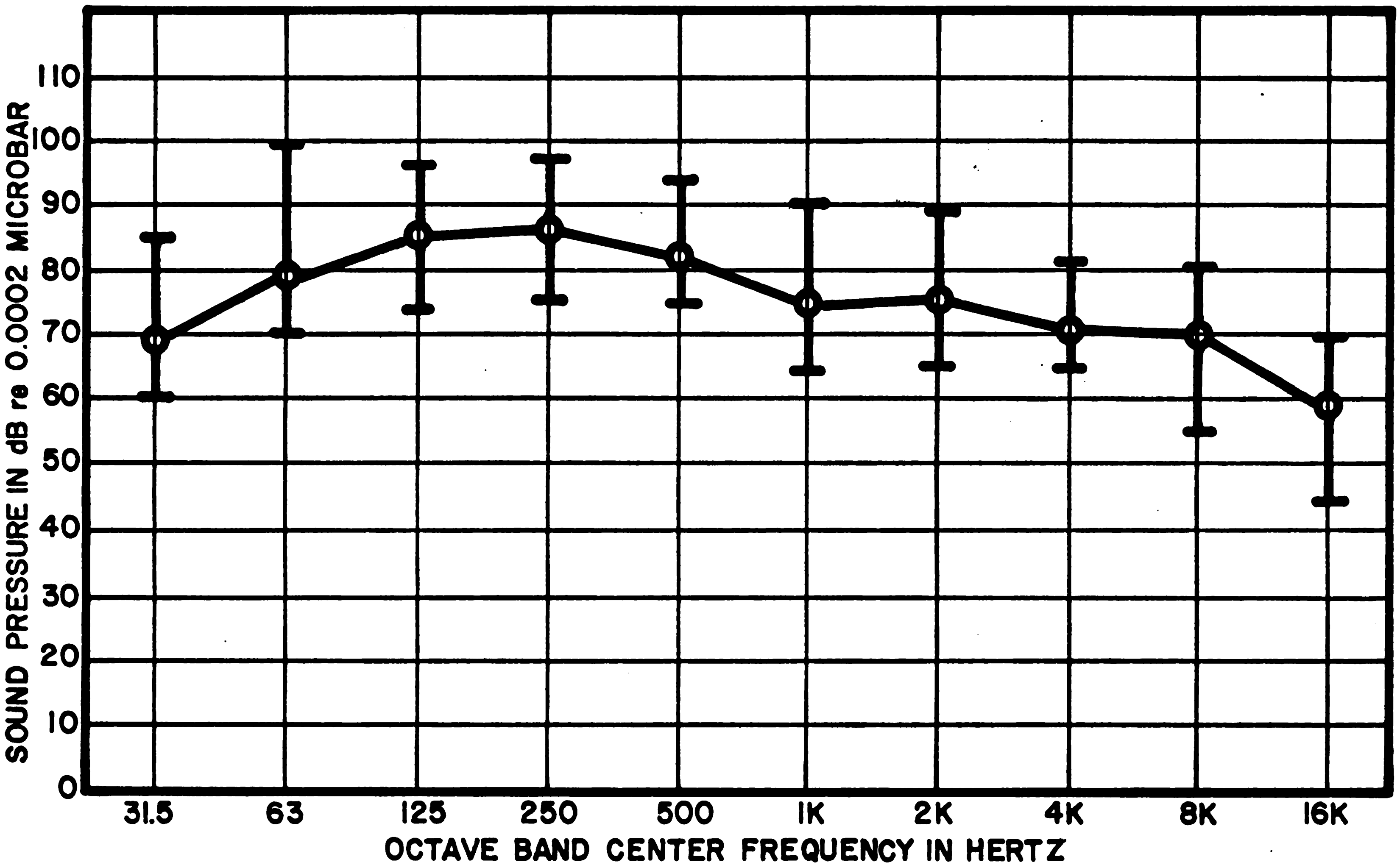

Figure 9. The mean and range of the octave band analysis in dB SPL of music played by four marching bands. The number of measurements for each octave band is 60.

PART TWO: LONGITUDINAL THRESHOLDS

The second portion of this study consisted of obtaining pure-tone air- and bone-conduction thresholds from six musicians who took part in the Rintelmann and Borus (1968) study and also in a study by Rintelmann and Smitley (1971). All measurements were made within a pre-fabricated double-walled IAC room. Since the pure-tone air- and bone-conduction thresholds were found to be interweaving ($\pm$ 5 dB), only the air-conduction thresholds are presented. Figure 10(A) presents a comparison of the mean audiograms for 1968, 1971, and 1974, rounded to the nearest five decibels, for the right ear of each of the six musicians. Figure 10(B) presents the same data for the left ear. Both of these figures demonstrate that there are no substantial (greater than 10 dB) differences between the musicians thresholds obtained in 1968, 1971, and 1974. It is also shown that the mean thresholds were within normal limits at each test session.

In order to demonstrate individual threshold differences between threshold measurements made of the six musicians in 1968 and in 1974, Table 8 is provided. This table shows the amount of individual threshold difference between the years 1968 and 1974 for each of the frequencies tested. For example, three musicians had a -10 dB difference in the right ear for the frequency of 125 Hz. That is, the individual's thresholds were more sensitive by 10 dB in 1974 compared to 1968.

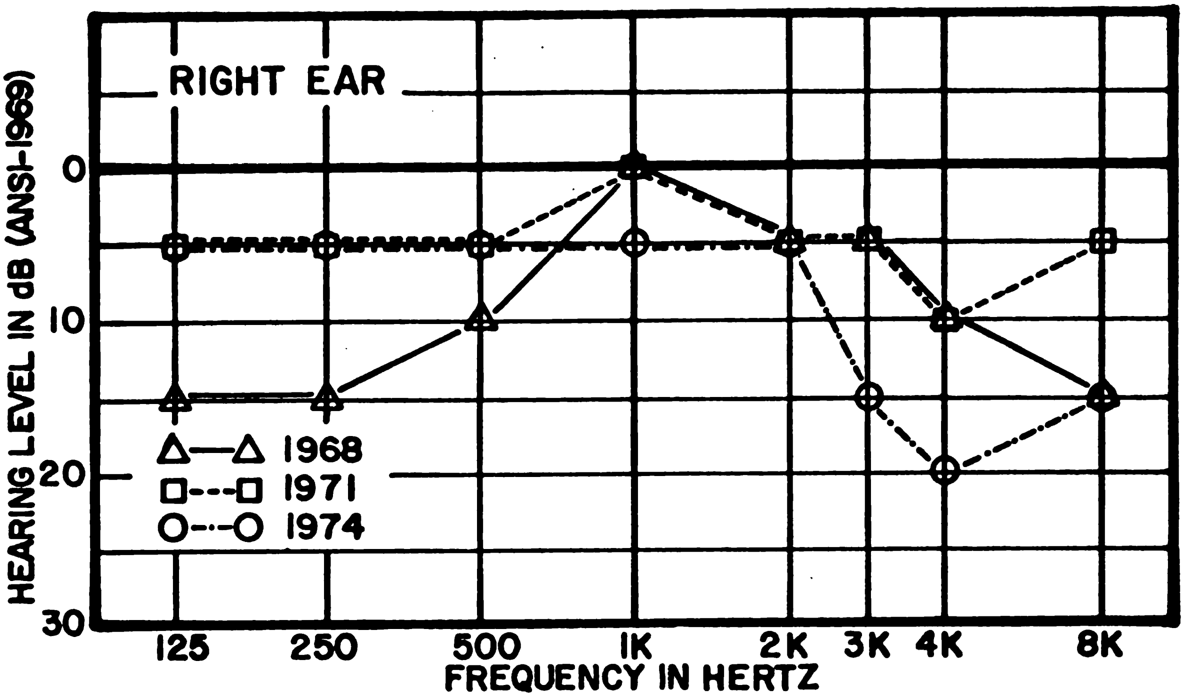

Figure 10(A). A comparison of the mean pure-tone air-conduction audiograms from 1968 to 1974, rounded to the nearest five decibels, for the six musicians' right ears.

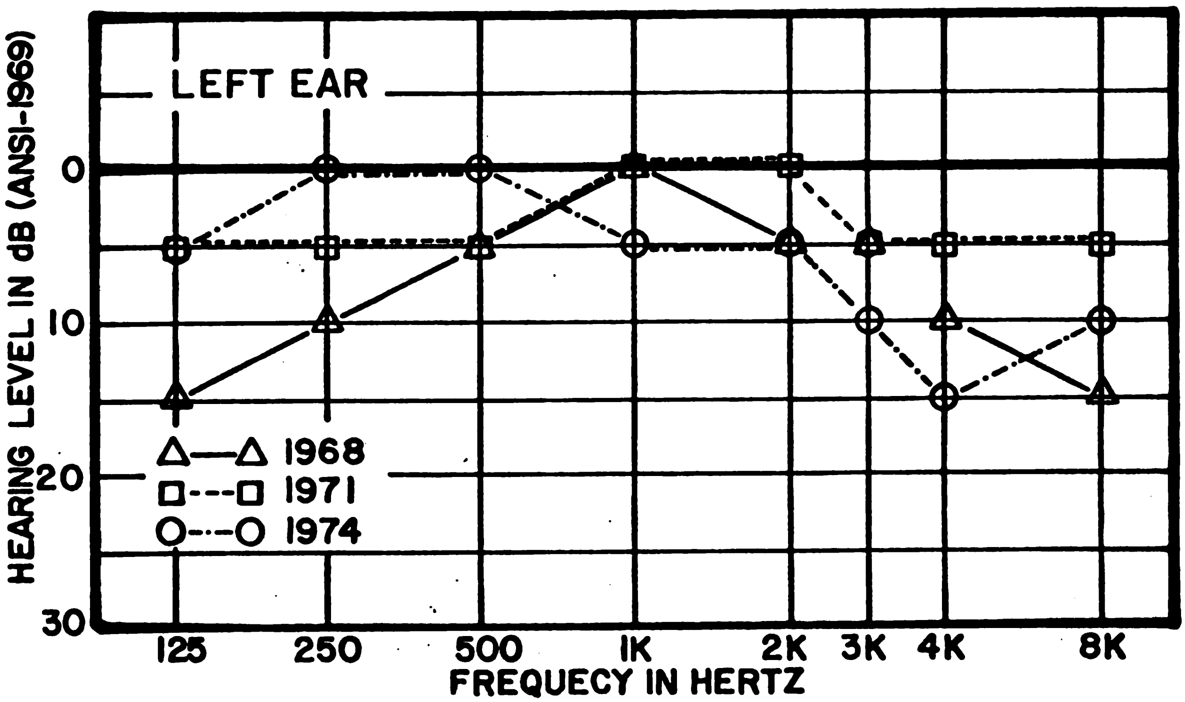

Figure 10(B). A comparison of the mean pure-tone air-conduction audiograms from 1968 to 1974, rounded to the nearest five decibels, for the six musicians' left ears.

Table 8. Amount of individual threshold difference for each subject between the years 1968 - 1974 for each of the frequencies tested. The right ear thresholds are plotted in the upper portion of the table and the left ear in the lower portion.

	RIGHT EAR	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	8000 Hz
*MINUS	-15 dB		XX	X					
	-10 dB	XXX	X	X					XX
	-5 dB	XXX	XXX	XX		XX		X	X
	0 dB			X	XX		X	XX	XX
PLUS	5 dB			X	XXX	XXXX	XX	X	
	10 dB				X		XX		
	15 dB							X	X
	20 dB								
	25 dB								
	30 dB							X	
	35 dB						X		

	LEFT EAR	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	8000 Hz
MINUS	-20 dB	X	X						
	-15 dB	X	XX	X					
	-10 dB	XXXX	XX					X	X
	-5 dB		X	XXX	X	XX	X	X	XX
	0 dB			XX	X	X	XX	XX	X
PLUS	5 dB				XXX	XXX	XX		XX
	10 dB				X				
	15 dB							XX	
	20 dB								
	25 dB						X		

*Differences were computed by subtracting thresholds obtained in 1968 from those obtained in 1974. Hence, a minus change indicates an improvement in threshold, whereas, a plus change represents a decrease in threshold sensitivity.

The differences plotted on this table were computed by subtracting the thresholds obtained in 1968 from the thresholds obtained in 1974 for each of the six musicians. It can be seen in this table that the majority of musicians demonstrated no substantial deterioration in thresholds, however, there were one or two subjects who demonstrated 15 dB or greater losses at 3000 Hz and at 4000 Hz in both ears. The musician who showed the largest change, a difference of 35 dB at 3000 Hz, was the only individual of those tested that demonstrated hearing outside normal limits.

Figure 11 shows the pure-tone air-conduction thresholds of this 26 year old male, who had played drums in a rock and roll band for a period of nine years but who had ceased playing for approximately one year prior to the time of his last audiometric test in 1974. As can be seen in the figure, this individual shows a classic noise-induced type of audiometric configuration. Based on the subject's history there was no apparent explanation to account for this hearing loss other than exposure to high intensity levels of rock music.

Since one musician demonstrated a loss in hearing, it can be said that the present study supports the notion that there are some individuals who are seemingly highly susceptible to a noise-induced hearing loss. However, it appears that the majority of individuals can be exposed to high levels of rock music, approximately 109 dB SPL, (or 103 dBA) for a period of 7.3 years consisting of an average of 22.5 hours per week without suffering substantial changes in their auditory thresholds.

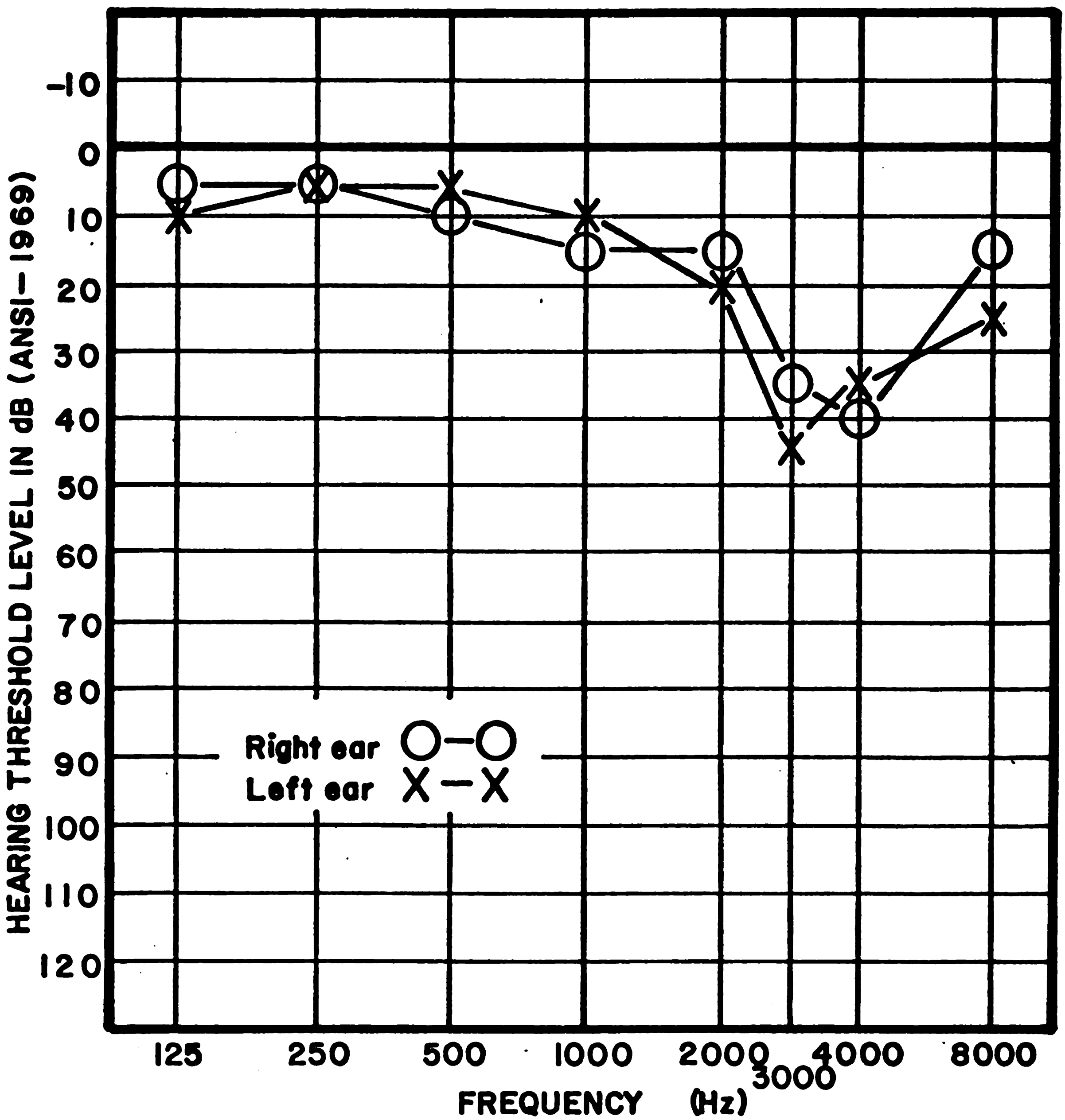

Figure 11. Pure-tone air-conduction thresholds for right and left ears of a 26 year old male rock and roll musician who played drums in a band for a period of nine years. Bone-conduction thresholds are not shown but were interweaving with the air-conduction thresholds.

PART THREE: TTS MEASUREMENTS

The third part of this study consisted of obtaining threshold measurements from a group of five rock and roll musicians to determine temporary threshold shifts (TTS). Pure-tone air- and bone-conduction thresholds were measured on all five musicians approximately one-half hour prior to their performance that evening. The amount of time that had elapsed between this test and their most recent performance was approximately 19 hours.

Appendix B shows the ambient noise levels of the test room used for this portion of the study. According to the ANSI standards for background noise in audiometer rooms (ANSI, 1960), the ambient noise had possibly interferred with the lower frequency threshold of 250 Hz. However, the high-frequency region which is more susceptible to TTS appears to be free from interferring ambient noise.

After the group had played four 40 minute "sets" and one 30 minute "set", with 20 minute breaks in between each "set", at overall intensity levels of approximately 108 dB SPL (or 102.2 dBA), pure-tone air- and bone-conduction threshold measurements were obtained. These measurements were made within seven to 25 minutes of the end of their performance. Figure 12 presents the average TTS for the five musicians as a function of frequency for both righ and left ears. This

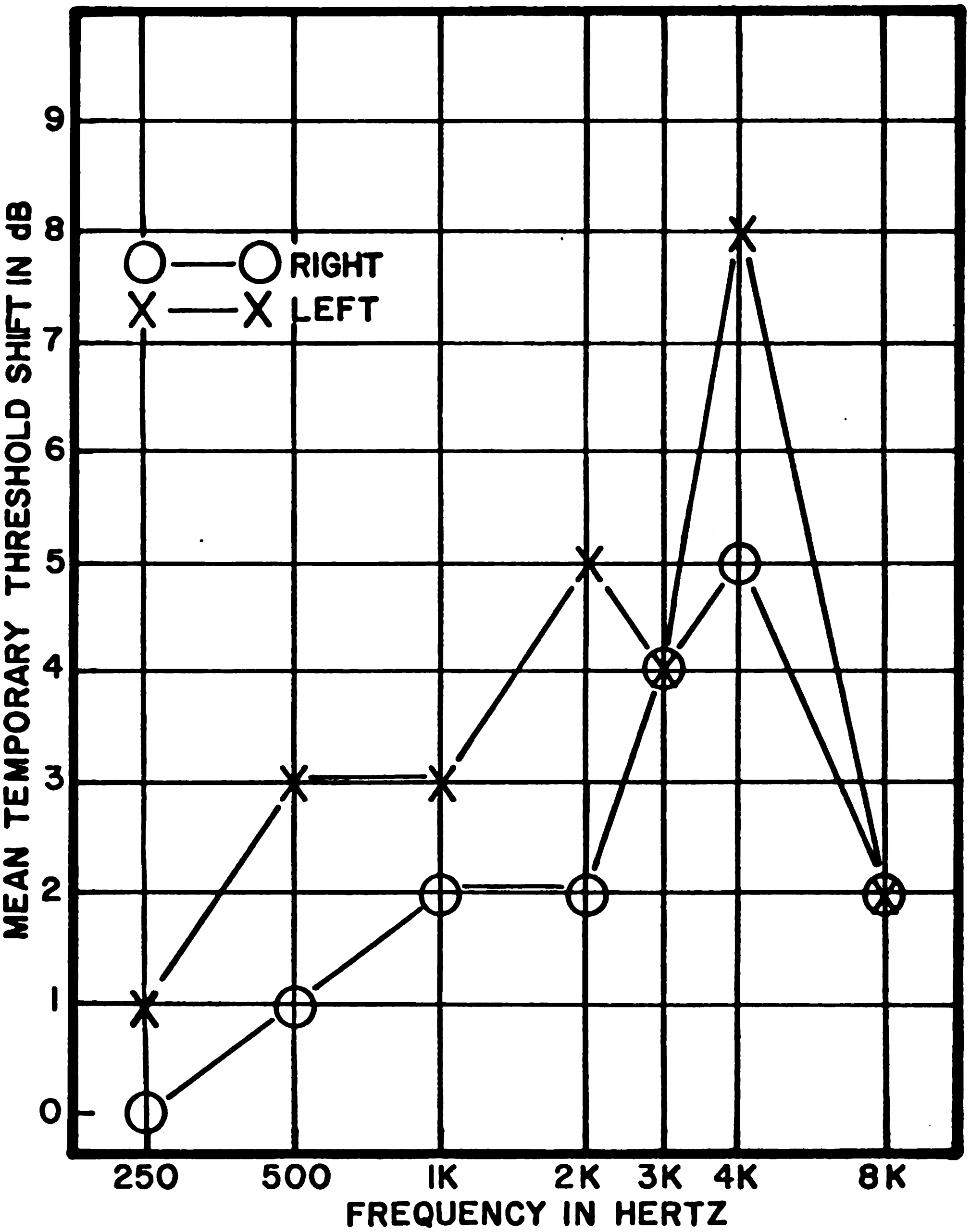

Figure 12. Amount of average temporary threshold shift (7 - 25 minutes post-exposure) resulting from playing rock and roll music for an evening. (N=5 musicians)

demonstrates that with the exception of the left ear at 4000 Hz, the mean TTS was five dB or less at all test frequencies. Thus a minimal amount of TTS was found.

The TTS exhibited by each subject as a function of frequency is shown in Table 9. This table reveals that in no instance did any musician receive more than 10 dB of TTS at any frequency. In fact, except for the left ear at 4000 Hz, most musicians demonstrated five decibels or less TTS. It should be noted that these findings differ somewhat (show less TTS) from the results of previous studies. These differences will be discussed later.

Table 9. Amount of temporary threshold shift (7-25 minutes post-exposure) resulting from playing rock and roll music for an evening. (N=5 musicians).

TTS in dB	Frequency in Hertz						
RIGHT EAR	250	500	1000	2000	3000	4000	8000
-10	1*						
- 5				1			1
0	4	4	3	1	2		2
+ 5		1	2	3	2	5	1
+10					1		1
MEAN TTS:	-2	+1	+2	+2	+4	+5	+2
LEFT EAR	250	500	1000	2000	3000	4000	8000
-10							
- 5							1
0	4	2	2	2	2		1
+ 5	1	3	3	1	2	2	3
+10				2	1	3	
MEAN TTS:	+1	+3	+3	+5	+4	+8	+2

*The number indicates how many subjects displayed a given amount of TTS.

PART FOUR: LISTENER ATTITUDES

The fourth and final portion of this study consisted of obtaining attitudes towards loudly played music from 50 individuals. These 50 individuals were divided into two groups of 25. The first group consisted of rock musicians and individuals who were present where rock music was being played. The second group was composed of students who were attending a lecture on a college campus when the questions were given. Both groups were given a questionnaire asking the following five questions: 1.) "Estimate the percentage of time, out of your total music listening experience, you listen to <u>live</u> rock music", and "Estimate the percentage of time, out of your total music listening experience, you listen to <u>recorded</u> rock music". 2.) "Do you feel that rock music needs to be loud in order to enjoy it? If so, why?" 3.) "Do you think your hearing is being damaged from exposure to this type of music?" 4.) "Do you feel that rock music is typically too loud, too soft, or just about right?" 5.) "If it were a known fact that rock and roll music was damaging to your hearing would you continue to voluntarily expose your hearing to this type of hazard?" The answers obtained to these five questions are presented in Table 10.

In regards to question number one, the mean percentage of time the individuals in group one said they listened to

Table 10. Responses of 50 individuals to five questions regarding their attitudes towards loudly played music.

QUESTION			Group #1*: NUMBER	PERCENTAGE	Group #2**: NUMBER	PERCENTAGE
1.)	a.	live	-***	21.4%	-	11.0%
	b.	recorded	-	75.0%	-	61.6%
	c.	other	-	3.6%	-	27.4%
2.)	a.	not needed loud	22	88.0%	21	84.0%
	b.	needed loud	2	8.0%	2	8.0%
	c.	uncertain	1	4.0%	2	8.0%
3.)	a.	believe hearing damaged	10	40.0%	9	36.0%
	b.	do not believe hearing damaged	14	56.0%	16	64.0%
	c.	uncertain	1	4.0%	-	-
4.)	a.	too loud	5	20.0%	18	72.0%
	b.	just right	20	80.0%	7	28.0%
	c.	too soft	-	-	-	-
5.)	a.	would not continue	20	80.0%	17	68.0%
	b.	would continue	4	16.0%	4	16.0%
	c.	would, but not as frequently	1	4.0%	4	16.0%

*Group #1: Twenty-five musicians and audience members consisting of 19 males and 6 females ranging in age from 17 to 37 years with a mean age of 23.2 years.

**Group #2: Twenty-five students consisting of 6 males and 19 females ranging in age from 19 to 34 years with a mean age of 22.2 years.

***In question number one, subjects were asked to estimate their music listening experience in percentage of time, hence, number does not apply.

live rock music was 21.4%. The mean percentage of time, stated by this group, spent listening to recorded rock music was 75%. The remaining 3.6% of the time was spent listening to music other than rock. Group two answered with a mean percentage of 11% concerning the time spent listening to live rock music and a mean percentage of 61.6% listening to recorded rock music. Again, the remaining 27.4% of time was devoted listening to music other than rock.

With question number two, twenty-two (88%) of the individuals from group one felt that rock music did not need to be loud in order to enjoy while two people felt that it needed to be loud. The reason one of these individuals gave for answering yes was that "it's something about the vibrotact experience that adds to it." The other individual answered that his attitude would fluctuate from day to day in regards to whether or not rock music should be loud. In the second group twenty-one (84%) of the people felt that rock music did not need to be loud in order to enjoy it and two people felt that loudness was necessary. One person's comment was when the music is loud, its easier to get into a "relaxed mood of enjoyment." Two people in the second group responded that rock music sounds good loud, but then, it can also sound great when its quieter, depending on their particular mood.

The first group answered question number three with ten (40%) of the people stating that they believed their hearing was being damaged from exposure to rock music, fourteen (56%)

of the people disagreeing with that and one person "not knowing nor caring". Group two answered this question with nine (36%) of the people thinking their hearing was being damaged from exposure to rock music and sixteen (64%) disagreeing with this.

Twenty (80%) of the individuals in group one responded to question number four by saying that rock music is typically just about right in loudness while five (20%) of the people felt that it was typically too loud. Group two had almost the opposite response of group one. Eighteen (72%) of the people felt that rock music was typically too loud while only seven (28%) of the people thought it was just about right. It should be noted that the possibility existed that differences between these two groups responses were attributed to sex differences. Therefore, the groups were revised into two smaller groups of 12 each equated by sex, six males and six females. A comparison was then made between the revised groups one and two. Ten (83%) of the individuals in group one responded by saying that rock music is typically just about right in loudness while two persons felt that it was typically too loud. Again, group two had the opposite response. Nine (75%) of the people felt that rock music was typically too loud while only three people felt that it was just about right. Thus, the differences between groups one and two regarding their responses to question four did not change when these groups were equated for sex.

The answers to question number five fell into three categories. The majority of individuals, 20 (80%) in group one and 17 (68%) in group two, responded by saying they would not continue to voluntarily expose their hearing to rock music if it was known to be hazardous. One person in group one said he would continue to listen to rock music, but not as frequently. In group two, four people said they would also listen to rock music, but not as frequently. In both groups one and two, four individuals responded to this question by saying that they would voluntarily continue listening to this type of music. Although five of these people did not give a reason for this response, two individuals in group one related this possible hazard to the known hazard of smoking. They said even though smoking is hazardous to ones health they still continue to smoke and rock music would be treated in the same fashion if indeed it was proven to be hazardous to ones hearing. One person in group two responded by saying that loud rock music serves as such a great "psychological stimulant" that it would be worth taking the chance of possible damage to the auditory system.

In general, the majority of subjects in both groups one and two listened to a great deal of rock music that was primarily recorded versus live, felt that rock music did not need to be loud in order to enjoy it, felt that their hearing was not being damaged by rock music, but said they would not continue to voluntarily listen to this type of music if it were known to be hazardous. The two groups, however, did vary in their answering of question number four. The majority of group one felt that rock music was typically just about right, while the majority of group two felt that it was typically too loud.

DISCUSSION

Acoustic Analysis of Rock Groups and Marching Bands:

According to Table 6 the results of the first portion of this investigation do not show substantial differences in the average overall sound pressure level in dB of rock groups from the majority of previous studies (Lebo et al. (1967), Rintelmann and Borus (1968), Speaks and Nelson (1968), Rintelmann (1969), Flugrath (1969), and Lipscomb (1969)). Rintelmann (1970) reviewed the results of these six independent studies and found the average intensity of rock music measured with the linear scale of a sound level meter to be approximately 104 to 111 dB SPL (re 0.0002 microbar). The measuring distances ranged from one to 20 feet from the stage. Results of the present investigation show the average intensity measured with the linear scale to be 108.9 dB SPL (re 0.0002 microbar) at five to 10 feet from the stage and 104.5 dB SPL at 11 to 20 feet from the stage.

According to Table 4, with the A scale of a sound level meter, the average intensity of the rock music was 98.1 dBA for distances ranging from five to 60 feet from the stage. Further, there seems to be little variation in the octave band sound pressure levels obtained in this study from those obtained in previous studies by Rintelmann and Borus (1968) and Rupp et al. (1974).

Thus, the results of this study support the notion that the sound pressure levels of rock groups are not as intense as some investigators have indicated (Lipscomb, 1969). Also, it appears that the intensity levels of "live" rock music have not changed appreciably within the past few years. Thus, the notion that "live" rock music has become more intense in recent years due to the availability of more powerful amplifying systems, is not supported by the results of the present study.

When applying the guidelines proposed by Cohen, Anticaglia, and Jones (1970) concerning the safe levels for noise exposure in non-occupational environments, the average sound level obtained in this study (98.1 dBA) is 13 dB higher than the safe damage risk criterion level proposed by Cohen et al.. This is assuming an individual listened to rock music for a period of two hours continuously. The proposed guidelines of Cohen et al. (1970) are reviewed below:

LIMITING DAILY EXPOSURE TIMES FOR NON-OCCUPATIONAL NOISE CONDITIONS	SOUND LEVEL IN dBA
Less than 2 minutes	115 dB
Less than 4 minutes	110 dB
Less than 8 minutes	105 dB
15 minutes	100 dB
1/2 hour	95 dB
1 hour	90 dB
2 hours	85 dB
4 hours	80 dB
8 hours	75 dB
16 - 24 hours	70 dB

Cohen et al. (1970, p. 13)

According to these guidelines an individual could listen to rock music at levels obtained in this study (98.1 dBA) for a period of 15 to 20 minutes without concern of damage to the hearing mechanism as a result of the music.

If applying the damage risk criterion put into effect by the Occupational Safety and Health Administration (1971), a person could listen to rock music at a level of 98.1 dBA for a period of nearly three hours, safely. However, since OSHA guidelines are primarily concerned with occupational noise, the guidelines of Cohen et al. (1970) concerning non-occupational noise appear more stringent and most likely safer.

The above statements primarily apply to audience members whereas the musicians are exposed to a somewhat higher level (an average of 103 dBA). Because of this, a greater amount of risk is involved. In order to be safely exposed to rock music at this level, an individual's exposure should be for a period of less than eight minutes, according to the criterion proposed by Cohen et al. (1970). However, if applying the OSHA (1971) standards, an individual could tolerate rock music at levels obtained in this study (an average of 103 dBA) for a period of nearly 1½ hours continuously.

The second segment of the acoustical analysis dealing with music produced by four marching bands is reviewed in Table 7. It is clear from these results that there is a substantial difference between rock music and music produced by marching bands. Not only is the average overall intensity considerably less for marching bands than for rock music, but the octave band SPL's are also substantially different. For example, when comparing the dBA results in Tables 4 and 7 there is a notable difference in the grand means (nearly 14 dB) between the music produced by marching bands and the music produced by rock groups (84.8 dBA and 98.1 dBA respectively). It should be noted that all measurements of the marching bands were made outdoors whereas measurements for eight of the ten rock groups were gathered in an enclosed environment. Hence, reverberation contributed to the higher SPL output for the rock music compared to the marching bands. When the damage risk criterion proposed by Cohen et al. is applied to the marching band music, it is apparent that an individual could listen to this music for a period of two hours. The OSHA guidelines, on the other hand, state that an individual could listen to marching band music at a level of 84.8 dBA for a period greater than eight hours without concern of damage to the hearing mechanism. These statements, however, primarily pertain to audience members while the musicians of these bands would be exposed to a more intense level (89.3 dBA) of music. When applying this level to the guidelines proposed by Cohen et al. (1970) it can be seen that an individual could be exposed to this music for one hour, safely. However, if the OSHA (1971) guidelines are employed a person could perform in a marching band for an eight-hour period.

With the completion of this analysis, it is apparent that music produced by the marching bands is also a hazard for the musicians, but not as hazardous as that music produced by the rock bands analyzed in this study.

Measurements of Possible Noise-Induced Hearing Losses Present in Musicians:

According to Figures 10 (A) and 10 (B), the six rock musicians of the present study, when averaged as a group, revealed no substantial hearing loss over slightly more than a seven year period. During this time the musicians spent an average of 22.5 hours performing per week. However, when these musicians are reviewed separately as in Table 8, one individual out of six had incurred a mild noise-induced hearing loss. Thus, the present study supports the supposition that there are some individuals who are apparently more susceptible to noise-induced hearing losses than others. More importantly, this study demonstrated that the majority of individuals can be exposed to levels of rock music of approximately 109 dB SPL without producing deterioration in pure-tone thresholds. This longitudinal investigation on a small sample of rock and roll musicians lends support to the earlier findings of Rintelmann and Borus (1968), namely, that exposure to rock music does not represent an undue hazard to hearing for the majority of individuals exposed.

Threshold Measurements to Determine Amount of Temporary Threshold Shift:

The amount of temporary threshold shift found in the group of rock and roll musicians who had performed for an entire evening in an acoustic environment of approximately 108 dB SPL was minimal (see Figure 12 and Table 9). In most

cases less than five dB of TTS was found. There were, however, temporary threshold shifts greater than five dB in four of the five musicians but there were no musicians that revealed a shift of more than 10 dB. This finding was not unforeseen and agrees somewhat with a previous study completed by Speaks and Nelson (1968). In contrast, however, Jerger and Jerger (1970) stated that out of nine musicians, eight showed temporary threshold shifts in excess of 15 dB for at least one frequency between 2000 and 8000 Hz within one hour of the concert's termination. According to the Committee on Hearing, Bioacoustics and Biomechanics (CHABA) Working Group 46, Kryter et al. (1966), noise is considered hazardous if it produces more than 20 dB TTS_2 at 4000 Hz during a work day over a period of years. Since the above cited damage risk criterion is based on TTS measured two minutes post-exposure, direct comparison with the results of the present study (TTS measured within seven to 25 minutes post-exposure) is somewhat difficult. However, Rintelmann et al. (1972) have demonstrated that recovery patterns for both continuous and intermittent music follow the logarithm of time rule. They found at 4000 Hz, an average TTS of approximately 25 dB two minutes post-exposure and approximately 13 dB at 30 minutes post-exposure. Applying the above Rintelmann et al. (1972) extrapolation and the CHABA (1966) Damage Risk Criterion to the present study, it appears that the musicians did not receive sufficient TTS at 4000 Hz to be regarded as hazardous. Hence, based upon the amount of temporary threshold shift

found, one would predict only a minor risk, or perhaps even no risk, to the musicians auditory mechanisms as a result of exposure to the rock music.

Attitudes Regarding Loudly Played Rock Music:

The attitudes of two separate groups towards loudly played rock music were obtained. Group one consisted of musicians and people attending a rock concert and group two was made up of people attending a college lecture. There were not large differences between the two groups with respect to four of the five questions. The majority of both groups listened to a greater amount of recorded rock music versus live rock music, felt rock music did not need to be loud in order to enjoy it, did not believe their hearing was being damaged from exposure to rock music, and would not continue to voluntarily expose their hearing to this type of music if proven hazardous. However, there were differences manifested when given the question regarding whether rock music is typically too loud, just about right, or too soft. The majority of group one felt that rock music was just about right while the majority of group two felt that it was typically too loud. Though the feelings of group one regarding this question were somewhat unexpected, the opinions of group two were not surprising and tend to agree with those obtained in a 1968 study by Rintelmann and Borus.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This study consisted of four parts: (1) an acoustical analysis of ten rock and roll groups and four marching bands; (2) threshold measurements on six musicians exposed to rock and roll music for a period of approximately seven years; (3) temporary threshold shift (TTS) measurements of five musicians after playing for an entire evening; and (4) an evaluation of attitudes of two groups of 25 young adults towards loudly played rock and roll music.

SUMMARY

Music played by ten rock and roll groups and four high school marching bands was acoustically analyzed. Measurements of intensity of the dBA, dBC, and Linear scale, plus octave band analyses were obtained on each group.

Rested (non-noise fatigued) pure-tone air-conduction thresholds from six musicians exposed to loud rock and roll music for approximately seven years were determined at octave intervals of 125 through 8000 Hz with the half octave of 3000 Hz. Pure-tone bone-conduction thresholds were determined at octaves 250 through 4000 Hz plus the half octave of 3000 Hz.

For purposes of determining the amount of temporary threshold shift, pure-tone air-conduction thresholds at octaves 250 through 8000 Hz with the half octave of 3000 Hz were obtained from a group of five rock and roll musicians prior to and immediately following an evening of performing. Their performance consisted of four 40 minute "sets" and one 30 minute "set" with 20 minute breaks between each "set".

Fifty young adults, divided into two groups, were given five questions to be answered in regards to their attitudes towards loud rock and roll music. Group one consisted of musicians and audience members at a local discotheque and group two consisted of students attending a college lecture.

CONCLUSIONS

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

1.) There were no substantial differences in the acoustical analyses of "live" rock and roll music obtained in the present study from the majority of measurements obtained in previous studies. Within a range of five to 60 feet from the sound source, average measurements were 98.1 dBA and 104.6 dB (Linear) SPL (re 0.0002 microbar).

2.) There were substantial differences, in both overall intensity levels and spectral distribution, between rock and roll music and music produced by marching bands. Music produced by the marching bands, within a range of five to 60 feet from the sound source averaged 84.8 dBA and 92.7 dB (Linear) SPL (re 0.0002 microbar). This difference in overall intensity level of approximately 13 and 12 dB repectively between marching band music and rock music demonstrated that rock groups produce substantially more intense music than do high school marching bands.

3.) Generally, there were no substantial (greater than 10 dB) changes in the pure-tone thresholds in five out of six musicians who had been in contact with loud rock and roll music for a period of approximately seven years. Hence, when musicians were followed over a period of approximately seven years, deterioration of auditory thresholds was not found

4.) There was no sizeable amount (most cases five dB or less) of TTS present in a group of five rock and roll musicians after an evening of playing.

5.) When the attitudes of a group of musicians and spectators in a discotheque were compared to the attitudes of a group of college students in a classroom, the majority of musicians and spectators felt that rock music is just right while the majority of the second group felt that rock music is too loud.

6.) There were no substantial differences among the four remaining questions between the two groups concerning their opinions towards loudly played rock and roll music. Specifically, these young adults stated:

    a.) they listened to a greater amount of <u>recorded</u> music versus <u>live</u> rock music.
    b.) rock music did not need to be loud in order to enjoy it.
    c.) they felt that their hearing was not being damaged from exposure to rock music.
    d.) they would not continue to voluntarily expose their hearing to this type of music if proven hazardous.

RECOMMENDATIONS

1.) The overall sound pressure levels of music played by rock and roll bands should be measured in one to two years to determine whether the intensity levels of this type of music is remaining stable, increasing or decreasing.

2.) Music produced by marching bands both in enclosed and outdoor environments should be acoustically analyzed and compared to determine whether there are substantial differences resulting from these

two types of environments. If the SPL output is increased in an enclosed environment (e.g. music practice room), the potential damage risk must be re-evaluated.

3.) In order to continue to determine long-term effects of rock and roll music, a group of musicians should be tested annually (if possible) for at least ten years. During this period the results from pure-tone, speech, and various site of lesion tests (e.g. tone decay) should be gathered. This would permit a detailed evaluation of the potential effects upon the auditory system.

4.) The present TTS study should be replicated with the following changes. Threshold measurements from both musicians and listeners should be obtained periodically during the course of an evening to determine possible cumulative TTS. Therefore, post-exposure threshold measurements should be obtained following each "set" so that differences throughout the evening can be measured.

APPENDICES

APPENDIX A

INDIVIDUAL THRESHOLDS OF EACH MUSICIAN IN 1968, 1971, AND 1974 SHOWN BOTH IN TABULAR AND IN AUDIOMETRIC FORM.

APPENDIX A

INDIVIDUAL THRESHOLDS OF EACH MUSICIAN IN 1968, 1971, AND 1974 SHOWN BOTH IN TABULAR AND IN AUDIOMETRIC FORM.

Table A-1. Subject 1 - Pure-tone air-conduction thresholds in dB Hearing Level (1968, 1971, 1974) for right and left ears of a 28 year old male rock and roll musician who played woodwinds in a band for a period of 10 years. Bone-conduction thresholds are not shown but were interweaving with the air-conduction thresholds.

	RIGHT			LEFT		
Hz	1968	1971	1974	1968	1971	1974
125	20	--	10	20	--	10
250	20	15	10	15	10	5
500	20	10	5	10	10	5
1000	0	0	0	-5	0	0
2000	0	0	-5	5	5	0
3000	10	--	10	0	--	5
4000	30	25	25	0	0	15
8000	45	10	35	20	15	10

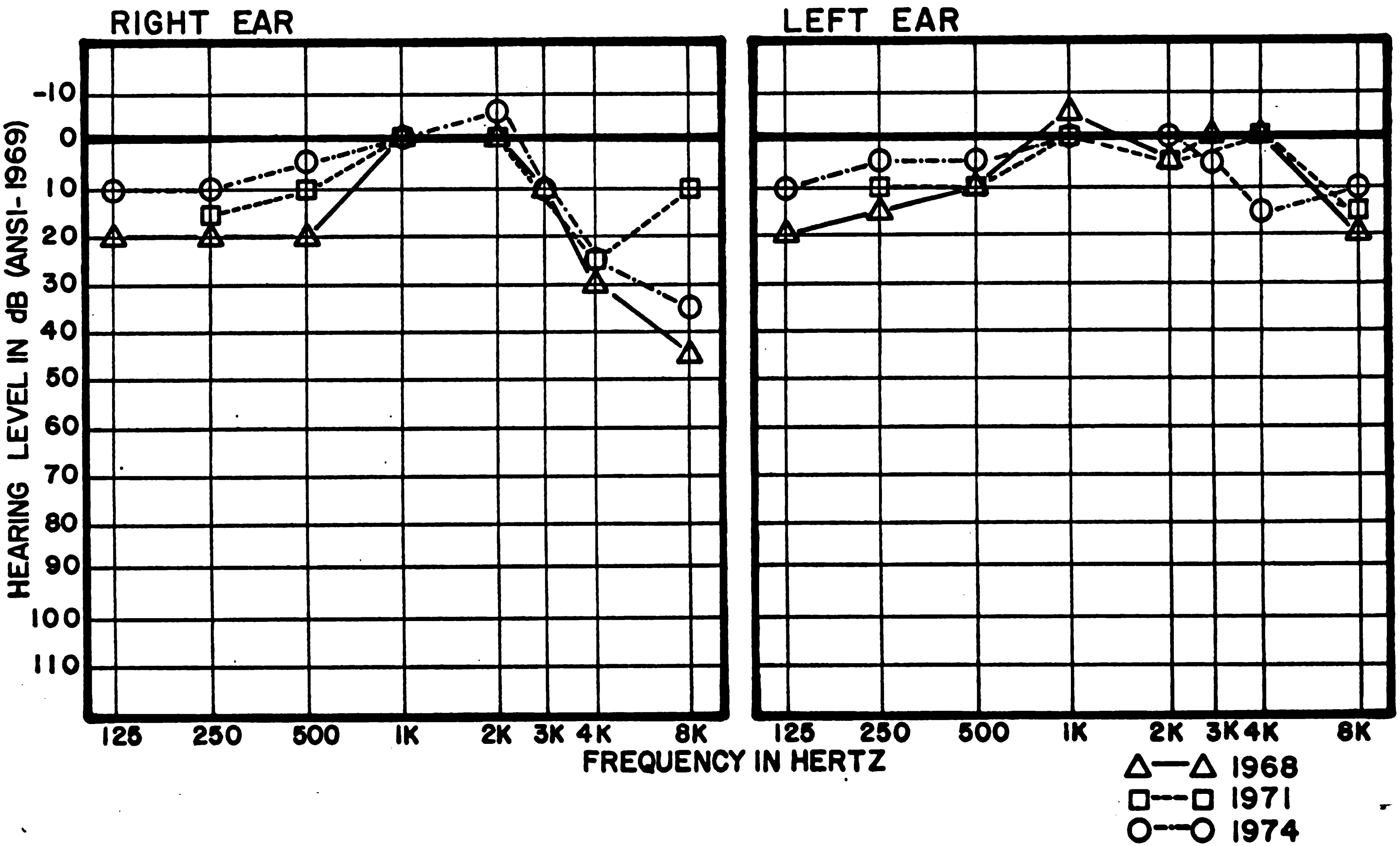

Figure A-1. Subject 1

Table A-2. Subject 2 - Pure-tone air-conduction thresholds in dB Hearing Level (1968, 1971, 1974) for right and left ears of a 26 year old male rock and roll musician who played guitar (lead and bass) for a period of seven years. Bone-conduction thresholds are not shown but were interweaving with the air-conduction thresholds.

	RIGHT			LEFT		
Hz	1968	1971	1974	1968	1971	1974
125	5	5	0	15	10	-5
250	15	5	0	15	0	-5
500	10	5	0	10	5	-5
1000	0	5	5	10	5	5
2000	0	10	5	5	0	5
3000	5	15	15	5	5	5
4000	15	20	20	10	5	10
8000	30	25	25	10	5	15

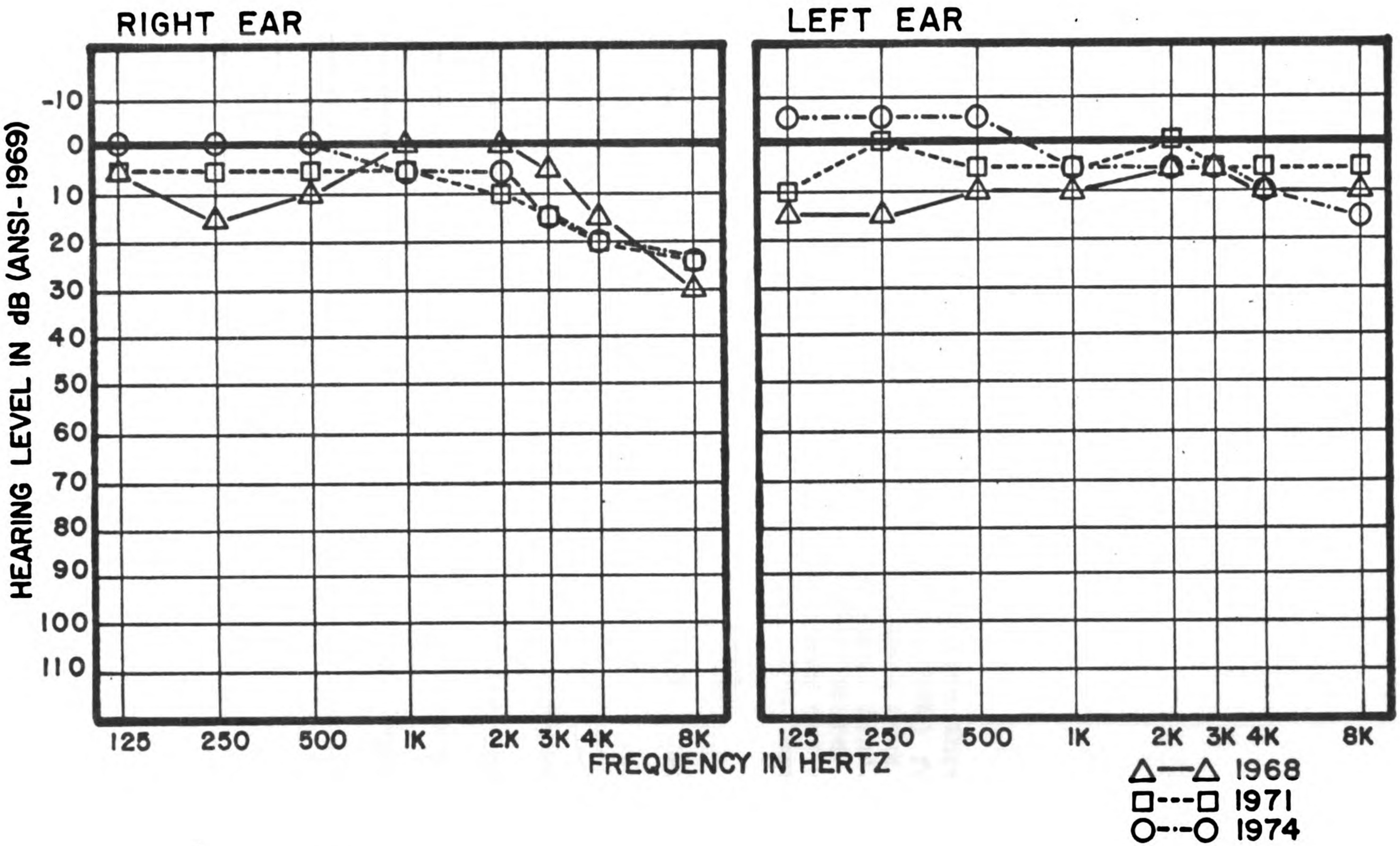

Figure A-2. Subject 2

Table A-3. Subject 3 - Pure-tone air-conduction thresholds in dB Hearing Level (1968, 1971, 1974) for right and left ears of a 26 year old male rock and roll musician who played guitar (rhythm, lead, bass, and drums), for a period of seven years. Bone-conduction thresholds are not shown but were interweaving with the air-conduction thresholds.

	RIGHT			LEFT		
Hz	1968	1971	1974	1968	1971	1974
125	15	15	5	15	15	0
250	15	10	0	10	15	-5
500	5	0	0	5	0	0
1000	0	0	5	5	0	10
2000	0	0	5	0	-5	5
3000	0	0	5	0	0	-5
4000	0	0	0	5	0	5
8000	0	0	0	5	-10	5

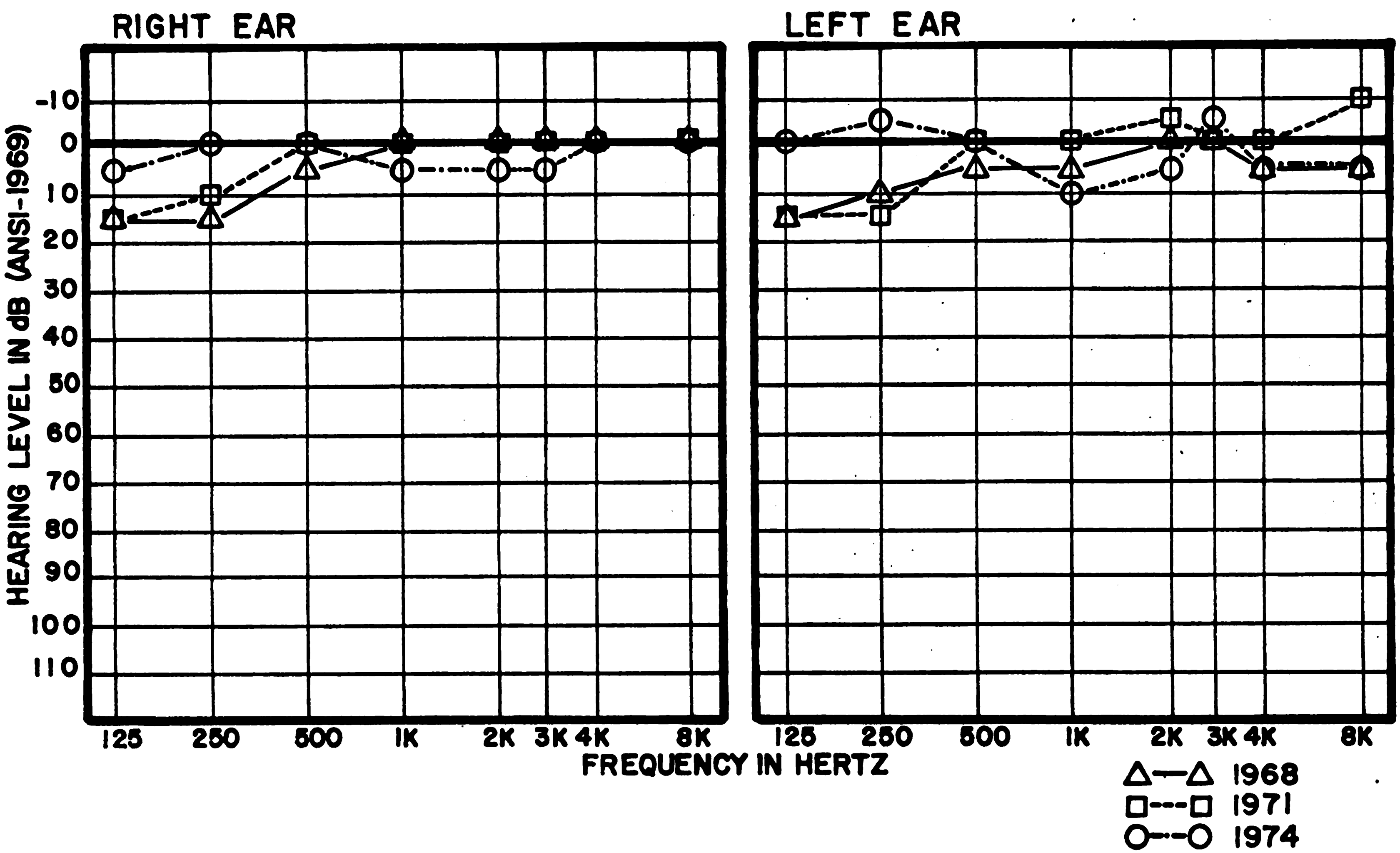

Figure A-3. Subject 3

Table A-4. Subject 4 - Pure-tone air-conduction thresholds in dB Hearing Level (1968, 1971, 1974) for right and left ears of a 26 year old male rock and roll musician who played the drums in a band for a period of nine years. Bone-conduction thresholds are not shown but were interweaving with the air-conduction thresholds.

	RIGHT			LEFT		
Hz	1968	1971	1974	1968	1971	1974
125	10	5	5	20	5	10
250	10	0	5	20	0	5
500	5	0	10	10	0	5
1000	5	0	15	0	0	10
2000	10	5	15	15	5	20
3000	0	5	35	20	10	45
4000	10	0	40	20	5	35
8000	0	5	15	20	10	25

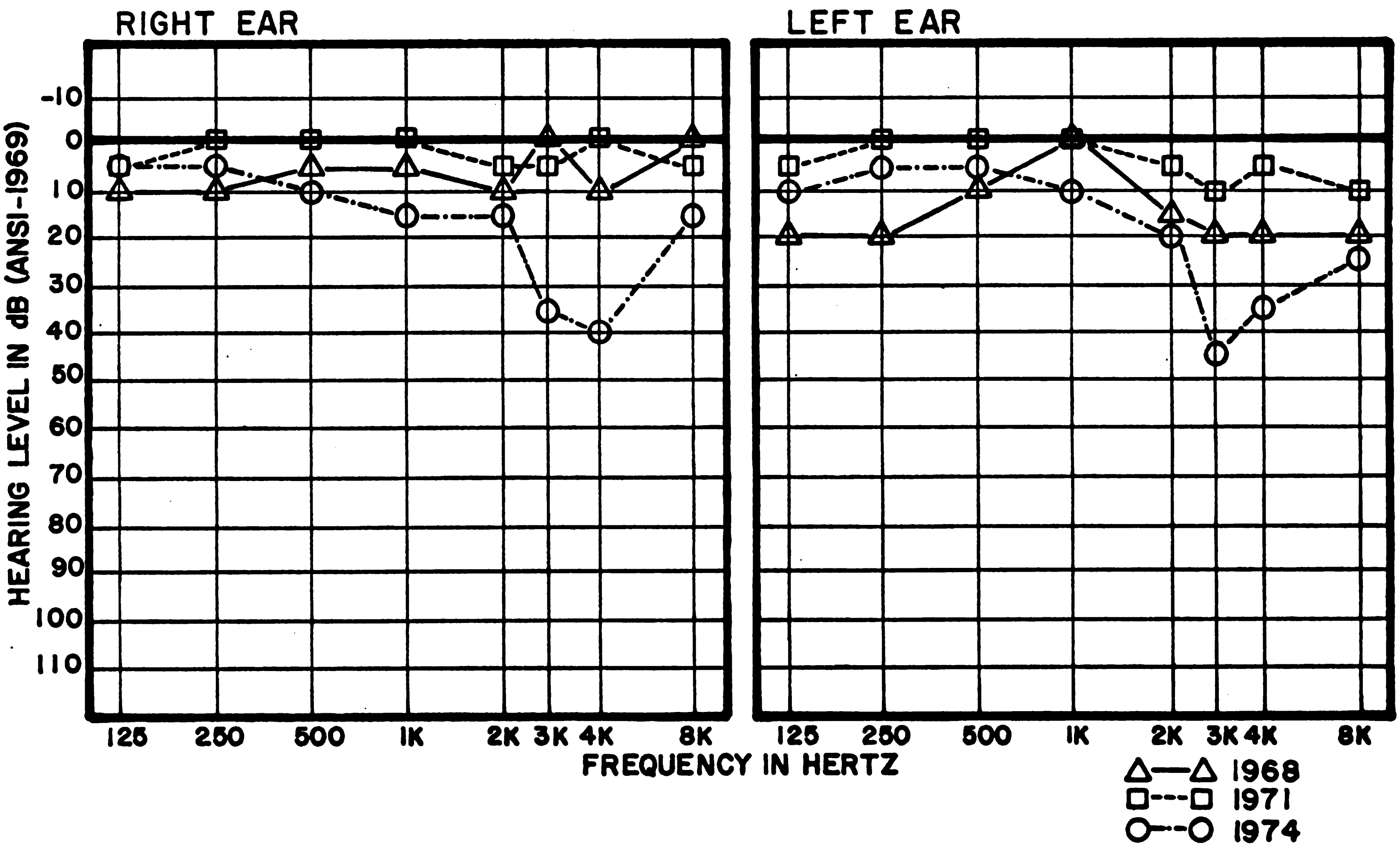

Figure A-4. Subject 4

Table A-5. Subject 5 - Pure-tone air-conduction thresholds in dB Hearing Level (1968, 1971, 1974) for right and left ears of a 25 year old male rock and roll musician who played bass guitar for a period of five years. Bone-conduction thresholds are not shown but were interweaving with the air-conduction thresholds.

	RIGHT			LEFT		
Hz	1968	1971	1974	1968	1971	1974
125	10	0	0	10	0	0
250	10	0	5	5	0	0
500	5	0	5	0	0	0
1000	5	0	5	0	0	0
2000	10	5	5	10	0	5
3000	5	5	10	5	0	5
4000	10	0	10	25	5	15
8000	10	0	0	5	5	0

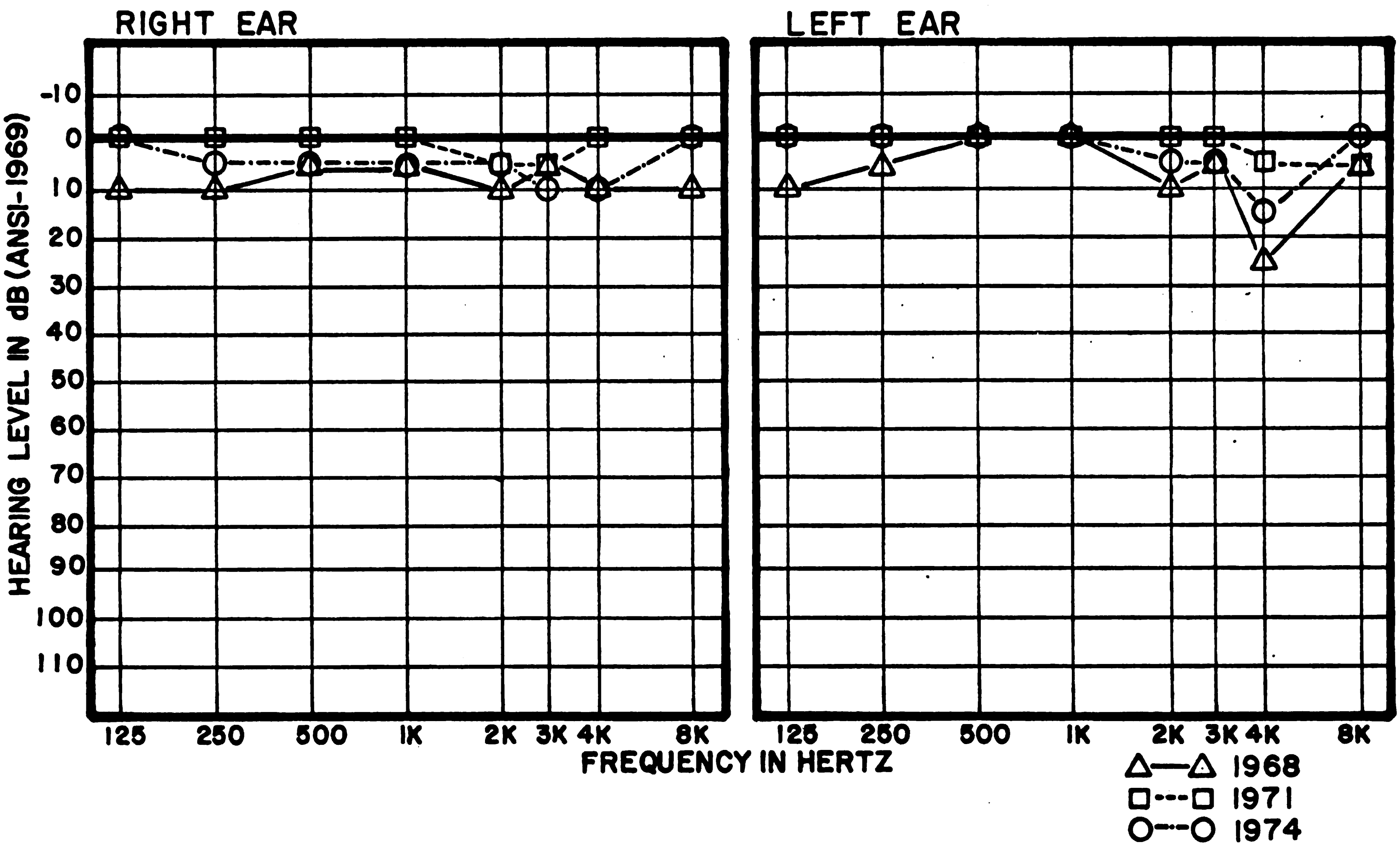

Figure A-5. Subject 5

Table A-6. Subject 6 - Pure-tone air-conduction thresholds in dB Hearing Level (1968, 1971, 1974) for right and left ears of a 25 year old male rock and roll musician who played lead guitar for a period of six years. Bone-conduction thresholds are not shown but were interweaving with the air-conduction thresholds.

	RIGHT			LEFT		
Hz	1968	1971	1974	1968	1971	1974
125	15	10	10	10	10	0
250	10	5	5	10	0	0
500	5	5	0	0	0	0
1000	0	0	5	-5	0	0
2000	-5	0	0	-5	0	0
3000	-5	0	5	0	0	5
4000	5	0	20	5	5	0
8000	10	0	10	15	0	10

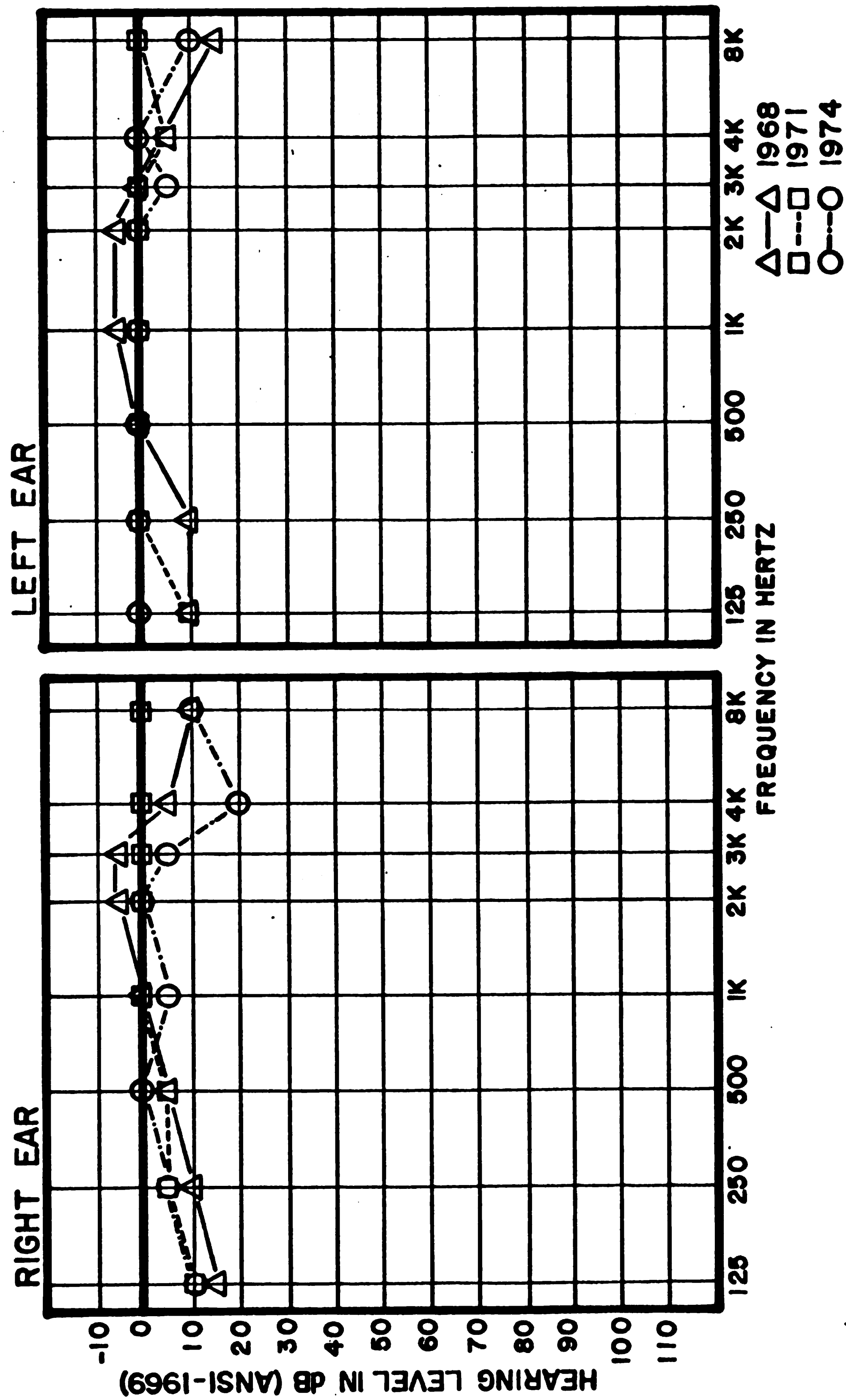

Figure A-6. Subject 6

APPENDIX B

AMBIENT NOISE LEVELS MEASURED IN THE TEST ROOM FOR THE TTS INVESTIGATION.

APPENDIX B

AMBIENT NOISE LEVELS MEASURED IN THE TEST ROOM FOR THE TTS INVESTIGATION.

Table B-1. Means and ranges of the overall sound pressure levels and octave bands in decibels of the ambient noise measured in the test room for the TTS investigation prior to and following the rock performance. The number of measurements made is shown in parantheses.

PRIOR TO PERFORMANCE

	dBA	dBC	dB Lin.	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1K Hz	2K Hz	4K Hz	8K Hz
MEAN	47.6(5)	65.2(5)	68.8(5)	60(2)	65(2)	53(2)	49(2)	40(2)	35(2)	35(2)	25(2)	12(2)
RANGE	47-49	64-66	68-69	59-61	65-65	52-54	48-50	40-41	34-35	35-35	25-26	12-13

FOLLOWING PERFORMANCE

	dBA	dBC	dB Lin.	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1K Hz	2K Hz	4K Hz	8K Hz
MEAN	47.6(5)	62.8(5)	66.2(5)	59.5(2)	64(2)	54.5(2)	49.5(2)	40(2)	34(2)	34(2)	26(2)	12(2)
RANGE	46-49	60-64	64-68	59-60	64-64	54-55	49-50	40-40	33-35	34-34	26-26	11-13

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