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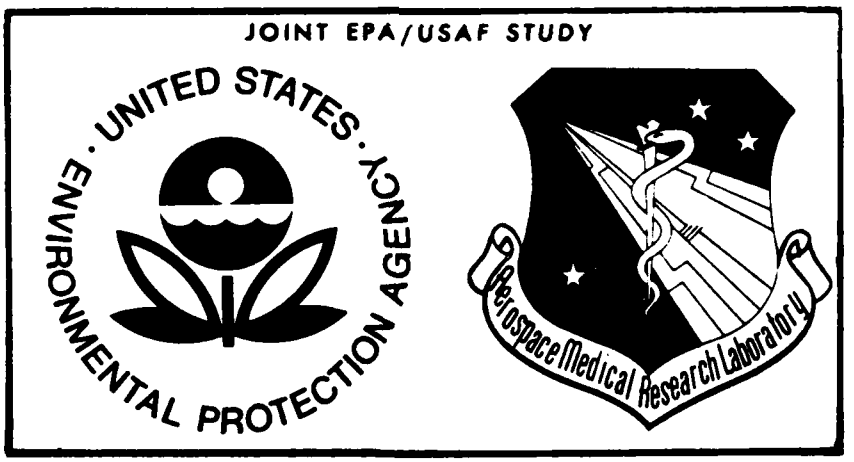
LONGITUDINAL STUDY OF HUMAN HEARING: ITS RELATIONSHIP TO NOISE AND OTHER FACTORS III. RESULTS FROM THE FIRST FIVE YEARS

ALEXANDER F. ROCHE
W. CAMERON CHUMLEA
ROGER M. SIERVOGEL

FELS RESEARCH INSTITUTE AND
DEPARTMENT OF PEDIATRICS
WRIGHT STATE UNIVERSITY
SCHOOL OF MEDICINE
800 LIVERMORE STREET
YELLOW SPRINGS, OHIO 45387



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FOR THE COMMANDER

HENNINGE. VON GIERKE, Dr Ing
Director
Biodynamics and Bioengineering Division
Air Force Aerospace Medical Research Laboratory

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Analyses have been made of serial data from children aged 6 to 18 years. These data relate to auditory thresholds, noise exposure obtained from questionnaires and dosimetry records and the results of otoscopic, tympanometric and speech discrimination tests. For those children also enrolled in the Fels Longitudinal Study of Growth and Development, there are serial data for body size, maturity, and blood pressure.

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SUMMARY

This report describes a serial study of auditory thresholds in children 6 to 18 years of age. In addition, data have been obtained from 58 participants after the age of 18 years, and the analysis of these data is included in the present report. Pure-tone air-conduction auditory thresholds, and data relating to physical size, maturity, tympanometry, otological inspections, otological, recreational, and medical histories, and 24-hour dosimetry records of noise exposure are obtained serially from a group of Southwestern Ohio children and young adults.

The major aims of the study are to determine the variation among children in patterns of change in pure-tone air conduction thresholds (AC thresholds) with age and to analyze the relationships between these changes in thresholds and environmental and biological factors. The present report includes a description of the design of the study (a more complete account is available in AMRL-TR-76-110 and AMRL-TR-79-102) and analyses of the data collected in the first five years of the study.

Satisfactory auditory threshold examinations have been obtained since 26 January 1976, after initial difficulties with audiometric test equipment. The data analyzed in this report were collected through 15 March 1980. The means of the recorded thresholds are near but slightly below audiometric zero (ANSI-1969) for the lower tonal frequencies, but are 2 to 3 dB higher at 4000 to 6000 Hz. The older participants have lower mean thresholds at all frequencies than the younger ones, and age is negatively and significantly correlated with thresholds. Hearing ability appears to increase during adolescence, but older children are also more able to perform the testing tasks. A total examination effect across age of about 4 dB was detected in the data, and it was correlated with age. All examination effects were removed from the data before subsequent analyses. In general, the mean and median thresholds are 2 to 6 dB lower than those recorded in U.S. national surveys for children of the same age and sex. There are indications some abnormal otological findings are associated with a reduction in hearing ability and that lateral differences in thresholds occur primarily in younger children.

Quantitative scores have been derived from 1478 interval noise exposure histories which relate to noise exposure since the previous examination. Questionnaire data indicate an increase in total noise exposure (all sources combined) with age. This change with age is more pronounced in boys. There is, however, little evidence that the interval noise scores are reflective of children's daily noise exposure, as determined by 24-hour dosimetry for selected children.

The associations between questionnaire noise scores or $L_{eq(24)}$ and threshold levels are, in general, not significant, although some trends are present. Twenty sound sources categories were determined from activity diaries kept by participants wearing Metrosonics dosimeters. The highest average levels of sound come from lawnmowers, live music, riding a school bus, at recesses and assemblies at school; each of these sound sources have an average $L_{eq(24)}$ greater than 80 dB.

There is suggestive evidence that rate of maturation is associated with auditory thresholds. Around puberty or menarche, more mature girls have lower thresholds (better hearing). There is little association between speech discrimination scores and auditory thresholds. There is no evidence that blood pressure is significantly correlated with auditory thresholds.

There are no previous studies of children dealing with auditory thresholds, and possible environmental, biological and developmental factors that could affect these thresholds. Yet such studies are necessary to determine whether the changes in thresholds observed in cross-sectional surveys are due to marked changes in a sub-sample of children or changes in all children.

The information from the study in relation to the effects of environmental noise on the hearing levels of children and youth will be of great value to the Environmental Protection Agency and the USAF, particularly when the serial data extend until these individuals become adult menbers of the work force. Even the identification and quantification of sources of noise exposure in children is important in light of the complete lack of information in this area.

This study aims to determine the changes in auditory patterns with age during childhood and into young adulthood and to relate these patterns to environmental and biological factors. The study is appropriate in design and has a great potential to determine the relationships between auditory thresholds, noise exposure and strictly biological variables.

PREFACE

This work was supported by the Environmental Protection Agency and the Bioacoustics Branch of the Aerospace Medical Research Laboratory at Wright-Patterson Air Force Base, Ohio.

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INTRODUCTION

It is well-recognized that environmental noise can adversely affect people of all ages, but children require special consideration. One reason is the possibility that they are more susceptible to a loss of hearing ability as a result of noise exposure than adults. Another reason is that children, at various times, may be exposed to particular types of noise that may not be recognized as possibly influencing their hearing. The noise exposure of a pre-school child who lives near a busy freeway or rides a bus to school each day are examples. It has been suggested that noise has a more marked effect on physiological functions when the person exposed to the noise has no control over it and, therefore, it is associated with more psychological stress (Glass and Singer, 1972; Cohen et al., 1979). This is especially true for children. For example, children do not determine their places of residence or the purchase of noise products used around the house, e.g., power tools.

Furthermore, the effect of a marked hearing loss on the functioning of a child may be more severe than for an adult due to the learning disability to which it may lead. Good hearing abilities are necessary for learning and communication, especially in childhood when hearing and speech abilities and listening strategies are less well-developed than in adulthood. Even if a loss of hearing ability did not lead to learning disabilities, any permanent reduction in the hearing abilities of a child can be considered more significant than a similar reduction in an adult simply because the child can be expected to live longer. Nevertheless, there have not been effective studies of hearing abilities in children in relation to environmental factors.

The determination of serial auditory thresholds and speech discrimination in the same children, and their analysis in relation to other information, including noise exposure, health, and maturity, is essential if proper and timely decisions are to be made with respect to control of various environmental noise sources. Currently, most analyses of environmental noise impact assume that occupational noise exposure data from industrial situations can be applied directly to estimate the effects of noise on children. The validity of this assumption has not been demonstrated. From occupational noise exposure data and laboratory studies, it is known that the auditory frequencies from 3 kHz to 6 kHz are the most susceptible to typical environmental noise. The maximum levels of exposure acceptable for adults are at least tentatively established. There are no existing data on which corresponding levels for children could be based.

Hearing abilities in children are probably positively correlated with the same abilities during adulthood, although relevant data have not been reported. A convincing demonstration of this assertion requires the analysis of serial data for the same individuals; data at two points in time yielding a single increment for each individual are unlikely to provide a convincing answer. Increased knowledge and understanding of the factors that influence hearing abilities during childhood, prior

to any changes associated with occupational noise exposure, will allow better understanding of the precursors and of the significance of changes in hearing abilities due to occupational noise exposure. In turn, this could lead to controls and safeguards for important sources of occupational and non-occupational noise, e.g., lawnmowers.

Circumstantial evidence that children may be exposed to hazardous levels of noise, especially in the older teenage years, is provided by data from the Health Examination Surveys conducted by the National Center for Health Statistics (Glorig and Roberts, 1965; Roberts and Huber, 1970). These cross-sectional surveys of large representative U.S. populations show no practical sex difference in the distributions of hearing levels at 4 kHz at age 11 years but, by the age of 18 to 24 years, there is a definite worsening in the hearing levels of men while those of women remain unchanged. This may be associated with greater noise exposure in boys than girls after the age of 15 years, for which the present study provides some evidence. This continues into adulthood so that distributions of hearing levels at 3 kHz and 4 kHz in the 20-year-old men are approximately the same as those for 40-year-old women. There is no corresponding effect for thresholds at 1 kHz.

The cause of this sex difference in the hearing abilities of older teenagers and young adults is unknown. Noise exposure may be greater for teenage boys than for girls, as occurs in the present study population, but proof is lacking that this exposure is the responsible factor. Other factors might account for all or part of the difference. There could be sex-associated differences in susceptibility to noise, or in the way in which normal hearing develops irrespective of noise exposure. Furthermore, health-related factors could influence the distribution of of hearing thresholds at the age of 18 years. This study was planned to answer such questions and related questions concerning speech discrimination. Clearly, as pointed out by Ciocco in 1936, if age and sex differences appear during childhood, all studies of hearing ability should begin during childhood so that the etiology can be determined.

These cross-sectional National surveys provide excellent reference data, but they cannot provide information about changes within individuals. The sex differences in the National survey data require further documentation, the distribution of changes within individuals must be established, and these changes must be related to possible environmental and biological causal factors. Potential biological factors include previous illnesses, otological status, body size and rate of maturation.

This is the third comprehensive report from the present study. Considerable steps have been taken to obtain the answers needed. To assist in answering such questions, this report contains analyses of examination ("learning") effects in the serial data. The estimated effects for individuals have been used to adjust the recorded data to what would have been observed in a cross-sectional study. This greatly improves the accuracy of our analyses of hearing thresholds because the influence of a major intervening variable has been removed. A major addition to this longitudinal study is the determination of noise source exposure levels for children. Detailed dosimetry data are presented. Furthermore, other findings are related to shifts in auditory thresholds, otoscopy, tympanometry and speech discrimination. The data currently

available, however, allow detailed analyses of variations among individuals in susceptibility of hearing abilities to environmental factors such as noise. The development of individual hearing threshold patterns, after adjustment for examination effects, will be studied in the next phase of this study. Since the commencement of the study, 51 of the participants have passed the age of 18 years. These individuals are being recalled for examinations at biannual intervals. At these examinations, data are collected that correspond to those collected from the younger participants. This aspect of the study, which concerns the relationships between environmental and biological influences on hearing ability in childhood and the corresponding relationships within and between individuals in young adulthood will provide information that is not currently available.

This report provides a cross-sectional data base after adjustment for examination effects. These auditory thresholds are related to noise exposure, health histories, otological inspections, anthropometric examinations, and assessments of maturity. The findings are compared with those reported by others. These analyses show that when more data become available during the continuation of the study, and when more complex curve fitting techniques are applied to longer runs of serial data, it is reasonable to expect significant contributions will be made to understanding the development of hearing abilities in children and the quantitative effects of environmental noise and other factors on the hearing abilities and communication of children.

HEARING ABILITY IN CHILDREN

Newhart (1940), using pure-tone audiometry, studied 6,344 children in Minneapolis and found significant increases in thresholds in 5.4%. Ciocco and Palmer (1941) studied 13,982 school children in Washington, D.C. Unfortunately, most of the observations were made using a phonographic audiometer to test the hearing ability of the children in groups of about forty. There is ample evidence this procedure lacks specificity and sensitivity, and that it is unreliable (Fowler and Fletcher, 1926, 1928; Rodin, 1927, 1930; Laurer, 1928; Burnap, 1929; Freund, 1932; Rowe and Drury, 1932; Partridge and MacLean, 1933; Rossell, 1933). Ciocco and Palmer (1941) did, however, obtain air conduction thresholds for about 1400 of their group (700 with hearing losses and 700 with normal hearing based on testing with the phonographic audiometer). Also, they retested some children after intervals of 3 and 5 years and reported the prevalence of audiograms within categories. Abnormal records were more common at older ages, and more common in boys than girls for high frequencies. Losses at high frequencies were common and often bilateral.

Jordan and Eagles (1963) studied 4078 school children who were broadly representative of school children that age in the Pittsburgh area, except that non-whites were somewhat over-represented. The median auditory thresholds, when adjusted to ANSI-1969 standards, are all considerably above zero. There were only slight differences in thresholds between whites and non-whites, and between boys and girls. There was an increase in hearing sensitivity to about 12 years, after which the cross-sectional data show a decrease in sensitivity. This change occurred about one year earlier in girls than boys, indicating that the rate of maturation might be involved directly or indirectly. Jordan and Eagles did not attempt to establish relationships between auditory threshold levels and noise exposure.

Roberts and Humber (1970) reported U.S. population estimates for auditory threshold levels in children aged 6 to 11 years. The data were obtained by individual air conduction testing with pure-tone audiometers. The data were reported with reference to the 1951 American Standard for Audiometric Zero; for the present report, they have been adjusted to compensate for the differences between this Standard and ANSI-1969. The median thresholds reported by Roberts and Huber (1970) are very close to those of Jordan and Eagles (1963). In these cross-sectional data, the auditory thresholds decrease with age, especially at lower frequencies (Roberts and Huber, 1970). Also, other workers have reported increases in hearing sensitivity from 3 to 15 years in cross-sectional data (Black, 1939; Reyment and Rotman, 1946; Kennedy, 1957). These findings may reflect differences in levels of attention or differences in ability to follow directions or differences in the fit of the earphones rather than auditory sensitivity. Richardson et al. (1977) however, report decreases in hearing ability from 7 to 16 years that may have been due to recent changes in the levels of noise exposure experienced by teenagers.

Roberts and Ahuja (1975) reported corresponding U.S. national estimates for auditory thresholds in youths aged 12 to 17 years. Using the ANSI-1969 reference values, substantially less than half the youths had thresholds below zero; only at 1.0 and 2.0 kHz did about half the youths reach this level. The thresholds increase with frequency; this increase is rapid in the 2 to 6 kHz range as progressively older ages are considered. Also, Lipscomb (1972, 1972a) reported a dramatically higher prevalence of high school and college students failing audiometric tests at higher frequencies compared with sixth grade students. These higher frequencies are

particularly important in speech perception (Kryter, 1963; Machrae and Birgden, 1973; Suter, 1978). Berger and others (1977) reported that thresholds tended to be higher in North Carolina boys than in girls and higher in rural than in urban groups. In each of the latter groups, however, the means are higher than ANSI-1969 zero levels. Glorig and Roberts (1965) reported population estimates for auditory thresholds in United States adults. Data from their youngest age group (18-24 years) will be useful later for comparative purposes.

Carter and others (1978) reported descriptive statistics for auditory thresholds in 386 children aged 10 to 12 years in Sydney, Australia, attending schools selected as representative of quiet or noisy environments. They obtained pure-tone thresholds, and conducted impedance testing and otolaryngological examinations. The data were used to establish reference values for children free of aural disease and risk factors. In these data, the variance of auditory thresholds changes little with frequency and is similar in each sex except for a greater variance at higher frequencies in the left ears of boys.

Lenihan and co-workers (1971) reported data from 886 Scottish school children aged 5, 9 or 14 years. They excluded those who were abnormal on an otoscopic examination. In each sex for all age groups, the thresholds were higher at 0.5 kHz than at higher frequencies up to 0.4 kHz. The means decreased with age in the boys. In the girls thresholds did not change from 5 to 9 years, but they decreased from 9 to 14 years.

Most of these studies are based on somewhat unselected samples in regard to otological normality. Few have restricted their analyses to children who match the ISO-389 criteria: "An otologically normal subject is understood to be a person in a normal state of health who is free from all signs or symptoms of ear disease and from wax in the ear canal, and has no history of undue exposure to noise." While restriction to such children is theoretically desirable, the resulting differences would be unimportant clinically, except perhaps at 6 kHz, although these differences would be relevant to studies that aim to standardize audiometric zero (Robinson et al., 1979).

SEX-ASSOCIATED DIFFERENCES

Roberts and Huber (1970) did not find sex differences in median thresholds in the 6-to 11-year age range. Median thresholds have been reported to be slightly higher in boys than girls at ages 5 to 14 years (Jordan and Eagles, 1963). Roberts and Ahuja (1975) found that in youths aged 12 to 17 years, median thresholds are higher for boys than girls although these differences, based on the better ear, are very slight at 1 and 2 kHz. These sex-associated threshold differences increase with age at the higher frequencies (4 and 6 kHz). Robinson et al. (1977) found no significant sex differences in thresholds for large samples of English children examined at 7, 11 and 16 years except for significantly higher thresholds in boys than girls at 4 kHz when aged 16 years. Ciocco and Palmer (1941) reported hearing losses are about 2.5 times more common in boys than girls at high frequencies. Because this difference is present at each age, they considered factors associated with puberty could not be responsible. In an earlier study of almost 1400 children, Ciocco (1936) reported that the prevalence of high frequency hearing loss was 5 times as great in boys as in girls. Cozad and others (1974) reported a survey of 18,600 Kansas children aged 6 to 18 years. Hearing loss was more common in boys than girls at all ages; the prevalence of hearing loss increased with age only in the boys. Most of the hearing losses occurred at higher frequencies. Others have reported similar findings indicating that hearing losses are more common in boys than girls (Kodman et al., 1957; Crum, 1968; Lipscomb, 1972; Sheridan, 1972).

LATERAL DIFFERENCES

There is considerable evidence that there is a lack of systematic lateral differences in hearing sensitivity in children (Ciocco and Palmer, 1941; Kodman et al., 1957; Jordan and Eagles, 1963; Lenihan et al., 1971; Cozad et al., 1974; Robinson et al., 1979; Carter et al., 1978). Glorig and his co-workers (1957) reported, however, that right ear thresholds were lower than left ear thresholds at most frequencies in boys although the reverse occurred in girls at higher frequencies. Conversely Kodman and Sperazzo (1959), in a study of 1000 children with significant hearing loss, found losses were more common in the left than the right ear in each sex.

Roberts and Huber (1970) found no tendency for hearing sensitivity to be better on a particular side in children aged 6 to 11 years, but the magnitude of lateral differences increased with the frequency of the test tone. The lateral differences in youths aged 12 to 17 years also increase at higher frequencies (Roberts and Ahuja, 1975). The differences are larger than those found in younger United States children, aged 6 to 11 years. Furthermore, in those aged 12 to 17 years and in adults, the right ear thresholds tend to be lower than those for the left ear (Glorig and Roberts, 1965; Roberts and Huber, 1970; Roberts and Ahuja, 1975).

LEARNING EFFECTS

Soon after the introduction of pure-tone audiometry, it became apparent that "learning" played a role in these tests. Peterson (1944) reported that when those who failed the test were re-screened, almost half passed the second test, leading the American Public Health Association (1956) to ascribe failure on the first test to immaturity, excitement, lack of concentration or experience, misunderstanding of directions or hearing loss. Experimental studies of learning effects in relation to audiometric testing have been reported by Zwislocki (1958). During 6 tests at one-week intervals, an examination effect was noted until the third test after which, in agreement with Ward (1957), there was little change. Zwislocki presents some sparse data indicating the examination effect is greater in those with high initial thresholds; this would lead to an expectation that the variance of thresholds would tend to decrease with examination order. He considers the effect may occur because the subjects develop new detection clues. In these experiments, he noted some fatigue as evidenced by increases in thresholds during long experimental sessions. In the absence of reinforcement, the cumulative examination effect was about 6 dB during the 6 weekly sessions.

Learning effects in adults, during a test session with repeat tests, are about 1 dB and tend to be greater at lower frequencies (Robinson et al., 1979). Royster et al. (1980), using data from 7 annual examinations in adults, estimated that the total examination effect, on thresholds, was 4 to 8 dB.

DEMOGRAPHIC CHARACTERISTICS

Preschool children from lower socioeconomic groups make more errors in auditory discrimination tests than more privileged children, even after the effects of chronological age and intelligence quotient are partialled out (Clark and Richards, 1966). The possible effects of factors such as illness, nutrition, motivation, were not taken into account. Roberts and Ahuja (1975) found no consistent pattern of differences in auditory thresholds dependent upon size of place of residence or when comparisons were made between urban and rural groups. The thresholds tend to be higher in low income groups and in groups with low levels of parental education. In the sample studied by Carter and his associates (1978), however, socioeconomic status and the mothers' country of origin had little association with auditory thresholds. The range

of socioeconomic status in the latter group may have been less than that in those studied by Roberts and Ahuja (1975).

TYMPANOGRAPHIC AND OTOLOGICAL ASSOCIATIONS

The tympanogram (impediance measurements) is used in conjunction with otoscopy as a clinical tool to screen children with middle ear pathologies (Shurin et al., 1977; Liden and Renvall, 1980; Lindholdt et al., 1980; Norther, 1980). Middle ear pressures of $\geq$ -150 mm H_2O are associated with elevations of AC (air conduction) thresholds of greater than 20 dB in some children (Lindholdt et al., 1980), and similarly the absence of an acoustic reflex is associated with a hearing loss (Katz, 1978). Each 50 mm of H_2O decrease in middle ear pressure is associated with a change in AC thresholds of about 5 dB at low frequencies, and a change of about 2 to 3 dB at higher frequencies (Brooks, 1979). In normal children, the associations between middle ear pressures and AC thresholds have not been analyzed serially, and the relationships between the acoustic reflex and changes in AC thresholds are unknown.

There is a high degree of agreement between the findings from tympanography and from otoscopy in normal subjects (Paradise et al., 1976; Roeser et al., 1977; Northern, 1980). Tympanography is a sensitive test for middle ear effusion being positive in 87 to 99% of true cases (Brooks, 1979), but otoscopy is less effective because of its high subjectivity (Northern, 1980). However, otoscopy in combination with tympanography is an effective method of identifying those children with middle ear problems.

Roberts and Federico (1972) reported data concerning the prevalence of ear, nose and throat abnormalities and their relationship to hearing threshold levels and medical events. The data were obtained from a U.S. national probability sample of 7119 children, aged 6 to 11 years. The data were weighted to obtain national estimates. The prevalence of abnormalities was obtained by averaging the prevalence for the two sides. The external auditory meatus was completely occluded in 7.2 percent, the drum was invisible in 10 percent, dull in 5.7 percent, bulging in 0.3 percent, red in 1.2 percent and perforated in 0.4 percent of ears. These authors reported higher thresholds in children with a history of earache (difference from normal about 1.5 dB), in those with perforated drums (difference about 2 dB), in those with running ears (difference about 1.5 dB) and in those with abnormal or red drums (difference about 3 dB).

Ciocco and Palmer (1941) reported that serial changes in AC thresholds, at medium frequencies only, are related to the later state of the tympanic membrane rather than the earlier state as determined by otoscopy. In addition, Roberts and Federico (1972), reporting national estimations for U.S. children aged 6 to 11 years, found higher AC thresholds in children with perforated drums (difference about 2 dB), and with discharge from the ears (difference about 3 dB). Others, (Ciocco and Palmer, 1941; Jordan and Eagles, 1961, 1963; Eagles et al., 1967; Carter et al., 1978) have reported that, when the tympanic membrane is abnormal, AC thresholds tend to be higher by 2 or 3 dB and, if it is perforated, the thresholds are from 12 to 15 dB higher.

Carter and others (1978) reported significantly higher thresholds, and increased variances of thresholds in those with abnormal ears or at risk because of their medical history. The effect of removing such children from a sample on the observed distributions of auditory thresholds was shown in a review by Robinson and Sutton (1978). Clearly, the effect of such removal is dependent on the loss of hearing ability in affected children and the prevalence of such children. Robinson et al. (1979), in a small group tested before and after wax was removed from the external auditory meatus, found a mean difference in thresholds of about 3 dB. These differences were larger at the lower frequencies and may be confounded by an "examination" effect associated with the repeating testing. These workers found only negligible differences in thresholds between those with wax in the meatus, although some were completely occluded, and the normal group. This is not in agreement with the findings of Saltzman (1949). Robinson et al. (1979) postulate that this wax has little effect on thresholds unless it is hard and impacted. In fact, in their data, soft wax was associated with slightly lower thresholds (1.5 dB) at 2 and 3 kHz which are the frequencies associated with external and middle ear resonance.

SERIAL FINDINGS

Ciocco and Palmer (1941) reported data for school children re-examined for pure-tone air conduction thresholds after intervals of 3.5 (N = 543) and 5 years (N = 552). About half of each group had been selected as having a probable hearing loss, and about half as being normal after group testing with a phonographic audiometer. There were marked differences between pairs of records; for example, 90 percent of the pairs separated by 3.5 years differed by 5 dB or more with both increases and decreases. The changes tended to be greater at high frequencies and similar in each ear. Eagles and others (1967) found a marked tendency for serial thresholds to decrease. Wishik and others (1958) reported serial data for children whose pure-tone thresholds were measured at the age of 5 to 6 years and again about 6 years later. Among those who passed at the first examination, about 1 percent failed the second examination; whereas among those who failed the first examination, about 30 percent passed the second examination. Peckham and Sheridan (1976) reported a follow-up study of 46 children with severe unilateral hearing loss at the age of 7 years; when re-examined 4 years later, half had recovered. None of these studies took effective account of examination effects, measurement error, and age effects.

There is a need for serial data relevant to the damaged ear theory (Ward, 1976). According to this theory, ears with hearing loss are more likely than normal ears to show further loss on exposure to noise; there is some doubt about the truth of the theory, but it appears that ears with temporary threshold shifts may be more susceptible to permanent changes.

NOISE EXPOSURE AND HEARING ABILITY

Throughout this report the words "noise" and "sound" are used interchangeably. The sources of noise and the levels to which children are exposed have not been thoroughly investigated; this is one goal of the current study. Children may require special consideration in regard to environmental noise. They may be more susceptible to a loss of hearing ability as a result of noise exposure than adults and may be exposed to types of noise that may not be recognized as possibly influencing hearing.

To avoid hearing loss from environmental noise, the Environmental Protection Agency (EPA) has published guildlines for maximum noise levels "requisite to protect the public health and welfare" (EPA, 1974). The EPA recommends that the daily average 24-hour log equivalent sound level [$L_{eq(24)}$] over a period of a year, be less than 70 dB. The EPA estimated that many children regularly experience noise levels in excess of this "safe" exposure level (Von Gierke, 1974). Although this 70 dB exposure level is said to contain an "adequate margin of Safety," some children are receiving excessive noise exposure (Roche et al., 1980; Siervogel et al., 1981). Therefore, it is important for individual as well as public health reasons to measure accurately the level of noise to which children are exposed.

The EPA has estimated that the typical average daily noise exposure [$L_{eq(24)}$] for "school children" is about 77 dB in both urban and suburban locations (EPA, 1974; Von Gierke, 1975). These estimates were based on assumptions including established EPA average day and night urban and suburban noise levels, and levels for various activities based on previous EPA reports on appliance, transportation, and aircraft noise. There are very few reports of the actual noise exposure of children. Schori and McGatha (1978a, 1978b) reported dosimetry data for 50 individuals aged 5 to 54 years. The average $L_{eq(24)}$ was 73.3 dB; sex differences were not observed and age trends were not examined. In that study, participants wore Loomis or Bruel and Kjaer dosimeters 24 hours per day for seven consecutive days while they went about their normal activities. One category of ten children aged 5 to 16 years ($\bar{X}$ = 12.4 years) included in this study had a mean $L_{eq(24)}$ of 76.2 dB, which was the highest mean $L_{eq(24)}$ of any category, although it was not significantly different from the others. Other categories (all adults) were "factory/commercial", "office", "homemaker", and "college". Little variation occurred in daily $L_{eq(24)}$ values within participants, indicating that a single daily sample was representative of the individual noise exposure for a week. While one should use caution in extrapolating from these findings, it is considered that a one day 24-hour sampling of noise is fairly representative of typical noise exposure for an individual.

It is not clear whether noise is more likely to cause temporary threshold shifts in children than in adults (Mills, 1975; Saunders and Bock, 1978). Consequently, the report of Task Group 3 (1973) and the Environmental Protection Agency Levels Document (1974) do not distinguish between children and adults in regard to permissible noise exposure. Some experimental data indicate a greater sensitivity to noise in children than in adults, but these are unconvincing because the thresholds were recorded too soon after the stimulus or under conditions that differed between tests (Hirsch and Bilger, 1955; Harris, 1967; Fior, 1972). Others have suggested that the ears of the young are less susceptible than those of adults to noise-induced hearing loss, but they recover more slowly (Ward et al., 1958; Wagemann, 1967; Hétu et al., 1977). However, higher level noise exposures have been shown to cause more histological damage and more loss of hearing acuity in young than in adult animals, and these losses do not recover more quickly (Jauhiainen et al., 1972; Price, 1972; Dallos, 1973; Falk et al., 1974; Coleman, 1976; Price, 1976; Saunders and Hirsch, 1976; Bock and Saunders, 1977; Dodson et al., 1978; Lenoir and Pujol, 1980). This difference in susceptibility to noise effects might be closely related to age. In guinea pigs, there is a vulnerable period at about 8 days of age when auditory damage due to noise is more likely than at younger or older ages (Falk et al., 1974).

Temporary threshold shifts in children and adolescents have been reported after exposure to the noise associated with toy cap guns (Marshall and Brandt, 1974), model airplanes (Bess and Powell, 1972), snowmobiles (Bess and Poynor, 1972) and rock and roll music (Rintelmann et al., 1971; Ulrich and Pinheiro, 1974; Hanson and Fearn, 1975). Hanson (1975) in a study of young adults (age range 18 to 24 years) found statistically significant losses in hearing ability among those who admitted frequent attendance at pop music entertainment. The losses are larger at 2 and 4 kHz than at other frequencies. It has been suggested permanent changes in thresholds due to noise are noted first in boys aged 16 to 18 years and that firearms and farm machinery are the common contributing noise sources (Weber et al., 1967; Litke, 1971). There also may be a relationship between age and the sensitivity of hearing ability to noise among adults (Kup, 1966; Nowak and Dahl, 1971, 1971a).

Crum (1968), in a study of 100 children aged 13 to 16 years, found a marked association between noise exposure, expecially to loud music, and a loss of hearing ability. Such losses were more common in boys. A lack of a close association between noise exposure and hearing ability was reported by Carter and his associates (1975, 1976, 1978) who found no evidence that the general level of environmental noise affects hearing ability in children or young adults. However, Lukas and Swing (1978) reported that reductions in hearing ability were more common in schools with noisy external environments.

Children, like adults, also receive noise exposure as a result of the environment in which they live. For example, Cohen and others (1973) found high negative correlations between outside noise levels and floor level of the apartment in which children live. Significant positive correlations existed between floor level and scores on subsets of intelligence tests for those children living in the apartment 4 years or longer. The authors concluded the duration of residence in the apartment, and therefore, the duration of the noise was related to the impairment of auditory discrimination, and that this led to learning handicaps. This conclusion may be correct, but there were no data on whether the children differed in hearing ability before they came to live in the apartment. Furthermore, it is unreasonable to assume that the total noise exposure of the children occurred within the apartment building.

Children from noisy primary schools lag in the acquisition of reading and other skills compared with children in quiet schools. This retardation is more marked in backward students (Crook and Langdon, 1974; Bronzaft and McCarthy, 1975; Grosjean, Lodi and Rabinowitz, 1976) and could lead to life-long deficits. Deutsch (1964) hypothesized that a child reared in a noisy environment would become inattentive to acoustic cues and have a deficit in auditory discrimination. In the presence of noise, young children do more poorly on speech discrimination tests than older children which may reflect differences in noise susceptibility or maturation (Humes, 1978). It has been reported also that children from homes with high noise levels have slower responses on visual search tests and are less distractible (Heft, 1979). It has been claimed that physiological and psychological stress effects from noise are more likely in children than adults because children have less control over the noise to which they are exposed (Glass et al., 1969; Cohen et al., 1979, 1980). There is no clear distinction between children and adults in this regard. Certainly, the children in the present study controlled most of the noise to which they were exposed.

NOISE EXPOSURE AND BLOOD PRESSURE

There is a considerable literature concerning possible associations between noise exposure and blood pressure; much of this literature concerns occupational groups. In almost all these studies, it is difficult to separate the possible effects of noise from those that may be due to other sources of stress. There are few, if any, convincing studies of children although it has been reported that blood pressures tend to be higher in children attending schools near streets with a heavy traffic flow than in children whose schools are on quiet streets (Karsdorf and Klappach, 1968. Similarly, children in schools exposed to high levels of noise from aircraft have higher blood pressures than children in quiet schools (Cohen et al., 1980). In this study, the difference was most marked after the children had been in the noisy schools about 2 years; the decrease in the effect with longer attendance at these schools indicates a possible adaptation.

Clearly, noise can affect cardiovascular variables. Studies in rats have demonstrated, for example, that plasma renin activity can be increased substantially by broadband noise (white noise) at an intensity of 115 dB in animals eating normal diets and at lower intensities (90 to 100 dB) in those on a low sodium diet (Vander, 1977) Numerous studies have demonstrated that peripheral vascular tone and blood pressure can be influenced by sound in rats, monkeys and man (Borg, 1978; Peterson et al., 1980, 1981; Andren et al., 1978, 1980). While short-term cardiovascular changes have been demonstrated clearly, long-term changes due to noise exposure have not been established unequivocally. For example, Borg and Moller (1978) found no difference in levels of blood pressure between non-noise exposure control rats and either hypertensive or normotensive rats with lifelong exposure to noise.

There is a similar controversy regarding the relationship between noise and blood pressure in human beings. It has been reported that women textile workers exposed to considerable noise have higher blood pressures than control groups (Andriukin, 1961; Andrukovich, 1965; Chemin, Bramerie, and Chemin, 1970). Systolic and diastolic blood pressure are significantly higher in industrial workers with a noise-induced hearing loss than in age-matched co-workers with normal hearing (Jonsson and Hansson 1977; Manninen and Aro, 1979). This implies that the high-noise environment producing the hearing loss may have contributed to the elevated blood pressure. Takala et al.(1977) found no such difference in a similar study involving men aged, on the average, about 10 years younger than those studied by Jonsson and Hansson (1977). Likewise, Hedstrand et al. (1977), Lees and Roberts (1979), and Cohen et al. (1980) found no difference in blood pressure between industrial workers with noise-induced hearing loss and age-matched co-workers with normal hearing. A lack of association between noise-induced hearing loss and blood pressure has been reported in many earlier studies as well (Bunch, 1929; Bunch and Raiford, 1931; Miller and Ort, 1965; Cartwright and Thompson, 1975; Drettner et al., 1975). In an extensive study of older Egyptian adults, essential hypertension was associated with a loss of hearing acuity (Fakhre et al., 1976). A concordant finding has been reported for U.S. air traffic controllers,but possible effects of age were not removed in the latter study (Rose, 1978). It is not clear whether a corresponding association occurs in children.

In experimental situations, an increase of diastolic pressure, but not systolic pressure, with noise exposure has been reported in man (Ponomarenko, 1966a, b; Mosskov and Ettema, 1977a, b). In similar studies, others have reported noise-associated decreases in both systolic and diastolic pressure (Terent'ev et al., 1969. 1969). Cartwright and Thompson (1975) found no significant changes in blood

pressure in adults exposed to 91 dB broadband noise but Argnelles at al. (1970) found an increase in both systolic and diastolic pressure on exposure to 2 kHz at 90 dB. When such effects are noted, they are usually ascribed to peripheral vasoconstriction (Glass and Singer, 1972).

Krasilschikov (1967) reported industrial workers exposed to loud noise had decreases in blood pressure and pulse rate towards the end of the shift; if ear protectors were worn, these effects were not observed. Several have shown the association between noise exposure and higher blood pressure is closer for intermittent noise than for continuous noise (Shatalov et al., 1962; Pokrovskii, 1966; Maksimova et al., 1974; Tavtin, 1976; Kanevskaya et al., 1977) and that the association is more marked in young than in older workers (Shatalov et al., 1962; Shatalov, 1965; Pokrovskii, 1966; Meinhart and Renker, 1970; Maksimova et al., 1974; Kachny, 1977; Manninen and Aro, 1979). It has been reported that young factory workers tend to have decreases in blood pressure during the working day (Pokrovskii, 1966; Meinhart and Renker, 1970; Maksimova et al., 1974; Kachny, 1977), but this effect tends to reverse with increasing job experience (Kachny, 1977). These diurnal changes may be due to fatigue or other factors rather than noise.

Reports concerning the effects of vibration are relevant to possible associations between noise exposure and blood pressure. There is disagreement among the few relevant reports. Fentem and Shakir (1977) reported a lack of real changes in blood pressure when large vibrating pads were worn. Others have reported increases in blood pressure with whole body vibration (Hood and Higgins, 1965) and that vasoconstriction occurs when adolescents are exposed to noise in combination with vibration (Tsysari, 1967).

Any noise-blood pressure relationship may result from psychological stress induced by noise. Von Gierke (personal communication) has indicated that, in a large scale study of U.S. Air Force personnel, individuals in high noise environments did not have higher levels of blood pressure than those in low noise environments. It has been postulated that loud noises are not stressful to the individual, if they are under his/her control, e.g., a jet pilot might not be stressed by the jet engine noise during a flight.

In summary, while there are numerous reports in the literature dealing with possible noise-blood pressure associations, studies on children are rare. The data available about such associations, even for adults, are not definitive although some trends have been observed. Therefore, it is important for individual, as well as public, health reasons to measure accurately the level of noise to which children are exposed and to determine if it is associated with their blood pressure levels. As pointed out by Rylander (1979), previous studies of human beings relating to noise exposure and blood pressure have design problems related to self-selection and in regard to how the experimental reaction, chronically elevated blood pressure, is recorded.

A review of other non-auditory effects of noise on children will not be attempted. However, it is appropriate to point out that intuitively there is little doubt that hearing abilities are important in relation to language acquisition and scholastic performance during childhood. However, recent careful critical reviews of the literature have concluded that, while the above assumption appears true, the reported studies do not meet appropriate standards of rigor (Rapin, 1979; Naremore, 1979). Nevertheless, there is little doubt that noise in the home is

associated with reduced attentional skills (Heft, 1979). There is evidence that noise has slight but real effects on growth (Schell, 1980) perhaps through its effects on the pituitary-adrenal mechanisms (Sackler et al., 1959: Arquelles et al., 1962).

IRIS PIGMENTATION

Associations have been reported between hearing ability and iris pigmentation judged from eye color. Albinos tend to have less sensitive hearing (Turaine, 1955), and associations between these variables have been described in those with lateral differences in pigmentation and in some syndromes (Przibam, 1908; Fisch, 1959; Bonaccorsi, 1965). Such observations lead to animal experiments showing a relationship between hearing deficits due to industrial noise and the amount of melanin in the stria vascularis of the cochlea (Bonaccorsi and Galioto, 1965); in turn, the amount of melanin in the stria vascularis is correlated with the amount in the iris (Bonaccorsi, 1965). Others have reported that hearing loss in industrial populations is associated with iris pigmentation (Carlin and McCroskey, 1980; Carter, 1980; Ward, 1980).

Experimental findings in man are conflicting partly because of methodological differences. Tota and Bocci (1967) reported the size and duration of temporary threshold shifts after exposure to a continuous tone (1 kHz at 110 dB SPL) is related to iris pigmentation. These findings were not confirmed by Karlovich (1975) who used the same noise exposure but a pulsed tone at 1.414 kHz; this choice maximizes the possibility of demonstrating fatigue but excludes the possibility of showing adaptation (Thwing, 1955).

RELIABILITY

Howell and Hartley (1972), in testing young adults, reported a mean interobserver difference of 5 dB with differences up to 21.2 dB. There was a significant systematic difference between the two observers. Jordan and Eagles (1963) reported mean interobserver differences of 1.3 to 8.8 dB with the larger differences tending to occur at lower frequencies. The audiometers used were graduated in 5 dB steps.

SPEECH DISCRIMINATION

There is little doubt speech discrimination under everyday conditions of noise exposure is adversely affected by reductions in hearing ability. The relationships among speech discrimination scores, auditory thresholds and noise exposure are particularly important during childhood because of their relevance to education. Some individuals with mild levels of hearing loss may have a small but potentially important reduction in speech discrimination scores. For example, children are not able to fill in missed auditory cues masked by noise. Adults use their knowledge of language to compensate for missed auditory information; whereas children may not have a sufficiently sophisticated knowledge of language to fill in missing words.

Various methods and word lists are used to test the adequacy of speech discrimination. However, any such test covers only a small part of everyday speech materials and speech conditions. Such tests are designed to be homogeneous with respect to intelligibility, hopefully providing a consistent measure of threshold intelligibility (Quiggle et al., 1957).

Fletcher (1929) was one of the first to detect an association between the ability to discriminate words and air conduction thresholds. He found that these thresholds at 2 and 3 kHz are correlated highly with speech discrimination scores, as is the difference between the AC thresholds at 0.5 and 2 kHz. In addition, the threshold at 2 kHz is closely associated with speech discrimination scores (Yoshioka and Thornton, 1980). Such data are, however, ear and speech perception level dependent. Speech discrimination scores are related more closely to AC thresholds in the better ear than to those in the worse ear (Macrae and Brigdon, 1973). Also normal speech discrimination scores of 86 to 100% may occur as long as AC thresholds remain below an average of 40 dB at 0.5, 1 and 2 kHz (Yoshioka and Thornton, 1980; Jerger and Jordan, 1980; Thompson and Hoel, 1962). However, high frequency hearing loss causes difficulty in speech in a noisy environment (Quist-Hanssen et al., 1979).

The effects of the use of a noisy background on performance in speech discrimination tests is unclear. Surr and Schwartz (1980) report that a competitive noise stimulus, at +12, +6 and OdB signal to noise ratios had little effect on the scores of participants with high frequency hearing loss using the California Consonant Test (Owens and Schubert, 1977). However, Hutcherson and co-workers (1979) report that signal-to-noise ratios affect speech in noise scores if speech discrimination tests are administered at levels near the thresholds for speech (Kalikow et al., 1977).

One major drawback of current research in speech discrimination has been the use of small samples, the absence of serial investigations, the limited number of studies conducted with children, and the variety of speech discrimination tests. Also, the relationship of speech discrimination to noise exposure and middle ear compliance have not been studied in children.

SUMMATION

The literature relating to hearing ability in children indicates that:

-- hearing sensitivity tends to increase until 12 years; later there is a loss in sensitivity, particularly in boys, that is marked in some studies of older teen-age groups,

-- sex differences in thresholds are slight to 12 years but marked hearing loss is more common in boys,

-- lateral differences tend to increase with age; hearing sensitivity tends to be poorer in the left ear,

-- national U.S. data indicate auditory thresholds tend to be higher in lower socioeconomic groups; no such tendency is present in data from Australia,

-- auditory thresholds are 2 to 3 dB higher in those with abnormal findings at otoscopic examinations,

-- data relating auditory thresholds to noise exposure are sparse, but there is evidence temporary shifts occur and exposure to certain sources, e.g., firearms may be hazardous. It has been reported these are less marked in younger children but recovery from them is slower.

-- there is evidence to support the hypothesis that exposure to continuous loud noise is associated with increased blood pressure in industrial workers. Corresponding data for children have not been reported,

-- little is known of the amounts of noise to which children are exposed or the major scorces of this noise,

-- serial findings are scarce. Apparently, rapid changes in hearing sensitivity with age are common, particularly at higher frequencies. Threshold changes are related to the later but not the earlier state of the tympanic membrane.

Because so many of the above statements are tentative, it is essential that hearing ability be studied serially in children in relation to factors likely to be associated with hearing ability, particularly environmental noise. There are no satisfactory studies of hearing ability as a function of age in children. The factors responsible for the development of a sex difference in these levels after 12 years are unknown; it is not even clear whether these factors are biological or environmental. Finally, hazardous noise criteria have not been separately developed for children. Thus it is not known to what level of noise children can be subjected without experiencing increases in hearing thresholds or a loss of ability to discriminate speech. These questions will remain unanswered until a serial study is based on appropriate data collected over a sufficient time span. The present study was planned with this in mind. This report describes the design of the study briefly and provides analyses of some data from the first five years. A start has been made, but longer serial records are needed before fully effective longitudinal analyses will be possible.

SAMPLE AND METHODS

SAMPLE

The total study sample of 270 children, all of whom have English as their primary language, includes two distinct groups each approximately equally divided by sex. The larger group of 223 children includes only participants in The Fels Longitudinal Study who were between 6 and 18 years at their first audiometric examination. At the start of this study in 1975, it was assumed that auditory thresholds within individual children might change markedly during pubescence or early adolescence; therefore, in order to increase the sample size at these ages, a group of middle school students was enrolled from the Yellow Springs school district. All these 47 children were aged 12.5 to 13.5 years at the start of this study in 1975, and all of these students have now graduated from high school. Of the total of 270 participants, 263 remain active; one participant died, three moved out of state, one could not be tested reliably and was dropped from the study, and two have refused further cooperation.

Participants in the Fels Longitudinal Study live in Southwestern Ohio and were born between 1957 and 1973. They were enrolled before birth at the rate of about 15 per year. Their homes are within 30 miles of Yellow Springs, about 35 percent living in cities of medium size (populations 30,000 to 60,000), about half in small towns (populations 500 to 5000) and the remainder on farms. The educational and occupational patterns of these three groups do not follow the usual urban-rural differences. About 15 percent of the fathers are professionals or major executives, 35 percent are businessmen, 35 percent are tradesmen or white collar workers and the remaining 15 percent are skilled or semi-skilled laborers. About 60 percent of the parents attended a year or more of college, and about 60 percent of them were born in Ohio. In general, they are of middle socioeconomic level. The middle school children are reasonably representative of the Yellow Springs community; in general they are of middle socioeconomic status. The children in each group are "normal" in the sense that they were not selected because of the presence of any recognized disease or disorder.

Children in The Fels Longitudinal Study were enrolled into the program prenatally. Data were recorded serially, and continue to be recorded, at regularly scheduled visits that are fixed in timing and are unrelated to the illness experience of the participants. Examinations are scheduled at 1, 3, 6, 9, and 12 months and then each 6 months to 18 years of age. Afterwards, participants make annual visits until 24 years in boys and 22 years in girls. At each visit, radiographs of the left knee are obtained (for the assessment of skeletal maturity), stature, weight, and other anthropometric dimensions are taken and a detailed medical history is obtained. Until mid-1975, a complete physical examination was made at each visit, but this has been replaced by an interval medical history accompanied by the measurement of blood pressure and pulse rate. Consequently, there is a very large body of early and concurrent data about the growth, maturation and health for these Fels participants that are relevant to auditory thresholds.

TESTING PROCEDURES

Otological and Tympanometric Inspection -- Immediately before a participant's auditory threshold levels are assessed, each tragus, meatus, and ear drum is examined by a trained research assistant. The findings are recorded on the "Auditory

Threshold Level Recording Form."* Following the otological examination, the same research assistant tests the middle ear compliance of each participant.

Thresholds -- At each six-month examination, audiometric thresholds are determined for 1, 2, 4, 6, 1, and 0.5 kHz with the right ear being tested first. Only the second 1 kHz value is used in the data analysis. All thresholds are measured relative to ANSI-1969 audiometric zero. This testing is conducted by a single observer, randomly assigned. Frequency specific thresholds are obtained by increasing the sound intensity from a low value until the participant responds. The attenuation of the signal is then progressively decreased by 10 dB increments until the participant fails to respond. Then the signal is increased by 6 dB steps with subsequent small decreases and increases so as to determine the threshold as accurately as possible. This procedure is repeated at least three times for each frequency for each ear.

The thresholds are recorded in 2 dB steps on the "Auditory Threshold Level Recording Form". Comments about the continuity and completeness of testing and the nature of the responses by the participant are recorded both in general and for each frequency.

Speech Discrimination in Noise -- In October, 1975, a speech discrimination in noise test was implemented for each participant. This test is administered following the threshold testing in the audiometric booth. This test is given to the participant through a separate set of monophonic headphones. The speech discrimination in noise test uses the NU-6 word list with a 12-person babble as background at a 0.0 dB signal to noise ratio. In August 1980, a new speech discrimination in noise tape replaced the original tape. This new tape also employed the NU-6 word list, but it had a female voice rather than the male voice as on the first tape. A 12-person babble was again usedas a background but at a +6 dB signal to noise ratio. The NU-6 word list consists of 200 words divided into 4 lists of 50 words each. The words for each list are randomly selected so that all of the 4 lists are equal in their testing ability (Katz, 1978). However, at their visit, each participant was given list I, and at their second visit, list II, etc. When the second tape was introduced in August 1980, each participant was again given list I at their first visit and lists II, III, and IV at subsequent visits.

For both speech discrimination in noise tests, the speaker's voice was recorded at the University of Maryland; the 12-person babble was recorded by Bolt, Beranek, and Newman Inc.; and both tracks combined by the 6570th Aerospace Medical Research Laboratory, Wright Patterson Air Force Base in Dayton, Ohio.

Questionnaires -- A set of very detailed questionnaires has been developed to ascertain the major sources of noise exposure for each child. The data obtained using these questionnaires allow analyses of the relationships between auditory thresholds and environmental factors.

There are two very similar questionnaires:

(i) "The Biographical, Noise Exposure and Otological History" was administered to each participant at the first audiometric examination (Appendix B). The data obtained by means of this questionnaire concern: personal identification, family structure and occupations, recreational activities, work activities, noise exposure

* A copy of this form is included as Appendix A in AMRL-TR-76-110; Roche et al., 1977.

history (guns, toys, hobbies, mechanical equipment, place of residence, TV, music) and an otological history (family and personal information concerning hearing loss, previous testing, infections, discharge, tinnitus). This noise exposure history provides a quantitative noise exposure score for each individual for his/her lifetime prior to the first examination.

(ii) The "Interval Audiometry Questionnaire" (Appendix C) is very similar to the otological history part of the preceding questionnaire, and is administered at the second and subsequent audiometric examinations. It contains questions relating to change of address, noise exposure, otological history, changes in general health and the possible occurrence of menarche since the previous visit. The figures written beside the coding squares on this questionnaire are the weightings applied in the computation of the noise scores. The interval noise exposure questionnaire provides a total noise exposure score for each individual for the 6-month interval prior to testing. In addition, the data provide an event score, a chain saw score, and a gun score (Appendix D in AMRL-TR-76-110; Roche et al., 1977). These scores are used to identify those individuals most likely to have been injured by noise exposure. In September 1976, this questionnaire was extended to include information relating to school buses, relationship of testing to underwater weighing (being done in another study) and provide space for recording the blood pressures and pulse rates of the "middle school participants"

Dosimetry -- Each participant is asked at each visit to wear a noise dosimeter for the following 24-hour period. If the participant agrees, the dosimeter is calibrated, a new battery installed and given to the participant along with a digital watch, note pad and pencil. The participant is instructed to keep a diary of his or her acitivities for the next 24 hours using the watch to record the time. The day after the 24-hour period, the participant is visited by a research assistant. Besides collecting the equipment, the research assistant attaches the Metrosonics Metrologger to the Metrosonic Metroreader. The research assistant then reviews the participant's 24-hour diary with a record of sound measurements per 3 minute intervals throughout the day as provided by the Metroreader. If a record of a high 3-minute level appears on the printout, the reasearch assistant checks the participant's diary for a specific event at that time of day and may elicite more information about the event from the participant. The children from whom dosimetry records were collected were self-selected from the total sample on the basis of their willingness to wear a dosimeter, without regard to other factors such as location of residence, previous noise exposure history, or hearing threshold levels. The activities are coded according to the scheme in Appendix D.

EQUIPMENT

Some of the equipment being used is described in detail in an earlier report (AMRL-TR-76-110; Roche et al., 1977). The present description, as it applies to the original equipment, will be brief. An audiometric booth (Tracor RE142B) provides a noise reduction of 44 to 69 dB at the tonal frequencies being tested. The booth is in a very quiet part of the building. At the beginning of the study, there were some problems with the test equipment. As a result, there are doubts about the accuracy of auditory thresholds recorded before 26 January, 1976 and they have not been analyzed. The other data (questionnaires, histories, otological inspection, size, maturity), recorded since 12 August, 1975, were, of course, not influenced by these equipment difficulties.

Dosimetry data have been collected since 2 May, 1978. From 2 May, 1978 to 18 October, 1978, dosimeters from Loomis Laboratories (Model #3573), Bruel and Kjaer (Model #4424), General Radio (Model #1954-9780) and Computer Engineering (Model #139) were tried. The Loomis equipment was unreliable and difficult to read and calibrate. The Bruel and Kjaer equipment had a limited dynamic range and the preamplifier was heavy. We were unable to obtain satisfactory results with the Computer Engineering equipment. Due to experience with the other dosimeters, General Radio dosimeters were used exclusively from 18 October, 1978 to 29 March, 1979. At the latter date, the project was provided with two Metrosonics dosimeters. Since 7 July, 1980, three Metrosonics dosimeters have been used exclusively to collect noise exposure data from the participants.

Two Metrosonics dB 301 Metrologgers have noise exposure ranges of 60 to 123 dB, and the third has a range of 40 to 103 dB. These dosimeters have a dynamic range of 64 dB at a resolution of 1 dB. Noise levels are sampled by a ceramic microphone with a sensitivity of -40 dB with a figuring response that meets ANSI S1 4-1971 Type II requirements. Metrologgers sample sound at four samples/second $\pm$ 1% and compute and store an L_{eq} for each three-minute period up to a maximum of 480 periods (24 hours). Metrologgers require a dosimeter-reader, called a Metroreader (Model dB 651, Metrosonics, Inc.), to recover the stored data. One particular advantage of the Metrosonics dosimeter over the General Radio dosimeter is that the Metrosonics is lighter and can be worn easily on a belt at the waist. The microphone is attached near the participant's collar so as to sample noise similar to that entering the participant's ears. The activity diary, to be described, includes information as to whether earphones or ear protectors were worn during particular activities.

The dosimeters are calibrated before and after each use. The General Radio 1954-9780 Noise Exposure Meter is read and calibrated with the General Radio 1945 Indicator at 116.5 dB and 1 kHz. The Metrosonics dB-301 Metrologgers (dosimeter) are calibrated with either the General Radio Type 1562-A Sound-Level Calibrator at 114 db and 1 kHz, or the Quest Calibrator, Model CA-11 at 102 dB and 1 kHz.

A Grason-Stadler Model 1707 audiometer is used to test audiometric thresholds at the test frequencies of 0.25, 0.5, 0.75, 1, 2, 3, 4, 6, and 8 kHz between hearing levels varying from -12 to +90 dB HL re ANSI 1969. The accuracy of the hearing level ranges from $\pm$3 to $\pm$5 dB depending upon the test frequency. Routine maintenance checks of the audiometer are common and it was calibrated at the National Bureau of Standards, Washington D. C. In addition, the audiometer was calibrated at the Fels Research Institute 5 times during the present contract by a trained audiologist from the 6570th Aerospace Medical Research Laboratory at Wright Patterson Air Force Base, Dayton, Ohio; changes were not necessary.

The otological examination is conducted with a Welch -Allyne otoscope, Model 2400 with a disposable speculum. The tympanogram is recorded on a Grason-Stadler 1722 Middle Ear Analyzer. The mobility of the middle ear system is measured in millimhos (mmho) at an accuracy of $\pm$0.05 mmho at 20 to 30°C. The pressure change ranges from -300 to +200 mmH_2O with an accuracy of $\pm$10 mm H_2O. A probe tone frequency of .22 kHz $\pm$ 3% is used at an intensity of 85 dB $\pm$0.5 dB for a 0.5 to 2.0 ml cavity. The acoustic reflex is measured with a 1 kHz $\pm$ 3% stimulus at 102 dB $\pm$3 dB, with time multiplexing of 45 msec on, 45 msec off $\pm$ 10% with 7.5 msec rise and fall time $\pm$ 10%, and tone presentation of two stimulus periods: 1 second on, 2 seconds off, 1 second on $\pm$ 10%, 60 Hz.

OTHER PROCEDURAL ASPECTS

(i) The audiometric testing alone requires the participant to be in the Institute for about 40 minutes. Because of the large amount of data obtained from each participant, both for this study and for others, some additional visits specifically for the audiometric study are necessary.

(ii) Skeletal maturity assessments by the RWT method (Roche, Wainer and Thissen, 1975) to the nearest tenth of a year plus a standard error for each assessment have been made for the left knee of children in the Fels Longitudinal Study. These assessments have not been made for the Middle School participants.

(iii) The stature, weight and blood pressure of each participant have been recorded. Stature is measured to the nearest mm at each examination using a Harpenden stadiometer. Weight is measured to the nearest 0.5 kg using a standard beam balance scale. Blood pressure, (systolic, 4th and 5th phase diastolic) is measured with a mercury sphymomanometer mounted to a wall. Blood pressure is measured with the participant seated using a cuff of appropriate size on the left upper arm in mm Hg to the nearest even number.

(iv) Some children with chronic auditory problems have been identified and referred to appropriate physicians. There are 9 such children; their data have not been used in any analyses. In addition, pathological or other changes that could affect the test results were present in other participants at 52 specific visits. Due to abnormal tympanograms or complete blockage of a meatus by wax, the data for these examinations have been excluded from analyses, even if the criteria for exclusion were met by only one ear. The data from such examinations have been retained only for study of significant threshold shifts, noise exposure and activities.

RELIABILITY

The otological history of the Fels participants is highly reliable because relevent data have been obtained at 6-month intervals from birth until the physical examinations were replaced by medical histories at 6-month intervals in mid-1975. Health histories obtained at longer intervals may be less reliable (Ciocco and Palmer, 1941).

Inter-and intra-observer differences are available for all measurements made at the Fels Research Institute. The differences from the Fels Study are from one-third to one-half as large as these from other growth studies. For thresholds obtained with the present audiometer, these differences are small for all frequencies tested (Table 1) and compare favorably with those reported earlier in this study (Roche et al., 1979) and with similar data reported by others. The inter-observer differences tend to be smaller than the intra-observer differences, perhaps, in part, due to longer intervals between the latter.

Stature, weight and blood pressure measurements are highly accurate. Mean inter-observer differences for stature are about 0.2 cm, for weight about 0.02 kg and for blood pressure 3 to 6 mm Hg for children 5 to 20 years of age (Chumlea and Roche unpublished). These means with their standard deviations and sample sizes are presented in Table 2. In addition mean inter-observer differences for replicate assessments of RWT skeletal age at the Fels Research Institute are 0.17 years (S.D. 0.21 years).

DATA ANALYSIS

Only a minimal amount of computer programming was necessary under this contract. This programming was needed to facilitate data management, i.e., data entry, constructing data files, etc. All data analysis has been accomplished using preprogrammed statistical analysis packages. The primary package used was SAS (Helevig and Council, 1979) which is available on the IBM 370 computer at the Wright State University Computer Center.

TABLE 1 - REPLICABILITY OF AUDITORY THRESHOLDS (dB) IN THE FELS STUDY

Frequency	Mean	S.D.
	Intra-observer differences (n = 20)	
.5 kHz	2.60	2.35
1.0 kHz	3.90	3.64
2.0 kHz	3.30	2.70
4.0 kHz	4.90	4.13
6.0 kHz	5.10	6.47
	Inter-observer differences (n = 30)	
.5 kHz	2.80	2.08
1.0 kHz	3.33	3.17
2.0 kHz	3.60	2.43
4.0 kHz	3.33	3.08
6.0 kHz	6.53	4.75

TABLE 2 - INTER-OBSERVER DIFFERENCES IN THE FELS STUDY

	5-10 years			10-15 years			15-20 years		
Variable	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
Stature (cm)	0.24	0.21	151	0.20	0.20	210	0.23	0.24	91
Weight (kg)	0.01	0.03	151	0.02	0.04	209	0.02	0.04	90
SBP (mm Hg)	3.44	3.70	146	3.74	5.35	208	3.55	3.72	91
DBP, 4th (mm Hg)	3.66	4.87	129	6.39	3.93	185	3.33	3.69	86
DBP, 5th (mm Hg)	3.72	4.16	145	4.19	5.20	208	4.11	4.97	91

SBP = systolic blood pressure; DBP = diastolic blood pressure.

RESULTS

DATA BASE

A total of 1964 audiometric examinations were made between 12 August 1975 and 15 April 1981. Because of initial equipment difficulties, the only auditory threshold data included in the present analyses are those obtained after 26 January 1976. Nevertheless, the data from the noise exposure histories, interval questionnaires, health histories, and otological inspections from 12 August 1975 have been included in the analyses. The number of children in each age group is fairly uniform except for the larger numbers at 13 to 18 years (Figure 1) due to the addition of local school children to the Fels sample in this age range. The distribution of children at each age is almost evenly divided between the sexes. The distribution of the participants by number of examinations (Figure 2) show that the groups with 10 or 11 serial examinations are larger than the others.

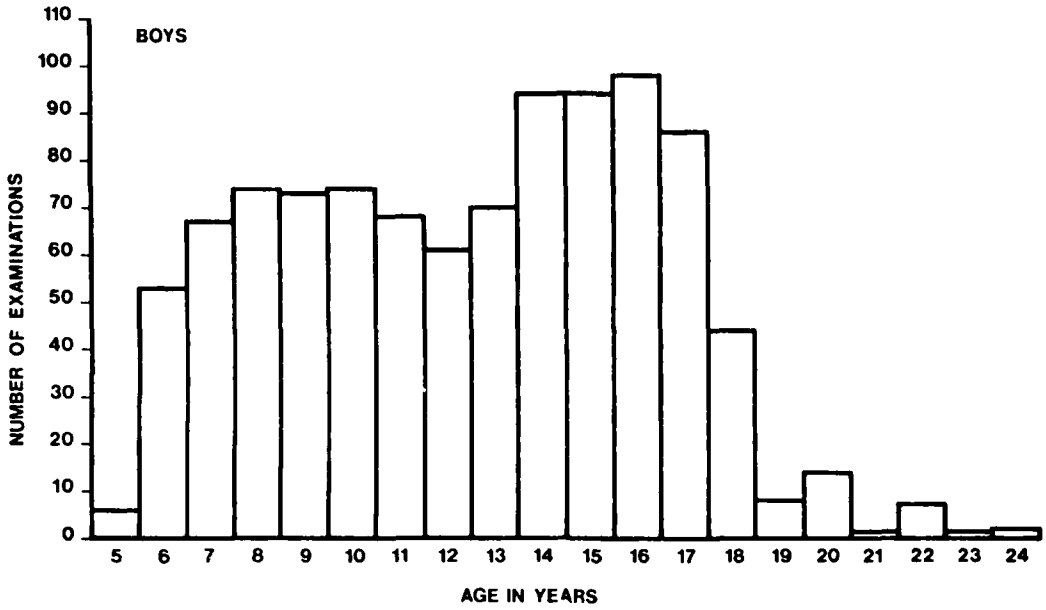
Since 26 January 1976, there have been 1782 examinations of 278 individuals from 4 to 26 years of age. Among these examinations, 905 are of boys and 877 are of girls. The data subsequent to 26 January 1976 come from examinations of 231 Fels participants and 47 local school children. However, the data for 9 participants have been excluded from all analyses because of various permanent pathologies. The data recorded at 52 examinations for other participants have been excluded from the analyses because an abnormal tympanogram or abnormal otoscopic findings were recorded at these examinations. The criterion for the tympanogram exclusions was a pressure of less than -150 mmH_2O or a value of less than 0.25 millimhos or both. The criterion for exclusion on the basis of otoscopic findings was a completely obstructed meatus.

Audiometric examinations of participants are made six monthly, approximately on birthdays and "half-birthdays." Therefore, in the findings from the analyses, an age, for example, "6 years", refers to all those children measured on or about their sixth birthday (i.e., children between 5.75 and 6.24 years of age).

TESTING CONTINUITY AND PARTICIPANT RESPONSES

Continuity and completeness of all testing procedures and the quality of participant responses were evaluated by the technician at each examination. The findings regarding these aspects of the air conduction (AC) auditory threshold testing are included in Table 2. The definition of the rating codes for continuity of testing and quality of responses are given in the footnotes to Table 3. The prevalences of each score for boys and girls of two age groups (6 to 11 years; 12 to 18 years) are derived from all examinations since August, 1975. Complete test data were obtained in about 92 percent of those aged 6 to 11 years and in about 97 percent of those aged 12 to 17 years.

Continuity - Sixty-two percent of the younger boys completed the AC threshold testing without interruption (score = 0), while 83 percent



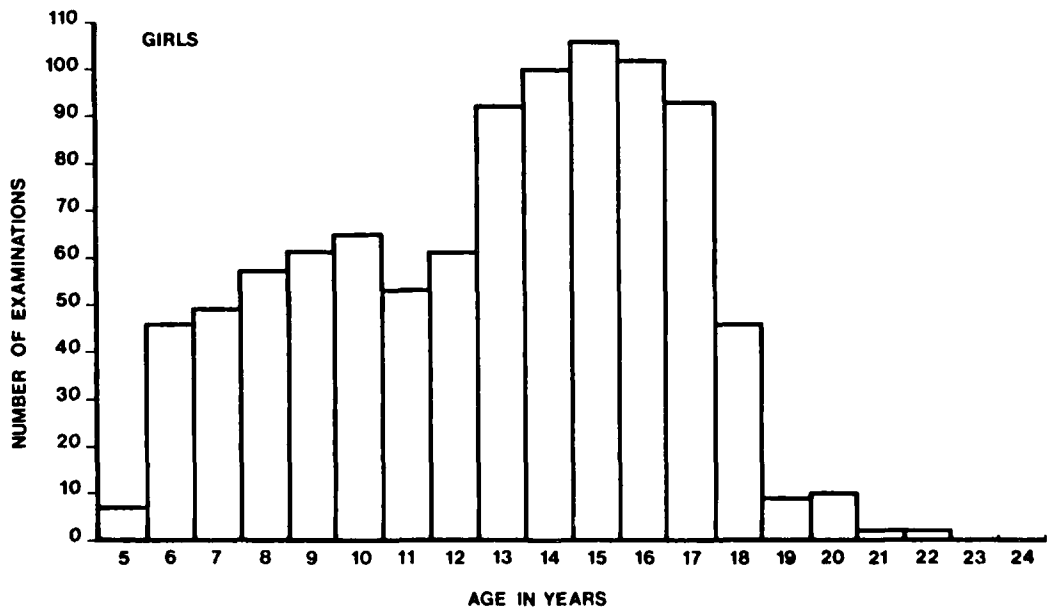


Figure 1. Number of examinations of boys and girls at each age through 15 April 1981.

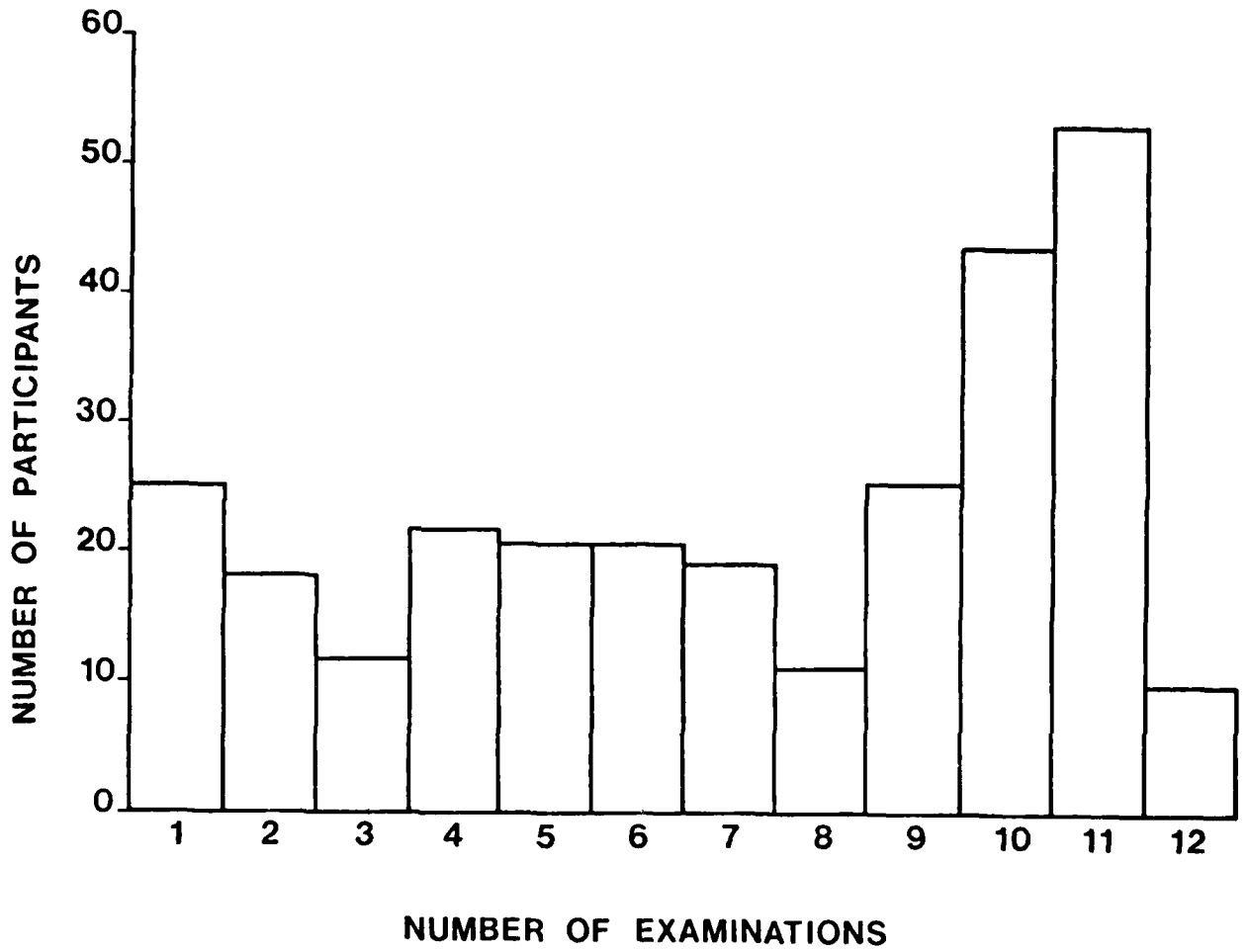


Figure 2. Number of examinations per participant through 15 April 1981.

of the older boys completed the test without interruption. The corresponding percentages for girls are 55 percent for younger girls, and 85 percent for older girls. A short interruption in the testing between ears (score = 1) for each sex was much more common in the younger children than in the older children, although there was little evidence of a systematic age difference in the frequency of interruptions during the testing of a particular ear (scores 2 or 3). Multiple interruptions in the overall testing procedure (score = 4) were slightly more common in the younger children than in the older children.

There was little difference between the two age groups in the percentage of participants who had to be retested at one or more frequencies (score = 5). While 1 percent of the younger boys and 4 percent of the younger girls insisted that the test be discontinued (score = 6), none

TABLE 3 - NUMBER OF EXAMINATIONS (AND PERCENTAGES) OF CHILDREN WITH SPECIFIC CHARACTERISTICS RATING THE CONTINUITY* AND QUALITY OF AUDITORY THRESHOLD TESTING

Age Group	Rating Code	BOYS				GIRLS			
		Continuity of Testing		Quality of Responses		Continuity of Testing		Quality of Responses	
		n	%	n	%	n	%	n	%
6-11 years									
	0	203	62	217	65	150	55	174	64
	1	71	21	14	4	78	28	27	10
	2	2	1	0	0	4	1	1	0
	3	4	1	12	4	9	3	11	4
	4	19	6	12	4	10	4	4	1
	5	7	2	3	1	1	0	1	0
	6	4	1	8	2	10	4	5	2
	7	7	2	0	0	3	1	0	0
	8	14	4	49	15	10	4	37	13
	9	1	0	17	5	1	0	16	6
Total		332		332		276		276	
12-18 years									
	0	352	83	297	69	383	85	324	73
	1	31	7	35	8	21	5	40	9
	2	8	2	0	0	8	2	2	0
	3	7	2	11	3	9	2	18	4
	4	9	2	3	1	7	2	1	0
	5	9	2	1	0	10	2	0	0
	6	0	0	16	4	0	0	22	5
	7	1	0	0	0	0	0	0	0
	8	8	2	63	15	9	2	40	9
	9	1	0	0	0	2	0	2	0
Total		426		426		449		449	

* Continuity Ratings

0 = testing completed, no breaks
1 = testing completed, one short (< 5 min) break between ears
2 = testing completed, one short (< 5 min) break during testing of right ear
3 = testing completed, one short (< 5 min) break during testing of left ear
4 = testing completed, took more than one break (see written comments)
5 = testing completed, certain frequencies retested (see written comments)
6 = testing discontinued, participant insisted (tired, restless, etc.)

FOOTNOTES CONTINUTED TO TABLE 3

7 = testing discontinued, responses too erratic (lack of cooperation, etc.)
8 = other--miscellaneous written comments

+Quality Ratings

0 = normal good responses or better
1 = often signaled when no tone played
2 = participant disinterested, not trying hard
3 = participant's responses seemed somewhat erratic
4 = participant very restless and "fidgety"
5 = participant talked frequently throughout test
6 = participant claimed to hear extraneous noises during test (see written comments)
7 = participant's parent in booth during testing
8 = other--miscellaneous written comments
9 = participant did well at the beginning but lost concentration toward end of test

of the older children made a corresponding request. These findings are consistent with our earlier findings concerning a higher frequency of incomplete examinations in children younger than 6 years old (Roche et al., 1979).

Responses - There was little difference between the sexes in the prevalences of good responses (score = 0), though good responses were slightly more common among the older children than among the younger children. From 2 to 10 percent of the children frequently gave false responses (score = 1) during a test. This was almost as common in younger as in older children, and about as common in boys as in girls. Erratic responses, talking, disinterest, and restlessness of participants during the testing of AC thresholds (scores 2, 3, 4, 5, or 9) were slightly more common in younger than in older children.

OTOLOGICAL INSPECTION

At the start of each auditory testing examination, every participant was given an otological inspection and deviations from normality were recorded applying codes given in Table 4. A score of zero indicates a normal finding in each category. Tables 5 through 8 give the percentages prevalence of each rating code for the right and left ears of boys and girls aged 6 to 11 and 12 to 18 years. The sample represented in these tables includes all children examined since testing commenced in August, 1975.

Tragus - There is little difference between age groups, ears or sexes in the frequency of abnormal tragi, almost all being normal. A maximum of 1 percent in any age group was considered "very large" (score = 1).

Meatus - The most frequent meatal abnormalities concerned obstructions of the external auditory canal. There is little sex or age difference in the prevalence of obstruction of meati. When the meatus was completely obstructed (Code 1) on one or the other code, the data for both left and right ears were excluded from some of the analyses as detailed later.

TABLE 4 - DEFINITION OF RATING CODES USED IN OTOLOGICAL EXAMINATIONS

Item	Code		Definition
Tragus			
	0	=	normal
	1	=	very large
	8	=	other--miscellaneous written comments
	9	=	no examination
Meatus			
	0	=	normal
	1	=	completely closed
	2	=	badly obstructed with wax, dirt, hair, almost closed
	3	=	very small or slit-like opening but unobstructed
	4	=	small opening badly obstructed with wax
	5	=	much wax, etc. in canal but not obstructed
	6	=	canal open but rather inflamed (very red) looking
	8	=	other--miscellaneous written comments
	9	=	no examination
Ear Drum			
	0	=	normal
	1	=	perforated
	2	=	not seen because meatus small or obstructed
	3	=	scarred
	8	=	other--miscellaneous written comments
	9	=	no examination
Ear Drum, Cone of Light			
	0	=	cone of light seen
	1	=	cone of light not seen (meatus too small or obstructed)
	2	=	cone of light not seen for other reasons
	8	=	other--miscellaneous written comments
	9	=	no examination

TABLE 4 - DEFINITION OF RATING CODES USED IN OTOLOGICAL EXAMINATIONS (CONTINUED)

Item	Code		Definition
Ear Drum, Color			
	0	=	normal
	1	=	very red and inflamed looking
	2	=	dull
	3	=	yellowish
	4	=	redder than normal, but not inflamed looking
	8	=	other--miscellaneous written comments
	9	=	no examination
General Health at Time of Test			
	0	=	normal, not ill
	1	=	has "cold," but no ear problems
	2	=	is congested due to "sinus allergy"
	3	=	both ears "stopped up"
	4	=	right ear "stopped up"
	5	=	left ear "stopped up"
	6	=	has ear infection, but no earache
	7	=	has ear infection, with earache
	8	=	other--miscellaneous written comments
	9	=	not recorded

Tympanic Membrane - Only one percent of the children had a perforated tympanic membrane (ear drum) when examined, and a similar percentage had scarred drums. The most common abnormalities concern the ability to see the cone of light reflected from the ear drum on otoscopic inspection. In about 20 percent of the inspections, the cone of light was not seen because of occlusion of the external auditory canal. In about 18 percent of the examinations, the cone of light was not seen for other reasons (code = 2). Five to 8 percent of boys and girls had dull drums that lacked the luster typical of the normal tympanic membrane. There was little difference between the age groups in this respect. From 1 to 2 percent of the children had red tympanic membranes, suggesting some inflammation. The prevalences of additional comments (score = 8) indicate that many of the observed conditions did not match the code categories.

TYMPANOMETRY

Since 14 May 1979, each participant has received a tympanometric examination to complement the otoscopic inspection. Ninety-seven percent of these examinations resulted in normal tympanograms including the presence of acoustic reflexes. A normal tympanogram was defined as one in which the peak of the pressure curve was in region 1, 2, or 3 on the Grason-Stadler chart for middle ear analyser 1722 or between -150 to +100 mmH_2O and 0.2 to 2.5 millimhos (Figure 3). When an abnormal tympanogram was recorded all the data from that examination for both ears were excluded from analyses even if the tympanogram was abnormal in one ear only.

TABLE 5 - PERCENTAGE OF EXAMINATIONS OF CHILDREN 6 to 11 YEARS OF AGE WITH SPECIFIC CODES ON OTOLOGICAL INSPECTIONS (LEFT EAR)[1]

Code	Tragus	Meatus	Ear Drum	Cone of Light	Color
Boys					
0	99	72	84	69	79
1	0	0	1	15	2
2	--	7	8	14	5
3	--	3	1	--	0
4	--	1	--	--	1
5	--	13	--	--	--
6	--	1	--	--	--
8	1	3	5	2	10
9	0	0	1	0	3
Total	100	100	100	100	100
Girls					
0	100	70	78	63	70
1	0	1	0	19	1
2	--	10	13	15	6
3	--	3	0	--	0
4	--	2	--	--	2
5	--	9	--	--	--
6	--	2	--	--	--
8	0	3	8	3	15
9	0	0	1	0	6
Total	100	100	100	100	100

[1]See Table 4 for code definitions.
Based on data from 383 examinations in boys and 320 examinations in girls.

TABLE 6 - PERCENTAGE OF EXAMINATIONS OF CHILDREN 12 TO 18 YEARS OF AGE WITH SPECIFIC CODES ON OTOLOGICAL INSPECTIONS (LEFT EAR)[1]

Code	Tragus	Meatus	Ear Drum	Cone of Light	Color
Boys					
0	99	77	84	69	74
1	1	1	0	14	2
2	--	8	8	14	8
3	--	1	0	--	0
4	--	0	--	--	1
5	--	10	--	--	--
6	--	1	--	--	--
8	0	2	7	3	12
9	0	0	1	0	3
Total	100	100	100	100	100
Girls					
0	100	79	85	66	77
1	0	1	0	17	1
2	--	8	8	15	6
3	--	1	0	--	0
4	--	1	--	--	1
5	--	7	--	--	--
6	--	1	--	--	--
8	0	2	6	2	12
9	0	0	1	0	3
Total	100	100	100	100	100

[1]See Table 4 for code definitions.
Based on data from 494 examinations in boys and 528 examinations in girls.

TABLE 7 - PERCENTAGE OF EXAMINATIONS OF CHILDREN 6 TO 11 YEARS OF AGE WITH SPECIFIC CODES ON OTOLOGICAL INSPECTIONS (RIGHT EAR)[1]

Code	Tragus	Meatus	Ear Drum	Cone of Light	Color
Boys					
0	99	70	83	69	80
1	0	0	0	13	1
2	--	9	8	15	5
3	--	3	1	--	0
4	--	1	--	--	0
5	--	13	--	--	--
6	--	1	--	--	--
8	1	3	7	3	11
9	0	0	1	0	3
Total	100	100	100	100	100
Girls					
0	100	68	82	63	76
1	0	0	0	20	1
2	--	12	11	14	6
3	--	2	0	--	0
4	--	3	--	--	1
5	--	11	--	--	--
6	--	1	--	--	--
8	0	3	7	3	13
9	0	0	0	0	3
Total	100	100	100	100	100

[1]See Table 4 for code definitions.
Based on data from 383 examinations in boys and 320 examinations in girls.

TABLE 8 - PERCENTAGE OF EXAMINATIONS OF CHILDREN 12 TO 18 YEARS OF AGE WITH SPECIFIC CODES ON OTOLOGICAL INSPECTIONS (RIGHT EAR)[1]

Code	Tragus	Meatus	Ear Drum	Cone of Light	Color
Boys					
0	99	74	85	66	79
1	1	1	0	17	0
2	--	9	9	15	5
3	--	1	0	--	0
4	--	0	--	--	1
5	--	11	--	--	--
6	--	1	--	--	--
8	0	3	6	2	12
9	0	0	0	0	3
Total	100	100	100	100	100
Girls					
0	100	76	85	66	77
1	0	2	0	18	1
2	--	9	10	13	5
3	--	1	0	--	0
4	--	1	--	--	0
5	--	8	--	--	--
6	--	1	--	--	--
8	0	2	4	3	13
9	0	0	1	0	4
Total	100	100	100	100	100

[1]See Table 4 for code definitions.
Based on data from 494 examinations in boys and 528 examinations in girls.

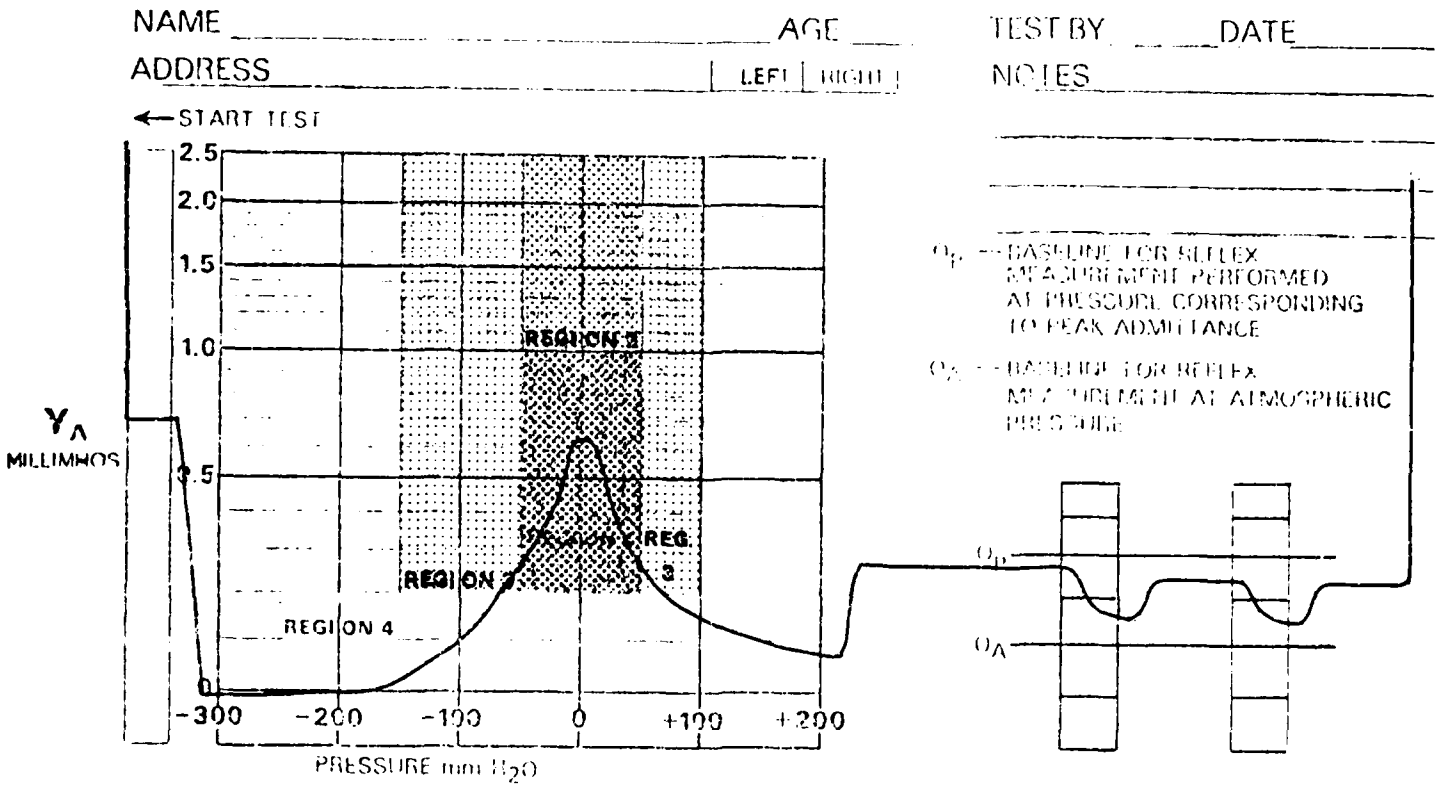


Figure 3. The chart used for recording and classifying data from tympanometry.

GENERAL HEALTH

The participants are questioned about their health at each examination. If the child is younger than 9 years, the parent is asked about the child's health so that more reliable data will be obtained. Sixty-nine to 76 percent of all the participants reported normal health at the time of the audiometric examination (Table 9). The most common complaint was "a cold" without ear complications, except in older children who had a slightly greater prevalence of "stopped-up" ears. The written comments recorded by the technicians concern items such as "had recently been swimming and had water in the ears" or "had a cold with an earache last week but not at present." Also some comments indicated the child had positive responses for several of the general health codes. At present, only one code can be selected. The coding scheme will be altered so that multiple categories can be recorded without use of the "other" category.

TABLE 9- PERCENTAGE OF EXAMINATIONS OF CHILDREN WITH SPECIFIC CODES FOR GENERAL HEALTH AT EACH TEST.[1]

Code	6 to 11 years		12 to 18 years	
	Boys	Girls	Boys	Girls
0	76	76	69	70
1	11	14	14	15
2	4	3	6	4
3	1	0	3	2
4	0	0	0	0
5	1	0	0	0
6	0	0	0	0
7	0	0	0	0
8	6	7	8	9
9	1	0	0	0
Total	100	100	100	100

[1]See Table 4 for code definitions.
Based on data from 758 examinations of boys and 725 examinations of girls.

Examination effects. A serial design was chosen for the present study because it was considered critical that changes within individuals be recorded and analyzed. Such analyses are possible only if serial data are available. However, when analyzing serial data it is necessary to recall that there may be "examination effects" upon the data. The term "examination effects" is used to refer to any change in the recorded data associated with the order of the examination. Such effects might result from the participants learning proper listening skills and how to respond to the test stimulus, to do the tests, from their habituation to the test environment including the technicians, from changes in motivation with continuing participation in the study and alterations in noise exposure during the study that are associated with participation. The present analyses estimate the total examination effects on the recorded thresholds but do not attempt to separate the effects by source. In addition, serial data are autocorrelated. Consequently, only one set of data per participant, or the mean of multiple sets, has been used in any cross-sectional analysis.

"Examination effects" in the Fels data, independent of age, were analyzed for all frequencies for the first 8 examinations using a multivariate analysis of variance for repeated measures (Bock, 1975). Data from participants with permanent pathologies were excluded as were data recorded at examinations when temporary pathologies were present. As is necessary with this method, data from individuals who missed examinations were excluded. Age at first examination was used as a factor in the between-subjects part of the design. Although the marginal distributions of thresholds for each examination are skewed, Bock's methodology is robust under the assumption of multivariate normality.

This analytic method is based on the following considerations. Let $\underline{Y}_i$ be a p-component vector of observations pertaining to p occasions and let there be n subjects. The design matrix is of order nxp and assumed to be of full rank. The linear model assumed is $\underline{Y}_i = \underline{\mu} + \underline{\varepsilon}_i$ where $\underline{\mu}$ = pxl vector of occasion means and $\underline{\varepsilon}_i$ = pxl random vector of errors distributed N $(\underline{0},\Sigma)$ in the population. Let us consider the polynomial representation of $\underline{\mu}$, the occasion means, as

$$\underline{\mu} = \begin{bmatrix} \mu_1 \\ \mu_1 \\ \cdot \\ \cdot \\ \cdot \\ \mu_p \end{bmatrix} = \beta_o \begin{bmatrix} 1 \\ 1 \\ \cdot \\ \cdot \\ \cdot \\ 1 \end{bmatrix} + \beta_1 \begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_p \end{bmatrix} + \beta_2 \begin{bmatrix} x_1^2 \\ \cdot \\ \cdot \\ \cdot \\ x_p^2 \end{bmatrix} + \ldots + \beta_q \begin{bmatrix} x_1^q \\ \cdot \\ \cdot \\ \cdot \\ x_p^q \end{bmatrix}$$

$$= \underset{pxq}{X} \quad \underset{qx1}{\underline{\beta}},$$

where X is a Vandermonde's matrix of order N x (q + 1), q being the highest degree of the polynomial fitted. The equally spaced points permit the

polynomial representation, as $\underline{\mu} = X\,(T^{-1})'\,T'\,\underline{\beta} = PT'\underline{\beta} = PT'\underline{\beta} = P\underline{\gamma}^*$

where T is triangular and P is the matrix of orthogonal polynomial and $\underline{\gamma}^*$ are the orthogonal polynomial coefficients. The transformed vector of occasion means is thus $P'\,\underline{Y}_i = P'\underline{\mu}+P'\underline{\varepsilon}_i = \underline{\gamma}^*+\varepsilon_i^*$, and $\underline{\varepsilon}$ is distributed N $(\underline{o}, P'\Sigma P)$.

Thus, $\underline{\gamma}^*$ is the p x 1 vector of transformed occasion means and its least square estimate is the transformed sample mean $\hat{\underline{\gamma}}^* = \frac{1}{N}\sum_{i=1}^{n} p'\underline{Y}_i = P'\underline{Y}$

and the least squares coefficients $\underline{\beta}$ can be computed as $\hat{\underline{\beta}} = (T^{-1})'\hat{\gamma}^*$

and the corresponding estimator for the transformed error dispersion matrix $\Sigma^* = P'\Sigma P$ is $\hat{\Sigma}^* = \frac{P'(SSE)P}{N-1}$, where SSE is the estimate of untransformed Σ. The transformation matrix P is thus a contrast matrix of orthogonal polynomials.

In the within-participants part of the design, frequency, examination, and ear and their interactions were arranged in a hierarchy that gave rise to 60 contrasts in the P-matrix. The between-participants portion included linear, quadratic, cubic, quartic and quintic effects of age at first examination. The analysis is conditional in that the significant effects, if any, are controlled for by testing for additional main effects.

There is a significant linear effect of age at first examination on air conduction (AC) thresholds in the direction that thresholds decrease with age. The examination effects independent of age are about 4 dB during a sequence of 8 visits at 6-month intervals; the total effects are similar for all frequencies tested and for each ear. The trend for 4 kHz appears to differ from the others (especially from 2 kHz); this might have contributed to the significant frequency by examination interaction ($p < .007$). There is no evidence that the examination effects attenuate up to the eighth visit (Figure 4). When data for all frequencies are combined, the examination effects differ by ear being larger for the right than the left (Figure 5).

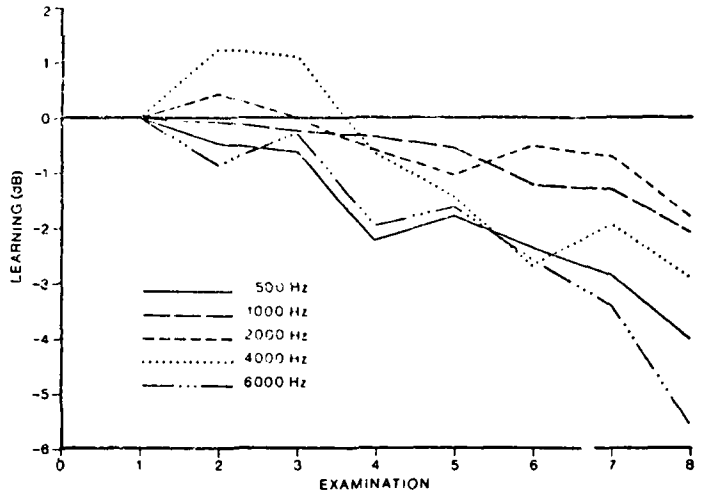


FIGURE 4 EXAMINATIONS EFFECTS BY FREQUENCY.

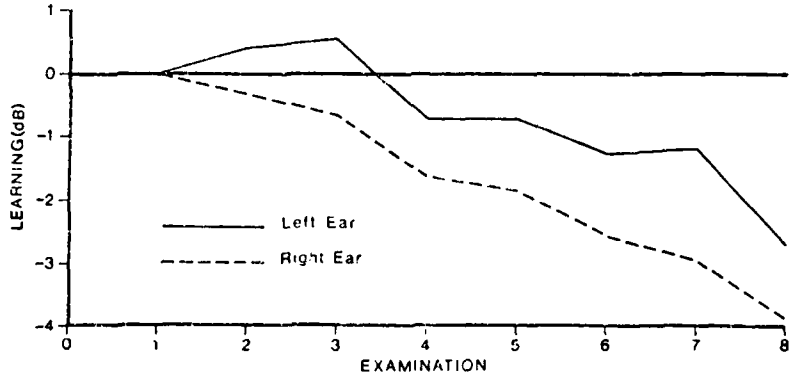


FIGURE 5 EXAMINATION EFFECTS BY EAR FOR ALL FREQUENCIES COMBINED.

An alternative analysis of examination effects has been made applying a regression approach to all the data for each ear and each frequency within each sex, excluding data from participants with permanent pathologies and data recorded when temporary pathologies were present. The latter examinations have been included, however, to establish the order of examinations. Also, data recorded after the age of 18 years were excluded because of the different spacing of examinations.

The group findings are in general agreement with those from the multivariate analysis of variance for repeated measures. The estimates of examination effects from the regression analysis have been used to "adjust" the recorded data so that examination effects are removed and all the data approximate those that would have been obtained at first examinations. These regression estimates are preferred to those from the analysis of variance because the regression method is simpler, and it makes use of all the data except those for participants with pathological changes at the time of an examination.

The findings are presented in Table 10. The findings from the regression analyses show significant linear examination effects, but there are no significant quadratic examination effects. These linear effects do not show significant sex or ear differences, but there are significant differences among frequencies. The mean slopes are all negative indicating that the observed thresholds tend to decrease with examination order for each frequency. The rate of decrease (dB/examination) is larger for thresholds at 6 kHz and for thresholds at 4 kHz than for those at 0.5, 1 and 2 kHz ($p<.05$). However, there are no significant differences between the slopes for thresholds at 4 and 6 kHz or among the slopes for thresholds at 0.5, 1 and 2 kHz. The standard deviations of the slopes are small but the means are small also. Therefore, the coefficients of variability are fairly large for thresholds at 1 and 2 kHz (30 and 35% respectively) but are 9 to 16% for the other frequencies tested.

TABLE 10 EXAMINATION EFFECTS FROM A REGRESSION ANALYSIS POOLING DATA FOR TWO SEXES AND THE TWO EARS FOR THE AGE RANGE 6 TO 18 YEARS (N OF SETS = 1559)

Frequency (kHz)	Slope (dB/examination)	
	Mean	s.e.
0.5	-0.38	0.06
1	-0.30	0.09
2	-0.37	0.13
4	-0.60	0.07
6	-0.72	0.07

Also the regression method was used to analyse learning effects within 3 age groups (6.0 to 10.0 years; 10.1 to 14.0 years and 14.1 to 18.0 years). There are significant ($p<.05$) age effects with learning being more rapid in the younger and older age groups (-0.54 and -0.59 dB/examination respectively) than in the 10 to 14 year group (-0.28 dB/examination). There are significant frequency x age interactions and also significant sex x age interactions. The latter result mainly from the large sex difference in the examination effects for the youngest group (-0.70 dB/examination for boys; -0.38 dB/examination for girls).

Age effects. After adjustments had been made for examination effects, linear regressions were calculated of thresholds against age for data from boys and girls combined. The intercepts tend to be higher for the right than for the left ear at each frequency tested. These lateral differences are significant only at .5 kHz. The variances of the intercepts tend to be similar for each ear at each frequency tested except for higher variances for the left ear at 6 kHz and for the right ear at 4 kHz (Table 11). The mean slopes do not differ significantly between the two ears, and the variances of the slopes are small (Table 12).

The slopes (rate of change in dB/year) for the age range 6 to 18 years were analysed further, using analysis of variance. There are no significant sex differences or differences between ears after the data have been adjusted for frequency. However, there is a significant difference between frequencies in the slopes of thresholds against age after the data have been adjusted for sex and ear effects.

The age effects at 0.5 and 1 kHz have larger negative slopes than those at 2, 4 and 6 kHz, indicating that the decrease in threshold levels with age is more rapid at lower than at higher frequencies. A significant ($p<.05$) age effect is apparent when the data for three age ranges (6.0 to 10.0 years; 10.1 to 14.0 years; and 14.1 to 18 years) are compared, after the data have been adjusted for ear, sex and frequency effects. There are no differences in slopes against age between the two younger age ranges, but the slopes for the oldest age range show a significantly ($p < .05$) smaller tendency for decreases in threshold levels with age than those of either of the two younger age ranges.

The regressions of thresholds against age do not show significant sex effects over all ages combined, but there are significant sex x age group interactions. The youngest group (6.0 to 10.0 years) shows a slope of -0.36 dB/year for boys but -0.70 dB/year for girls. The corresponding values are -0.98 dB/year for boys and -0.28 dB/year for girls in the group aged 10.1 to 14.0 years and -0.05 dB/year for boys and -0.19 dB/year for girls in the group aged 14.1 to 18.0 years. Thus, the improvement in thresholds with age tends to be more rapid in girls than boys from 6 to 10 years, but there is a reverse sex difference from 10 to 14 years, and little sex difference in this respect from 14 to 18 years. Consequently, it is not surprising that there are significant ear x frequency interactions after possible effects of sex and age have been removed.

There are also significant ear x age interactions, after the effects of frequency and sex have been removed. There is little difference in these interaction effects between ears for the older age groups (10 to 14 years vs 14 to 18 years), but for the 6 to 10 year group the interaction effects are about -0.8 dB/year in the left ear but only -0.3 dB/year in the right ear, indicating more improvement in thresholds with age in the left ear than in the right ear.

There are significant frequency x age interactions, after the effects of sex and age have been removed. The mean slopes are -0.35 dB/year for the right ear and -0.50 dB/year for the left ear for all frequencies combined. Each of these means is significantly different from zero ($p < .05$).

Other regression analyses were made of age-related changes in thresholds using data from first examinations only. Unfortunately, because of equipment problems early in the study, most first examinations did not provide acceptable measures of threshold levels. The present analyses were made of 76 sets of data for both sexes combined (mean age 12.0 years; s.d., 3.4 years). Of course, the thresholds recorded at these first examinations do not need adjustments for examination effects. Distribution statistics for the thresholds at these examinations are given in Table 13. There are no significant sex differences; therefore, data for the two sexes have been combined.

Regression analyses of these data do not show significant sex differences in regressions of thresholds against age, after ear and frequency effects are removed, but there are significant age effects at each frequency after sex and ear effects are removed. Finally, there are differences between ears in the regressions of thresholds against age after sex and frequency effects are removed. The mean slope against age for the right ear is -0.60 dB/year whereas that for the left ear is -0.39 dB/year. These findings, which are free of examination effects, are in general agreement with those from the larger set of data that was adjusted for estimated examination effects.

TABLE 11 MEAN INTERCEPTS (dB) FOR LINEAR REGRESSIONS OF THRESHOLDS* ON AGE FOR BOYS AND GIRLS COMBINED, 6 TO 18 YEARS OF AGE (N = 216 CHILDREN; 1559 EXAMINATIONS)

Frequency (kHz)	Ear	Mean	S.D.
.5	L	6.19+	0.43
1	L	4.11	1.22
2	L	2.65	0.81
4	L	2.91	0.35
6	L	6.84	2.22
.5	R	7.67	0.21
1	R	5.98	1.54
2	R	4.03	1.17
4	R	6.14	3.01
6	R	5.99	0.14

*all thresholds corrected for examination effects

+$p < 0.05$ between ears

TABLE 12 MEAN SLOPES (dB/year) FOR LINEAR REGRESSIONS OF THRESHOLDS* ON AGE FOR BOYS AND GIRLS COMBINED, 6 TO 18 YEARS OF AGE, BOTH EARS COMBINED (N = 216 CHILDREN; 3118 EXAMINATIONS)

Frequency (kHz)	Ear	Mean	S.D.
.5	R	-0.59	0.03
1	R	-0.52	0.08
2	R	-0.36	0.00
4	R	-0.31	0.27
6	R	-0.26	0.11
.5	L	-0.56	0.06
1	L	-0.48	0.01
2	L	-0.40	0.10
4	L	-0.11	0.01
6	L	-0.31	0.09

*all thresholds corrected for examination effects

TABLE 13 DISTRIBUTION STATISTICS FOR THRESHOLD LEVELS (dB) AT FIRST EXAMINATIONS (SEXES COMBINED: TOTAL N = 76)

Frequency	Right Ear		Left Ear	
(kHz)	Mean	S.D.	Mean	S.D.
0.5	2.13	6.50	2.13	6.50
1	0.63	6.02	-1.06	6.56
2	-0.29	6.08	-2.09	6.84
4	1.42	6.34	-0.52	7.81
6	2.24	10.24	0.88	9.18

Cross-sectional statistics. The data in Tables 14 through 39 are for children at each year of age, e.g., the data for boys aged 10 years includes data for boys examined between 9.75 and 10.25 years. To save space, tables based on data recorded close to half-birthdays have not been included. The data recorded near half-birthdays are consistent with those recorded near birthdays; both types of data have been used in the analyses. In the descriptive statistics, a participant contributes data from only one examination to the pool of data used for any table. However, since this is a serial study, data from one person contribute to the pools of data for successive tables.

The distribution statistics in these tables were obtained after excluding data from individuals with permanent aural pathology and the data for examinations made when temporary pathologies were present. Also, the data have been adjusted for examination effects as described earlier. These adjustments for examination effects were obtained from a regression analysis of data recorded from 6 through 18 years. Therefore, data recorded near but outside this range, e.g., 5.9 years, 18.1 years, were not adjusted. Consequently, the sample sizes of adjusted data at 6 and at 18 years are considerably smaller than those for unadjusted data. In a later analysis, it is intended to extend the regression analysis to the age range 5.75 through 18.25 years which will lead to the inclusion of more sets of adjusted data for 6-year-old and 18-year-old children.

Each table includes the number of participants and the mean and median threshold levels at each frequency tested. Comparisons between the mean and median assist judgments as to whether the data are skewed. The standard deviations of the mean and selected percentiles are included also. These calculated values are given for thresholds at 0.5, 1, 2, 4 and 6 kHz. Thresholds at 1 kHz were obtained at the beginning and at the end of the testing for each ear; the second of each pair of thresholds at 1 kHz was used in all analyses. Values are provided for the means of the thresholds at 0.5, 1 and 2 kHz (M512), which has been suggested as a functionally important measure of speech reception threshold. Distribution statistics for D4, the differences between thresholds at 1 kHz and 4 kHz (1 kHz less 4 kHz), are given because the effects of noise are greater on thresholds at 4 kHz than on those at 1 kHz, and this could be reflected in the D4 value.

These distribution statistics are presented for the right and left ears and also for the better and worse ears according to AMA hearing impairment guidelines. The thresholds for the better ear are important in the assessment of the functional significance of the loss. However, the thresholds for the worse ear may be a better indicator of early noise-related impairment of hearing sensitivity. Statistical values are given for left-right differences in thresholds and the results of tests of the significance of these differences from zero.

General examination of these tables shows that the median thresholds for the left and right ears are generally higher than audiometric zero, most of them being about +2 dB until 13 years in boys and 11 years in girls, after which the medians are near zero.

At young ages, the means and medians tend to be high (+4 to +6 dB) in each sex at 0.5, 1 and 6 kHz, but they are from 0 to +2 dB for the other frequencies. At the older ages, the means and medians are about -2 to 0 dB for boys at all frequencies and for girls at 4 and 6 kHz. The corresponding values for girls at 0.5, 1 and 2 kHz are considerably lower (-4 to -6 dB).

The standard deviations are about 5 to 10 dB and tend to decrease slightly with age. They do not appear to differ systematically with frequency. The differences between pairs of means and medians and the spacing between percentiles do not indicate marked tendencies to skewness in these data. The differences between either pairs of mean or pairs of median values for the better and the worse ears are generally about 2 to 4 dB. The means and medians for M512 in the right or left ear, do not show marked lateral or sex differences, but these values tend to be positive until about 14 years in boys and 11 years in girls after which they are close to 0 dB or have negative values. The means and medians for D4 do not show sex differences or a clear tendency to change with age. The means and medians for D4 are almost all negative, being

TABLE 14 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 6 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	8	6.60	8.97	10.41	4.5	6.6	19.4
1000	8	2.44	8.41	10.63	0.0	2.4	20.5
2000	8	1.48	1.61	9.87	-8.3	1.5	9.7
4000	8	2.61	3.71	5.85	-0.6	2.6	9.9
6000	8	4.00	8.12	10.54	1.7	4.0	11.2
M512	8	4.50	6.50	9.15	0.0	4.5	14.5
D4	8	2.61	4.71	8.07	10.0	2.6	0.0
LEFT EAR							
500	5	2.00	4.93	7.55	-1.1	2.0	12.4
1000	5	0.50	3.50	5.69	-0.8	0.5	9.3
2000	6	0.00	1.39	6.10	-3.7	0.0	7.2
4000	6	4.00	4.86	4.95	0.6	4.0	10.3
6000	5	9.34	8.00	6.54	2.0	9.3	13.3
M512	5	1.00	4.00	5.57	-0.5	1.0	10.0
D4	5	-0.56	-1.94	6.79	3.7	-0.6	-8.3
BETTER EAR							
500	8	3.00	4.79	10.21	-2.1	3.0	13.6
1000	8	0.47	4.67	8.26	0.0	0.5	10.1
2000	8	-3.61	0.32	10.17	-8.3	-3.6	9.6
4000	8	0.53	3.15	5.87	-0.7	0.5	9.8
6000	8	3.83	7.08	10.91	0.4	3.8	10.0
M512	8	0.50	3.75	8.83	-2.5	0.5	10.0
D4	8	0.69	1.52	5.12	5.5	0.7	-1.6
WORSE EAR							
500	8	7.74	9.26	10.37	4.5	7.7	19.4
1000	8	3.50	8.68	10.54	0.0	3.5	20.5
2000	8	2.00	3.34	8.54	-2.2	2.0	9.7
4000	8	5.61	5.21	5.82	-0.1	5.6	10.9
6000	8	9.67	10.79	9.93	3.0	9.7	14.4
M512	8	6.00	7.25	8.83	1.3	6.0	14.5
D4	8	2.64	3.47	9.39	10.0	2.6	-4.0
LEFT-RIGHT DIFFERENCES							
500	5	-4.00	-6.23	8.81	-14.7	-4.0	1.1
1000	5	-2.00	-5.56	10.52	-14.0	-2.0	1.1
2000	6	-0.09	0.58	5.48	-4.5	-0.1	6.4
4000	6	-0.08	1.25	4.73	-1.2	-0.1	4.0
6000	5	-0.32	2.61	7.81	-4.0	-0.3	10.7
M512	5	1.00	0.00	6.00	-5.5	1.0	5.0

TABLE 15 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 7 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	28	2.75	2.57	8.16	-3.0	2.7	7.1
1000	29	0.66	2.07	8.29	-2.4	0.7	6.7
2000	30	0.96	0.38	6.19	-3.1	1.0	4.2
4000	30	2.44	2.95	7.11	-0.2	2.4	8.3
6000	30	2.90	2.65	8.09	-3.5	2.9	6.8
M512	28	2.00	2.04	6.62	-2.5	2.0	6.8
D4	29	-0.76	-0.41	6.71	3.0	-0.8	-5.0
LEFT EAR							
500	28	2.54	2.20	7.95	-3.8	2.5	6.6
1000	30	-1.50	-0.26	9.23	-7.1	-1.5	4.8
2000	30	-0.83	0.12	8.26	-5.6	-0.8	6.3
4000	30	2.59	2.59	8.18	-2.9	2.6	7.6
6000	29	4.68	5.78	11.24	-3.3	4.7	13.3
M512	28	0.00	1.00	7.16	-4.8	0.0	5.8
D4	30	-1.70	-2.87	8.18	1.8	-1.7	-9.3
BETTER EAR							
500	29	1.32	0.52	7.95	-4.9	1.3	5.3
1000	30	-2.40	-1.45	8.51	-7.8	-2.4	4.7
2000	30	-1.02	-2.26	6.23	-9.2	-1.0	1.2
4000	30	1.22	-0.40	6.77	-7.2	1.2	4.6
6000	30	1.49	1.01	8.37	-6.6	1.5	5.4
M512	29	0.00	-0.52	6.62	-6.0	0.0	3.5
D4	30	-0.84	-1.06	7.35	2.6	-0.8	-6.9
WORSE EAR							
500	29	4.88	4.46	7.45	-1.1	4.9	8.9
1000	30	0.66	2.80	8.79	-1.9	0.7	8.5
2000	30	2.44	2.76	7.40	-1.9	2.4	8.0
4000	30	7.06	5.93	7.15	1.3	7.1	11.4
6000	30	6.49	7.44	10.06	-0.2	6.5	13.0
M512	29	2.00	3.62	6.72	-0.5	2.0	8.0
D4	30	-1.40	-3.12	8.15	1.4	-1.4	-8.6
LEFT-RIGHT DIFFERENCES							
500	27	0.28	-0.12	6.33	-1.6	0.3	4.3
1000	29	-1.91	-1.98*	5.58	-6.9	-1.9	1.1
2000	30	-2.18	-0.26	6.49	-4.3	-2.2	3.7
4000	30	-0.24	-0.36	8.07	-4.7	-0.2	4.3
6000	29	3.36	3.77*	7.81	-2.4	3.4	9.5
M512	28	0.00	0.82	4.67	-2.8	0.0	3.0

* p<.05

TABLE 16- DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 8 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	33	1.50	1.75	8.09	-3.1	1.5	4.0
1000	33	0.86	1.55	7.07	-2.3	0.9	5.1
2000	33	3.92	1.63	7.63	-4.4	3.9	6.9
4000	33	2.44	1.73	5.84	-2.3	2.4	6.1
6000	33	3.66	4.19	7.58	-0.9	3.7	8.5
M512	33	2.00	2.00	5.93	-1.5	2.0	5.0
D4	33	-0.78	-0.18	5.98	3.0	- 0.8	- 4.6
LEFT EAR							
500	34	0.76	0.74	7.86	-3.8	0.8	3.4
1000	34	0.13	0.90	8.02	-4.8	0.1	4.8
2000	34	-0.05	0.01	7.22	-6.0	-0.1	5.2
4000	34	1.59	1.40	7.21	-3.5	1.6	6.8
6000	34	3.68	4.80	10.21	-4.2	3.7	11.5
M512	34	1.00	0.82	6.05	-5.0	1.0	4.0
D4	34	-1.40	-0.50	5.89	3.7	- 1.4	-4.9
BETTER EAR							
500	34	-0.90	-0.85	7.35	-6.7	-0.9	2.2
1000	34	-1.29	-0.99	7.27	-6.3	-1.3	2.9
2000	34	-2.03	-2.06	6.86	-9.1	-2.6	4.0
4000	34	1.05	-0.72	6.05	-7.2	1.0	3.2
6000	34	2.01	1.39	7.78	-6.6	2.0	4.7
M512	34	0.00	-0.71	5.69	-5.3	0.0	3.3
D4	34	-1.47	-0.27	5.18	2.1	-1.5	-3.3
WORSE EAR							
500	34	2.64	3.02	8.21	-2.3	2.6	7.0
1000	34	3.66	3.09	7.46	-1.1	3.7	5.2
2000	34	4.92	3.36	7.14	-2.0	4.9	8.4
4000	34	3.83	3.54	6.52	-0.6	3.8	6.0
6000	34	8.07	7.25	9.31	-0.3	8.1	12.1
M512	34	4.00	3.50	6.42	-0.3	4.0	6.0
D4	34	0.05	-0.45	5.41	3.3	0.0	-4.9
LEFT-RIGHT DIFFERENCES							
500	33	0.28	-0.71	4.88	-5.4	0.3	2.6
1000	33	0.12	-0.30	5.77	-2.9	0.1	4.1
2000	33	-0.45	-1.33	7.29	-5.4	-0.4	4.5
4000	33	-0.32	-0.02	5.71	-3.4	-0.3	5.5
6000	33	-0.80	0.99	8.64	-3.8	-0.8	5.7
M512	33	0.00	0.27	4.09	-2.0	0.0	2.0

TABLE 17 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 9 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	34	2.25	4.15	11.11	-1.3	2.2	7.3
1000	34	1.65	3.50	11.77	-1.6	1.6	7.1
2000	34	1.88	3.62	10.00	-2.9	1.9	9.4
4000	34	2.13	2.88	7.24	-1.2	2.1	8.4
6000	34	2.04	3.91	7.80	-1.2	2.6	8.5
M512	34	2.50	4.00	9.67	-0.3	2.5	7.0
D4	34	-1.34	0.62	8.77	5.2	-1.3	-4.9
LEFT EAR							
500	31	1.06	1.72	7.73	-2.9	1.1	5.8
1000	31	0.50	0.40	7.40	-4.8	0.5	5.0
2000	32	0.97	0.85	8.25	-6.4	1.0	6.3
4000	32	1.65	1.45	6.95	-4.3	1.6	5.5
6000	31	6.02	6.34	10.07	0.7	6.0	14.7
M512	31	1.00	1.52	5.82	-2.0	1.0	6.0
D4	31	-1.12	-1.08	7.60	3.8	-1.1	-6.0
BETTER EAR							
500	34	-0.74	1.94	11.46	-3.8	-0.7	4.8
1000	34	0.56	0.79	11.43	-6.7	0.6	4.7
2000	34	-1.56	0.84	9.82	-6.4	-1.6	4.5
4000	34	-0.95	-0.13	6.87	-4.5	-0.9	2.1
6000	34	2.22	1.76	8.31	-6.4	2.2	5.6
M512	34	0.00	1.66	9.62	-2.0	0.0	5.0
D4	34	-0.85	0.93	8.21	5.3	-0.9	-2.9
WORSE EAR							
500	34	2.65	5.21	10.92	0.6	2.6	7.8
1000	34	2.38	4.04	11.36	-1.2	2.4	8.8
2000	34	3.16	4.77	10.06	-1.0	3.2	10.9
4000	34	1.05	5.15	7.47	0.6	4.0	9.7
6000	34	8.68	8.88	8.47	2.3	8.7	15.7
M512	34	3.00	5.03	9.63	0.8	3.0	8.0
D4	34	-2.36	-0.51	7.39	3.0	-2.4	-5.1
LEFT-RIGHT DIFFERENCES							
500	31	-1.16	-1.27	4.48	-5.0	-1.2	2.4
1000	31	0.09	-1.71	5.82	-5.8	0.1	2.1
2000	32	-2.22	-1.72*	5.47	-4.5	-2.2	-0.4
4000	32	-2.32	-0.79	7.55	-4.5	-2.3	3.6
6000	31	4.72	3.10*	8.83	-4.8	4.7	9.5
M512	31	0.00	0.42	3.59	-2.0	0.0	2.0

* p<.05

TABLE 18 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 10 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	34	0.95	2.11	7.78	-2.4	0.9	6.4
1000	34	-1.01	0.18	6.69	-4.0	-1.0	3.0
2000	34	1.44	2.71	7.63	-2.6	1.4	8.9
4000	34	1.52	3.97	6.90	-1.6	4.5	8.9
6000	34	3.15	3.39	7.68	-2.6	3.1	8.6
M512	34	1.70	2.00	5.57	-1.0	1.0	5.0
D4	34	-5.34	-3.79	7.30	-0.8	-5.3	-7.0
LEFT EAR							
500	33	0.20	0.64	6.87	-3.6	0.2	4.8
1000	33	-1.00	-0.27	6.14	-4.4	-1.0	3.4
2000	33	-2.05	-0.68	7.42	-7.9	-2.0	5.1
4000	33	2.12	2.61	6.70	-2.1	2.1	8.2
6000	33	4.68	1.69	8.10	-1.0	4.7	8.7
M512	33	0.00	0.30	5.16	-2.0	0.0	3.5
D4	33	-2.24	-2.88	7.13	2.2	-2.2	-7.1
BETTER EAR							
500	34	-1.26	-0.43	6.79	-4.5	-1.3	2.6
1000	34	-2.66	-1.74	5.64	-4.8	-2.7	1.7
2000	34	-2.45	-1.20	7.19	-7.8	-2.5	4.1
4000	34	1.12	0.40	6.29	-5.0	1.1	5.3
6000	34	1.34	1.52	7.31	-5.1	1.3	6.1
M512	34	0.00	-0.59	4.92	-3.3	0.0	1.3
D4	34	-2.63	-2.14	6.63	2.1	-2.6	-5.6
WORSE EAR							
500	34	2.52	3.42	7.44	-1.4	2.5	7.2
1000	34	0.70	1.69	6.60	-2.1	0.7	6.0
2000	34	1.94	3.06	7.62	-2.6	1.9	9.2
4000	34	6.05	6.17	5.94	2.0	6.0	11.2
6000	34	6.25	6.61	7.54	-0.6	6.2	11.6
M512	34	3.00	2.91	5.74	0.0	3.0	7.0
D4	34	-5.16	-4.48	6.38	-1.7	-5.2	-7.0
LEFT-RIGHT DIFFERENCES							
500	33	-0.74	-1.26	5.14	-4.0	-0.7	1.7
1000	33	0.12	-0.43	4.41	-3.9	0.1	2.3
2000	33	-2.81	-3.07**	4.45	-6.4	-2.8	-0.7
4000	33	-2.56	-1.43	7.36	-4.8	-2.6	5.3
6000	33	1.20	1.39	6.80	-3.4	1.2	5.4
M512	33	0.00	-0.24	3.00	-1.5	0.0	1.5

** p<.01

TABLE 19 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 11 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	32	0.65	3.22	11.55	-3.1	0.6	5.3
1000	32	2.66	3.06	10.84	-2.6	2.7	5.6
2000	32	2.12	2.79	9.28	-4.1	2.1	6.1
4000	32	5.86	4.31	9.11	-1.6	5.9	8.7
6000	32	4.81	4.74	6.84	-2.1	4.8	10.6
M512	32	3.00	3.34	7.06	-0.8	3.0	5.0
D4	32	-2.56	-1.25	7.74	1.8	-2.6	-6.2
LEFT EAR							
500	32	1.64	2.36	7.54	-3.0	1.6	6.2
1000	32	2.00	1.55	6.37	-3.9	2.0	4.0
2000	32	-0.65	-0.37	7.40	-6.7	-0.9	2.9
4000	32	2.12	2.56	8.05	-2.9	2.1	8.0
6000	32	6.01	4.29	7.69	-2.5	6.0	10.0
M512	32	1.00	1.44	5.24	-1.0	1.0	3.8
D4	32	-0.98	-1.04	7.44	3.6	-1.0	-5.1
BETTER EAR							
500	32	0.40	0.68	7.49	-3.9	0.4	4.4
1000	32	0.50	0.21	6.59	-4.4	0.5	2.8
2000	32	-1.44	-0.96	7.53	-6.9	-1.4	2.1
4000	32	0.50	0.92	7.79	-5.1	0.5	6.8
6000	32	3.56	2.10	6.44	-2.6	3.6	7.4
M512	32	0.50	0.53	5.32	-2.0	0.5	2.8
D4	32	-1.55	-0.71	6.60	4.9	-1.5	-4.7
WORSE EAR							
500	32	3.86	4.84	11.21	-1.1	3.9	7.1
1000	32	3.64	4.39	10.33	-0.7	3.6	5.9
2000	32	2.36	3.38	8.93	-1.5	2.4	6.1
4000	32	6.88	5.97	8.69	-0.1	6.9	10.2
6000	32	8.91	6.93	7.25	1.5	8.9	11.3
M512	32	4.00	4.41	8.90	0.0	4.0	7.0
D4	32	-2.38	-1.58	7.21	2.0	-2.4	-6.3
LEFT-RIGHT DIFFERENCES							
500	32	-0.37	-0.92	7.03	-3.1	-0.4	2.3
1000	32	0.03	-1.51	6.63	-3.8	0.0	2.2
2000	32	-2.31	-3.16**	5.70	-5.6	-2.3	-0.2
4000	32	-1.52	-1.72	5.86	-6.5	-1.5	3.4
6000	32	-0.48	-0.45	6.64	-3.2	-0.5	3.6
M512	32	0.00	-1.06	7.95	-3.0	0.0	0.0

** p<.01

TABLE 20 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 12 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	29	0.10	1.13	7.93	-3.3	0.1	4.9
1000	29	1.54	0.85	6.73	-4.1	1.5	3.0
2000	29	-0.08	1.40	6.93	-4.6	-0.1	4.2
4000	29	2.27	2.81	5.68	-0.6	2.3	6.9
6000	29	5.13	5.24	7.11	-1.7	5.1	9.8
M512	29	1.00	1.41	4.92	-0.5	1.0	3.0
D4	29	-3.12	-1.95	7.46	1.9	-3.1	-7.8
LEFT EAR							
500	28	-0.24	1.04	10.07	-4.5	-0.2	3.4
1000	28	-1.63	-0.97	5.01	-4.1	-1.6	1.3
2000	28	-0.49	0.17	7.72	-5.2	-0.5	4.6
4000	28	0.12	-0.12	6.96	-6.1	0.1	4.2
6000	28	3.03	2.66	7.57	-2.7	3.0	7.2
M512	28	0.00	0.64	5.81	-2.8	0.0	1.0
D4	28	-0.80	-0.85	7.98	5.4	-0.8	-6.1
BETTER EAR							
500	29	-1.10	-1.54	5.47	-6.1	-1.1	1.3
1000	29	-2.50	-1.87	4.69	-4.7	-2.5	1.1
2000	29	-1.27	-1.90	6.36	-6.7	-1.3	0.5
4000	29	-0.94	-0.87	6.09	-6.0	-0.9	3.8
6000	29	0.69	1.88	7.17	-4.0	0.7	6.4
M512	29	-1.00	-1.10	3.77	-3.5	-1.0	0.5
D4	29	-0.73	-1.00	6.97	5.3	-0.7	-6.1
WORSE EAR							
500	29	1.50	3.73	10.78	-2.9	1.5	6.6
1000	29	1.54	1.92	6.61	-1.9	1.5	3.9
2000	29	2.86	3.54	7.12	-1.9	2.9	8.3
4000	29	3.83	3.80	6.00	0.2	3.8	7.2
6000	29	5.81	6.15	6.96	0.2	5.8	10.7
M512	29	2.00	3.14	6.11	0.0	2.0	5.0
D4	29	-3.06	-2.18	7.54	2.8	-3.1	-7.3
LEFT-RIGHT DIFFERENCES							
500	28	-1.09	-0.07	10.40	-5.1	-1.1	2.5
1000	28	-1.76	-2.03*	4.55	-3.9	-1.8	0.3
2000	28	-0.99	-1.19	7.54	-4.6	-1.0	1.7
4000	28	-2.64	-2.77**	5.52	-4.6	-2.6	1.2
6000	28	-1.66	-2.55**	4.98	-6.6	-1.7	-0.4
M512	28	-1.50	-1.32	3.13	-4.0	-1.5	0.0

* p< .05

**p<.01

TABLE 21 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 13 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	29	1.20	0.27	7.93	-4.5	1.2	3.9
1000	29	-2.00	-1.49	6.14	-5.8	-2.0	1.4
2000	29	-2.10	-2.09	4.23	-4.1	-2.2	0.8
4000	29	1.05	0.81	6.07	-5.0	1.0	5.8
6000	29	5.90	4.01	9.29	-5.2	6.0	10.6
M512	29	-1.00	-0.59	4.95	-2.5	-1.0	1.5
D4	29	-2.29	-2.29	6.79	1.1	-2.3	-6.9
LEFT EAR							
500	29	-0.48	-0.21	6.99	-4.2	-0.5	2.8
1000	29	-1.75	-1.50	5.68	-5.0	-1.8	1.1
2000	29	-4.44	-4.46	4.30	-8.7	-4.4	-0.5
4000	29	-2.29	-1.01	6.68	-6.2	-2.3	6.4
6000	29	2.01	2.09	7.80	-4.6	2.0	7.7
M512	29	-1.00	-1.45	4.67	-4.0	-1.0	0.0
D4	29	0.04	-0.49	6.56	3.9	0.0	- 5.3
BETTER EAR							
500	29	-1.36	-1.28	7.10	-5.1	-1.4	1.9
1000	29	-2.68	-2.92	5.35	-6.8	-2.7	0.3
2000	29	-4.85	-5.29	3.70	-8.7	-4.9	-2.9
4000	29	-2.62	-2.31	5.79	-6.6	-2.8	2.9
6000	29	-1.32	0.31	7.79	-6.2	-1.3	6.7
M512	29	-2.00	-2.52	4.50	-5.5	-2.0	0.0
D4	29	-0.48	-0.61	6.11	2.6	-0.5	- 4.2
WORSE EAR							
500	29	1.52	1.34	7.60	-3.2	1.5	4.6
1000	29	-0.24	-0.06	6.08	-3.2	-0.2	3.1
2000	29	-1.17	-1.77	4.22	-3.9	-1.1	2.1
4000	29	3.22	2.11	6.29	-3.5	3.2	7.4
6000	29	6.04	5.80	8.52	-2.3	6.0	14.1
M512	29	0.00	0.45	4.77	-2.0	0.0	2.0
D4	29	-2.52	-2.17	6.74	1.7	- 2.5	-7.5
LEFT-RIGHT DIFFERENCES							
500	29	-0.80	-0.48	3.21	-3.1	-0.6	2.6
1000	29	0.12	-0.01	4.14	-1.9	0.1	2.3
2000	29	-0.90	-2.37**	5.06	-5.9	-0.9	-0.3
4000	29	-2.16	-1.82*	5.46	-5.4	-2.2	0.4
6000	29	-1.28	-1.92	6.59	-6.6	-1.3	2.8
M512	29	0.00	-0.93	3.29	-4.0	0.0	1.0

* p<.05

**p<.01

TABLE 22 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 14 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	38	-1.80	-1.92	5.62	-6.2	-1.8	2.9
1000	38	-2.12	-2.01	4.23	-5.4	-2.1	0.7
2000	38	-2.16	-1.71	6.01	-6.8	-2.2	3.6
4000	38	-0.08	0.05	7.26	-7.2	-0.1	5.9
6000	38	0.07	1.04	8.00	-4.5	0.1	5.9
M512	38	-1.90	-1.24	3.59	-4.0	-1.0	1.3
D4	38	-2.00	-2.06	7.70	4.0	-2.0	-9.2
LEFT EAR							
500	38	-2.46	-1.64	5.06	-6.0	-2.5	2.7
1000	38	-2.38	-2.80	5.13	-6.7	-2.4	0.4
2000	38	-2.85	-2.16	5.73	-6.0	-2.9	0.1
4000	38	1.24	0.81	7.37	-4.2	1.2	5.6
6000	38	0.67	1.03	8.65	-8.0	0.7	6.3
M512	38	-1.50	-1.61	3.54	-4.0	-1.5	0.0
D4	38	-2.40	-3.61	7.57	2.1	-2.4	-10.3
BETTER EAR							
500	38	-4.44	-3.61	5.07	-7.4	-4.4	-0.1
1000	38	-4.50	-4.37	4.04	-7.4	-4.5	-2.2
2000	38	-4.00	-3.70	5.07	-8.5	-4.0	-0.5
4000	38	-2.08	-1.55	6.47	-7.9	-2.1	3.7
6000	38	-2.53	-1.37	7.72	-8.0	-2.5	4.0
M512	38	-2.50	-3.05	3.55	-6.0	-2.5	0.0
D4	38	-2.70	-2.82	6.33	2.3	-2.7	-7.4
WORSE EAR							
500	38	0.05	0.05	4.97	-3.9	0.6	4.1
1000	38	-0.23	-0.44	4.51	-2.5	-0.2	2.9
2000	38	-1.19	-0.16	6.07	-4.8	-1.2	4.0
4000	38	2.00	2.41	7.58	-3.5	2.0	8.2
6000	38	3.25	3.45	8.21	-2.9	3.3	7.9
M512	38	0.00	0.24	3.49	-2.3	0.0	2.0
D4	38	-2.06	-2.85	7.58	2.7	-2.1	-9.2
LEFT-RIGHT DIFFERENCES							
500	38	0.42	0.28	4.90	-3.1	0.4	2.5
1000	38	0.03	-0.60	5.27	-4.0	0.0	2.1
2000	38	-0.45	-0.45	4.50	-3.0	-0.4	3.0
4000	38	-0.12	0.76	5.17	-4.0	-0.1	5.3
6000	38	-0.40	-0.01	6.00	-3.6	-0.4	2.9
M512	38	0.00	-0.05	2.97	-2.0	0.0	1.3

TABLE 23 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 15 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	44	-2.05	-0.84	6.37	-4.4	-2.0	3.6
1000	44	-2.46	-1.43	5.61	-5.1	-2.5	1.8
2000	44	-0.84	-1.06	6.67	-6.8	-0.8	3.5
4000	44	3.35	3.24	7.23	-2.3	3.4	9.0
6000	44	1.90	2.86	8.66	-4.5	1.9	7.7
M512	44	-1.00	-0.48	4.67	-4.0	-1.0	2.0
D4	44	-5.36	-4.67	6.89	0.5	-5.4	-9.5
LEFT EAR							
500	44	-2.36	-1.21	5.42	-5.8	-2.4	2.8
1000	44	-1.88	-2.00	5.60	-5.9	-1.9	0.5
2000	44	-2.63	-1.06	7.00	-6.0	-2.6	1.5
4000	44	2.71	1.97	7.22	-3.6	2.7	6.5
6000	44	2.34	2.27	8.51	-4.0	2.3	7.4
M512	44	-1.00	-0.75	4.38	-3.0	-1.0	0.0
D4	44	-4.84	-3.97	8.98	3.4	-4.8	-11.9
BETTER EAR							
500	44	-3.82	-3.15	5.26	-7.1	-3.8	1.9
1000	44	-4.02	-3.68	5.13	-7.1	-4.0	-1.6
2000	44	-4.83	-3.26	5.83	-7.6	-4.8	0.2
4000	44	-0.29	0.07	6.58	-6.5	-0.3	4.0
6000	44	0.07	-0.24	6.95	-6.5	0.1	4.1
M512	44	-3.00	-2.57	3.81	-5.0	-3.0	-1.0
D4	44	-4.76	-3.75	7.63	2.8	-4.8	-10.5
WORSE EAR							
500	44	0.69	1.10	5.76	-3.1	0.9	5.5
1000	44	0.38	0.26	5.35	-2.9	0.4	2.6
2000	44	1.06	1.14	7.04	-4.1	1.1	4.4
4000	44	5.71	5.15	6.97	0.1	5.7	9.5
6000	43	5.56	5.38	9.11	-2.0	5.6	10.5
M512	44	0.00	1.27	4.55	-1.0	0.0	3.0
D4	44	-5.77	-4.89	7.01	0.6	-5.8	-9.2
LEFT-RIGHT DIFFERENCES							
500	44	-0.16	-0.38	5.60	-3.3	-0.2	4.6
1000	44	0.07	-0.57	4.79	-3.9	0.1	2.3
2000	44	-0.76	-0.00	7.11	-3.7	-0.8	1.8
4000	44	-0.60	-1.27	6.69	-4.6	-0.8	3.3
6000	44	-1.12	-0.59	7.39	-4.5	-1.1	4.3
M512	44	0.00	0.07	3.93	-1.8	0.0	2.0

TABLE 24 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 16 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	43	-0.20	-0.08	6.09	-3.4	-0.2	4.4
1000	43	-2.66	-1.50	4.61	-4.5	-2.7	1.8
2000	43	0.40	0.49	5.66	-2.6	0.4	4.8
4000	43	3.83	3.79	7.50	-1.6	3.8	9.0
6000	43	4.15	4.48	7.21	-1.8	4.1	8.1
M512	43	0.00	0.16	4.41	-2.0	0.0	4.0
D4	43	-6.34	-5.30	6.67	-1.9	-6.3	-10.3
LEFT EAR							
500	43	-1.80	-1.29	5.68	-5.1	-1.8	3.3
1000	43	-1.25	-2.05	6.36	-8.5	-1.3	1.3
2000	43	-3.27	-0.47	7.43	-5.3	-3.3	4.3
4000	43	4.65	3.58	8.01	-3.9	4.6	9.6
6000	43	6.01	4.61	7.96	-0.6	6.0	9.3
M512	43	-1.00	-0.77	5.13	-5.0	-1.0	3.0
D4	43	-6.64	-5.63	7.79	-0.6	-6.8	-11.4
BETTER EAR							
500	43	-2.00	-2.55	5.32	-6.9	-2.0	2.1
1000	43	-2.90	-3.35	5.31	-8.5	-2.9	1.1
2000	43	-3.60	-2.21	5.97	-6.6	-3.6	1.9
4000	43	1.06	0.51	6.93	-6.3	1.1	6.0
6000	43	2.15	1.69	6.63	-3.7	2.1	6.5
M512	43	-3.00	-2.07	4.51	-6.0	-3.0	1.0
D4	43	-3.60	-3.86	7.07	-0.7	-3.8	-7.9
WORSE EAR							
500	43	0.90	1.18	5.88	-3.1	0.9	5.1
1000	43	0.50	-0.20	5.35	-4.3	0.5	3.3
2000	43	2.40	2.24	6.47	-2.6	2.4	6.4
4000	43	7.27	6.87	7.20	1.0	7.2	12.4
6000	43	7.35	7.39	7.40	1.5	7.3	10.0
M512	43	1.00	1.56	4.86	-1.0	1.0	5.0
D4	43	-7.80	-7.07	6.39	-3.6	-7.8	-11.4
LEFT-RIGHT DIFFERENCES							
500	43	-1.16	-1.21*	4.67	-3.3	-1.2	2.7
1000	43	0.15	-0.55	3.98	-3.8	0.1	2.1
2000	43	-0.27	-0.96	5.56	-6.3	-0.3	3.5
4000	43	-0.24	-0.21	7.66	-6.3	-0.2	5.6
6000	43	1.20	0.13	7.34	-4.3	1.2	5.7
M512	43	0.00	0.00	3.14	-1.0	0.0	2.0

* $p<.05$

TABLE 25 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 17 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	47	-1.10	-0.39	6.57	-5.4	-1.1	6.6
1000	47	-3.50	-2.91	5.63	-6.2	-3.6	0.4
2000	47	-2.72	-2.04	6.22	-7.2	-2.7	3.4
4000	47	0.44	1.03	8.09	-6.5	0.4	6.3
6000	47	0.49	2.54	7.98	-4.5	0.5	9.8
M512	47	-1.00	-1.26	4.77	-5.0	-1.0	2.0
D4	47	-2.73	-3.93	7.53	0.0	-2.7	-8.7
LEFT EAR							
500	47	-3.10	-2.49	4.77	-6.0	-3.2	1.1
1000	47	-3.25	-3.45	5.14	-8.3	-3.3	0.5
2000	47	-3.27	-1.43	8.60	-8.5	-3.3	4.7
4000	47	-0.94	1.10	8.20	-5.2	-0.9	6.2
6000	47	0.69	2.53	10.63	-6.0	0.7	7.3
M512	47	-3.00	-1.79	4.65	-5.0	-3.0	1.0
D4	47	-3.40	-4.56	6.77	0.9	-3.4	-8.2
BETTER EAR							
500	47	-4.92	-3.41	5.16	-7.1	-4.9	0.9
1000	47	-5.12	-5.04	4.93	-10.0	-5.1	-1.5
2000	47	-5.06	-4.07	6.45	-9.3	-5.7	-1.1
4000	47	-3.35	-1.66	7.01	-7.2	-3.3	2.6
6000	47	-2.04	-0.38	7.35	-6.2	-2.0	5.1
M512	47	-4.00	-3.36	4.20	-7.0	-4.0	0.0
D4	47	-2.79	-3.38	5.73	-0.6	-2.8	-7.9
WORSE EAR							
500	47	-0.80	0.53	5.79	-3.9	-0.8	6.6
1000	47	-2.25	-1.32	5.18	-5.3	-2.3	2.4
2000	47	-1.04	0.59	7.75	-4.5	-1.0	5.2
4000	47	2.27	3.79	8.26	-2.3	2.3	9.0
6000	47	5.37	5.45	10.25	-3.3	5.4	11.7
M512	47	0.00	0.36	5.04	-3.0	0.0	3.0
D4	47	-5.17	-5.11	7.02	-0.8	-5.2	-8.7
LEFT-RIGHT DIFFERENCES							
500	47	-1.30	-2.11**	4.48	-5.6	-1.3	1.1
1000	47	0.15	-0.55	4.79	-3.9	0.1	2.2
2000	47	-0.36	0.61	5.99	-2.6	-0.4	3.6
4000	47	-0.56	0.08	7.01	-5.0	-0.6	5.0
6000	47	-0.32	-0.01	8.39	-4.3	-0.3	4.4
M512	47	1.00	0.49	3.79	-2.0	1.0	3.0

**p<.01

TABLE 26 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF BOYS 18 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	20	-1.66	-0.09	7.57	-7.2	-1.6	7.2
1000	20	-1.47	-1.05	5.79	-6.0	-1.5	3.5
2000	20	-1.16	-1.42	5.51	-5.2	-1.2	0.4
4000	20	-2.03	0.10	7.02	-5.6	-2.0	7.1
6000	20	1.39	3.25	8.38	-4.4	1.4	10.5
M512	20	0.00	-0.30	4.91	-4.3	0.0	2.5
D4	20	-1.51	-1.15	7.47	3.9	-1.5	-4.0
LEFT EAR							
500	20	-1.56	-0.20	7.39	-7.5	-1.6	5.8
1000	20	-1.13	-1.54	5.76	-7.3	-1.1	1.8
2000	20	-2.85	-3.85	4.67	-8.5	-2.9	-0.5
4000	20	-0.76	-0.36	5.81	-5.7	-0.8	4.3
6000	20	1.35	2.32	8.68	-5.0	1.3	6.7
M512	20	-1.00	-1.15	4.37	-4.0	-1.0	2.5
D4	20	-0.62	-1.17	5.27	1.9	-0.8	-5.5
BETTER EAR							
500	20	-2.07	-1.83	6.77	-8.9	-2.1	4.5
1000	20	-1.47	-2.75	4.77	-7.6	-1.5	1.0
2000	20	-2.85	-3.93	4.77	-8.5	-2.9	-0.5
4000	20	-4.06	-2.83	5.46	-7.2	-4.7	1.0
6000	20	-1.97	-0.02	7.46	-5.8	-2.0	2.5
M512	20	-2.00	-2.10	4.18	-5.0	-2.0	0.8
D4	20	0.04	0.08	4.75	3.4	0.0	-2.6
WORSE EAR							
500	20	-0.86	1.55	7.74	-5.5	-0.9	9.5
1000	20	-1.13	0.16	6.29	-5.8	-1.1	5.4
2000	20	-1.16	-1.33	5.38	-5.2	-1.2	0.4
4000	20	1.27	2.56	6.16	-2.5	1.3	8.7
6000	20	5.07	5.60	8.59	-2.2	5.1	10.7
M512	20	0.00	0.55	5.13	-2.8	0.0	3.8
D4	20	-2.56	-2.40	7.16	1.8	-2.6	-6.5
LEFT-RIGHT DIFFERENCES							
500	20	-0.88	-0.11	4.15	-2.9	-0.9	3.1
1000	20	0.12	-0.49	4.05	-3.7	0.1	1.7
2000	20	-0.99	-2.43**	2.62	-4.3	-1.0	-0.7
4000	20	-1.40	-0.46	7.28	-4.8	-1.4	3.1
6000	20	-1.68	-0.93	6.96	-4.9	-1.7	5.5
M512	20	0.00	-0.75	2.99	-3.0	0.0	1.0

**p<.01

TABLE 27 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 6 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	8	3.00	3.70	3.92	0.8	3.0	5.5
1000	9	4.00	3.84	2.72	1.4	4.0	6.0
2000	9	-3.14	-1.49	5.55	-4.6	-3.1	5.0
4000	8	4.00	3.84	2.05	1.5	4.0	6.0
6000	8	5.00	6.83	5.25	4.0	5.0	10.5
M512	8	1.50	2.25	3.15	0.0	1.5	5.5
D4	8	-0.27	-0.63	0.87	0.0	-0.3	-1.6
LEFT EAR							
500	5	0.00	-0.90	1.88	-2.6	0.0	0.4
1000	5	-1.40	-1.36	1.44	-2.7	-1.4	0.0
2000	5	-2.00	-1.46	6.60	-6.8	-2.0	4.2
4000	5	5.16	6.06	4.65	2.0	5.2	10.6
6000	5	3.40	5.36	10.25	-4.0	3.4	15.7
M512	5	0.00	-0.40	2.30	-2.5	0.0	1.5
D4	5	-8.56	-7.42	4.72	-8.0	-8.6	-11.3
BETTER EAR							
500	8	0.38	2.19	5.01	-0.9	0.4	5.5
1000	9	0.00	1.78	4.23	-1.7	0.0	6.0
2000	9	-4.00	-3.10	6.05	-7.6	-4.0	2.0
4000	8	3.00	3.09	2.24	1.4	3.0	5.5
6000	8	3.70	2.84	5.25	-2.7	3.7	5.5
M512	8	-1.00	0.75	3.92	-1.8	-1.0	5.0
D4	8	-1.39	-2.19	2.51	0.0	-1.4	-4.6
WORSE EAR							
500	8	3.00	3.70	3.92	0.8	3.0	5.5
1000	9	4.00	3.84	2.72	1.4	4.0	6.0
2000	9	2.36	1.34	4.37	-3.1	2.4	6.0
4000	8	6.00	6.29	3.07	4.3	6.0	8.4
6000	8	9.00	10.09	6.03	4.5	9.0	16.0
M512	8	2.50	3.00	2.51	1.0	2.5	5.5
D4	8	-1.00	-3.08	4.07	0.0	-1.0	-7.3
LEFT-RIGHT DIFFERENCES							
500	5	-2.00	-2.42	3.28	-5.0	-2.0	-0.0
1000	5	-4.00	-3.70**	1.64	-5.1	-4.0	-2.1
2000	5	2.00	2.20	10.00	-7.3	2.0	11.7
4000	5	3.78	2.71	5.87	-3.0	3.8	7.9
6000	5	-8.00	-1.18	13.62	-12.0	-8.0	13.0
M512	5	-2.00	-0.40	4.93	-4.5	-2.0	4.5

**p<.01

TABLE 28 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 7 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	25	1.60	3.97	6.82	-0.2	1.6	8.0
1000	25	0.00	1.30	7.93	-3.5	0.0	6.3
2000	25	0.80	0.28	5.46	-3.4	0.9	2.3
4000	25	2.07	3.34	7.20	-3.3	2.1	8.7
6000	25	2.68	2.49	6.05	-1.3	2.7	6.0
M512	25	0.00	2.24	5.90	-1.0	0.0	5.5
D4	25	-2.54	-2.04	7.30	4.6	-2.5	-8.1
LEFT EAR							
500	21	0.76	1.04	5.91	-2.4	0.8	3.3
1000	23	-1.10	1.08	11.73	-5.1	-1.1	2.6
2000	22	0.36	0.17	7.14	-3.3	0.4	5.0
4000	22	0.03	1.33	8.66	-5.1	0.0	8.1
6000	22	1.75	3.54	8.52	-2.6	1.7	7.8
M512	21	0.00	0.43	5.36	-2.5	0.0	1.5
D4	22	-0.98	-2.41	6.26	3.2	-1.0	-6.9
BETTER EAR							
500	25	-0.40	1.21	7.23	-2.4	-0.4	1.6
1000	25	-2.74	-1.26	7.73	-6.0	-2.7	1.9
2000	25	-1.14	-1.35	5.71	-4.5	-1.1	0.9
4000	25	-0.26	-0.03	6.67	-5.4	-0.3	4.4
6000	25	0.66	0.84	5.91	-3.3	0.7	6.0
M512	25	0.00	0.16	5.87	-4.5	0.0	1.0
D4	25	-0.56	-1.24	6.37	3.3	-0.6	-4.2
WORSE EAR							
500	25	3.20	5.00	6.89	1.0	3.2	8.4
1000	25	0.64	3.91	10.81	-1.1	0.8	7.3
2000	25	1.29	2.17	6.55	-1.9	1.3	6.3
4000	25	4.76	5.19	8.39	-2.1	4.6	10.7
6000	25	3.34	5.16	7.92	-0.3	3.3	11.4
M512	25	1.00	4.04	6.96	0.0	1.0	6.5
D4	25	-2.54	-1.28	9.87	3.8	-2.5	-9.3
LEFT-RIGHT DIFFERENCES							
500	21	-2.06	-2.05	6.20	-5.1	-2.1	-0.9
1000	23	-0.48	0.06	8.30	-6.2	-0.5	1.6
2000	22	-0.62	0.30	6.89	-3.3	-0.6	1.3
4000	22	-2.00	-1.72	9.88	-6.2	-2.0	1.6
6000	22	0.03	1.16	7.83	-3.9	0.0	2.1
M512	22	-0.50	0.66	5.36	-1.0	-0.5	2.0

TABLE 29 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 8 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	25	6.00	4.93	7.43	1.2	6.0	10.4
1000	25	2.84	3.17	6.45	-0.9	2.8	7.7
2000	25	0.15	0.49	7.32	-3.6	0.1	3.1
4000	25	7.45	6.62	8.14	0.8	7.4	11.4
6000	25	4.02	4.07	6.73	-2.3	4.0	10.7
M512	25	3.00	3.12	5.55	0.0	3.0	8.0
D4	25	-2.54	-3.46	8.32	0.6	-2.5	-9.4
LEFT EAR							
500	25	2.28	2.41	7.28	-1.5	2.3	7.3
1000	25	-0.50	0.46	6.38	-4.0	-0.5	3.9
2000	25	-1.64	-2.01	5.07	-3.6	-1.6	0.6
4000	25	2.90	1.95	6.03	-2.8	2.9	5.2
6000	25	2.00	2.82	8.62	-3.8	2.0	10.5
M512	25	0.00	0.56	4.52	-1.0	0.0	3.5
D4	25	-2.56	-1.50	9.76	2.6	-2.6	-7.1
BETTER EAR							
500	25	1.90	1.02	6.99	-5.5	1.9	5.9
1000	25	-0.80	-0.34	5.95	-4.3	-0.8	2.2
2000	25	-2.92	-3.31	4.42	-5.8	-2.9	0.4
4000	25	0.90	0.64	6.07	-4.3	0.9	4.6
6000	25	1.34	0.83	6.90	-4.6	1.3	6.1
M512	25	0.00	-0.32	4.09	-2.5	0.0	2.0
D4	25	-1.40	-0.98	8.83	1.0	-1.4	-5.4
WORSE EAR							
500	25	7.60	6.12	7.05	2.2	7.6	11.4
1000	25	3.26	3.96	6.42	0.9	3.3	8.3
2000	25	0.54	1.79	7.03	-2.5	0.5	5.3
4000	25	7.45	7.94	7.02	3.2	7.4	11.8
6000	25	7.50	6.06	7.65	-0.6	7.5	11.7
M512	25	4.00	4.16	5.53	1.5	4.0	8.5
D4	25	-2.81	-3.97	8.23	-0.2	-2.8	-10.2
LEFT-RIGHT DIFFERENCES							
500	25	-4.08	-2.72*	6.05	-6.1	-4.1	-0.1
1000	25	-2.60	-2.71**	5.01	-6.4	-2.6	-0.4
2000	25	-1.25	-2.50	7.55	-5.5	-1.2	1.0
4000	25	-6.22	-4.67**	8.82	-8.4	-6.2	1.4
6000	25	0.00	-1.24	7.02	-5.8	0.1	4.2
M512	25	0.00	-1.48	3.10	-4.5	0.0	0.0

*p<.05

**p<.01

TABLE 30 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 9 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	26	2.60	1.15	6.58	-4.8	2.6	6.2
1000	27	1.26	0.18	5.17	-3.5	1.3	3.4
2000	27	-0.56	-0.07	5.93	-4.7	-0.6	4.9
4000	27	5.38	5.36	7.14	0.8	5.4	10.8
6000	27	4.02	3.92	7.86	-1.3	4.0	8.7
M512	26	1.00	0.88	4.53	-2.3	1.0	4.3
D4	27	-4.54	-5.18	8.02	0.4	-4.5	-12.5
LEFT EAR							
500	26	1.71	1.17	6.00	-3.5	1.7	5.3
1000	27	-3.10	-1.33	6.24	-5.6	-3.1	4.1
2000	27	-1.46	-2.40	5.39	-7.6	-1.5	1.3
4000	26	2.61	2.23	6.34	-3.2	2.6	7.6
6000	26	3.85	3.48	7.45	-4.4	3.8	7.7
M512	26	0.50	-0.31	4.60	-3.3	0.5	2.0
D4	26	-3.12	-3.49	6.43	-0.7	-3.1	-8.0
BETTER EAR							
500	27	0.66	-0.29	6.00	-4.9	0.7	3.1
1000	27	-3.40	-2.21	5.39	-7.1	-3.4	2.1
2000	27	-3.10	-3.48	5.06	-9.1	-3.1	0.5
4000	27	-0.26	0.77	6.03	-3.9	-0.3	5.7
6000	27	2.10	0.89	6.44	-4.7	2.1	5.3
M512	27	-1.00	-1.37	4.35	-3.0	-1.0	1.0
D4	27	-2.44	-2.96	5.57	-0.2	-2.2	-6.8
WORSE EAR							
500	27	3.20	2.56	6.01	-0.8	3.2	6.3
1000	27	1.26	1.05	5.69	-3.2	1.3	5.3
2000	27	1.26	1.02	5.56	-3.0	1.3	6.6
4000	27	6.76	6.78	6.31	3.4	6.8	11.4
6000	27	6.10	6.56	7.57	2.7	6.1	9.4
M512	27	1.00	1.81	4.58	0.0	1.0	5.0
D4	27	-4.54	-5.73	7.19	-1.1	-4.5	-12.6
LEFT-RIGHT DIFFERENCES							
500	25	-0.10	0.05	4.20	-4.1	-0.1	3.9
1000	27	-0.72	-1.51*	4.36	-2.8	-0.7	1.0
2000	27	-1.50	-2.33*	6.35	-3.2	-1.5	2.3
4000	26	-1.71	-3.28*	7.86	-8.3	-1.7	2.1
6000	26	-0.85	-0.38	8.17	-5.8	-0.8	4.2
M512	26	0.00	-0.62	3.93	-3.0	0.0	1.0

* p<.05

TABLE 31- DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 10 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	30	2.00	1.32	5.31	-2.6	2.0	4.0
1000	30	0.47	0.91	4.54	-2.0	0.5	4.5
2000	30	0.79	2.04	6.42	-2.2	0.8	5.9
4000	30	2.79	4.77	7.24	-1.1	2.8	10.1
6000	30	1.35	2.78	7.51	-3.6	1.3	8.2
M512	30	1.00	1.80	3.60	-1.0	1.0	5.3
D4	30	-2.94	-3.86	8.56	1.6	-2.9	-7.9
LEFT EAR							
500	30	-1.46	-0.47	6.63	-4.1	-1.5	3.2
1000	30	-2.90	-2.16	6.68	-8.6	-2.9	2.2
2000	30	-2.74	-2.03	5.36	-5.7	-2.7	1.7
4000	30	1.22	1.96	7.70	-2.0	1.2	7.0
6000	30	-1.75	1.16	7.32	-5.0	-1.7	7.0
M512	30	-1.00	-0.90	4.71	-5.0	-1.0	2.0
D4	30	-3.26	-4.12	5.78	-0.3	-3.3	-7.3
BETTER EAR							
500	30	-2.30	-2.09	5.51	-6.7	-2.3	1.6
1000	30	-3.20	-3.47	5.68	-9.1	-3.2	1.2
2000	30	-3.28	-3.19	5.07	-7.7	-3.3	0.4
4000	30	0.16	0.56	7.24	-3.6	0.2	3.1
6000	30	-2.56	-0.60	6.84	-5.8	-2.6	1.5
M512	30	-2.00	-2.13	4.02	-5.0	-2.0	0.0
D4	30	-2.98	-4.02	6.65	-0.4	-3.0	-8.2
WORSE EAR							
500	30	2.00	2.94	5.51	-0.4	2.0	5.8
1000	30	2.20	2.21	4.60	-0.7	2.2	5.8
2000	30	2.60	3.20	5.62	-1.2	2.6	6.8
4000	30	5.30	6.17	6.85	1.2	5.3	10.9
6000	30	5.10	4.54	7.13	-1.8	5.1	8.7
M512	30	2.50	3.07	3.80	0.0	2.5	6.0
D4	30	-3.08	-3.95	6.96	0.7	-3.1	-8.7
LEFT-RIGHT DIFFERENCES							
500	30	-4.05	-1.79*	5.58	-6.1	-4.0	3.8
1000	30	-3.20	-3.07**	6.49	-6.5	-3.2	1.5
2000	30	-4.75	-4.07**	6.54	-8.6	-4.8	0.4
4000	30	-2.62	-2.81*	6.69	-7.4	-2.6	1.5
6000	30	0.10	-1.62	6.50	-5.7	0.1	4.1
M512	30	-2.00	-2.17	3.18	-5.0	-2.0	0.0

* p<.05

**p<.01

TABLE 32 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 11 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	24	-1.60	-1.13	5.84	-5.6	-1.6	3.9
1000	24	-0.85	-0.34	5.74	-3.1	-0.8	3.7
2000	24	-1.63	-0.95	6.75	-7.0	-1.6	3.9
4000	24	1.14	2.64	7.90	-2.4	1.1	8.9
6000	24	1.36	1.35	6.74	-3.1	1.4	7.2
M512	24	0.00	-0.25	4.82	-4.0	0.0	3.8
D4	24	-1.69	-2.99	8.64	2.4	-1.9	-9.1
LEFT EAR							
500	24	-2.53	-2.76	5.54	-7.7	-2.5	1.6
1000	24	-2.45	-2.33	5.85	-8.4	-2.4	1.7
2000	24	-3.10	-2.15	6.66	-7.8	-3.1	1.9
4000	24	0.93	2.97	8.28	-2.8	0.9	8.9
6000	24	3.80	5.12	8.94	-1.4	3.8	12.8
M512	24	-1.50	-1.83	4.58	-6.0	-1.5	1.0
D4	24	-4.68	-5.30	8.49	0.0	-4.7	-10.4
BETTER EAR							
500	24	-3.53	-3.65	5.16	-8.0	-3.5	-0.7
1000	24	-3.23	-3.21	5.31	-8.4	-3.2	1.1
2000	24	-3.92	-3.51	5.71	-8.7	-3.9	1.1
4000	24	-1.61	-0.37	6.58	-4.2	-1.6	1.5
6000	24	0.35	0.48	6.37	-4.1	0.4	4.4
M512	24	-2.50	-2.63	4.37	-7.0	-2.5	0.0
D4	24	-2.43	-2.84	7.45	-0.4	-2.4	-7.5
WORSE EAR							
500	24	-0.46	-0.24	5.78	-3.6	-0.5	4.0
1000	24	1.23	0.54	5.80	-3.0	1.2	4.2
2000	24	0.65	0.42	7.07	-6.3	0.7	5.1
4000	24	5.21	5.98	8.18	-0.3	5.2	10.4
6000	24	6.44	6.00	8.74	-0.2	6.4	12.8
M512	24	1.00	0.63	4.97	-3.8	1.0	5.0
D4	24	-5.52	-5.44	8.20	0.6	-5.5	-8.1
LEFT-RIGHT DIFFERENCES							
500	24	-2.10	-1.62*	4.23	-4.1	-2.1	-0.0
1000	24	-0.60	-1.98*	4.75	-6.0	-0.6	1.4
2000	24	-1.13	-1.20	5.66	-3.2	-1.1	0.4
4000	24	0.61	0.33	7.87	-6.7	0.6	5.3
6000	24	0.33	3.77**	6.97	0.1	0.3	10.2
M512	24	0.00	0.83	3.07	-1.0	0.0	3.8

* p<.05

**p<.01

TABLE 33 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 12 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	26	-0.60	-0.37	5.04	-3.7	-0.8	3.8
1000	27	0.52	-0.69	4.55	-2.3	0.5	2.2
2000	27	-0.13	-0.71	5.24	-4.6	-0.1	3.2
4000	27	3.52	2.99	7.57	-4.0	3.5	10.2
6000	27	1.34	1.70	8.31	-6.0	1.3	6.7
M512	26	0.00	-0.15	3.94	-1.5	0.0	3.0
D4	27	-5.89	-3.68	7.51	2.4	-5.9	-10.2
LEFT EAR							
500	26	-0.91	0.67	10.68	-4.5	-0.9	3.4
1000	26	-1.65	-0.32	11.09	-5.9	-1.6	0.3
2000	26	-6.64	-3.99	7.52	-10.3	-6.6	0.2
4000	26	0.93	0.72	8.87	-7.4	0.9	7.2
6000	26	4.20	2.78	10.47	-6.4	4.2	10.2
M512	26	-2.00	-0.58	8.78	-4.5	-2.0	1.0
D4	26	-0.70	-1.03	8.34	2.6	-0.7	-7.0
BETTER EAR							
500	26	-3.08	-2.59	5.24	-6.4	-3.1	0.5
1000	27	-2.00	-3.19	4.05	-6.8	-2.0	0.0
2000	27	-6.71	-4.93	5.74	-10.2	-6.7	-0.4
4000	27	-2.00	-1.14	7.12	-7.4	-2.0	6.1
6000	27	-0.40	-0.83	7.08	-6.6	-0.4	6.0
M512	26	-3.00	-2.92	3.92	-6.3	-3.0	0.0
D4	27	-1.12	-2.05	6.36	2.3	-1.1	-6.2
WORSE EAR							
500	26	1.08	2.90	9.84	-1.4	1.1	5.0
1000	27	0.84	2.12	10.39	-2.3	0.8	3.8
2000	27	0.00	0.53	6.36	-2.6	0.0	4.0
4000	27	7.22	4.68	8.28	-2.2	7.2	10.8
6000	27	4.10	4.98	10.47	-4.0	4.1	12.2
M512	26	0.50	2.23	6.07	-0.3	0.5	3.3
D4	27	-5.89	-2.55	9.12	2.6	-5.9	-10.2
LEFT-RIGHT DIFFERENCES							
500	26	-2.07	1.04	10.33	-4.1	-2.1	2.4
1000	26	-1.48	0.33	10.63	-4.6	-1.5	0.8
2000	26	-2.50	-3.10**	6.32	-8.1	-2.5	0.1
4000	26	-0.55	-2.54	8.94	-9.2	-0.5	1.0
6000	26	0.24	0.78	9.06	-2.3	0.2	4.7
M512	26	-1.00	0.12	6.51	-3.0	-1.0	2.0

** $p < .01$

TABLE 34 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 13 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	30	-0.00	0.47	6.30	-4.3	-0.0	5.4
1000	30	-0.16	-0.10	6.10	-4.2	-0.2	2.8
2000	30	-1.42	-0.72	6.81	-7.0	-1.4	3.9
4000	30	1.72	1.33	6.77	-4.6	1.7	6.5
6000	30	3.02	2.77	8.60	-4.1	3.0	9.5
M512	30	0.00	0.37	4.86	-3.0	0.0	3.0
D4	30	-1.46	-1.44	6.72	4.2	-1.5	-6.5
LEFT EAR							
500	30	-1.96	-1.43	6.20	-5.0	-2.0	3.4
1000	30	-4.50	-3.42	5.37	-7.8	-4.5	0.2
2000	29	-4.92	-4.13	7.60	-9.3	-4.9	-1.3
4000	30	-1.94	-0.66	7.75	-7.8	-1.9	6.1
6000	30	1.65	1.58	8.13	-5.4	1.8	8.3
M512	29	-3.00	-2.17	5.24	-6.0	-3.0	0.5
D4	30	-1.96	-2.75	5.34	1.4	-2.0	-6.6
BETTER EAR							
500	30	-3.26	-2.74	5.23	-6.9	-3.3	1.2
1000	30	-4.50	-4.31	4.42	-8.3	-4.5	-0.5
2000	30	-5.17	-4.70	6.12	-9.5	-5.2	-2.3
4000	30	-2.19	-2.24	6.36	-8.1	-2.2	3.4
6000	30	-0.30	-0.42	7.70	-7.5	-0.3	4.1
M512	30	-4.50	-3.10	4.25	-6.0	-4.5	0.0
D4	30	-1.48	-2.07	4.60	2.0	-1.5	-6.1
WORSE EAR							
500	30	0.00	1.77	6.49	-3.7	0.0	6.5
1000	30	0.00	0.79	6.22	-4.0	0.0	4.6
2000	30	-1.28	0.25	7.85	-6.2	-1.3	3.9
4000	30	4.03	2.91	7.33	-4.6	4.0	9.4
6000	30	7.60	4.77	8.22	-3.3	7.6	10.3
M512	30	1.00	1.40	5.43	-2.0	1.0	4.0
D4	30	-2.06	-2.13	6.09	2.3	-2.1	-6.5
LEFT-RIGHT DIFFERENCES							
500	30	-2.10	-1.90*	5.63	-6.0	-2.1	1.9
1000	30	-4.30	-3.31**	5.03	-6.4	-4.4	-1.0
2000	29	-2.50	-3.11**	6.63	-6.6	-2.5	0.3
4000	30	-1.10	-2.00	6.65	-6.3	-1.1	1.5
6000	30	0.10	-1.19	7.12	-5.8	0.1	4.1
M512	29	-1.00	-1.86	3.57	-4.0	-1.0	0.5

* p<.05

**p<.01

TABLE 35 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 14 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	45	-0.00	-0.09	5.37	-3.8	-0.0	2.0
1000	45	-2.74	-1.20	5.80	-5.7	-2.7	3.4
2000	45	-2.00	-0.90	5.92	-4.7	-2.0	3.6
4000	45	2.07	1.54	6.40	-3.6	2.1	6.4
6000	45	1.35	1.90	9.19	-6.0	1.3	7.4
M512	45	0.00	-0.16	4.02	-3.0	0.0	1.5
D4	45	-2.81	-2.74	6.87	2.9	-2.8	-6.8
LEFT EAR							
500	45	-1.24	-1.33	5.75	-5.5	-1.2	3.8
1000	45	-5.10	-4.02	5.39	-8.0	-5.1	-0.8
2000	45	-6.00	-5.46	5.80	-9.5	-6.0	-3.6
4000	45	-0.20	0.56	7.23	-4.7	-0.2	6.5
6000	45	1.50	2.16	7.80	-4.9	1.5	8.5
M512	45	-3.00	-2.84	4.44	-6.0	-3.0	0.0
D4	45	-4.00	-4.60	7.00	-1.3	-4.0	-9.7
BETTER EAR							
500	45	-1.72	-2.45	5.38	-6.8	-1.7	1.0
1000	45	-5.10	-4.73	4.88	-9.2	-5.1	-1.2
2000	45	-6.00	-6.00	4.84	-9.5	-6.0	-3.9
4000	45	-2.28	-1.85	5.91	-6.9	-2.3	2.1
6000	45	-2.64	-0.95	7.04	-6.6	-2.6	5.2
M512	45	-4.00	-3.53	3.91	-7.0	-4.0	0.0
D4	45	-2.81	-2.88	5.77	-1.0	-2.8	-6.3
WORSE EAR							
500	45	0.00	1.03	5.26	-3.2	0.0	5.0
1000	45	-2.00	-0.50	5.82	-4.9	-2.0	3.7
2000	45	-1.42	-0.36	6.31	-4.7	-1.4	4.1
4000	45	4.00	3.97	6.44	-1.2	4.0	9.3
6000	45	5.50	5.00	8.82	-1.3	5.5	10.2
M512	45	0.00	0.58	4.29	-2.5	0.0	3.0
D4	45	-4.00	-4.47	6.93	0.5	-4.0	-9.9
LEFT-RIGHT DIFFERENCES							
500	45	-2.00	-1.24*	4.14	-4.1	-2.0	1.8
1000	45	-2.24	-2.82**	5.05	-4.7	-2.2	0.3
2000	45	-4.50	-4.57**	5.14	-7.6	-4.5	-1.4
4000	45	-0.66	-0.95	7.59	-6.7	-0.7	3.4
6000	45	0.15	0.26	7.79	-4.9	0.1	6.1
M512	45	-1.00	-1.60	2.76	-4.0	-1.0	0.0

* p<.05
**p<.01

TABLE 36 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 15 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	46	-3.00	-2.51	5.50	-7.2	-3.0	1.2
1000	46	-2.11	-2.07	5.95	-6.8	-2.1	1.8
2000	46	-3.85	-3.54	4.56	-7.7	-3.8	-0.2
4000	46	0.76	0.32	6.16	-4.5	0.8	4.8
6000	46	-0.65	-0.48	7.24	-7.3	-0.7	4.2
M512	46	-2.00	-1.98	4.01	-5.0	-2.0	1.0
D4	46	-1.94	-2.38	6.87	1.0	-1.9	-8.7
LEFT EAR							
500	46	-4.67	-3.83	5.92	-9.1	-4.7	-0.4
1000	46	-5.55	-5.08	6.17	-10.5	-5.5	-2.7
2000	46	-6.92	-5.57	5.96	-10.3	-6.9	-3.4
4000	46	0.19	0.13	8.10	-7.3	0.2	5.7
6000	46	0.45	0.32	6.81	-6.6	0.4	5.4
M512	46	-4.00	-4.02	4.97	-8.0	-4.0	-1.0
D4	46	-4.10	-5.21	7.54	-0.8	-4.1	-8.9
BETTER EAR							
500	46	-5.24	-4.68	4.82	-9.3	-5.2	-0.9
1000	46	-5.58	-6.03	4.62	-10.5	-5.6	-3.1
2000	46	-7.37	-6.65	3.99	-10.3	-7.4	-3.6
4000	46	-2.55	-2.42	5.85	-7.9	-2.5	2.2
6000	46	-1.89	-2.09	6.15	-8.1	-1.9	2.8
M512	46	-5.00	-4.87	3.70	-8.0	-5.0	-2.0
D4	46	-2.90	-3.61	5.61	-0.8	-2.9	-7.7
WORSE EAR							
500	46	-2.64	-1.06	6.19	-6.3	-2.6	1.5
1000	46	-1.08	-1.12	6.67	-6.8	-1.1	1.8
2000	46	-2.99	-2.47	5.82	-6.6	-3.0	0.2
4000	46	3.41	2.87	7.42	-0.9	3.4	8.1
6000	46	1.75	1.93	7.28	-5.0	1.8	7.0
M512	46	-1.50	-1.11	4.87	-5.0	-1.5	1.0
D4	46	-4.22	-3.99	7.28	0.4	-4.2	-8.7
LEFT-RIGHT DIFFERENCES							
500	46	-2.05	-1.31*	3.83	-4.0	-2.0	-0.1
1000	46	-2.78	-3.01**	5.97	-6.5	-2.8	1.2
2000	46	-2.00	-2.03**	5.07	-4.8	-2.0	-0.2
4000	46	-0.55	-0.18	7.31	-4.5	-0.5	5.1
6000	46	0.21	0.80	5.40	-1.9	0.2	4.1
M512	46	-1.00	-0.70	3.37	-3.0	-1.0	1.3

* p<.05

**p<.01

TABLE 37 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 16 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	47	-2.00	-2.31	5.25	-7.2	-2.0	0.8
1000	47	-3.00	-2.80	4.72	-5.5	-3.1	-0.3
2000	47	-4.71	-3.08	5.46	-7.1	-4.7	-1.0
4000	47	2.14	1.90	5.56	-1.2	2.1	5.4
6000	47	-1.31	-0.42	6.40	-6.0	-1.3	4.0
M512	47	-2.00	-2.15	3.63	-5.0	-2.0	0.0
D4	47	-4.43	-4.70	6.24	0.9	-4.4	-9.6
LEFT EAR							
500	47	-4.10	-3.62	5.66	-8.6	-4.1	0.7
1000	47	-6.20	-4.32	5.76	-8.8	-6.2	0.1
2000	47	-5.64	-4.99	6.02	-10.7	-5.6	-2.7
4000	47	2.00	1.80	9.43	-6.2	2.0	3.7
6000	47	3.40	2.00	7.59	-5.1	3.4	7.5
M512	47	-4.00	-3.51	4.81	-7.0	-4.0	0.0
D4	47	-5.40	-6.12	8.58	-0.8	-5.4	-10.8
BETTER EAR							
500	47	-5.20	-4.87	4.50	-9.2	-5.2	-1.2
1000	47	-6.50	-5.82	4.06	-9.1	-6.5	-3.1
2000	47	-7.10	-6.24	4.95	-10.7	-7.1	-3.6
4000	47	-0.55	-1.44	5.24	-6.5	-0.5	2.9
6000	47	-2.66	-1.60	5.92	-7.1	-2.7	4.0
M512	47	-5.00	-4.70	3.75	-8.0	-5.0	-2.0
D4	47	-2.80	-4.38	4.74	-1.1	-2.8	-8.6
WORSE EAR							
500	47	-1.60	-1.06	5.72	-5.3	-1.6	2.7
1000	47	-1.90	-1.30	5.46	-4.6	-1.9	2.6
2000	47	-2.74	-1.83	5.80	-6.4	-2.7	2.1
4000	47	3.74	5.14	8.39	1.5	3.7	7.4
6000	47	4.20	3.18	7.41	-2.5	4.2	8.7
M512	47	-1.00	-0.89	4.28	-4.0	-1.0	2.0
D4	47	-5.44	-6.44	8.37	0.9	-5.4	-11.4
LEFT-RIGHT DIFFERENCES							
500	47	-2.10	-1.30	5.75	-4.1	-2.1	-0.1
1000	47	-2.24	-1.52*	5.83	-4.8	-2.2	1.2
2000	47	-1.75	-1.91*	5.84	-3.8	-1.8	0.8
4000	47	-2.00	-0.10	10.49	-4.7	-2.0	1.3
6000	47	0.21	2.42**	6.25	-1.8	0.2	6.3
M512	47	0.00	0.15	3.61	-2.0	0.0	1.0

* $p<.05$

** $p<.01$

TABLE 38 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 17 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	49	-3.00	-2.71	6.99	-8.4	-3.6	-0.4
1000	49	-3.48	-2.26	7.48	-8.2	-3.5	0.9
2000	49	-4.28	-2.56	6.29	-8.1	-4.3	0.7
4000	49	0.21	-0.07	6.33	-5.5	0.2	3.9
6000	49	-1.32	0.42	8.90	-6.0	-1.3	4.0
M512	49	-2.00	-1.78	5.82	-6.5	-2.0	0.0
D4	49	-1.89	-2.19	7.23	1.6	-1.9	-6.9
LEFT EAR							
500	49	-6.00	-3.90	6.06	-9.3	-6.0	0.0
1000	49	-4.60	-3.46	6.53	-9.0	-4.8	-0.9
2000	49	-6.74	-4.62	7.90	-10.4	-6.7	-1.4
4000	49	1.16	1.97	9.65	-5.8	1.2	7.4
6000	49	-0.40	1.79	8.20	-5.7	-0.4	8.2
M512	49	-4.00	-3.16	5.46	-8.0	-4.0	0.0
D4	49	-3.96	-5.43	8.19	-1.0	-4.0	-9.0
BETTER EAR							
500	49	-6.96	-4.85	5.44	-9.3	-7.0	-0.9
1000	49	-5.30	-4.87	5.29	-9.3	-5.3	-2.6
2000	49	-8.56	-6.30	5.33	-10.4	-8.6	-3.6
4000	49	-2.00	-2.00	5.36	-7.2	-2.0	2.1
6000	49	-2.40	-1.25	7.06	-7.2	-2.4	3.7
M512	49	-5.00	-4.43	4.25	-8.0	-5.0	-2.0
D4	49	-1.96	-2.67	5.02	-0.1	-2.0	-6.2
WORSE EAR							
500	49	-2.46	-1.75	7.20	-8.2	-2.5	1.6
1000	49	-2.00	-0.85	7.94	-6.2	-2.0	2.3
2000	49	-2.13	-0.88	7.79	-7.0	-2.1	3.6
4000	49	2.32	3.90	9.42	-3.3	2.3	8.9
6000	49	2.60	3.46	9.29	-5.7	2.8	9.9
M512	49	-1.00	-0.57	6.29	-5.5	-1.0	2.5
D4	49	-3.12	-4.75	9.23	-0.9	-3.1	-8.7
LEFT-RIGHT DIFFERENCES							
500	49	-0.18	-1.19*	4.81	-3.1	-0.2	-0.1
1000	49	-0.64	-1.20	7.04	-3.0	-0.8	1.5
2000	49	-2.25	-2.06*	7.33	-5.2	-2.3	-0.3
4000	49	-0.22	2.04	9.96	-1.0	-0.2	5.4
6000	49	0.27	1.37	7.52	-0.9	0.3	4.1
M512	49	0.00	-0.08	4.84	-1.5	0.0	1.0

* $p<.05$

TABLE 39 - DESCRIPTIVE STATISTICS OF AUDITORY THRESHOLD EXAMINATIONS OF GIRLS 18 YEARS OLD

FREQUENCY (HERTZ)	N	MEDIAN	MEAN	SD	25	MEDIAN	75
RIGHT EAR							
500	16	-6.20	-3.77	7.34	-8.3	-6.2	-1.2
1000	16	-7.27	-4.16	8.66	-9.1	-7.3	-1.1
2000	16	-3.77	-3.35	5.36	-7.6	-3.8	-1.1
4000	16	-2.24	-0.45	6.14	-5.0	-2.2	2.7
6000	16	-0.32	0.19	6.21	-4.8	-0.3	6.4
M512	16	-3.50	-2.94	6.51	-7.0	-3.5	-1.5
D4	16	-3.75	-3.71	8.38	-1.5	-3.8	-6.7
LEFT EAR							
500	16	-8.20	-6.89	3.38	-9.3	-8.2	-5.0
1000	16	-7.60	-7.24	3.14	-9.7	-7.6	-4.5
2000	16	-9.19	-7.94	2.94	-10.6	-9.2	-5.5
4000	16	0.16	2.66	13.03	-6.1	0.2	7.3
6000	16	0.25	0.24	7.80	-5.1	0.2	5.4
M512	16	-6.50	-6.25	2.41	-8.0	-6.5	-4.0
D4	16	-8.12	-9.89	12.74	-2.0	-6.1	-14.4
BETTER EAR							
500	16	-6.20	-6.89	3.38	-9.3	-8.2	-5.0
1000	16	-9.00	-8.23	2.27	-9.7	-9.0	-6.6
2000	16	-9.19	-8.36	2.38	-10.6	-9.2	-5.8
4000	16	-4.20	-3.64	4.05	-6.1	-4.2	-1.9
6000	16	-2.57	-3.11	4.65	-6.8	-2.6	0.3
M512	16	-7.00	-6.81	2.01	-8.8	-7.0	-5.0
D4	16	-3.70	-4.59	4.16	-2.0	-3.7	-6.8
WORSE EAR							
500	16	-6.20	-3.77	7.34	-8.3	-6.2	-1.2
1000	16	-5.32	-3.16	8.66	-7.9	-5.3	-0.4
2000	16	-3.44	-2.93	5.22	-6.9	-3.4	-1.1
4000	16	4.59	5.86	12.17	-1.9	4.6	7.7
6000	16	4.37	3.53	7.36	-2.1	4.4	7.8
M512	16	-3.00	-2.44	6.46	-6.8	-3.0	-1.0
D4	16	-6.87	-9.02	13.04	-3.5	-6.9	-13.5
LEFT-RIGHT DIFFERENCES							
500	16	-1.12	-3.12*	5.92	-4.1	-1.1	-0.1
1000	16	-0.76	-3.08	8.97	-5.9	-0.8	0.8
2000	16	-3.36	-4.59**	6.16	-7.1	-3.4	-1.6
4000	16	0.50	3.10	14.92	-4.5	0.5	10.6
6000	16	0.13	0.05	9.35	-7.8	0.1	4.1
M512	16	-0.50	-1.88	6.61	-5.3	-0.5	3.3

* p <.05

**p <.01

generally about -3 dB, indicating that thresholds at 4 kHz are mostly higher than those at 1 kHz. The lateral differences, calculated as left threshold minus right threshold (left-right differences), are significantly different from zero more commonly than would be expected due to chance especially in girls. About 90% of the significant differences are negative indicating that thresholds are higher on the right than the left side and, therefore, hearing sensitivity is poorer on the right side than on the left side.

Sex differences. Median values for thresholds at the tested frequencies are compared between boys and girls in Figures 6 through 15. Following common practice, these data are presented with the lower thresholds (negative values) placed higher in the figures than the higher thresholds (positive values). Consequently, a higher position on these figures is associated with greater hearing sensitivity. The words "higher" and "lower" and related statements about decreases and increases in the text refer to thresholds not to position on the figures.

The median thresholds at 0.5 kHz are generally lower in the left ear than the right, but in each ear there is an increase with age that is similar in each sex until the age of 14 years after which the changes in boys are small. Consequently, a sex difference becomes apparent at older ages. From 14 to 18 years, the values for boys indicate slight decreases in hearing sensitivity (0.2 dB, right ear; 0.9 dB left ear), but there are marked increases in girls during the same age interval (6.2 dB right ear; 7.0 dB, left ear).

Similar comparisons of median thresholds at 1 kHz (Figures 8 and 9) show these values tend to be higher for the right ear than for the left ear. There is little difference between ears or sexes in the patterns of change with age in thresholds or in general threshold levels except that the median thresholds for the left ear tend to be lower than those for the right in girls.

The median thresholds at 2 kHz decrease with age at similar rates in boys and girls until about 14 years of age after which the decreases are much more marked in girls than in boys (Figures 10 and 11). In each sex, the median thresholds for the left ear tend to be lower than those for the right ear.

Values for median thresholds at 4 kHz are compared between boys and girls in Figures 12 and 13. In each sex and for each ear, the median levels are similar and show little tendency to change with age.

Figures 14 and 15 present medians across age for thresholds at 6 kHz. These, and the median thresholds at 4 kHz, are considerably higher than those at the other frequencies tested. There is little tendency to a change with age except for a slight decrease in median thresholds for the right ear in girls. The sex differences are small in each ear.

Comparisons with NCHS data. It is appropriate to compare the present data with national estimates from U.S. surveys conducted by the National Center for Health Statistics (NCHS). The national data are cross-sectional, whereas, the present data are mixed longitudinal. However, the present data have been adjusted for examination effects. Comparisons between medians from the Fels and NCHS data sets are presented in Figures 16 through 25 for boys and girls at each frequency tested. These figures relate to the right ear; the

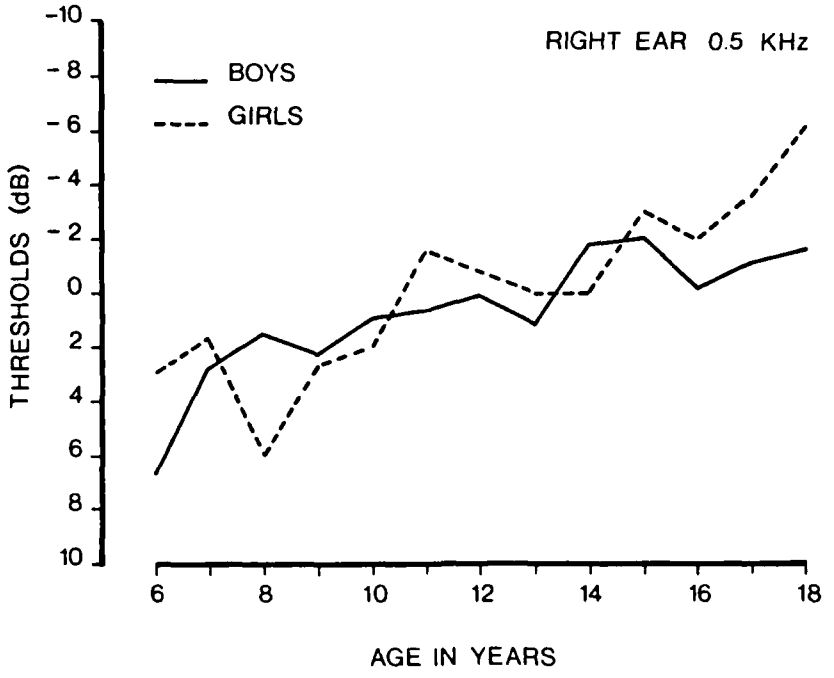


FIGURE 6. MEDIAN AUDITORY THRESHOLDS (dB) AT 0.5 kHz FOR THE RIGHT EARS OF BOYS AND GIRLS IN THE FELS STUDY

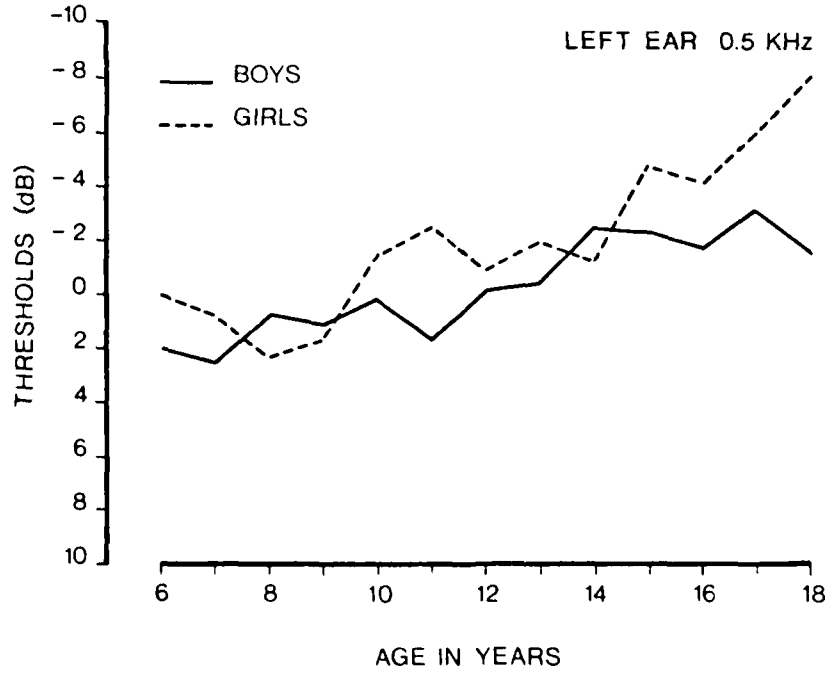


FIGURE 7. MEDIAN AUDITORY THRESHOLDS (dB) AT 0.5 kHz FOR THE LEFT EARS OF BOYS AND GIRLS IN THE FELS STUDY

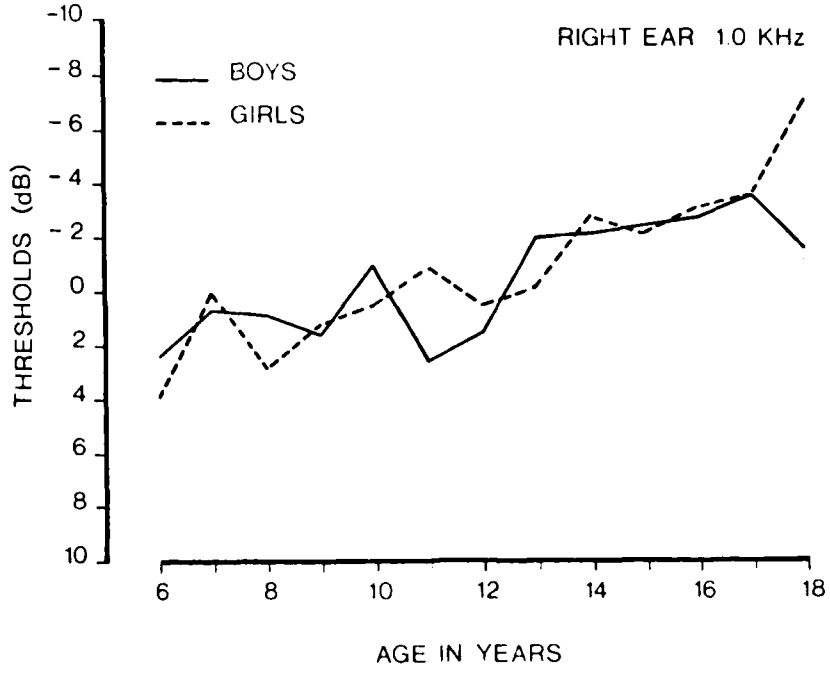


FIGURE 8. MEDIAN AUDITORY THRESHOLDS (dB) AT 1.0 kHz FOR THE RIGHT EARS OF BOYS AND GIRLS IN THE FELS STUDY

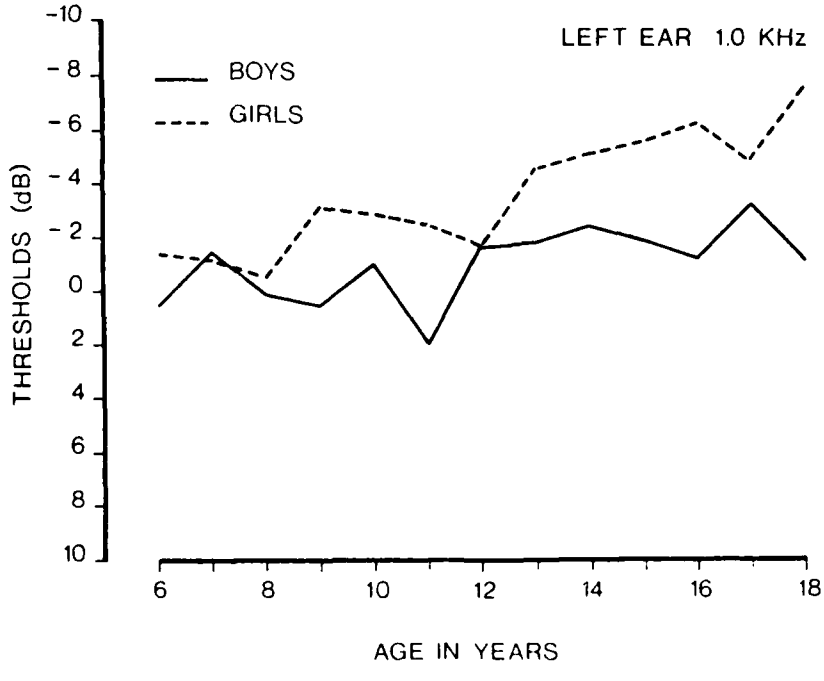


FIGURE 9. MEDIAN AUDITORY THRESHOLDS (dB) AT 1.0 kHz FOR THE LEFT EARS OF BOYS AND GIRLS IN THE FELS STUDY

FIGURE 10. MEDIAN AUDITORY THRESHOLDS (dB) AT 2.0 kHz FOR THE RIGHT EARS OF BOYS AND GIRLS IN THE FELS STUDY

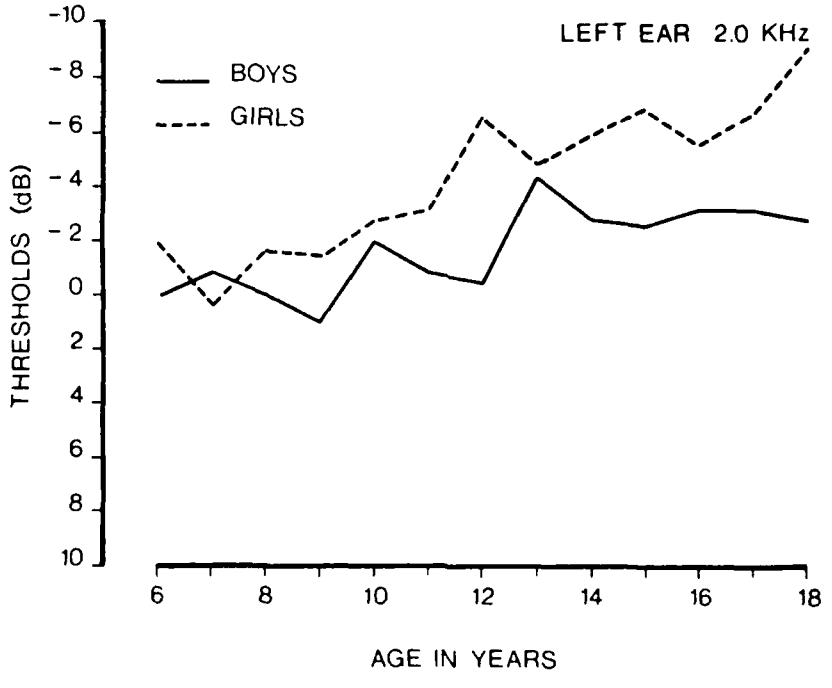


FIGURE 11. MEDIAN AUDITORY THRESHOLDS (dB) AT 2.0 kHz FOR THE LEFT EARS OF BOYS AND GIRLS IN THE FELS STUDY

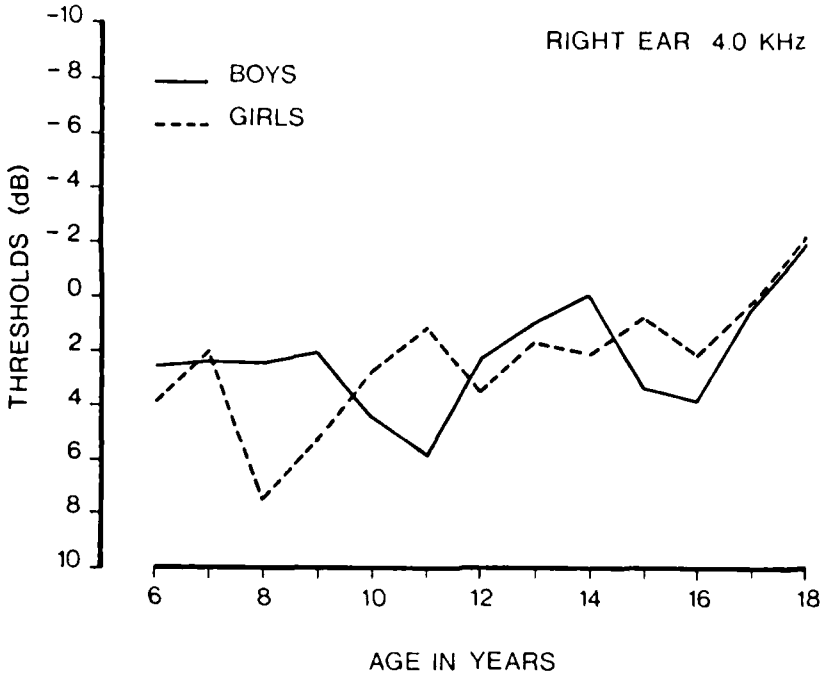


FIGURE 12. MEDIAN AUDITORY THRESHOLDS (dB) AT 4.0 kHz FOR THE RIGHT EARS OF BOYS AND GIRLS IN THE FELS STUDY

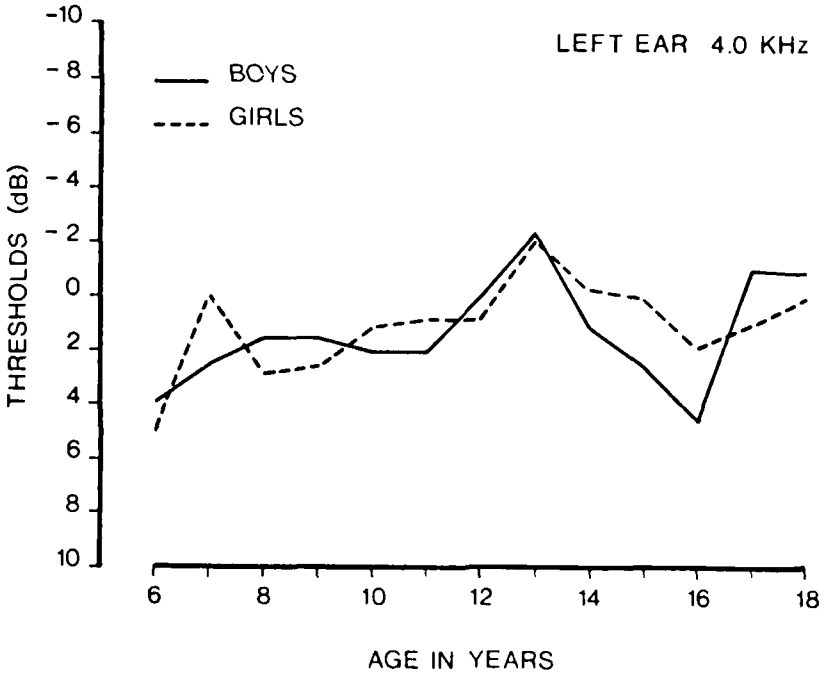


FIGURE 13. MEDIAN AUDITORY THRESHOLDS (dB) AT 4.0 kHz FOR THE LEFT EARS OF BOYS AND GIRLS IN THE FELS STUDY

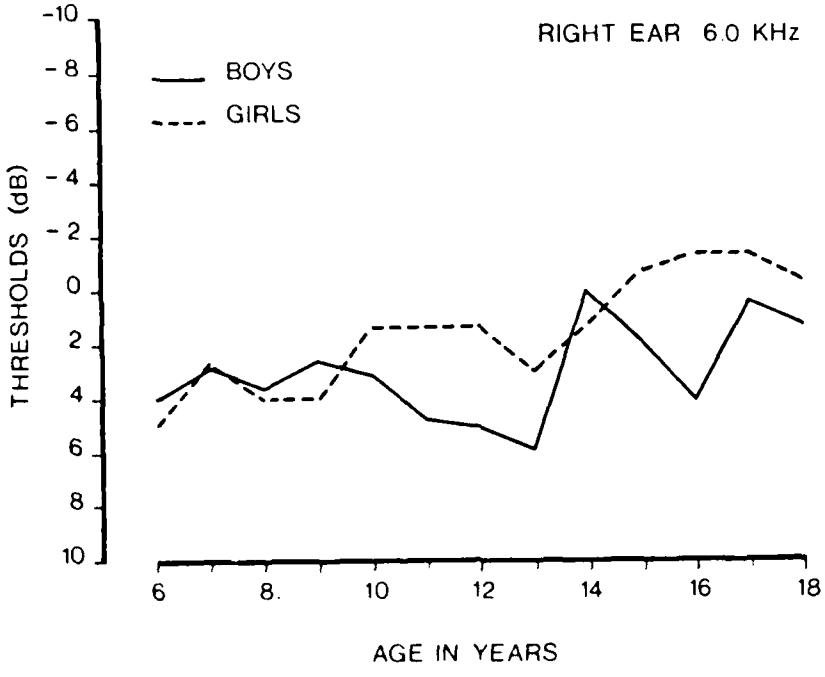


FIGURE 14. MEDIAN AUDITORY THRESHOLDS (dB) AT 6.0 kHz FOR THE RIGHT EARS OF BOYS AND GIRLS IN THE FELS STUDY

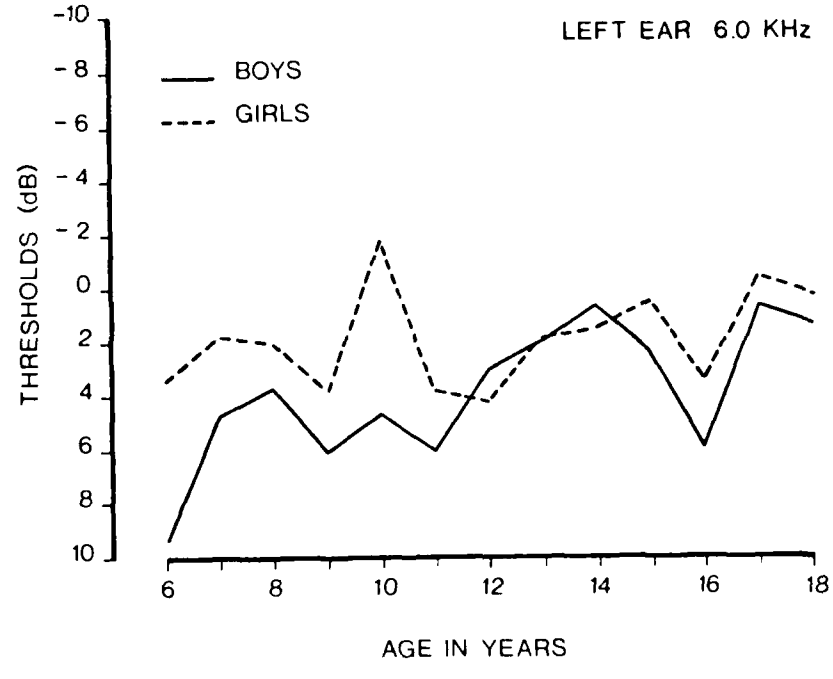


FIGURE 15. MEDIAN AUDITORY THRESHOLDS (dB) AT 6.0 kHz FOR THE LEFT EARS OF BOYS AND GIRLS IN THE FELS STUDY

findings for the left ear are similar. The Fels medians tend to be less regular across age than the NCHS medians. This may reflect differences in sample size between the two groups of data, the effects of which are not fully balanced by the fact that almost all Fels participants were examined serially.

The median thresholds at 0.5 kHz for the right ear are lower in the Fels group than in the NCHS data by about 2 to 4 dB to 10 years of age in each sex (Figures 16 and 17). After 10 years, the difference is greater by about 8 dB for boys and girls from 12 through 18 years. In the NCHS data for 0.5 kHz, and some other frequencies, there is a marked increase in the median threshold values from 11 to 12 years of age. The data for 6 to 11 years and those for 12 to 17 years are from different surveys. The possible factors responsible for this difference are discussed later, but it is difficult to conceive that the sudden increases of about 3 to 4 dB in each sex at 0.5 kHz are due to biological factors. Apart from this abrupt change in the NCHS data, threshold trends with age are similar for the two data sets except after 12 years of age when increases are noted for boys and girls in the Fels data but not in the NCHS data.

Figures 18 and 19 present corresponding findings at 1 kHz. At young ages, the median thresholds from the Fels data are about 2 dB lower than the corresponding NCHS values in boys and in girls. This difference increases to about 5 dB at older ages in each sex. Unlike the median values at 0.5 kHz, the NCHS medians for 1 kHz change little from 11 to 12 years of age. The patterns of change with age are similar for the medians from the two data sets except that the median thresholds for girls improve by at least 5 dB in the Fels study after 12 years of age, but show little change in the NCHS data.

Corresponding data for median thresholds at 2 kHz are presented in Figures 20 and 21. The general pattern of the NCHS data does not change with age in either sex. In the Fels data, there is little age trend until 12 years, after which the thresholds decrease for each sex. The Fels and NCHS values are closely similar until 12 years of age in each sex; after that age, the Fels medians are lower by about 3-5 dB. The NCHS medians for 2 kHz do not show any marked change from the values at 11 years to those at 12 years.

Figures 22 and 23 present median values for thresholds at 4 kHz in the Fels and NCHS studies. The corresponding values are similar in each study for both boys and girls from 6 to 11 years of age and age trends are slight during this period. From 11 to 12 years of age, there are marked increases of about 8 dB for boys and 7 dB for girls in the threshold values from the NCHS study. After these ages, trends with age are slight in each study except for a tendency for median thresholds to decrease in Fels boys. The major differences between the two sets of data is the marked increase at 11 years in the NCHS data and the difference between the two sets of data at older ages.

Median values for thresholds at 6 kHz in the right ear are shown for boys and girls in the Fels and NCHS studies in Figures 24 and 25. The major difference between corresponding points is in level; the values from the Fels study are about 7 dB lower than those from the NCHS study. In the boys, the patterns of change in medians with age are closely parallel in the two studies until 12 years, but the levels are about 7 dB lower for the Fels group. Later, the data from Fels study show irregular decreases in median thresholds while the NCHS medians increase. Consequently, the difference between the sets of

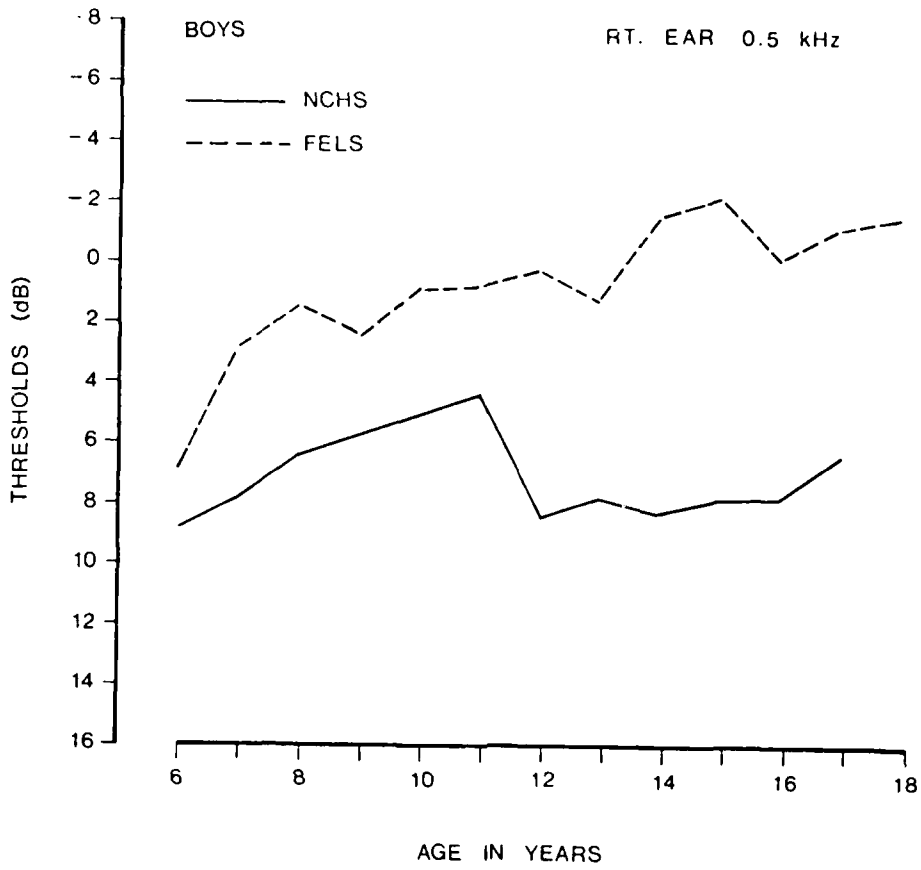


FIGURE 16. MEDIAN AUDITORY THRESHOLDS (dB) AT 0.5 kHz FOR THE RIGHT EARS OF BOYS IN THE FELS AND NCHS STUDIES

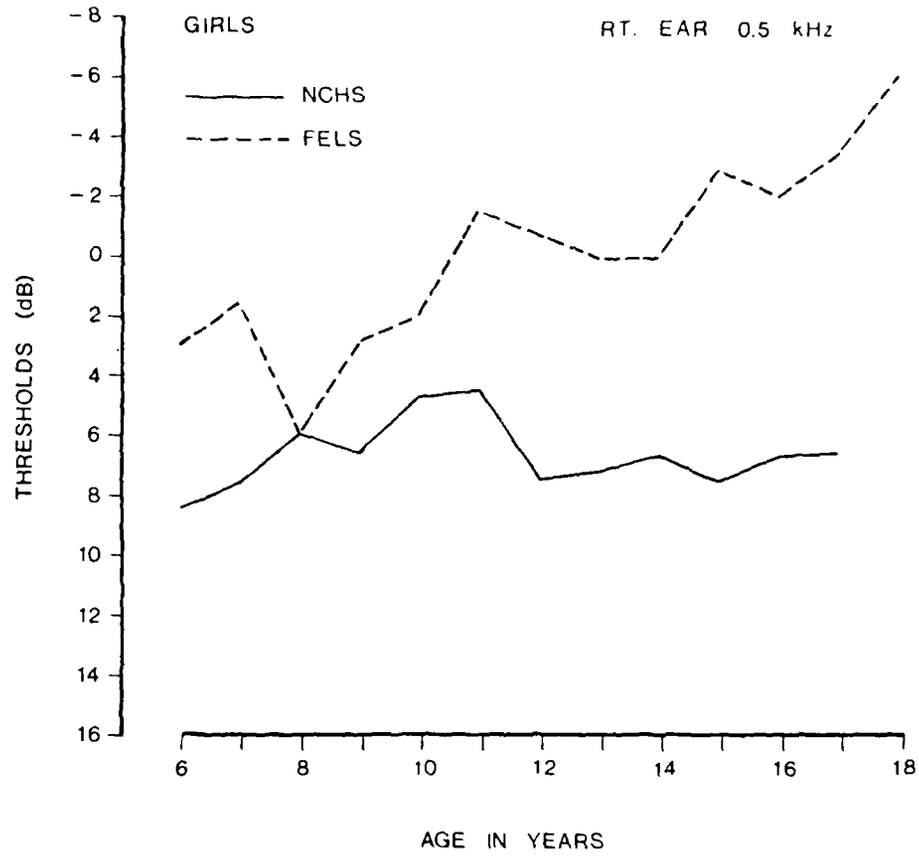


FIGURE 17. MEDIAN AUDITORY THRESHOLDS (dB) AT 0.5 kHz FOR THE RIGHT EARS OF GIRLS IN THE FELS AND NCHS STUDIES

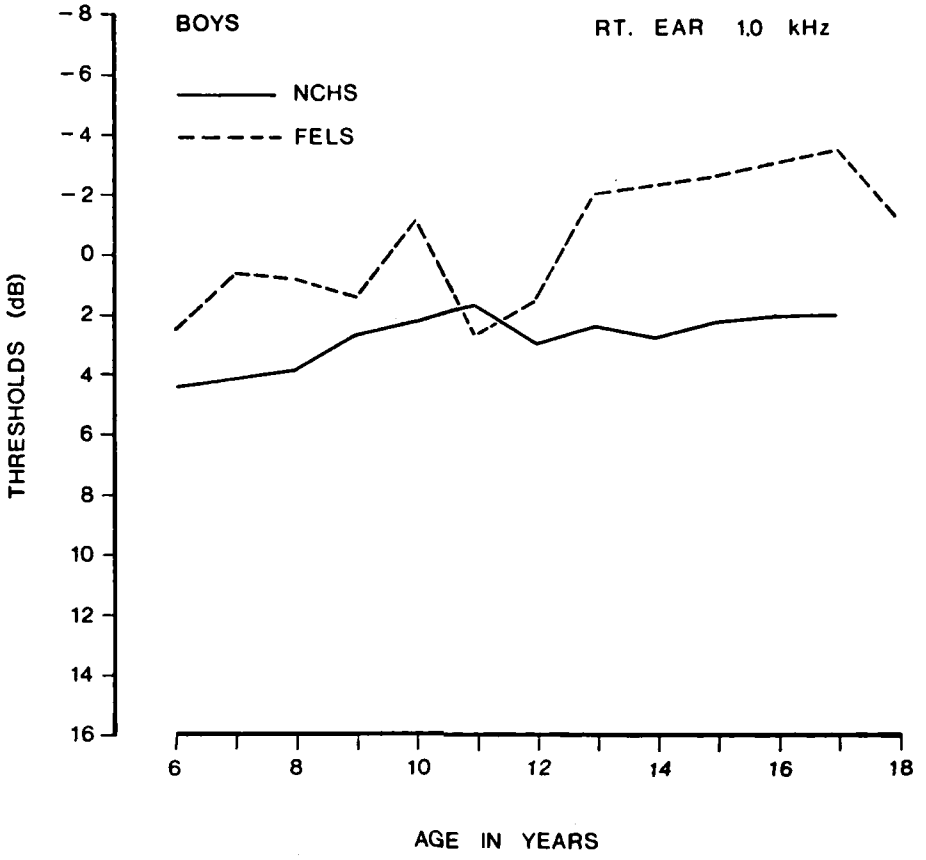


FIGURE 18. MEDIAN AUDITORY THRESHOLDS (dB) AT 1.0 kHz FOR THE RIGHT EARS OF BOYS IN THE FELS AND NCHS STUDIES

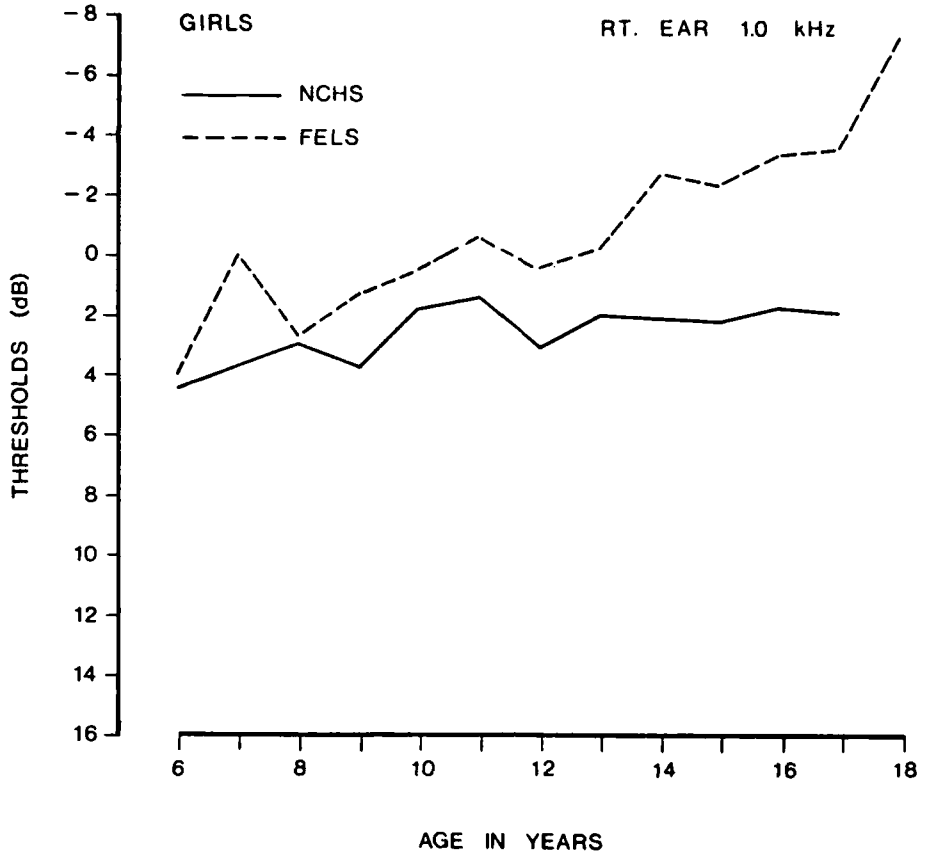


FIGURE 19. MEDIAN AUDITORY THRESHOLDS (dB) AT 1.0 kHz FOR THE RIGHT EARS OF GIRLS IN THE FELS AND NCHS STUDIES

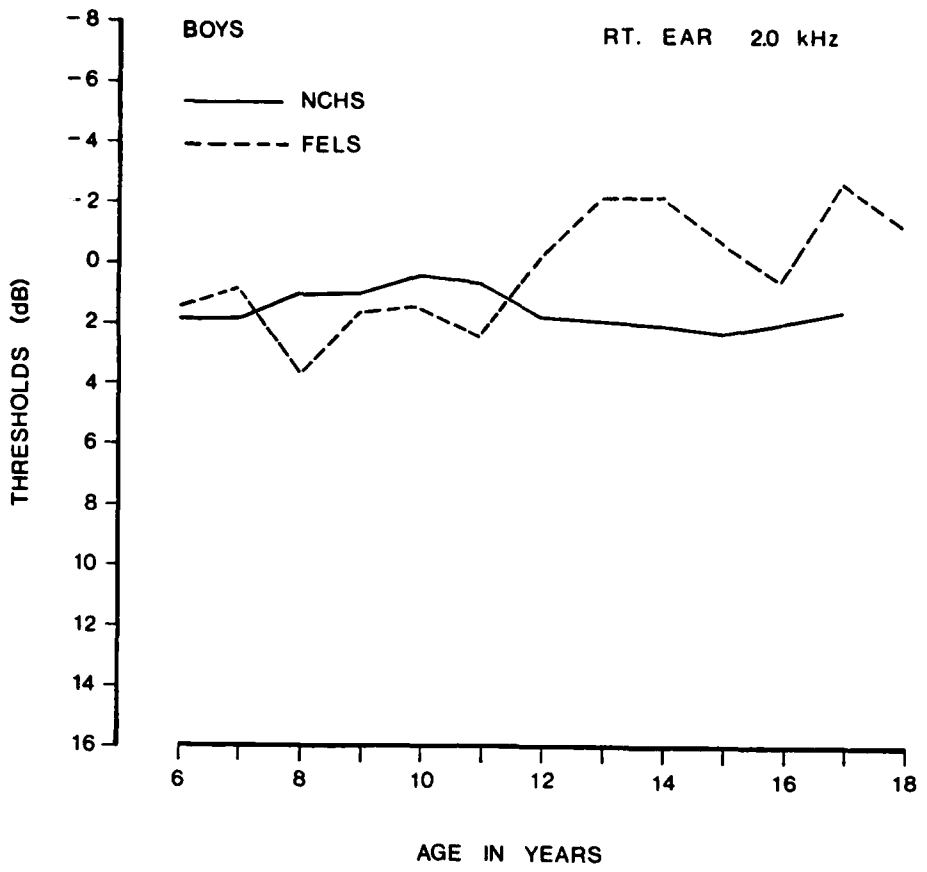


FIGURE 20. MEDIAN AUDITORY THRESHOLDS (dB) AT 2.0 kHz FOR THE RIGHT EARS OF BOYS IN THE FELS AND NCHS STUDIES

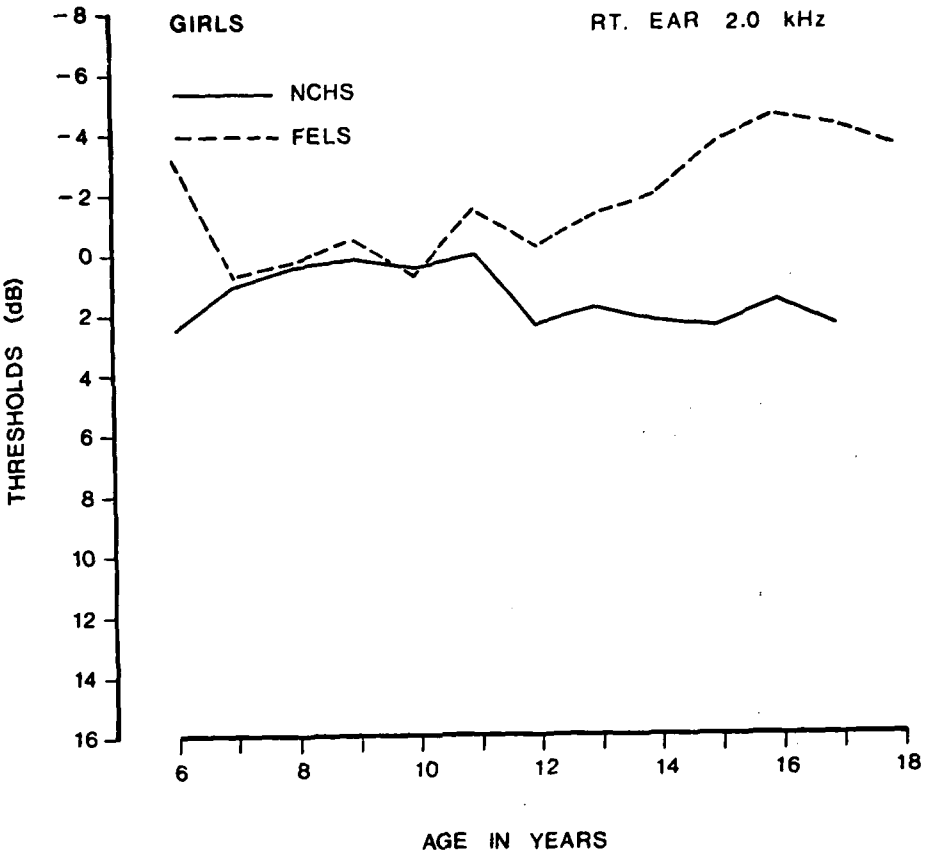


FIGURE 21. MEDIAN AUDITORY THRESHOLDS (dB) AT 2.0 kHz FOR THE RIGHT EARS OF GIRLS IN THE FELS AND NCHS STUDIES

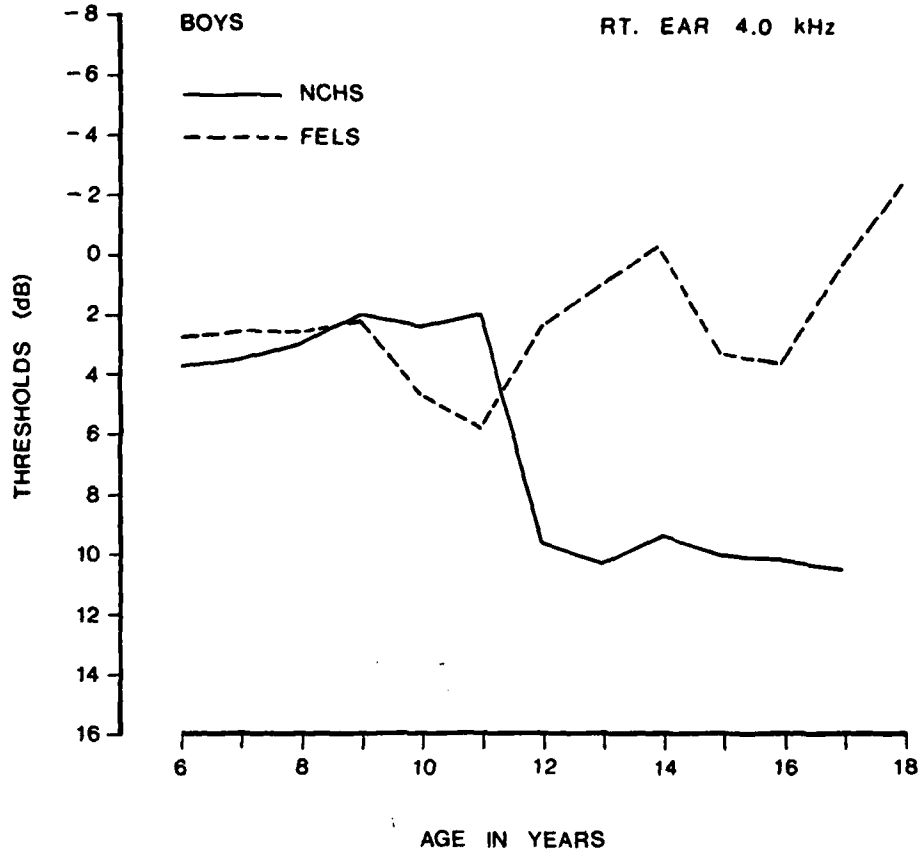


FIGURE 22. MEDIAN AUDITORY THRESHOLDS (dB) AT 4.0 kHz FOR THE RIGHT EARS OF BOYS IN THE FELS AND NCHS STUDIES

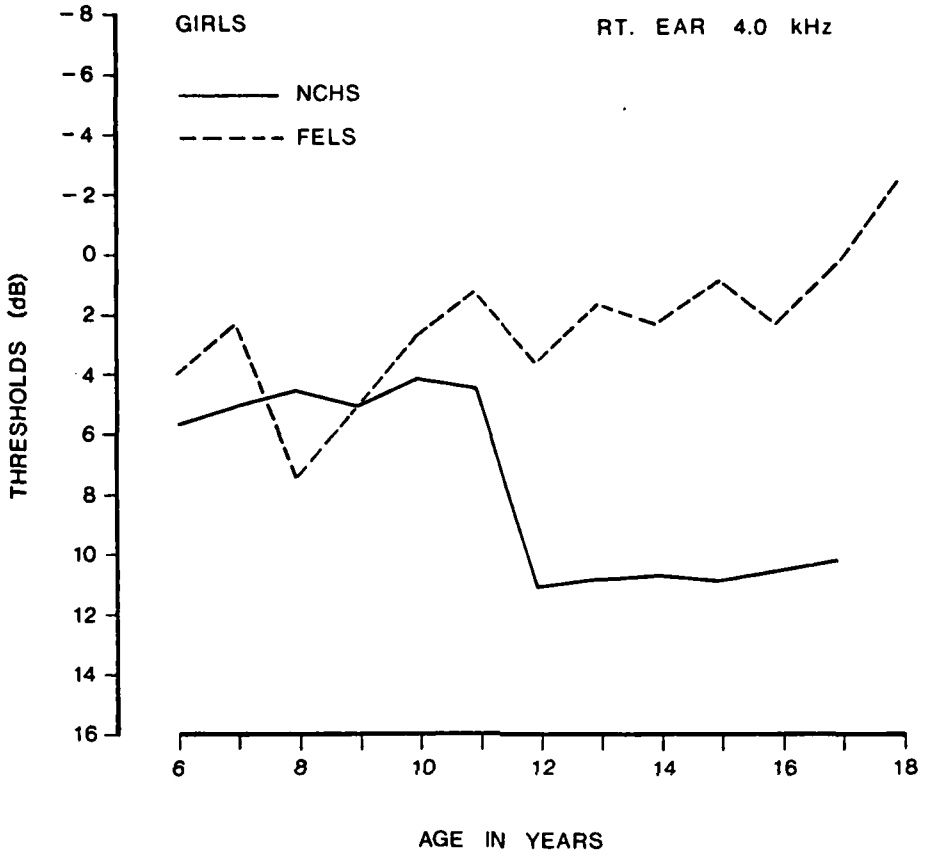


FIGURE 23. MEDIAN AUDITORY THRESHOLDS (dB) AT 4.0 kHz FOR THE RIGHT EARS OF GIRLS IN THE FELS AND NCHS STUDIES

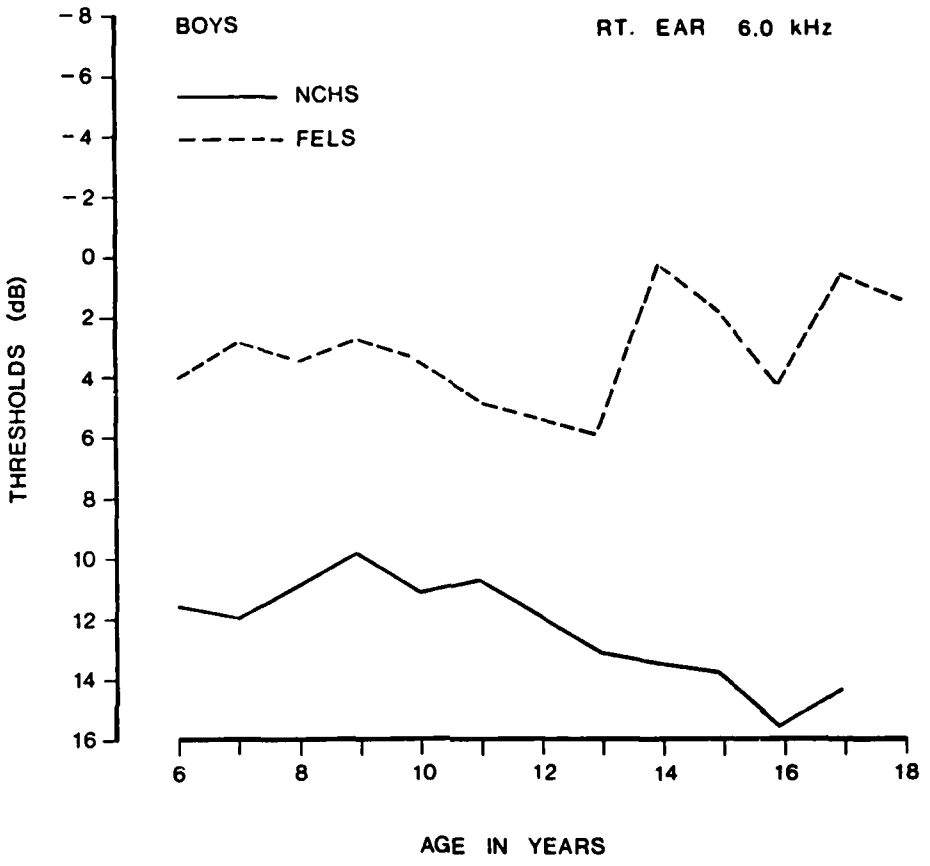


FIGURE 24. MEDIAN AUDITORY THRESHOLDS (dB) AT 6.0 kHz FOR THE RIGHT EARS OF BOYS IN THE FELS AND NCHS STUDIES

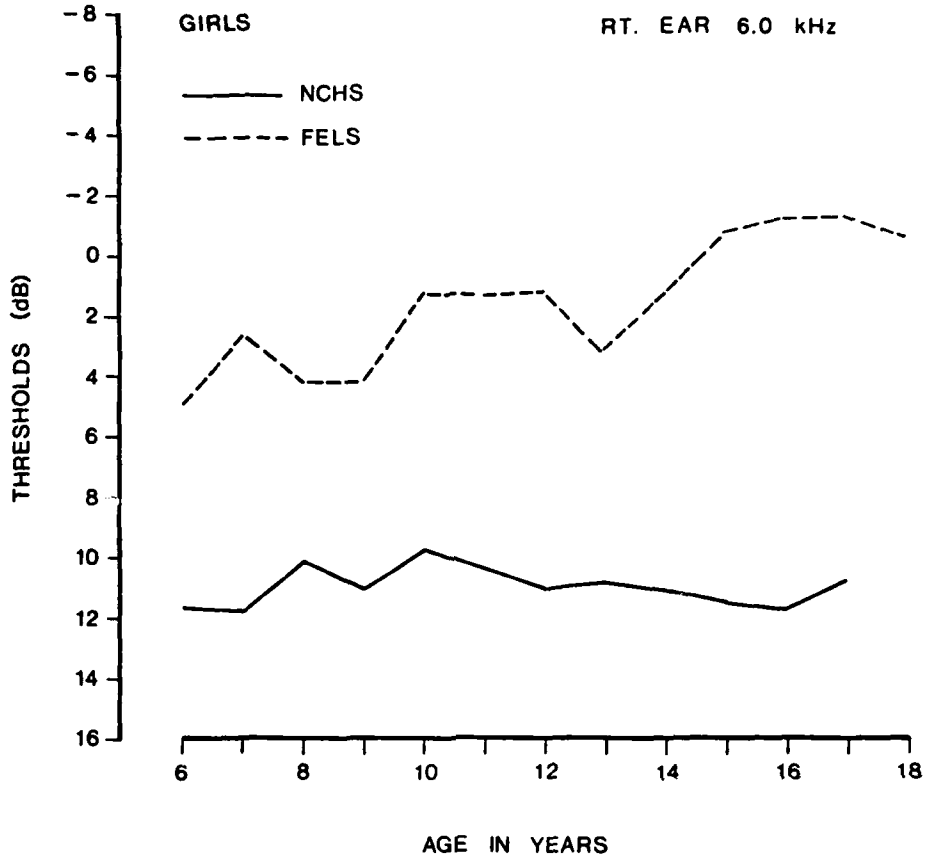


FIGURE 25. MEDIAN AUDITORY THRESHOLDS (dB) AT 6.0 kHz FOR THE RIGHT EARS OF GIRLS IN THE FELS AND NCHS STUDIES

medians increases to about 10 dB at 17 years. The median thresholds for girls change little with age in the NCHS data, but those from the Fels study decrease gradually with age. Consequently, the differences between the sets of medians for girls increase from about 6 dB at 6 years to 12 dB at 17 years.

Distributions of thresholds. Plots of cumulative frequencies are used to compare the distributions of thresholds in the better ears of boys and girls of the Fels Study at 4 kHz. These comparisons have been made at each age from 7 through 17 years (Figures 26-36). Data for children aged 6 and 18 years are not presented because of the small sample sizes.

Differences between pairs of cumulative frequency plots in "slopes" near the median levels (50 percent) are perhaps most important because they relate to the nature of the distributions near the modes. The left and right hand ends of the cumulative frequency plots relate to the extremes of the distributions where the estimates are limited in reliability given the present sample sizes.

The frequency distributions at 7 years shows only very small differences between the sexes in the distributions of thresholds at 4 kHz (Figure 26). At 8 and 9 years, however, the whole distributions for boys are slightly to the left of those for girls indicating greater hearing sensitivity (lower thresholds) in boys than in girls at all parts of the distributions (Figures 27 and 28). This difference is more marked at the upper ends of the distributions where it is about 3 to 4 dB. The extension of the distribution for boys to +28 dB is due to the inclusion of one outlying value.

There is little difference between the cumulative frequency distributions for the two sexes at 10 years (Figure 29). Also, the distributions at 11 years are similar in boys and girls except above the 40 percent level. The distribution for the girls is about 2 to 5 dB to the left of that for the boys from the 40 percent level to the 80 percent level (Figure 30).

The cumulative frequency distributions are similar for the two sexes at 12 to 14 years (Figures 31-33), but differences are present at 15 years (Figure 34) when the distribution for the girls is about 2 dB to the left of that for the boys between the 20 and 80 percent levels.

Markedly at 16 years and slightly at 17 years, the cumulative frequency distributions for the girls are steeper than those for the boys after the 40 percent level (16 years) or the 70 percent level (17 years). In association with this, the upper points of the distributions for boys are associated with poorer hearing sensitivity than the corresponding parts of the distributions for girls at these ages (Figures 35 and 36).

Frequency distributions were compared also between data from the Fels study and corresponding data from NCHS surveys for both sexes combined (Roberts and Huber, 1970; Roberts and Ahuja, 1975). Because of the way in which NCHS data were reported, the prevalences from each study have been calculated within 10 dB ranges after adjusting data to ANSI-1969 when necessary. The comparisons between the two data sets are restricted to the better ear because these are the only data for which NCHS cumulative frequencies are available within annual age groups.

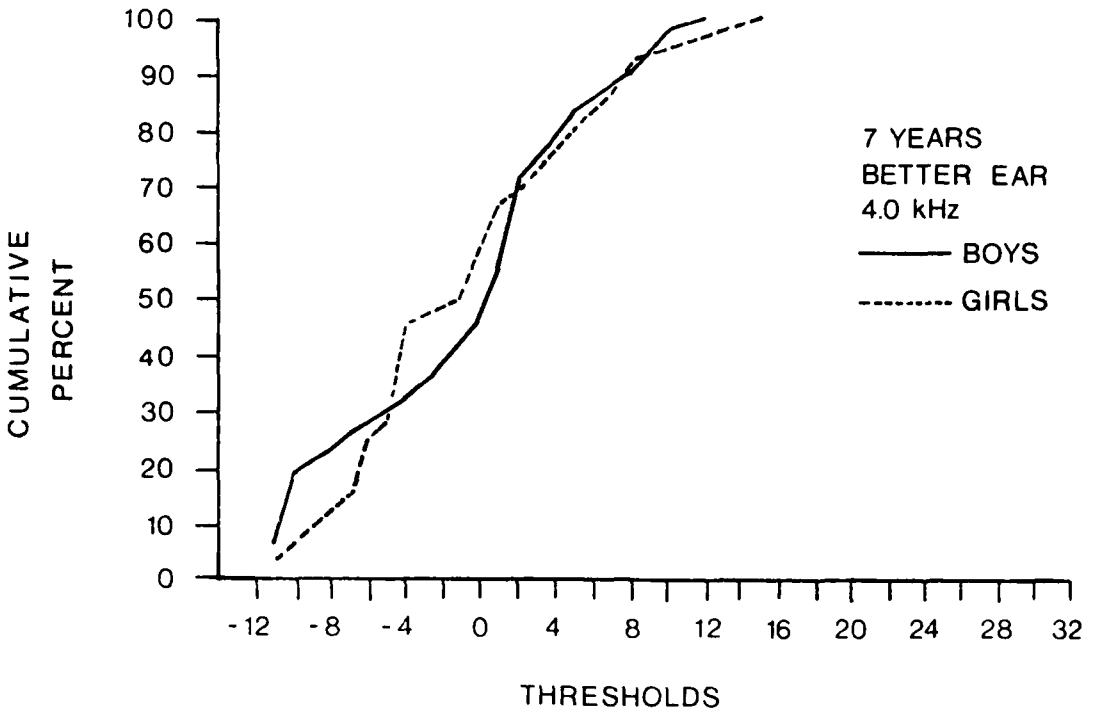


FIGURE 26 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 7 YEARS.

The data in Figures 37 through 47 show a tendency for the Fels plots to be to the left of those for NCHS data indicating better hearing sensitivity in the children included in the Fels Study. This difference between the two sets of data is approximately 2 dB at 7 through 9 years and at 11 years, but there is almost no difference between the two sets of data at 10 years (Figures 37 to 41). At older ages, the differences are larger indicating that hearing sensitivity is about 6 dB better in the Fels sample than in the NCHS sample at ages from 12 through 17 years (Figures 41 to 47). The NCHS distributions tend to extend further to the left than the Fels distributions, at least in part, because the audiometer used at Fels did not record lower than -12 dB. The NCHS distributions extend to the right of those for the Fels data near the upper limits of the frequency distributions. These differences are more marked after the age of 11 years. They may reflect the omission of data from children with relevant pathologies when the cumulative distributions for the Fels Study were constructed.

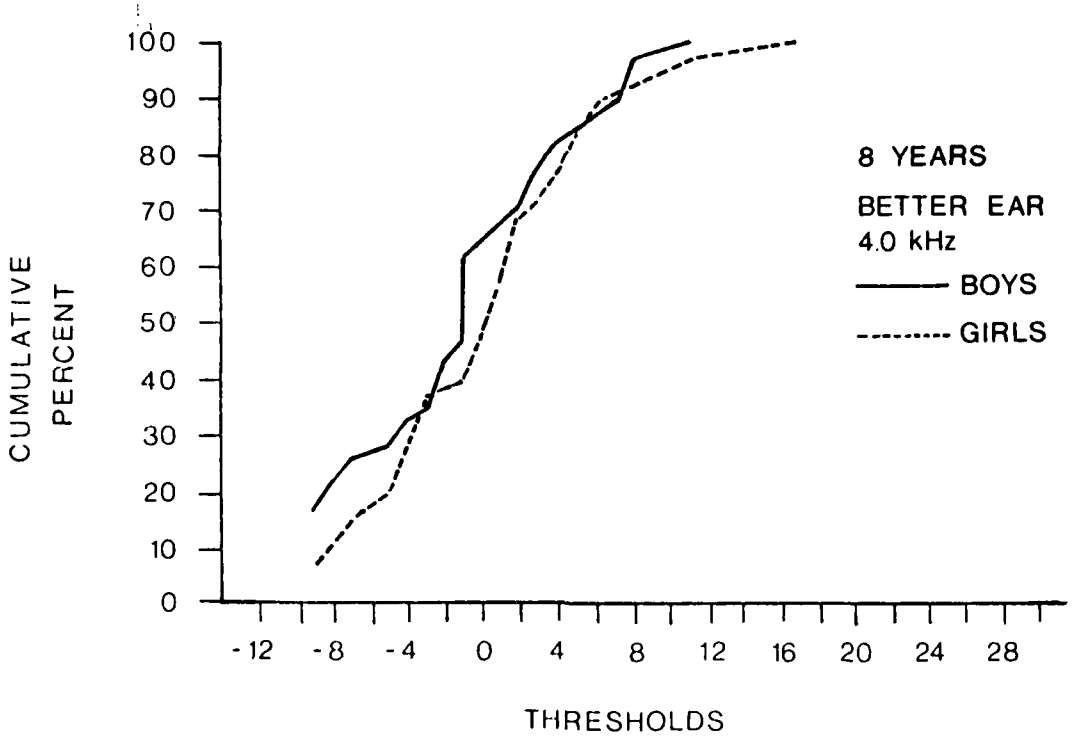


FIGURE 27 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOL AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS I. THE FELS STUDY AGED 8 YEARS.

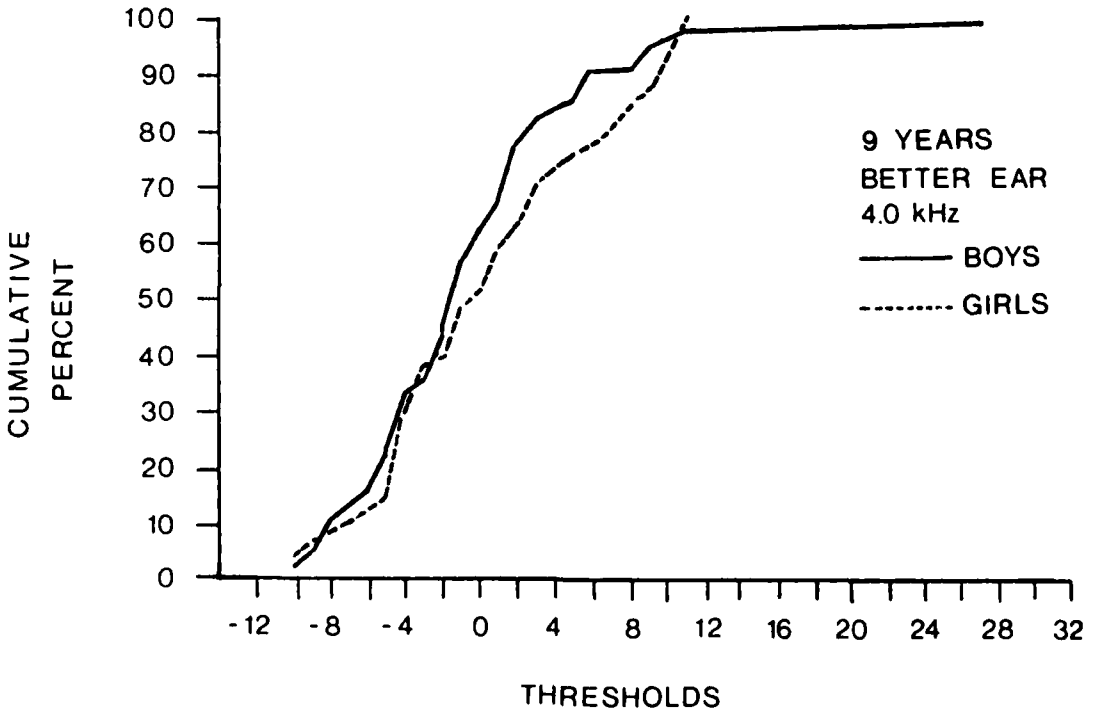


FIGURE 28 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 9 YEARS.

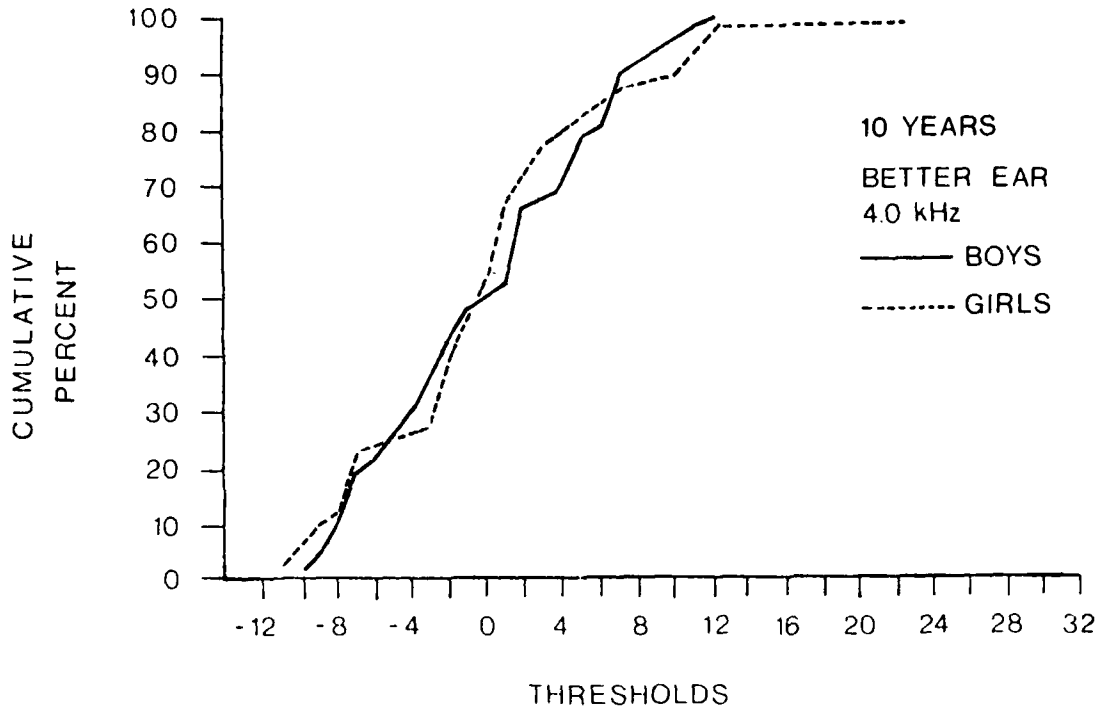


FIGURE 29 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 10 YEARS.

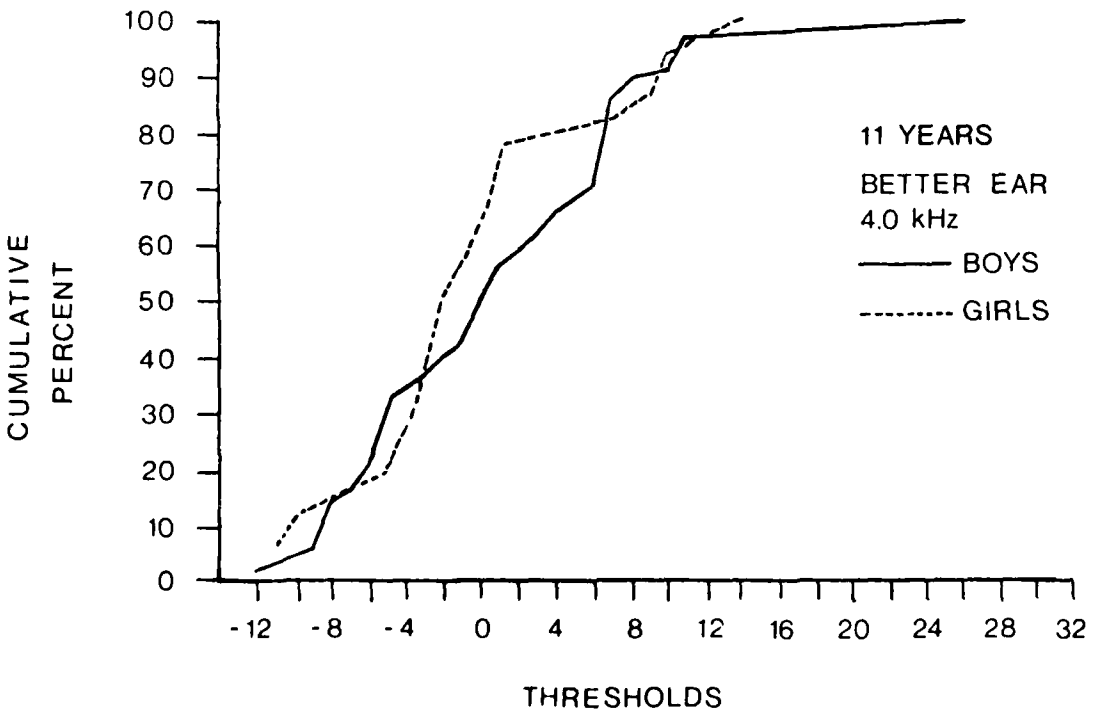


FIGURE 30 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 11 YEARS.

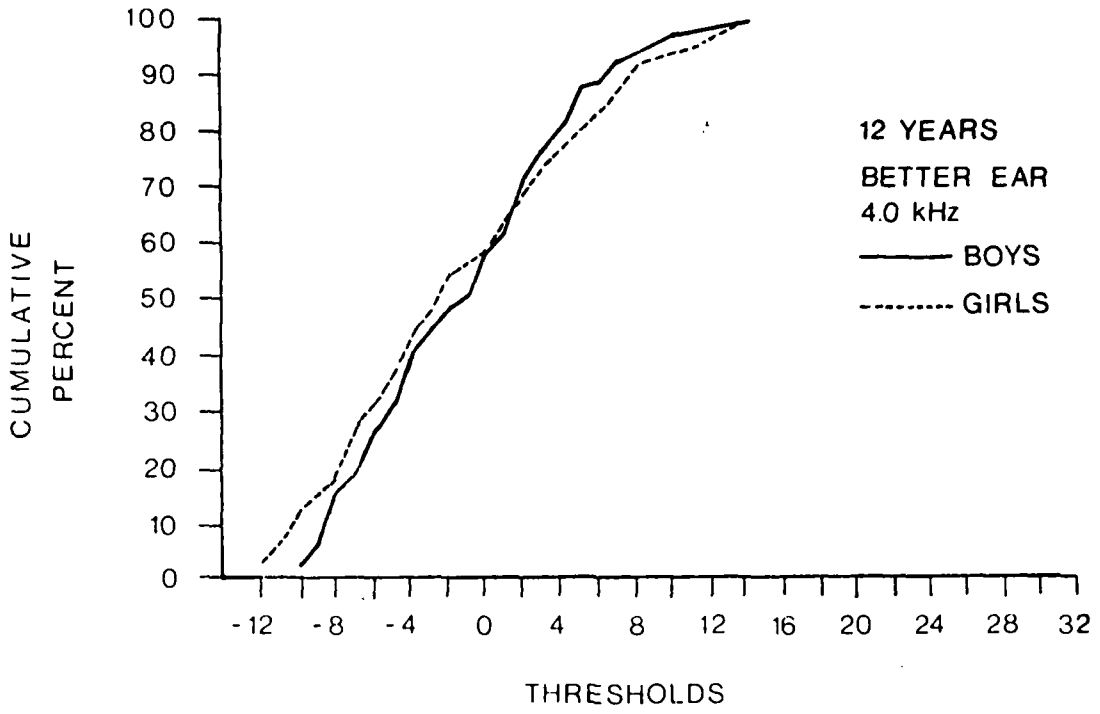


FIGURE 31 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 12 YEARS.

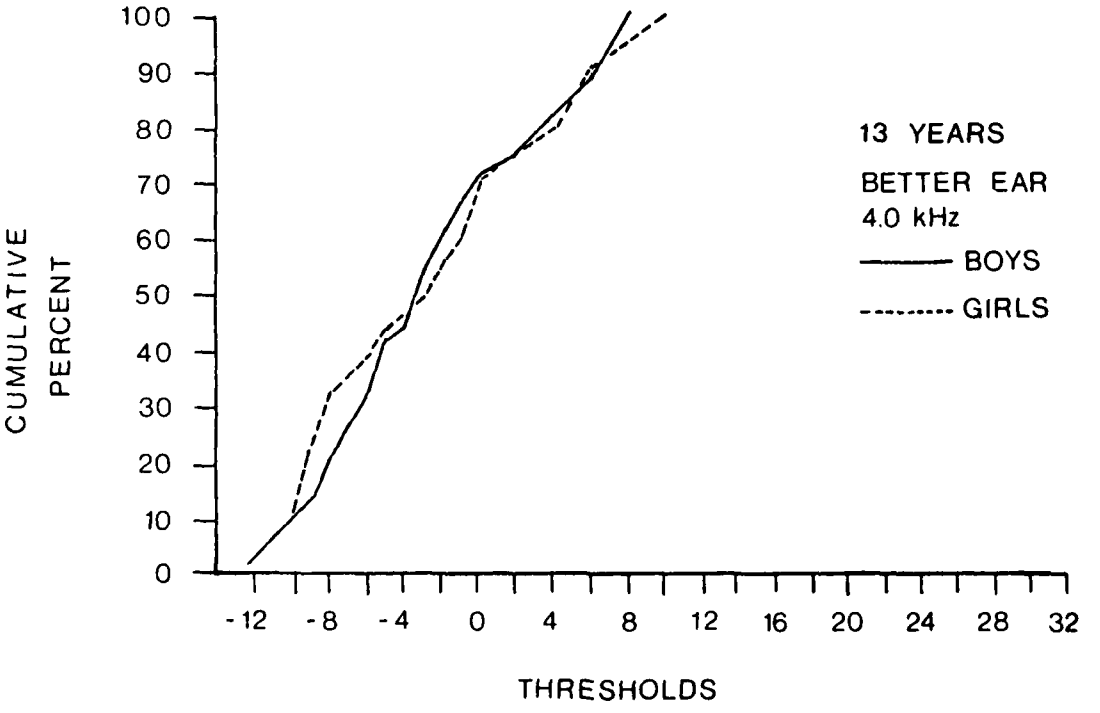


FIGURE 32 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 13 YEARS.

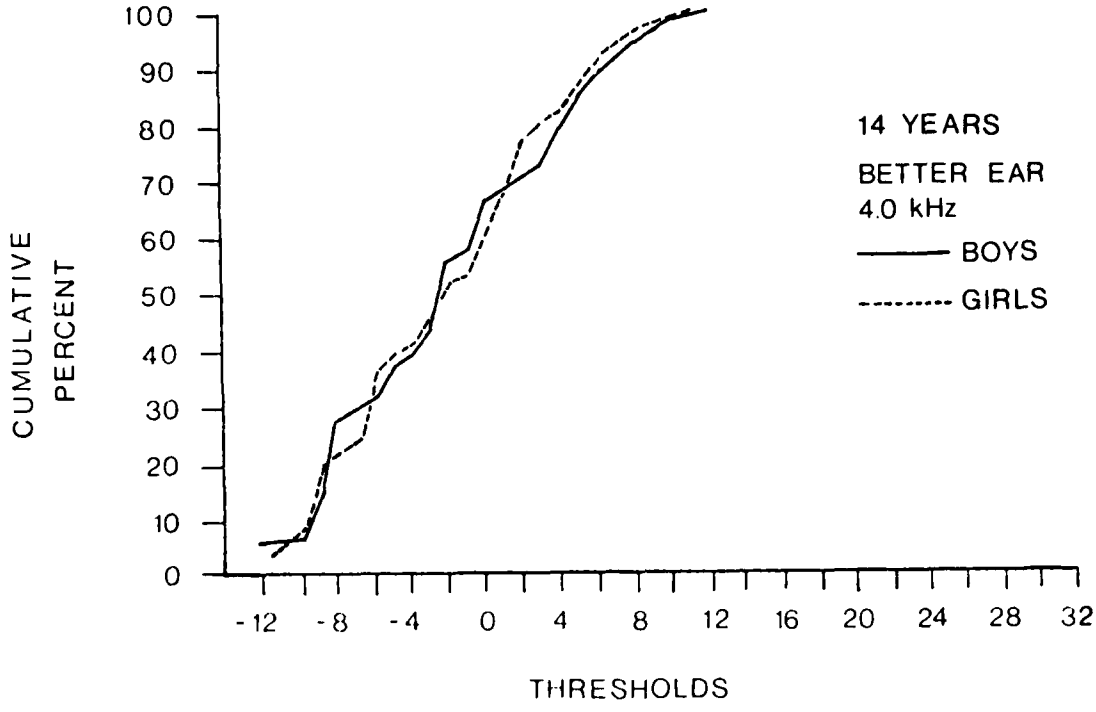


FIGURE 33 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 14 YEARS.

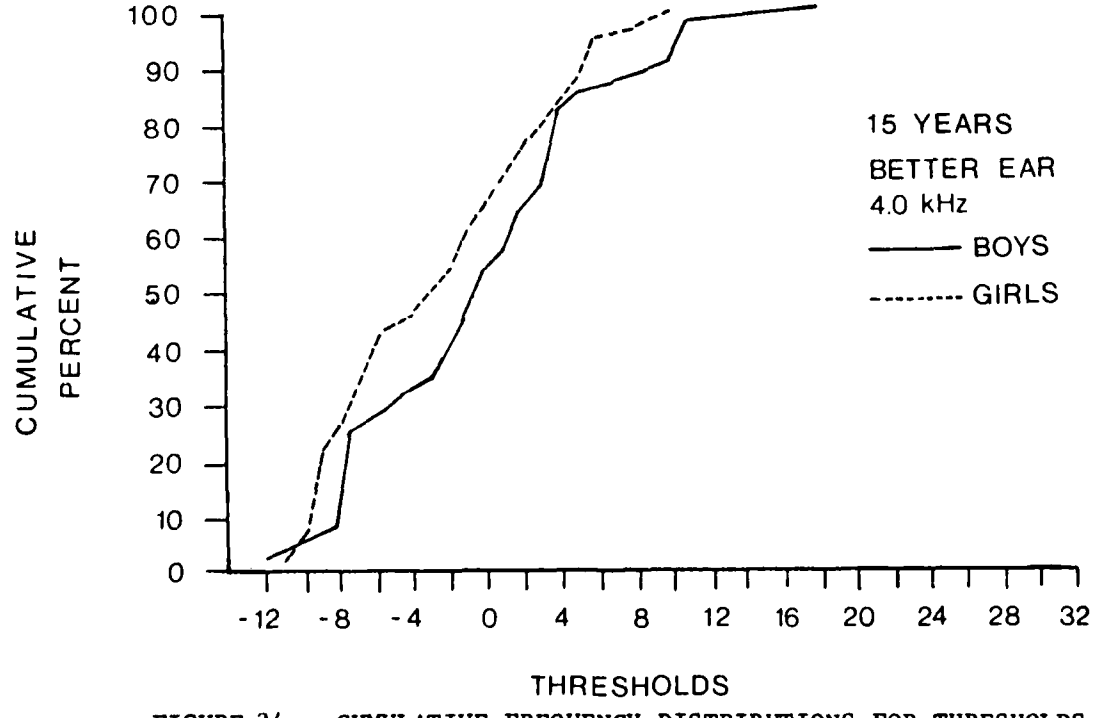


FIGURE 34 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 15 YEARS.

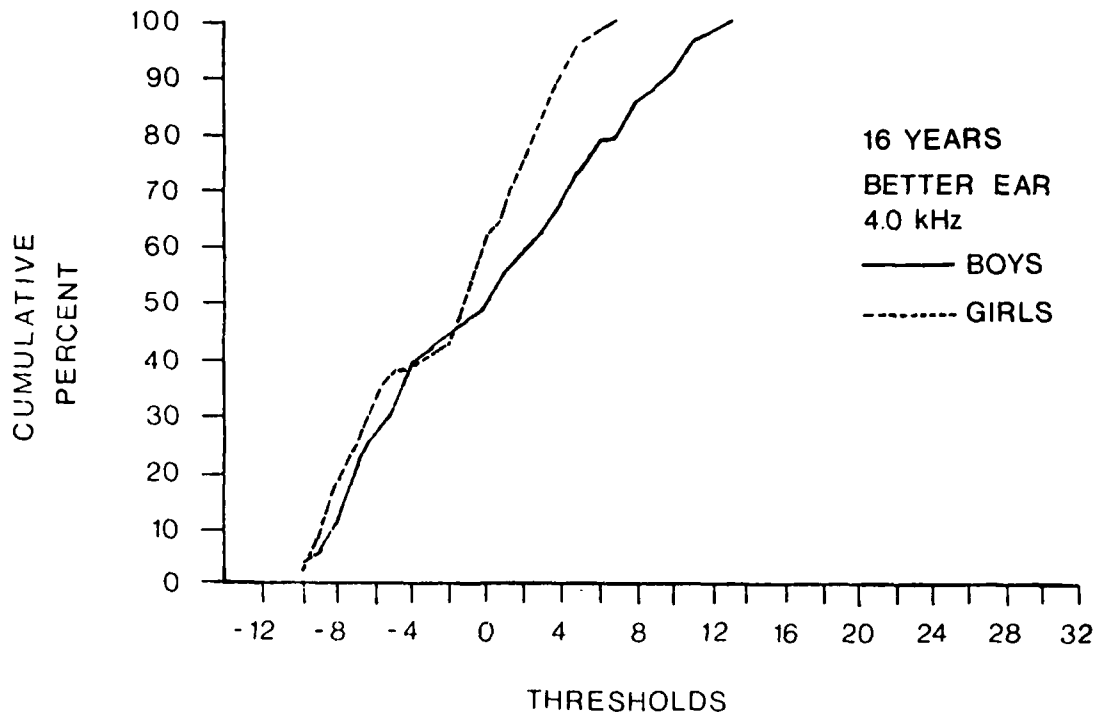


FIGURE 35 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 16 YEARS.

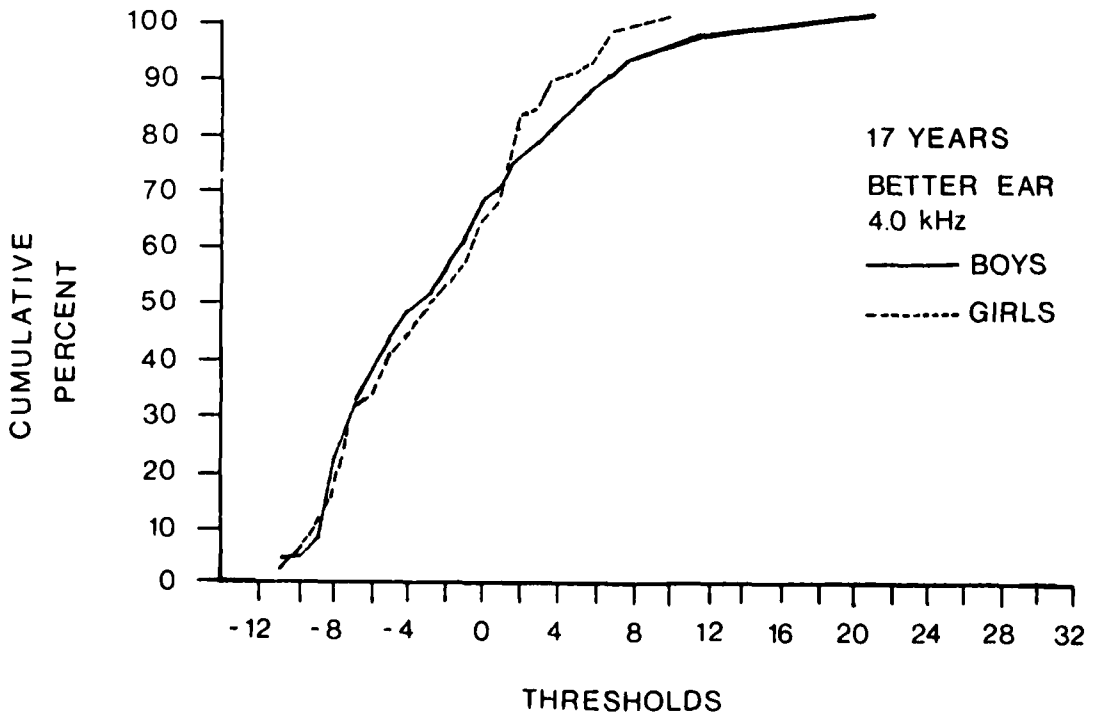


FIGURE 36 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EARS OF BOYS AND GIRLS IN THE FELS STUDY AGED 17 YEARS.

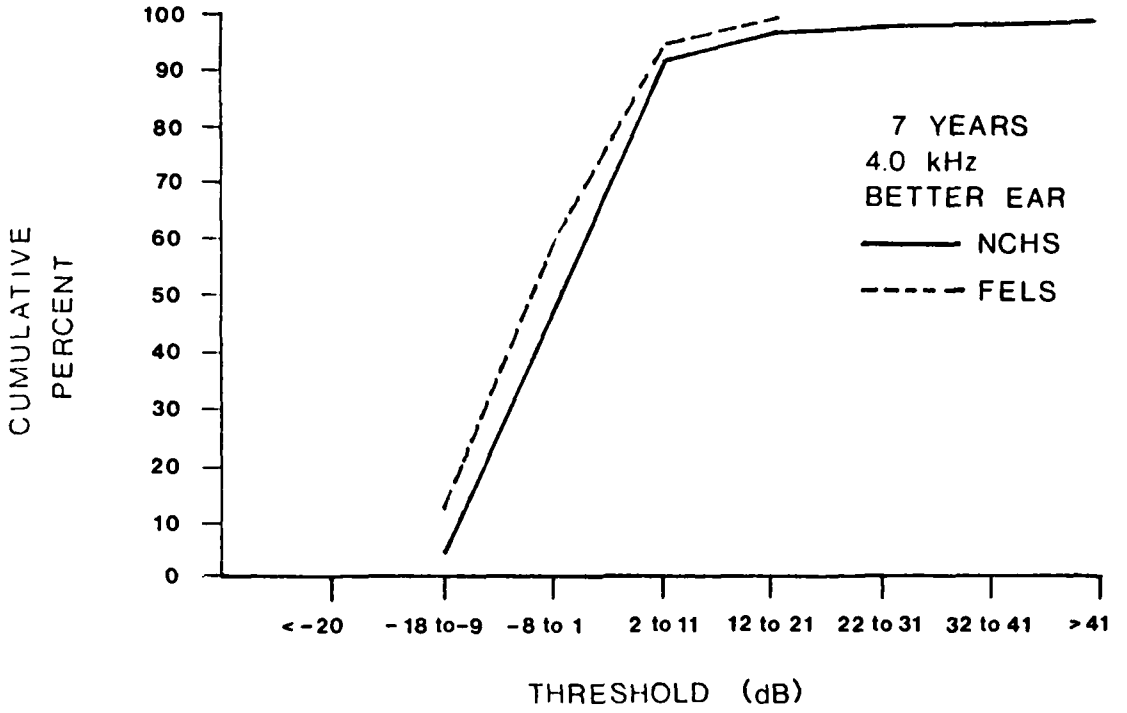


FIGURE 37 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 7 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

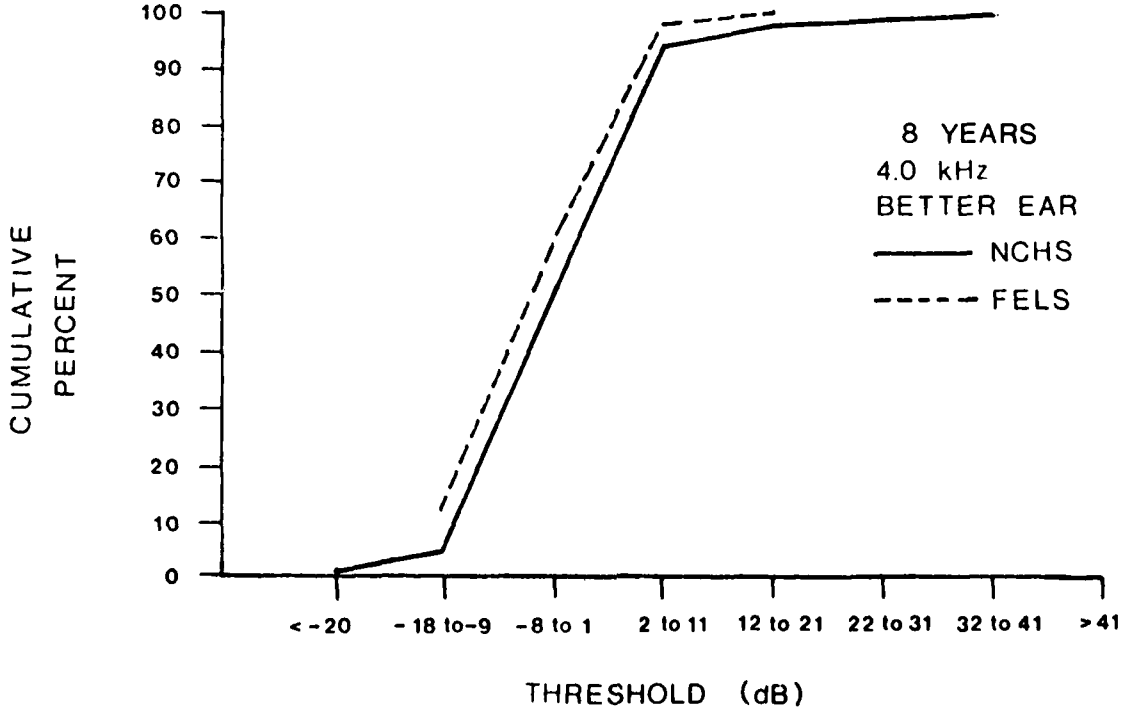


FIGURE 38 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 8 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

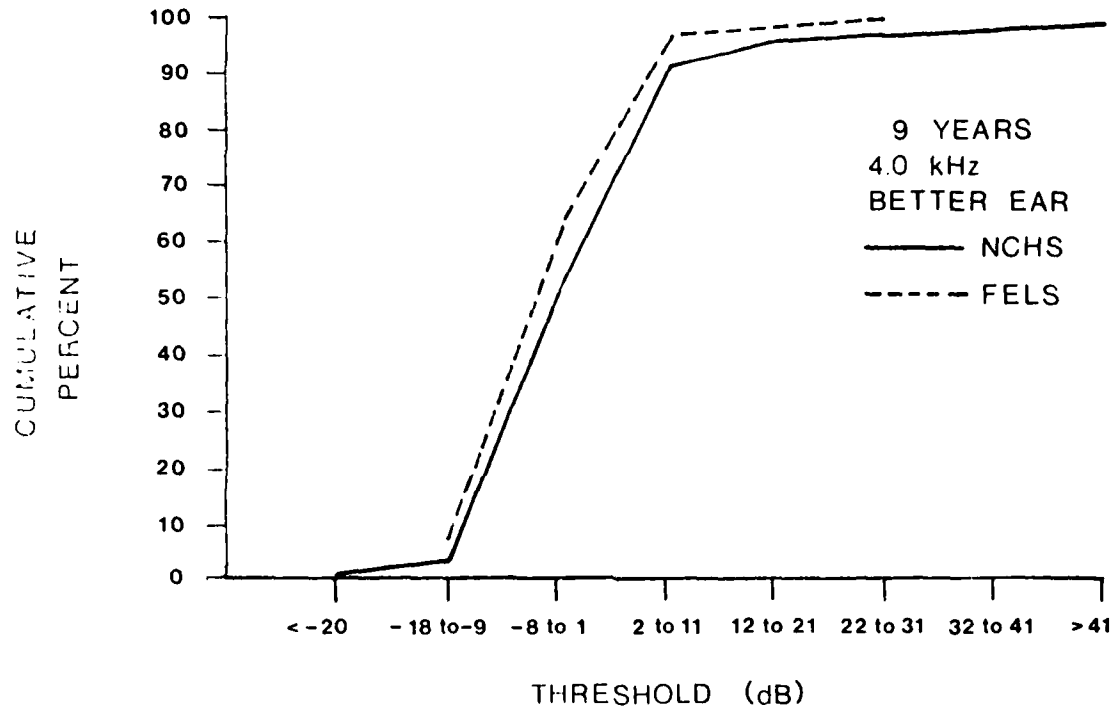


FIGURE 39 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 9 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

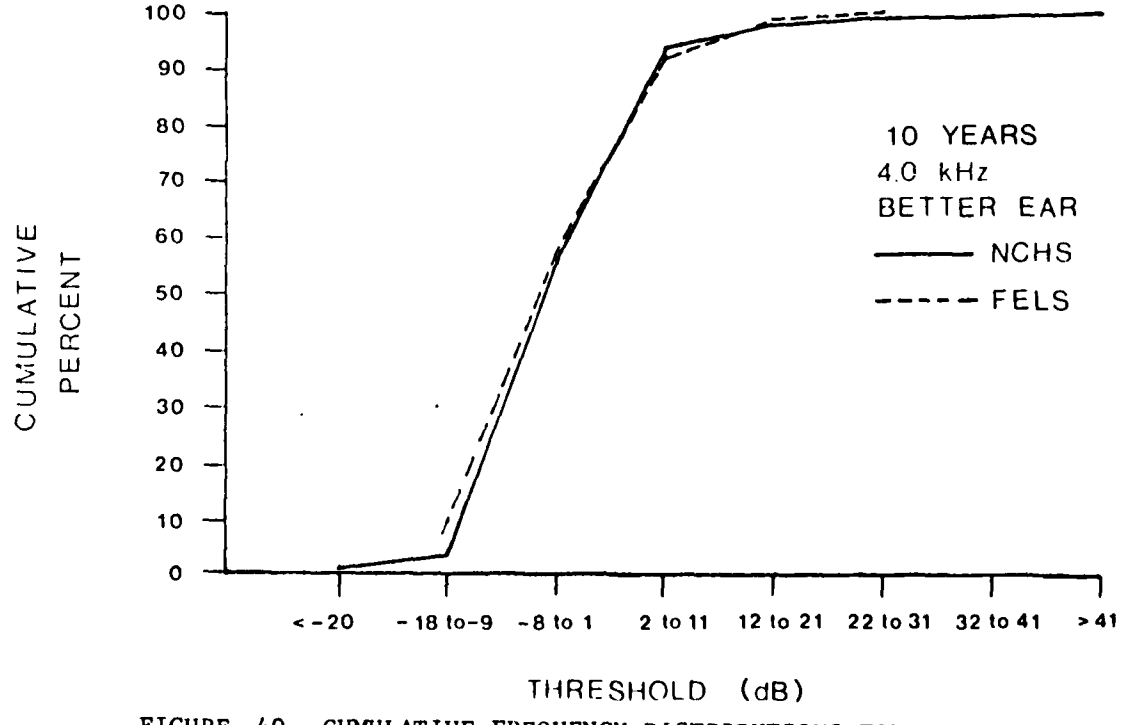


FIGURE 40 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 10 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

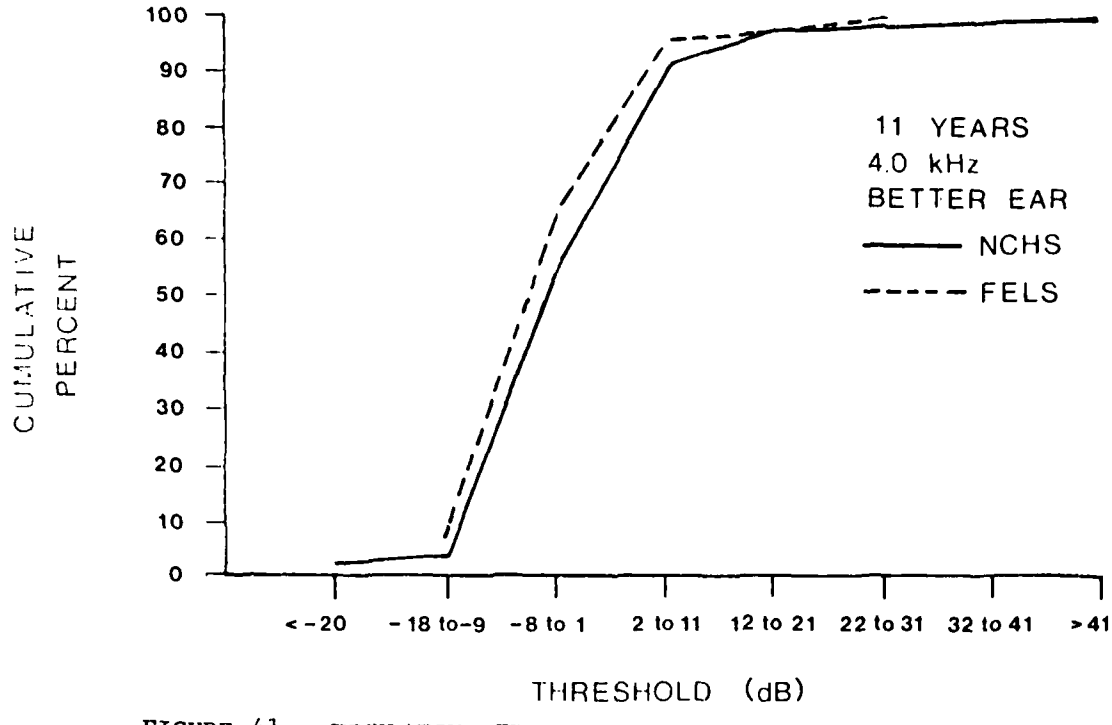


FIGURE 41 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 11 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

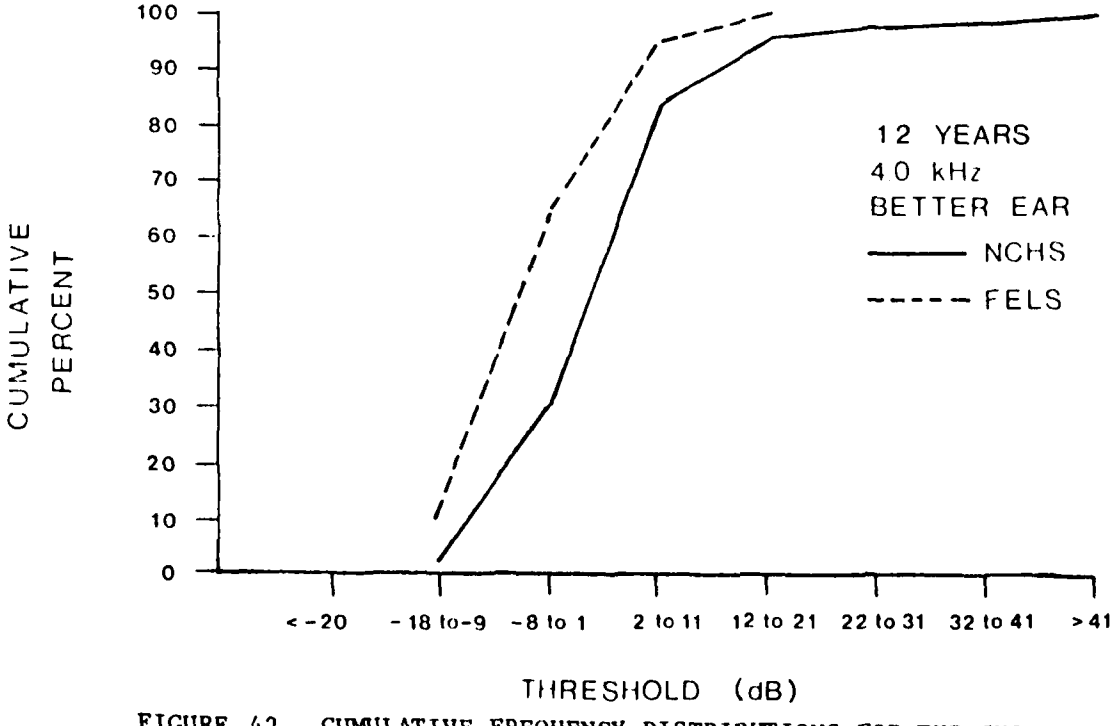


FIGURE 42 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 12 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

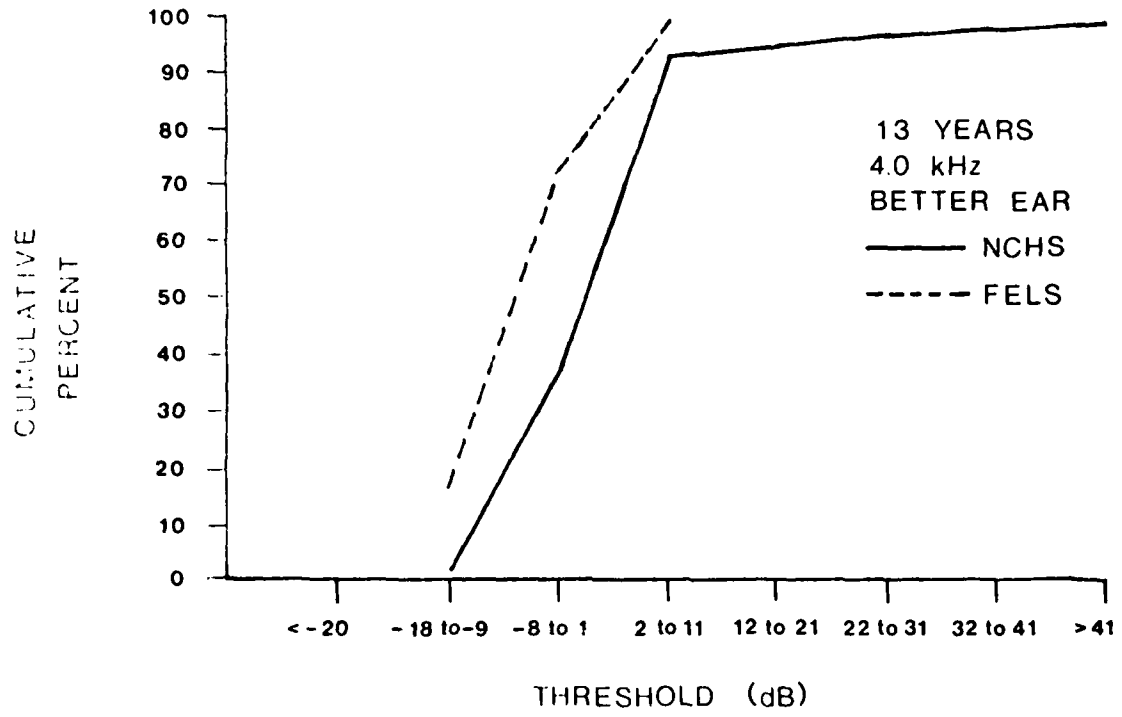


FIGURE 43 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 13 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

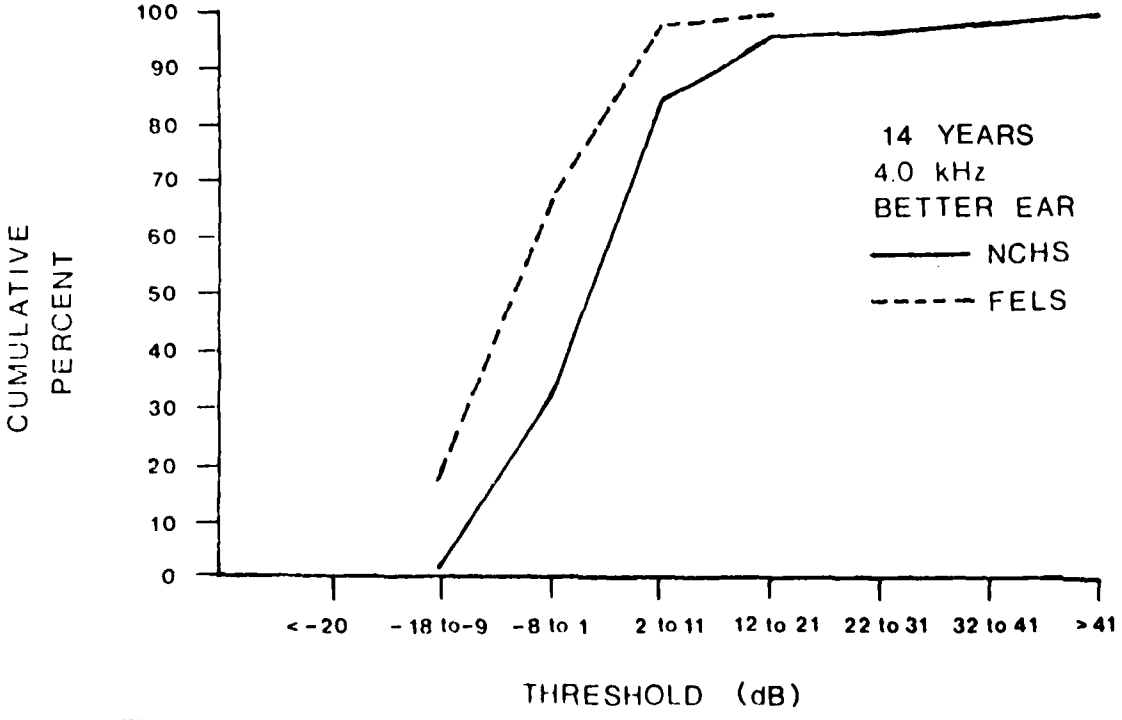


FIGURE 44 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 14 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

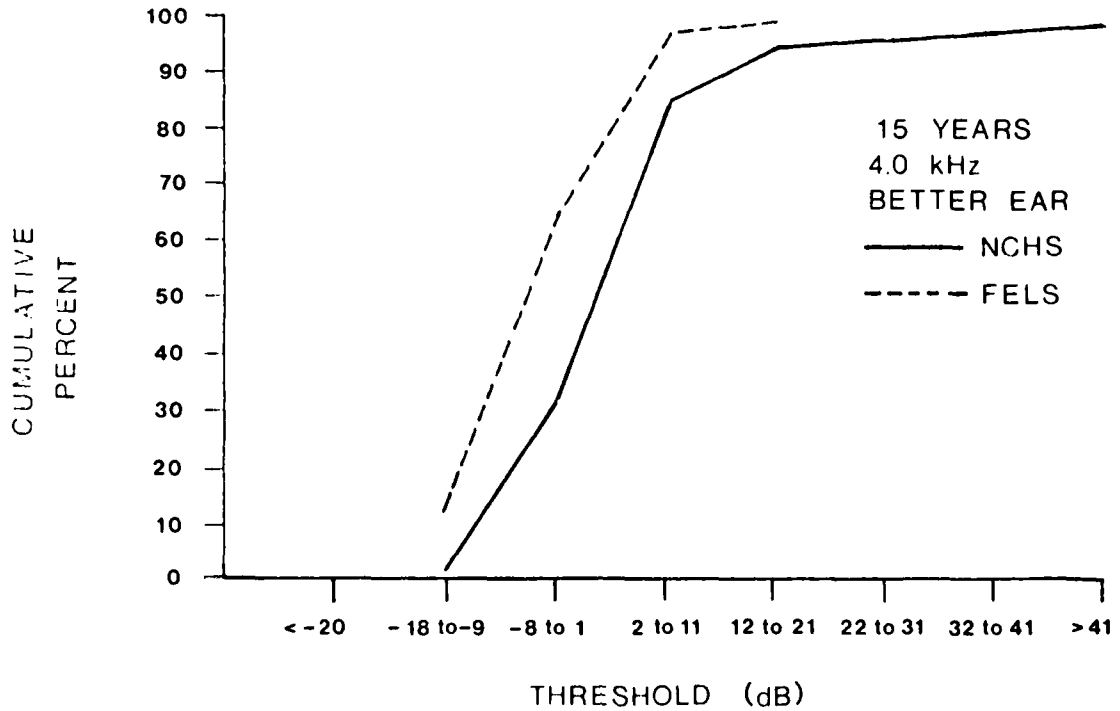


FIGURE 45 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 15 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

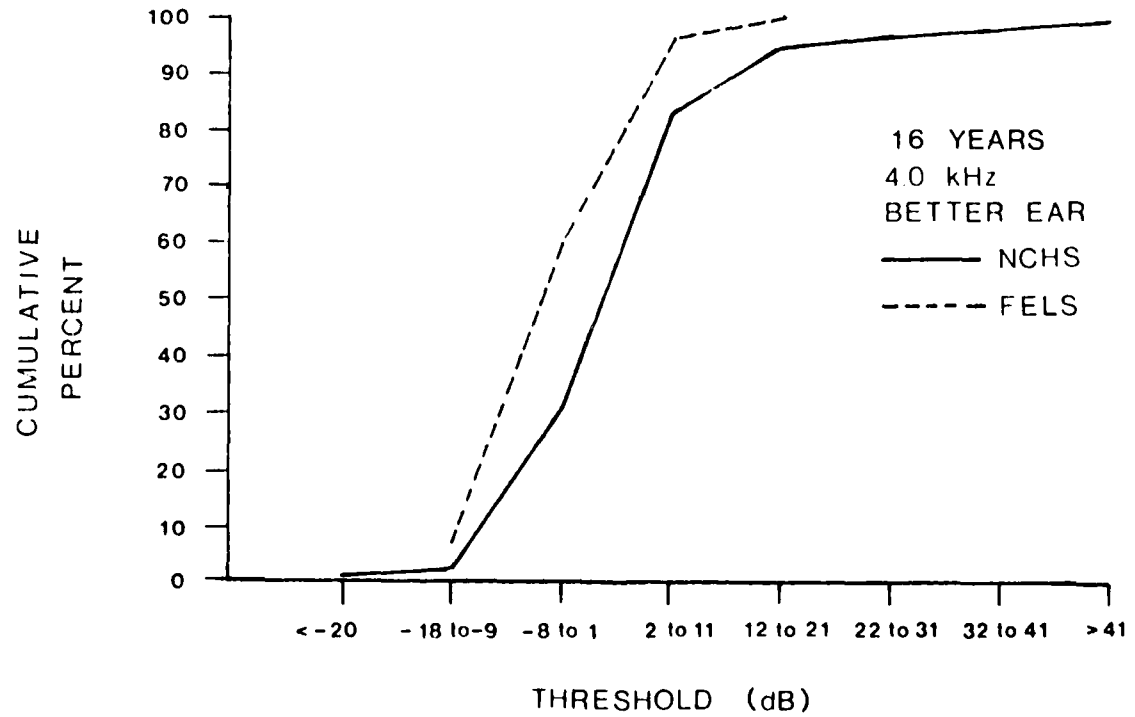


FIGURE 46 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 16 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

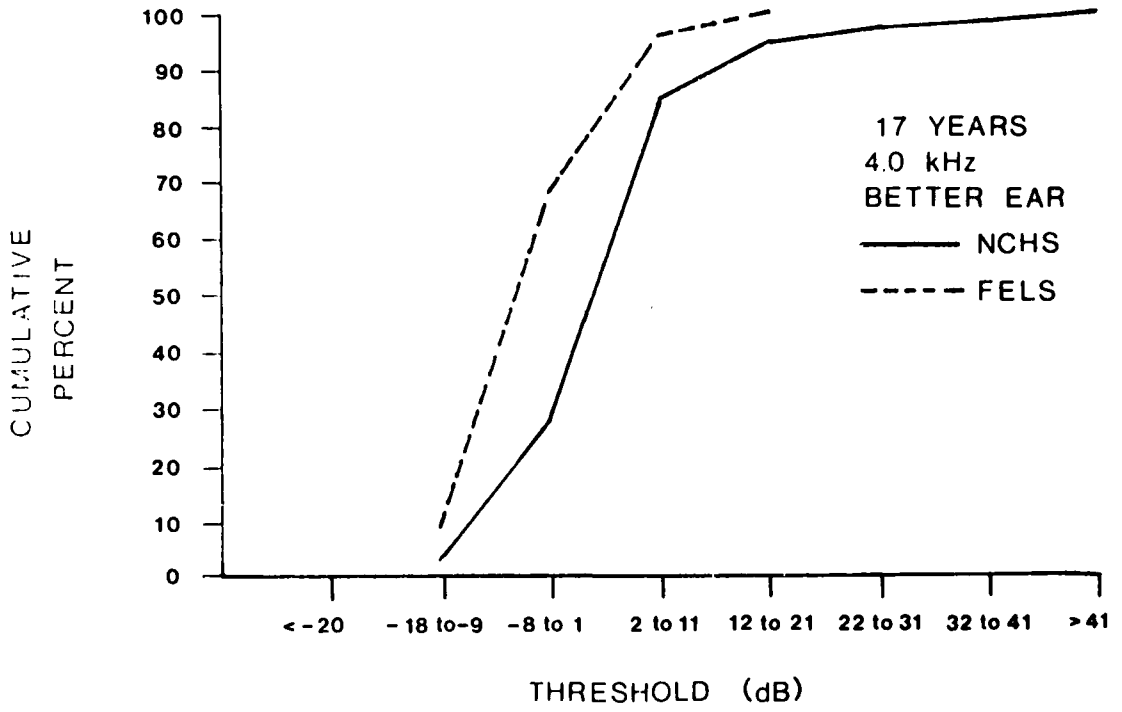


FIGURE 47 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 17 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS STUDIES.

The differences between these pairs of cumulative frequency distributions could be due, in part, to the fact that data from children in the Fels Study with permanent or temporary pathologies were excluded when the analyses were made, but corresponding exclusions were not made from the NCHS data. Consequently, further analyses were made without excluding such data from the Fels data set. As a result, the differences between pairs of cumulative frequency distributions were reduced, as would be expected. The differences between the distributions for the NCHS and Fels Studies, at ages from 7 through 11 years, become very small although there is a tendency for the AC thresholds to be lower for the Fels Study than for the NCHS Survey through 11 years. The comparative plots for 10-12 years are shown as examples (Figures 48-50).

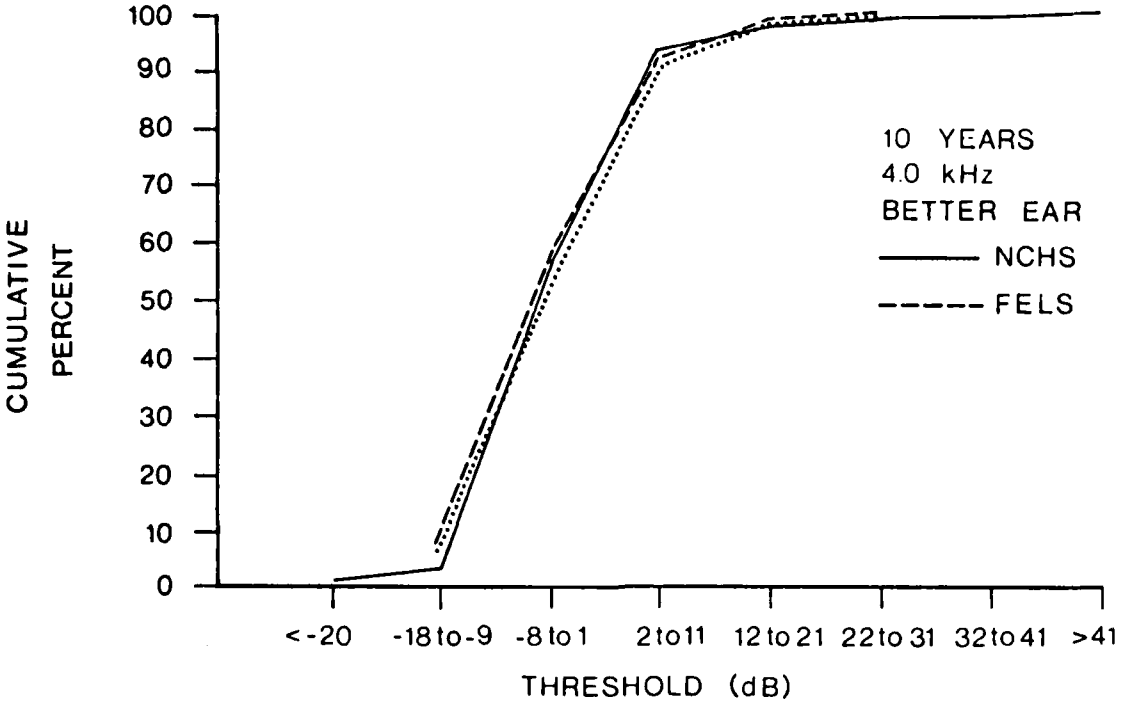


Figure 48 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 10 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS SAMPLES WITHOUT EXCLUSIONS BECAUSE OF PATHOLOGICAL CONDITIONS.

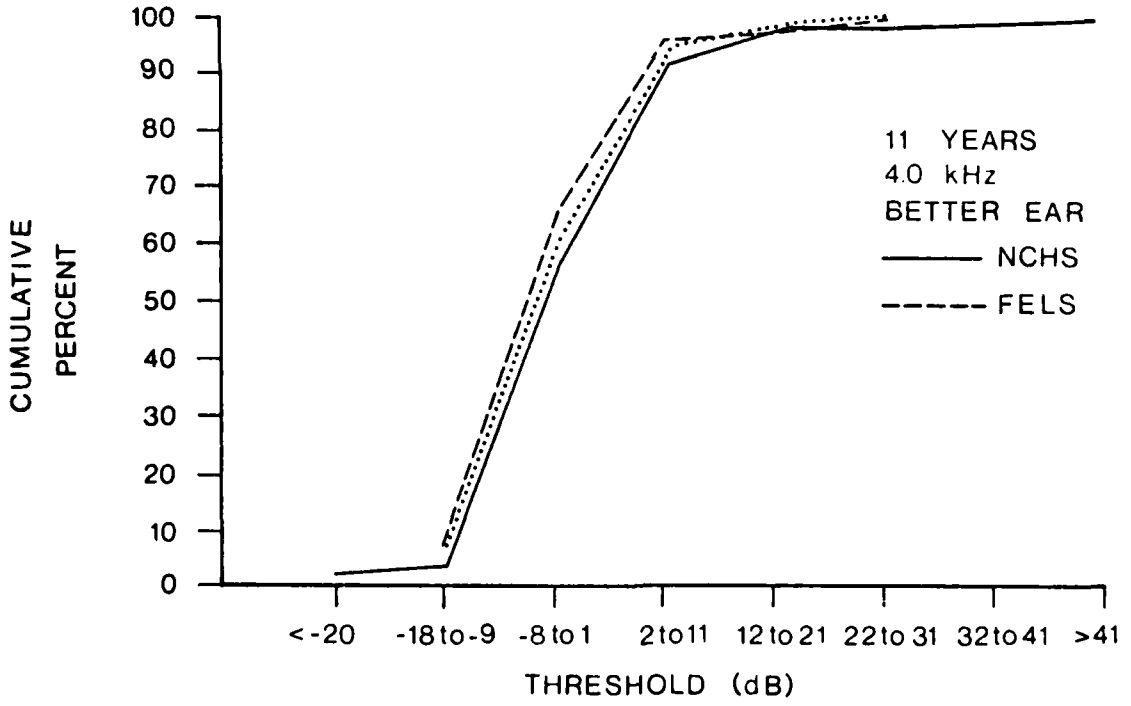


Figure 49 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 11 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS SAMPLES WITHOUT EXCLUSIONS BECAUSE OF PATHOLOGICAL CONDITIONS.

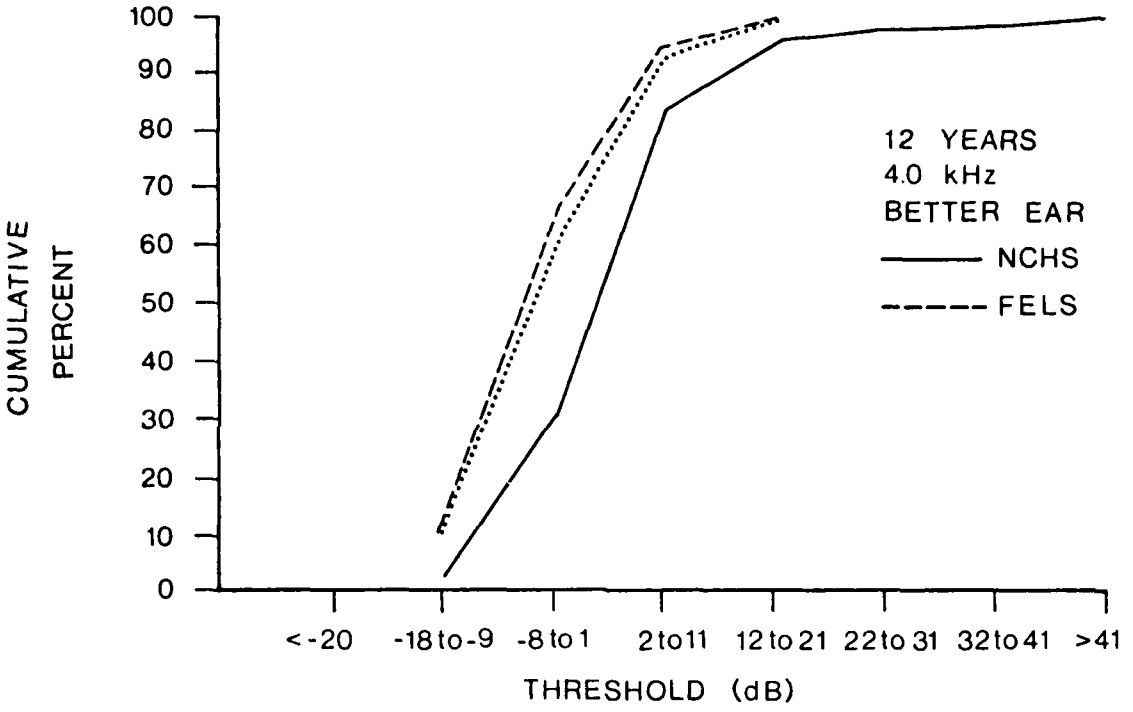


Figure 50 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 12 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS SAMPLES WITHOUT EXCLUSIONS BECAUSE OF PATHOLOGICAL CONDITIONS.

At 12 through 17 years, the pairs of cumulative frequency distributions for thresholds at 4 kHz still show marked differences between the two studies after data from children with temporary or permanent pathologies are retained in the Fels data set. Examples at 12 and 13 years are given in Figures 50-51. It is clear the examination effects and the exclusion of data from children with temporary or permanent pathologies do not completely explain the differences between the NCHS and Fels Studies in AC threshold levels. These differences are small before 12 years, but they are large after that age, particularly at 4 kHz.

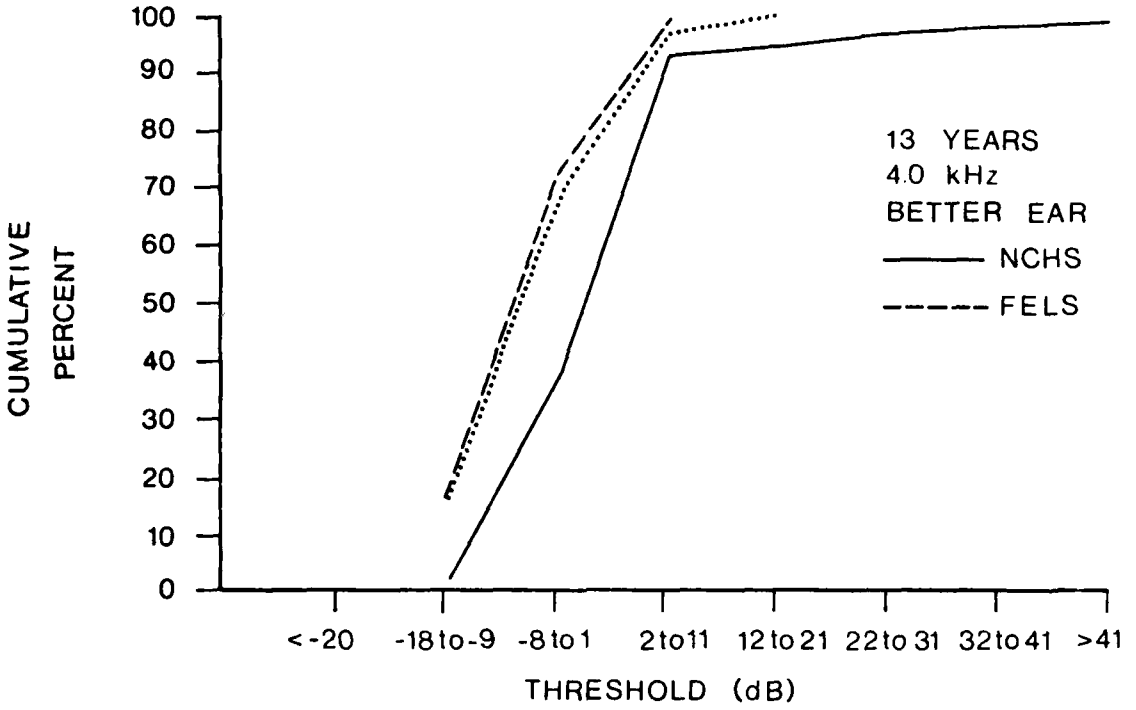


Figure 51 CUMULATIVE FREQUENCY DISTRIBUTIONS FOR THRESHOLDS AT 4 kHz IN THE BETTER EAR OF CHILDREN AGED 13 YEARS (BOTH SEXES COMBINED) IN THE NCHS AND FELS SAMPLES WITHOUT EXCLUSIONS BECAUSE OF PATHOLOGICAL CONDITIONS.

SIGNIFICANT THRESHOLD SHIFTS

Significant threshold shifts were analyzed using data from all examinations except those made of participants with permanent pathologies. The inclusion of data observed when temporary pathologies are present (abnormal tympanograms and/or complete blockage of the external auditory meatus) allows analyses relevent to whether this was an important factor associated with threshold shifts. For each participant with 4 or more serial sets of AC thresholds, sex-, ear-, and frequency-specific linear regressions of thresholds on age were computed, after the data had been adjusted for "examination effects".

Long-Term. From these regression equations, distribution statistics were computed for the intercepts and slopes of the regression lines for each sex, ear and frequency. These are interpreted in relation to long-term threshold shifts. Distribution statistics for intercepts are presented in Tables 40 and 41 for boys and girls respectively. There are no significant differences between the mean intercepts among frequencies within or between ears for boys. However, for girls, the mean intercepts for the right ear tend to be larger than those for the left ear irrespective of frequency, and this difference is significant at 4 kHz ($p < 0.05$). The largest mean intercept within an ear occurs at 4 kHz in both boys and girls. There are no significant differences among mean intercepts at 0.5, 4 and 6 kHz in either ear for girls. In addition, there are no significant difference among mean intercepts at 0.5, 1, 2 and 6 kHz for the left ear in girls. There are three groups of frequencies for the right ear in girls. The intercepts for 0.5, 1 and 6 kHz form one group and those for 1, 2, and 6 kHz form another group and those for 0.5, 4 and 6 kHz form a third group. Within each group, the mean intercepts do not differ significantly, but there are significant differences between the groups. The mean intercepts for girls are generally larger than those for the boys particularly in the right ear, but significant sex differences occurred only at 0.5 and 4 kHz in the right ear.

The standard deviations of the intercepts are large. This reflects the fact that some regression lines were fitted to short runs of serial data; the minimum was 4 sets. Also, the measurement of AC thresholds is subject to error with mean interobserver differences of about 3 dB (Table 2); this would have contributed to the variance of the intercepts. Finally, the intercepts are calculated as the value at age zero which involves considerable extrapolation.

The mean slopes from the regression equations of the boys are not significantly different from zero at any frequency for either ear (Table 42). However, the maximum slopes are very large in some boys (Table 43). The mean slopes for girls are all negative in sign, indicating an improvement in hearing sensitivity with age, and are all significantly different from zero except for the slope at 6 kHz in the left ear (Table 44). There are no significant differences in mean slopes among frequencies within either ear for boys or girls except at 6 kHz. The standard deviations of the means for the slopes are considerably larger in the boys than in the girls but differ little by frequency or by ear.

TABLE 40

DISTRIBUTION STATISTICS FOR INTERCEPTS (a values) FROM REGRESSIONS OF THRESHOLDS ON AGE FOR BOYS (N=112) WITH AT LEAST 4 SETS OF SERIAL DATA. THRESHOLDS FOR BOYS WITH TEMPORARY PATHOLOGIES ARE INCLUDED.

Frequency (kHz) (kHz)	Ear	Mean (dB)	S.D. (dB)
0.5*	R	3.4	24.3
1	R	2.5	24.8
2	R	-0.6	26.5
4*	R	3.9	29.8
6	R	2.4	31.6
0.5	L	2.2	25.0
1	L	1.1	27.0
2	L	1.4	27.7
4	L	5.5	28.7
6	L	1.5	32.9

*Sex difference $p < 0.05$

TABLE 41

DISTRIBUTION STATISTICS FOR INTERCEPTS (a values) FROM REGRESSIONS OF THRESHOLDS ON AGE FOR GIRLS (N=102) WITH AT LEAST 4 SETS OF SERIAL DATA. THRESHOLDS FOR GIRLS WITH TEMPORARY PATHOLOGIES ARE INCLUDED.

Frequency (kHz)	Ear	Mean (dB)	S.D. (dB)
0.5*	R	9.8	21.0
1	R	4.8	17.1
2	R	4.1	19.4
4†	R	12.9	25.8
6	R	8.1	27.9
0.5	L	5.2	18.5
1	L	1.1	15.7
2	L	1.0	14.5
4	L	6.1	21.6
6	L	4.0	26.7

* Sex difference $p < 0.05$

† Ear difference $p < 0.05$

TABLE 42

DISTRIBUTION STATISTICS FOR SLOPES (b values) FROM REGRESSIONS OF THRESHOLDS ON AGE FOR BOYS (N=112) WITH AT LEAST 4 SETS OF SERIAL DATA. THRESHOLDS FOR BOYS WITH TEMPORARY PATHOLOGIES ARE INCLUDED.

Frequency (kHz)	Ear	Mean (dB/year)	S.D. (dB/year)
0.5	R	-0.25	2.12
1	R	-0.24	2.26
2	R	0.13	2.28
4	R	-0.06	2.31
6	R	0.10	2.27
0.5	L	-0.22	2.55
1	L	-0.05	3.05
2	L	-0.16	2.78
4	L	-0.30	2.93
6	L	0.16	2.85

TABLE 43

MAXIMUM SLOPES (dB/years) OF AC THRESHOLDS AGAINST AGE AND INTERVAL FROM FIRST TO MOST RECENT EXAMINATION FOR CHILDREN WITH LARGEST INCREASES IN THRESHOLDS. ALL THOSE WITH THE LARGEST SLOPES ARE BOYS.

Frequency (kHz)	Slope (dB/year)	Interval (years)
0.5	3.9	3
1.0	3.4	6
2.0	2.3	3
4.0	2.8	6
6.0	4.5	4

TABLE 44

DISTRIBUTION STATISTICS FOR SLOPES (b values) FROM REGRESSION OF THRESHOLDS ON AGE FOR GIRLS (N=102) WITH AT LEAST 4 SETS OF SERIAL DATA. THRESHOLDS FOR GIRLS WITH TEMPORARY PATHOLOGIES ARE INCLUDED.

Frequency (kHz)	Ear	Mean (dB/year)	S.D.(dB/year)
0.5	R	-0.81*	1.53
1	R	-0.52*	1.28
2	R	-0.4 *	1.51
4	R	-0.83*	1.91
6	R	-0.42*	1.95
0.5	L	-0.64*	1.53
1	L	-0.41*	1.42
2	L	-0.47*	1.09
4	L	-0.47*	1.55
6	L	-0.09	2.19

* Significantly different from zero; $p < 0.05$

Comparisons were made between the mean intercepts and slopes from regressions of thresholds on age excluding data from children with temporary pathologies (Tables 11 and 12) and including data from children with temporary pathologies (Tables 40 to 44). The children in the latter group tend to have higher intercepts and greater slopes at corresponding frequencies which would be expected because children with pathologies are included.

Some of the children have very steep slopes of thresholds against age. These range as high as 4.5 dB/year in boys and 3.0 dB/year in girls. The records of the 10 children with the largest positive slopes (dB/year) indicate that long-term significant threshold shifts (a much greater than average increase in thresholds over time) tend to be more common in boys than girls (8 boys; 2 girls). The apparent factors for these long-term shifts are given in Table 45. One girl attended a rock concert 4 days before her most recent visit, and the other had a "stuffy nose." Most boys had either a head cold or sinus allergy at the time of their most recent examination or had been exposed to loud sounds such as firecrackers, during the 6 months preceding their most recent examination. For one boy, the large positive slopes of the regression lines were due to unusually low AC thresholds at his first examination at a young age. Also, the records for three boys do not help identify an apparent factor.

Short-Term. Short-term threshold shifts for individuals were detected from sex-, ear- and frequency-specific linear regressions of AC thresholds on age for those children with 4 or more examinations. This group of children included those with "temporary pathology". All the data were adjusted for "examination effects".

A short-term threshold shift was identified as the residual from the regression line with the largest absolute value. By this definition, each participant included in this part of the study had a maximum residual that was considered his or her largest short-term threshold shift. Many of these were small and clearly not functionally significant. Seventy-seven percent of the largest residuals for individual participants are positive in direction indicating that they are a non-random phenomenon, and that, for most children, the sign of the largest residual is in the direction of a reduction in hearing ability.

Distribution statistics of the short-term threshold shifts (largest residuals) are presented by ear and frequency in Tables 46 and 47 for boys and girls respectively. The means of the largest residuals do not differ statistically between ears or between boys and girls; however, 5 of the 8 children with values for largest residuals that are greater than +20 dB are boys.

The means of the largest residuals differ statistically among frequencies. In each sex, the mean of the largest residuals at 6 kHz is significantly larger than the mean of the largest residuals at the other frequencies, but the differences among the frequency-specific means of the largest residuals are small.

TABLE 45

FACTORS ASSOCIATED WITH LONG-TERM THRESHOLD SHIFTS IDENTIFIED FROM LARGE POSITIVE VALUES FOR SLOPES OF REGRESSIONS OF THRESHOLDS AGAINST AGE.

Factor	Boys	Girls
Marked sound exposure	1	1
Head cold or allergy	3	1
Low AC thresholds at first or second exam	1	0
No apparent factor	3	0
TOTALS	8	2

The largest residuals are negatively associated with age at the first visit, i.e. the values of the largest residuals are greater at younger than older ages. Removing the effects of age at the first visit from the data does not significantly change the statistical associations between sexes, or among frequencies for the means of the largest residuals. However, after removing the effect of age at the first visit, there is a slightly significant ($p < 0.02$) ear effect, with the mean largest residual being 0.4 dB greater in the left than the right ear of these children. In addition, the mean ages at which the largest residual occurred, after the effects of age at the first visit were removed, do not differ significantly between ears, sexes or among frequencies, although they tend to occur at slightly older ages in boys than girls.

A short-term threshold shift, whether large enough to be functionally significant or not, may tend to occur synchronously in the two ears and in all frequencies within one ear. Analyses of the data showed that short-term threshold shifts (largest residuals) do tend to occur at approximately the same age, $\pm$ one year, at all frequencies tested in each ear within a child. This occurred in 38.5% of the children for the left ear and 35% of the children for the right ear. These percentages are greater than those expected due to chance. Also, short-term threshold shifts in each frequency tested tend to occur at the same age, $\pm$ one year, in both ears within a child. This "synchronous" change occurred in 25% of the children which is markedly greater than that expected due to chance ($p < 0.0001$).

TABLE 46

DISTRIBUTION STATISTICS FOR SHORT-TERM THRESHOLD SHIFTS IN 88 BOYS AGED 6 TO 18 YEARS OF AGE (INCLUDING THOSE WITH TEMPORARY PATHOLOGIES) BY FREQUENCY AND EAR.

Frequency (kHz)	Ear	Mean (dB)	S.D. (dB)	Range (dB)
0.5	R	3.5	5.1	-7.7 to 22.9
1.0	R	2.7	4.2	-8.2 to 14.1
2.0	R	2.3	3.5	-5.6 to 10.2
4.0	R	4.0	5.3	-9.6 to 21.3
6.0	R	4.5	6.2	-9.3 to 28.4
0.5	L	4.3	6.2	-5.2 to 41.4
1.0	L	3.9	4.7	-6.2 to 17.6
2.0	L	2.9	4.6	-8.1 to 21.7
4.0	L	3.0	5.5	-11.8 to 13.4
6.0	L	4.9	6.5	-10.7 to 20.7

There are 8 participants whose largest short-term shifts exceeded 20 dB at one or more frequency. The original records for these participants were examined to determine whether apparent causes of the observed changes in threshold could be identified (Table 48). A check was made of the health and noise exposure records of these children and their otoscopic records were reviewed. The ears of 4 children (2 boys and 2 girls) were badly obstructed with wax, and one of the boys also had a sore throat. One girl was only 6 years old at the visit in question, and her data at this examination may be less reliable than the data in general. Finally, there are 3 boys in whom a cause for the elevated threshold was not apparent. It is noteworthy that none of tne children with large short-term threshold shifts had abnormal tympanometry findings or a completely obstructed meatus.

TABLE 47

DISTRIBUTION STATISTICS FOR THE SHORT-TERM THRESHOLD SHIFTS IN 81 GIRLS AGED 6 TO 18 YEARS OF AGE (INCLUDING THOSE WITH TEMPORARY PATHOLOGIES BY FREQUENCY AND EAR.

Frequency (kHz)	Ear	Mean (dB)	S.D. (dB)	Range (dB)
0.5	R	2.9	4.6	-6.6 to 16.8
1.0	R	3.3	5.1	-6.9 to 16.9
2.0	R	3.6	4.8	-6.8 to 25.8
4.0	R	3.6	4.9	-9.4 to 14.2
6.0	R	4.7	6.4	-11.8 to 19.7
0.5	L	4.2	6.2	-12.4 to 38.4
1.0	L	4.4	6.0	-6.9 to 40.0
2.0	L	3.9	4.3	-12.4 to 17.0
4.0	L	4.3	6.1	-12.0 to 21.3
6.0	L	5.3	7.3	-15.4 to 23.8

TABLE 48

APPARENT REASONS FOR THE OCCURRENCE OF SHORT-TERM SHIFTS GREATER THAN 20 dB AT ONE OR MORE FREQUENCIES.

Apparent Cause	Boys	Girls
Abnormal otoscopic findings	2	2
Head cold, sore throat	1	0
Young child	0	1
No apparent cause	3	0

RELATIONSHIPS OF AUDITORY AIR CONDUCTION (AC) THRESHOLDS TO AGE AFTER 18 YEARS.

Fifty-eight of the participants in the Fels Longitudinal Study received one or more annual audiometric tests after their 18th birthday. After this age, many young adults leave home for continued education, the military, or job opportunities. Therefore, profound changes occur in the sound environments of these individuals. Regressions of AC ;thresholds on age and visit were computed for this group of participants to determine whether their new noise environments affected their hearing ability.

Each of these 58 participants had a minimum of 8 audiometric tests with one to four of these tests occurring after 18 years of age. Forty-one of these participants were tested up to 25 years of age. Examination effects for each participant were removed for each ear and for each frequency tested by linear regressions of AC thresholds on examination order and the residuals retained. Due to the small sample size, the sexes were combined for further analyses.

Between 18 and 25 years of age, ear-, frequency-, and age-specific mean AC thresholds, after examination effects had been removed, ranged from -7.2 to +9.4 dB. At most ages and for most frequencies, these thresholds are not significantly different from zero. In addition, ear- and frequency-specific regressions of these thresholds on age or examination order for individuals, including their thresholds before 18 years of age, are linear with negative slopes. The frequency-specific slopes range from -0.1 to -0.6 dB per year for regressions on age and -0.2 to -0.8 dB per year for regressions on examination order. These results indicate a continued improvement in hearing ability after 18 years of age. However, for a few participants, the regressions are significantly quadratic rather than linear. This quadratic relationship between thresholds on age or examination order indicates a tendency for hearing ability to decrease with age but, this effect was small and was noted in only the few participants who had sufficient data points after 18 years of age for fitting of a quadratic function.

SPEECH DISCRIMINATION

Two speech discrimination tapes were added to the test paradigm during this period of data collection for children aged 6 to 18 years. Each tape includes the NU6 word lists consisting of 4 tests (A-D), each of 50 words, with Tape 1 using a male speaker and Tape 2 a female speaker. Tape 1 was used for about 6 to 8 months. At his or her first speech discrimination examination, each participant received Test A using Tape 1. During this period, a few participants received a second examination (6 months after the first) using Test B, of Tape 1.

After this period, and following a 3-month delay due to malfunctioning equipment, testing with Tape 2 began and Tape 1 was no longer used. Those participants who had taken Test A at their first speech discrimination examinations with Tape 1 were given Test B at their first speech discrimination examination with Tape 2. Similarly, those participants who had

taken Test A and Test B with Tape 1 received Test C at their first speech discrimination test with Tape 2. Only a few participants have taken Test C, and Test D ;has not been administered to any participants. The number of speech discrimination examinations by tape and test are presented in Table 49.

Because there are data for so few participants on Tape 1, Test B, and Tape 2, Test A or C, the data for these groups were omitted from the analyses. This restricted the analyses to date from Tape 1, Test A and from Tape 2, Test B. Consequently, a within-tape, between-test analysis was not possible. However, each of the four work-lists or tests available (A-D) has been developed so that inter-test reliability is high (Katz, 1978).

A speech discrimination score (SDS) was defined as the percentage of words correct within a test. The data in Table 50 show there are no sex differences for SDS within Tape 1, Test A, but boys have significantly lower SDS than girls ($p<0.03$) for Tape 2, Test B. Also, there are significant associations with age and SDS for each tape. For Tape 1, Test A, older children have significantly higher SDS than younger children (r for SDS vs age=0.28; $p<0.0002$). There is a similar finding for Tape 2, Test B, but the correlation between SDS and age is greater than for Tape 1, Test A for Tape 2 Test B, boys and girls are similar in their improvement in SDS with age (girls $r = .52$, $p<0.001$; boys, $r = .48$ $p<0.0001$.)

There are no significant correlations between SDS and air conduction thresholds for boys or girls with Tape 1, Test A, or for boys with Tape 2, Test B. However, SDS are significantly correlated with air conduction thresholds at three frequencies (0.5 kHz, left ear; 6 kHz, left ear; 4 kHz, right ear) for girls with Tape 2, Test B. The value of the coefficients in each of these significant correlations is about -0.26 ($p<0.04$).

In each sex, the SDS are larger for Tape 1, Test A, than for Tape 2, Test B. The mean percentages of words correct (SDS) are presented in Table 50 by tape and sex.

Because the full NU6 word lists were used instead of half-lists, the use of which has b been recommended to reduce fatigue among children (Chermak and Dengerink, 1981), analyses were conducted to determine if the prevalence of errors differed in relation to the sequence of words within tests. The tests or word lists were divided into 5 sequential groups of 10 words each, i.e., Group 1, words 1 through 10, etc. For Test A, Tape 1, there is a significant difference among groups ($p<0.0001$). Boys and girls have the most incorrect words in Group 1 (the first 10 words) of the test. They have the fewest incorrect words in Group 3 although there was no significant difference in the number of words incorrect among Groups 3,4, and 5 or Groups 2,4,and 5.

The results for Tape 2, Test B, are similar, but there is a sex difference. Boys have only a marginally significant difference in the number of words incorrect among groups ($p<0.07$). In boys, there are fewer incorrect words for Group 5 and little or no difference among the preceding 4 groups of words. However, in girls there is a significant difference for Tape 2, Test B, in the number of words incorrect between the 5 groups ($p<0.01$). Girls have the

TABLE 49

THE NUMBER OF SPEECH DISCRIMINATION EXAMINATIONS BY TAPE AND TEST.

	TAPE 1			TAPE 2		
	Test			Test		
	A	B	C	A	B	C
Boys	78	6	0	7	54	8
Girls	82	2	0	10	48	5

Total number of examinations = 302

TABLE 50

SPEECH DISCRIMINATION SCORES (percentage of words correct) FOR BOYS AND GIRLS BY TAPE (N = 262).

	TAPE 1 (TEST A)		TAPE 2 (TEST B)	
	SDS		SDS	
	Mean	S.D.	Mean	S.D.
Boys	85.8*	5.08	59.3*†	5.3
Girls	86.1*	5.06	62.2*†	8.1

*tape difference $p<0.001$

†sex difference $p<0.03$

number of words incorrect between the 5 groups ($p<0.01$). Girls have the fewest incorrect words for Group 4 but no significant differences between Groups 1, 2, 3 and 5. Although many of the difference are not significant, there is evidence of a general tendency for errors to be more common in the first group of 10 words than in groups presented later.

The speech discrimination scores obtained with Tape 2, Test B were about 15% lower than those obtained with Tape 1, Test A. Re-examination of the tapes showed that in addition to the male (Tape 1) and female (Tape 2) talker difference, the Tape 2 talker's voice presentation was melodic and the level of the key word dropped below that of the carrier phrase by 0 to 6 dB from test item to item. As a consequence of these variations in presentation, use of Tape 2 has been discontinued.

IRIS PIGMENTATION AND THRESHOLDS

Eye color was recorded using glass models of eyeballs with 12 grades of iris pigmentation. These grades are given in Table 51 together with the prevalence of grades by sex. Data for participants with permanent pathology and data recorded at examinations when temporary pathology was present were excluded from the analyses. Data from the black participants were excluded also so that the analyses could be made within a race; there are too few data to allow analyses within blacks.

Correlations were calculated between the ordered ranks of eye color grades, that are considered to reflect the amounts of iris pigmentation, and AC thresholds at each frequency tested. The thresholds used in these analyses were from the first acceptable examination of each participant. The thresholds were adjusted for examination effects if there had been an earlier examination near the beginning of the study when some of the equipment was not functioning satisfactorily and therefore acceptable thresholds were not obtained.

The correlations between iris pigmentation grades and auditory thresholds are not significant either within a sex or when data for the two sexes are combined. Also analyses of variance were performed with 12 groups of iris pigmentation and with iris pigmentation divided into 4 groups (blue, grey, hazel and brown); in each case the associations between iris pigmentation and thresholds were not significant. Next, the actual eye models were ordered according to mean thresholds at both 2 kHz and 4kHz. Inspection of this array did not suggest an association between iris pigmentation and auditory thresholds, but many of the samples within groups are small. The means and ranges for iris pigmentation grades are given in Table 52.

Table 51

PERCENTAGE PREVALENCE OF EYE COLOR GRADES

Grade		"Iris Pigmentation" Scale	Boys	Girls
Blue	- light	1	10.3	3.7
	- medium	2	5.1	4.9
	- dark	3	10.3	17.1
Grey	- light	4	2.6	3.7
	- medium	5	5.1	3.7
	- dark	6	1.3	6.1
Hazel	- light	7	1.3	1.2
	- medium	8	11.5	11.0
	- dark	9	14.1	12.2
Brown	- light	10	3.8	2.4
	- medium	11	15.4	13.4
	- dark	12	19.2	20.7
	TOTALS		100.0	100.0

TABLE 52 MEAN AC THRESHOLDS FOR THE RIGHT EAR WITHIN FIVE TEST-TONE FREQUENCIES FOR EACH OF THE IRIS PIGMENTATION GRADES

Test-tone Frequency (kHz)	Iris Pigmentation Blue (Grade 1)	Gray (Grade 2)	Hazel (Grade 3)	Brown (Grade 4)
.5	0.13	- 0.22	0.09	- 0.84*
	-11.20	-11.40	-11.20	-11.40**
	20.60	24.60	28.80	12.60***
1	- 0.89	- 1.90	0.29	- 0.94
	-11.16	-11.56	- 7.16	- 9.56
	22.44	16.44	24.89	14.44
2	- 0.56	- 0.65	2.03	- 0.68
	-11.14	-11.14	- 5.14	-11.04
	12.96	12.86	18.86	12.86
4	3.40	1.29	0.50	3.06
	-10.62	-10.78	-10.62	- 8.78
	15.38	17.22	7.38	21.38
6	3.76	2.89	4.29	3.57
	10.66	-10.66	-10.66	-10.34
	19.34	31.34	17.66	25.34

* = mean
** = minimum
*** = maximum

Comparison of Dosimeters. In this, and other sections of the report, the words "noise" and "sound" are used interchangeably when applied to the description of the acoustic environments of the participants. Because both General Radio (GR) and Metrosonics (METRO) dosimeters were used during this study, it was important to determine whether there is a difference in $L_{eq(24)}$ between the sound levels recorded by these dosimeters. Therefore, an analysis of variance with four groups corresponding to each dosimeter-dynamic range combination was performed using the first 234 dosimeter observations made during the study. This analysis was based on the number of observations rather than the number of children. Consequently, this number does not match the total in Table 53 . The F-value indicates that the null hypothesis of no difference among groups be rejected at the 0.0001 significance level. Duncan's multiple range test shows that two significantly different groups exist; one corresponding to the data from the GR dosimeters, and the other consisting of the data from the Metrologgers. There were no differences in the location of the microphones for the two types of dosimeters.

There are no significant differences between the $L_{eq(24)}$ values obtained using different dynamic ranges within a specific dosimeter. The sample sizes for the tests performed with the GR dosimeter at a 60-110 dB dynamic range and the Metrosonics dosimeter at a 40 to 104 dB dynamic range are small being 21 and 16, respectively. Thus, the power to detect a significant difference between dynamic ranges within a dosimeter type is low. Due to the apparent difference between devices, the data have not been pooled across dosimeters, although the data from the two different dynamic ranges within dosimeter types have been pooled in the subsequent analyses. Also, t-tests indicate no significant racial differences within either dosimeter; therefore, race has been ignored in subsequent analyses.

Table 53 gives the means, standard deviations, and sample sizes for $L_{eq(24)}$ and age in each group used in the test for differences between the records from the two types of dosimeters. The results of analysis of variance testing for dosimeter effects, sex effects and their interactions, indicated significant dosimeter effects [$F(^{1}_{230}) = 68.22$, $p<0.001$] and significant sex effects [$F(^{1}_{230}) = 4.44$, $p=0.036$], but no significant sex-dosimeter interaction [$F(^{1}_{230}) = 0.00$, $p = 0.988$]. The means of the values recorded with the GR dosimeters are about seven dB higher than the data that have been recorded with the Metrologgers (Table 52). Boys have levels of sound exposure that average about 2 dB higher than those of girls for each dosimeter type.

To determine if the group differences between dosimeter types could be explained by differing design philosophies of the General Radio and Metrosonics dosimeters, tests were conducted on these instruments at the

TABLE 53

DESCRIPTIVE STATISTICS, FOR $L_{eq(24)}$ AND AGE, BY DOSIMETER BRAND AND SEX, IN ANALYSES COMPARING SOUND LEVELS RECORDED WITH DIFFERENT DOSIMETERS.

	$L_{eq(24)}$ (dB)			Age (years)	
Dosimeter/sex	N	$\bar{X}$	S.D.	$\bar{X}$	S.D.
General Radio					
boys	54	84.8	4.6	13.8	3.9
girls	55	82.9	5.4	13.9	3.5
Metrologger					
boys	29	77.6	6.2	15.2	3.1
girls	29	75.8	5.0	14.6	3.4

Acoustics Laboratory, Wright-Patterson Air Force Base. The results of these tests demonstrate a consistent difference of approximately 2 dB (GR reading higher) between the two types of dosimeters when broad band noise (pink noise) is used instead of a single frequency (pure tone). However, there is generally no other difference between the dosimeters for steady noises lasting more than 5 seconds.

The sound energy of bursts of noise of less than 5 seconds is not fully measured by the Metrologgers, and the degree of this undermeasurement depends on the level of the noise burst. Figure 52 illustrates the results of one such test. For noise bursts of 1 second duration that begin every 15 seconds, and an ambient level of 80 dB, a 2 dB difference in recording between the dosimeters is apparent up to a noise burst that is 30 dB above the ambient. For greater separations between the noise burst and the ambient level, the difference between dosimeters increases until there is a 6 dB difference for a 40 dB separation (Figure 52). For noise bursts less than 1 second (not shown), the difference between dosimeters increases such that a 13 dB difference is measured for a 500 msec 120 dB noise burst (i.e., 40 dB separation). In these situations, the GR dosimeters deviate little from the theoretical calculated values, but the Metrologgers systematically under-record actual sound energy levels. This performance is predictable in view of the fact that the Metrologgers have a limited crest factor of only 10 dB, while the GR dosimeters have a crest factor of 25 dB.

However, the GR dosimeter also exhibits a behavior that causes measurement errors. For broad band noise that varies between 75 dB and 85 dB every 2, 5, or 10 seconds, the GR dosimeter with an 80 to 130 dB dynamic range reads from 3 to 5 dB greater than the calculated value.

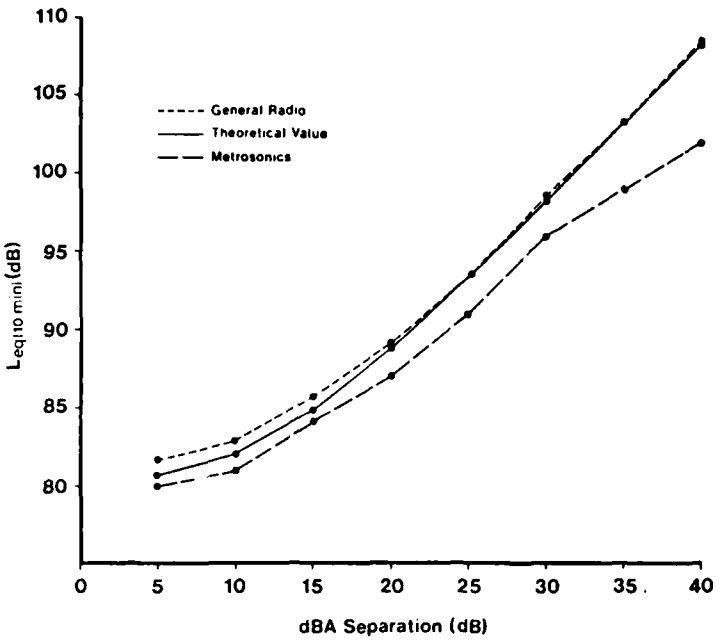


FIGURE 52 THEORETICAL $L_{eq(24)}$ VALUES AND THOSE RECORDED WITH GENERAL RADIO AND METROSONICS DOSIMETERS WHEN EXPOSED TO BROAD BAND ("PINK") NOISE AT AN AMBIENT LEVEL OF 80 dB WITH BURST (1 SECOND DURATION, EVERY 15 SECONDS) AT LEVELS GREATER THAN THE AMBIENT (i.e., dBA SEPARATION).

Further investigation demonstrated that the error arises from the fact that the GR dosimeter reads at least a 0.01 count each time the threshold is crossed from a value below threshold. The error from such an idiosyncrasy can be rather large. For instance, a sound that repeatedly cycles between 70 dB for 2 seconds and 80 dB for 2 seconds will cause a GR dosimeter (with an 80 to 130 dB dynamic range) to indicate an L_{eq} of 88.7 dB, instead of the theoretical value of 77.8 dB. Thus, both dosimeters appear to have idiosyncrasies that result in systematic measurement errors; the GR dosimeters systematically overestimate actual noise in certain situations while the Metrologgers underestimate actual noise levels in different situations. Together, the dosimeters probably bracket the actual noise level.

To eliminate other possibilities that could have contributed to group differences between dosimeters, the data were thoroughly analyzed with this possibility in mind. Table 52 shows that the children tested with GR dosimeters tend to be younger than those tested with the Metrologgers. Mean $L_{eq(24)}$ values from the two dosimeters were compared in children aged more than 16 years. In this subgroup, the mean ages of those tested by the two types of dosimeters were 17.2 years (General Radio) and 17.7 years, (Metrologger), which are not significantly different. However, the mean $\pm$ S.D. $L_{eq(24)}$

values of 83.9 ± 5.5 (n=45) and 76.4 ± 6.3 (n=32), for the groups tested with GR dosimeters and Metrologgers, respectively, are significantly different at the 0.0001 level of significance.

In a further attempt to address the problem of differences in $L_{eq(24)}$ between the groups tested with each dosimeter, data from children tested on multiple occasions were analyzed. At the time of this analysis, there were 54 cases in which children had successive tests with GR dosimeters, ten in whom successive tests were with Metrologgers, nine in whom a Metrologger was used first, followed by a GR dosimeter, and 34 in whom a GR dosimeter was used first followed by a Metrologger. Table 54 presents the mean difference (most recent record minus previous record) for each of these four categories. The mean differences are not significantly different from zero when the same type of dosimeter was used for both records. However, when both GR and Metrosonics dosimeters were used, the differences are significantly positive if the Metrologger was used to obtain the earlier record, and significantly negative when the GR was used to obtain the earlier record. These results again indicate that the recorded $L_{eq(24)}$ values are about five to eight dB higher with a GR dosimeter than with a Metrologger.

TABLE 54

DIFFERENCES IN $L_{eq(24)}$ BETWEEN 6-MONTH RECORDS CALCULATED AS VALUE AT MOST RECENT RECORD MINUS VALUE AT PREVIOUS RECORD, AND LEVEL OF SIGNIFICANCE (p) FOR T-TEST OF HYPOTHESIS THAT MEAN INCREMENT EQUALS ZERO. (GR = General Radio, METRO = Metrosonics).

Dosimeter Brand		$L_{eq(24)}$ increment			
Recent Record	Previous Record	N	$\bar{X}$	S.D.	p
GR	GR	54	-1.0	7.8	NS
METRO	METRO	10	-2.5	5.5	NS
GR	METRO	9	4.9	6.6	.028
METRO	GR	34	-8.5	8.5	<.001

Early in the study, two other dosimeters, Bruel and Kjaer (Model 4424) and Loomis Laboratories (Model 3573) dosimeters were used; observations with these devices yielded mean $L_{eq(24)}$ values of 78.6 dB (n=10) and 76.9 dB (n=16), respectively. These values did not significantly differ from those obtained with the Metrologger. In an attempt to conclusively demonstrate that the mean $L_{eq(24)}$ difference between groups was due to dosimeter differences, two participants each simultaneously wore both a GR dosimeter and a Metrologger. In each case, the $L_{eq(24)}$ for the GR dosimeter was about 7 dB higher than that recorded by the Metrologger.

When the data were analyzed, 134 sets of observations had been made using Metrologgers. Of these, 11 were unusable due to equipment failure. Of the remaining 123 observations, 12 were not analyzed because of incomplete records or permanent hearing pathologies in the participants. The 111 remaining sets of observations break down as indicated in Table 55 with respect to sex and multiple observations on participants.

TABLE 55

METROLOGGER RECORDINGS BY SEX.

Number of Observations	Number of Participants		
	Males	Females	Total
1	31	30	61
2	11	9	20
3	1	2	3
Totals	43	41	84

There is no significant difference between $L_{eq(24)}$ from the first and second observations in boys or girls with multiple observations. Thus, for most analyses described in the following sections, the $L_{eq(24)}$ value used for individuals with multiple observations is the mean of the separate observations. In some cases, the $L_{eq(24)}$ measured at the first observation was used, e.g., to examine associations with other variables recorded at about the same age.

In addition, 163 sets of measurements were made on 109 children using GR dosimeters (54 were multiple measurements). Because differences were detected between dosimeters, the data were not pooled or combined across dosimeters. The data analyzed included only a single value for each individual for a given dosimeter. When an individual had multiple measurements with the same type of dosimeter, the mean of these measurements was used, but if the multiple measurements involved both dosimeters, then the appropriate data were included in each group. As a result, the sample sizes for the sets of General Radio (GR) and Metrosonics (METRO) dosimeter data (109 and 111, respectively) total more than the number of different children tested.

The data were analyzed for age and sex effects within each dosimeter type. Scatter diagrams of $L_{eq(24)}$ plotted against age were examined and regression equations of $L_{eq(24)}$ on age were determined separately by sex. There are no significant age, age^2 or age^3 effects on $L_{eq(24)}$ values for either dosimeter type. However, definite sex effects are present regardless of which dosimeter type was used. As shown in Table 52, boys have a mean $L_{eq(24)}$ about 2 dB higher than that of girls for both GR and Metrosonics dosimeters.

Questionnaire data from all participants indicate that after 9 years of age boys are exposed to more noise than girls (Roche et al., 1978). The dosimetry results support these findings over all ages. The difference is significant ($P \approx 0.04$) with each type of dosimeter. Significant age effects are not noted in the dosimetry data.

Correlations between $L_{eq(24)}$ and left ear AC auditory thresholds (HTLs) at the examination closest to the dosimetry measurement are reported in Table 56. Typically, the AC thresholds for a participant were measured within a few days of the dosimetry assessment. The only significant correlations are for girls tested with the GR dosimeters; these correlations are positive, indicating increased thresholds are associated with increased noise exposure (Table 56).

A correlation implies a linear relationship across the entire range of values. However, individuals at an extreme of a distribution (e.g., for noise exposure) may show a relationship to another variable (e.g., AC auditory threshold) that would not be manifested as a significant correlation. For this reason, the AC hearing thresholds of children in the upper and lower $L_{eq(24)}$ quintiles were compared. The results indicate a positive relationship between AC auditory thresholds and $L_{eq(24)}$ in girls tested with GR dosimeters, but an association is not apparent in boys.

TABLE 56

CORRELATIONS BETWEEN LEFT EAR AC AUDITORY THRESHOLDS AND $L_{eq(24)}$ MEASURED BY GENERAL RADIO (GR) AND METROSONICS (METRO) DOSIMETERS.

	Boys		Girls	
Frequency (kHz)	GR (n=42)	METRO (n=43)	GR (n=43)	METRO (n=41)
1	.19	-.09	.37*	.12
2	-.04	-.06	.37*	.12
4	.12	-.04	.41**	-.08
6	.16	-.07	.57**	.02

* $0.01 < p \leq 0.05$

** $p \leq .01$

Most of the present dosimetric data were collected on weekdays (Monday through Friday). While the days of measurement are distributed throughout the year, there are insufficient data at this time to make a detailed investigation of possible "day of the week" or "seasonal" effects. However, since virtually all the participants are of school age, it was of interest to make a rough categorization by months approximating the school year. Two categories were obtained on the basis of the month in which the dosimetric data were obtained: "in school" (September through May) and "out of school" (June through August). There are no significant differences in mean $L_{eq(24)}$ levels between these two groups using either dosimeter. These findings suggest that children are exposed to similar noise levels whether or not school is in session. While some activities may differ considerably between the two periods, apparently there are compensating factors that tend to equalize noise exposure between "school months" and "non-school months."

SOURCES OF SOUND

Children wearing Metrosonics dosimeters keep a diary of their activities during each 24-hours they wear the noise dosimeters. These activities were coded into 189 categories. An activity category was coded for each 3-minute period throughout the 24 hours of dosimetry measurement; thus, there is an activity (sound source) code for each $L_{eq(3\ min)}$. For these analyses, the 189 sound source categories were arranged into 11 major groupings of sound sources, three of which have subgroupings. The total number of categories including subcategories is 20. These groupings were made after determining that further breakdown produced groups that had too few individuals to allow meaningful analysis.

The data were summarized for each individual by computing an $L_{eq(t)}$ for each activity category, where t is the total time (in multiples of 3 minutes) that the individual was engaged in the activity during the 24-hour period. The $L_{eq(t)}$ is computed as:

$$L_{eq(t)} = 10 \log_{10} \left[\frac{\sum_{i=1}^{n} 10^{\left(\frac{L_{eq(3)i}}{10}\right)}}{n} \right]$$

Where $L_{eq(3)i}$ is the 3 minute L_{eq} of the i^{th} interval, n is the number of 3 minute L_{eq}s corresponding to a specific activity category, and t is the total time in minutes spent on the activity.

In the analyses, the mean L_{eq} associated with a specific activity is computed as the arithmetic average of the $L_{eq(t)}$ over all individuals who spent any time at the specific activity. Thus, the $L_{eq(t)}$s are averaged across individuals without respect to the duration each individual spent at the specific activity and without respect to the total sound energy coming from the activity. An estimate of the latter can be obtained by examining mean $L_{eq(t)}$ and the mean duration. The duration is the average daily time in minutes individuals spent performing a specific activity.

The sound source (activity) categories and subcategories are given below along with a few examples of activities that fall within each category:

1) Home (inside)

   a) Conversation: talking, laughing, baby crying, eating at table, washing dishes by hand, playing with pets, using telephone.

   b) Radio, T.V.: watching T.V., listening to radio, stereo, alarm clock, or T.V. combined with any other activity.

   c) Small appliances: dishwasher, hair dryer, vacuum, fan, air conditioner, washer/dryer.

   d) Miscellaneous "at home": "messing around", bathing, thunderstorm.

2) Sleep: sleeping with or without radio on or other noise source.

3) Vehicle: in car with or without radio, heater, air conditioner, conversations, etc., overhead aircraft noise, traffic noise.

4) Outdoors: going for walk, unspecified outdoor play.

5) Shopping: eating out, malls, grocery store, other stores.

6) Office: Fels Research Institute, doctor's office, office work.

7) Sports, playgrounds: outdoor recreation, spectator or participant in organized sport, jogging, bowling, golf, roller skating, etc.

8) Live music: playing any instrument, singing, concerts.

9) Tools, engines:

   a) Lawnmower, boats: lawnmower, minibikes, boats.

   b) Small tools: drills, sanders, electronic games, other power tools.

10) School bus: riding to and from school on a school bus.

11) School:

   a) Normal class: homeroom, regular classes, e.g., English, math, history.

   b) Special class: shop, typing, movie, crafts.

   c) Assembly, recess: class change, pep rally, lunch time.

   d) Gym class: school sports, locker room.

   e) To and from school: walking, patrol duty, waiting for bus.

   f) Miscellaneous: "messing around."

Within each sound source category or subcategory, four general types of analyses were performed using the $L_{eq(t)}$ and duration as the variables of interest. These analyses were: 1) t-test for sex differences, 2) t-test for differences between those measurements made during the school year (September-May) and those made in the summer (June-August), 3) t-test for race differences, and 4) a regression of the variable on age (in boys, girls, and sexes combined).

Table 57 gives those analyses in which significant differences were observed between groups. There are several sex differences in average $L_{eq(t)}$. Boys experience higher $L_{eq(t)}$s at home than girls. Most of the boy-girl differences in "at home" sounds appear to come from radio and T.V. noise. Boys have a slightly higher $L_{eq(t)}$ for "sleep" than girls. In addition, boys experience more "at school" noise than girls. This is true both in their normal classes and in activities to and from school. In the present study, there are too few girls exposed to sound from tools and engines to make a sex comparison.

In general, there were few race or seasonal differences; in both cases this may partially reflect the fact that only 6 of the 111 observations were from blacks, and only 9 were made during the summer months. However, there is an indication that summer "sleep" noise is significantly higher than it is during the rest of the year. In addition, the sound levels from live music are higher in the summer than during the school year. There are no apparent race differences in $L_{eq(t)}$.

The relationship between age and sound exposure from all activities in which there is a significant age effect in boys or girls are given in Tables 58 and 59. For most activities in which any significant regression on age exists, it is negative, that is, less noise exposure with increasing age. The activities showing a significant negative regression on age are: at home conversation (significant in boys and girls), at home miscellaneous (significant in boys and girls), outdoor sound (significant in boys and girls), normal school classes (significant in boys only), school assembly and recess (significant in boys only), school gym (significant in boys only) and school bus (significant in girls only). There is one activity category in which the regression of sound level on age is positive, that is live music (significant for girls only).

The relationships between activity duration and age are also shown in Tables 58 and 59. Age effects of duration are significant in girls only. The slope is negative (less time spent at activity with increasing age) for sleep, outdoor activities, and normal school classes. Positive slopes occur for vehicle sounds and live music, that is, more time spent performing these activities with increasing age.

Perhaps the question of most compelling interest is, "Do the different sound sources result in different log equivalent sound levels, and what are the major sources of sound exposure for children?" An analysis of variance using the $L_{eq(t)}$ from the 20 sound sources, indicated significant differences among sources. Duncan's multiple range test yielded the groupings described in Tables 60 and 61 for boys and girls, respectively.

TABLE 57

DESCRIPTIVE STATISTICS FOR $L_{eq(t)}$ (dB) IN SOUND SOURCE CATEGORIES IN WHICH SIGNIFICANT ($p<0.05$) SEX, RACE OR SEASONAL EFFECTS ARE PRESENT.

		N	$L_{eq(t)}$	+S.D.	p
Sex					
Home, radio, T.V.	Boys	54	74.1	7.4	0.02
	Girls	52	70.8	7.7	
Sleep	Boys	56	58.3	6.4	0.02
	Girls	55	55.1	8.3	
School, normal class	Boys	25	74.5	5.7	0.002
	Girls	29	68.9	6.6	
To and from school	Boys	7	79.1	6.2	0.02
	Girls	9	69.1	8.2	
School year vs summer					
Sleep	School year	99	56.2	7.8	0.03
	Summer	12	61.2	2.2	
Live music	School year	35	82.4	9.0	0.03
	Summer	7	90.7	6.0	
Race					
No significant differences for any category					

TABLE 58

REGRESSION OF $L_{eq(t)}$ ON AGE AND DURATION ON AGE IN BOYS FOR ACTIVITIES IN WHICH THE SLOPE WAS SIGNIFICANTLY ($p<0.05$) DIFFERENT FROM ZERO IN AT LEAST ONE SEX

Activity	N	Intercept (dB)	Slope (dB/year)	Sig
$L_{eq(t)}$				
At home, conversation	51	85.3±3.4	-0.87±0.24	<.001
At home, miscellaneous	33	93.9±5.9	-1.46±0.42	.001
Outdoor	35	98.7±4.2	-1.77±0.31	<.001
School, normal class	25	84.8±3.4	-0.77±0.25	.005
School assembly recess	25	102.8±3.8	-1.36±0.27	<.001
School gym	8	133.3±17.5	-3.96±1.27	.020
School bus	11	94.5±4.5	-0.73±0.35	.064
Live music	16	81.4±9.0	+0.28±0.60	0.643
Duration		(hours)	(hours/year)	
Sleep	56	11.50±1.0	-0.12±0.07	0.082
Outdoor	35	2.0±0.7	-0.06±0.05	0.250
School, normal class	25	4.9±0.8	-0.05±0.05	0.397
Vehicle	52	0.59±0.37	0.02±0.03	0.432
Music	16	-0.18±1.67	0.13±0.11	0.268

TABLE 59

REGRESSION OF $L_{eq(t)}$ ON AGE AND DURATION ON AGE IN GIRLS FOR ACTIVITIES IN WHICH THE SLOPE WAS SIGNIFICANTLY ($p<0.05$) DIFFERENT FROM ZERO IN AT LEAST ONE SEX

Activity	N	Intercept (dB)	Slope (dB/year)	Sig
$L_{eq(t)}$				
At home, conversation	55	79.0±3.5	-0.55±0.25	.030
At home, miscellaneous	41	84.9±5.2	-0.81±0.36	.020
Outdoor	30	81.8±4.6	-0.81±0.34	.055
School, normal class	29	76.8±4.8	-0.57±0.34	.100
School assembly recess	26	87.7±5.6	-0.47±0.40	.260
School gym	2	--	--	--
School bus	13	108.7±6.2	-1.95±0.44	.001
Live music	26	68.9±7.4	+1.00±0.52	.065
Duration		(hours)	(hours/year)	
Sleep	55	11.89±0.7	-0.17±0.05	0.003
Outdoor	30	2.10±0.5	-0.09±0.03	0.008
School, normal class	29	5.7±0.9	-0.14±0.06	0.034
Vehicle	50	-0.07±0.5	0.08±0.03	0.020
Music	26	-0.62±0.71	0.12±0.05	0.023

TABLE 60

GROUPINGS OF SOUND SOURCE CATEGORIES IN BOYS RESULTING FROM DUNCAN'S MULTIPLE RANGE TEST. BARS CONNECTING CATEGORIES INDICATE MEAN $L_{eq(t)}$ ARE NOT SIGNIFICANTLY DIFFERENT AT THE 0.05 LEVEL OF SIGNIFICANCE WITHIN THE GROUP SO FORMED

Duncan Groupings	Mean $L_{eq(t)}$	N	Source
	91.1	6	lawnmowers, boats
	85.5	16	live music
	85.4	11	school bus
	84.4	25	school assembly, recess
	80.6	9	small tools
	79.6	8	school gym
	79.1	7	to and from school
	77.7	11	home small appliances
	76.7	52	vehicle
	76.4	8	school special classes
	76.3	8	school miscellaneous
	75.8	35	outdoors
	75.8	23	sports, playground
	74.5	25	school normal class
	74.3	22	shopping
	74.1	54	home radio, T.V.
	73.8	33	home miscellaneous
	73.4	51	home conversation
	66.9	28	office
	58.3	56	sleep

TABLE 61

GROUPINGS OF SOUND SOURCE CATEGORIES IN GIRLS RESULTING FROM DUNCAN'S MULTIPLE RANGE TEST. BARS CONNECTING CATEGORIES INDICATE MEAN $L_{eq(t)}$ ARE NOT SIGNIFICANTLY DIFFERENT AT THE 0.05 LEVEL OF SIGNIFICANCE WITHIN THE GROUP SO FORMED

Duncan Groupings	Mean $L_{eq(t)}$	N	Source
	82.8	26	live music
	81.5	13	school bus
	81.4	26	school assembly, recess
	77.2	2	small tools
	76.2	17	sports, playground
	75.1	10	school miscellaneous
	74.7	50	vehicle
	74.1	15	home small appliances
	73.0	30	outdoors
	72.2	41	home miscellaneous
	72.2	1	lawnmowers, boats
	71.6	2	school gym
	71.5	55	home conversation
	71.5	24	shopping
	70.8	52	home radio, T.V.
	70.2	7	school special classes
	69.1	9	to and from school
	68.9	29	school normal class
	65.7	31	office
	55.1	55	sleep

Table 62 gives the N, mean $L_{eq(t)}$ and standard deviations for 20 different sound source categories to which these children are commonly exposed. It presents essentially the same data as given in Tables 60 and 61, but in a manner designed to facilitate comparison of the sexes and comparisons with the corresponding mean durations and standard deviations given in Table 63. Although the means of $L_{eq(t)}$ for boys and girls are significantly different only in the cases indicated in Table 57, a sex trend is very apparent. For 19 of the 20 activity categories, the mean $L_{eq(t)}$ for boys is higher than that for girls, usually by several dB. In the single exception (sports playground), the mean for girls is only 0.4 dB higher than that for boys.

In both sexes, the activities resulting in the greatest average level of sound exposure are from motors ("lawnmowers, boats," and "small power tools"), "live music", "school bus", and "school assembly, recess". These activities are associated with average $L_{eq(t)}$ in excess of 80 dB. Sources of moderate sound exposure are from "school gym", "school special classes", "vehicle", "school miscellaneous", "home small appliances" and, in boys, going "to and from school".

As one might expect, the activity with the lowest average noise exposure is "sleep". The "office" environment to which these children are exposed is a source of very little sound exposure. The other activities including "home miscellaneous", "home conversation", "home radio, T.V.", "school normal classes" and "shopping" are associated with average $L_{eq(t)}$ in the low to mid 70 dB range for both boys and girls. Fortunately, the activities with the low sound exposures are those in which the children spend much of their time (Table 63). However, the activities associated with the highest sound levels (lawnmowers, live music, small power tools and school bus) had appreciable periods of exposure (usually more than one hour for the day of observation) in those children reporting exposure to these sources. There are significant sex differences (boys > girls) in $L_{eq(t)}$ for "to and from school"; school normal class; home, radio, T.V. and sleep. There are no significant sex differences in the durations of reported exposure.

As previously mentioned the mean $L_{eq(t)}$ referred to in Tables 60 and 61 is the arithmetic average of each individual's $L_{eq(t)}$. Thus it is averaged across individuals without respect to the duration each individual spent at the specific activity and without respect to the total sound energy coming from the activity. The mean $L_{eq(t)}$ provides an estimate of the average L_{eq} associated with each activity that an individual might experience, if exposed to the specific activity for any time period. For example, if a boy rode the school bus for one hour, we would estimate his $L_{eq(1\ hr)}$ to 85.4 dB. In this report, no attempt has been made to determine the sound sources from which children receive the greatest sound energy exposure (i.e. combining both duration and sound level).

TABLE 62

DESCRIPTIVE STATISTICS OF $L_{eq(t)}$(dB) FOR TWENTY SOUND SOURCE CATEGORIES IN 56 BOYS AND 55 GIRLS

	BOYS			GIRLS		
Category	N	Mean	S.D.	N	Mean	S.D.
Lawnmowers, boats, motor bikes	6	91.1	7.6	1	72.2	--
Live music	16	85.5	8.4	26	82.8	9.5
School bus	11	85.4	5.7	13	81.5	8.2
School assembly, recess	25	84.4	7.7	26	81.4	7.2
Small power tools	9	80.6	8.1	2	77.2	9.2
School gym	8	79.6	14.4	2	71.6	19.6
To and from school	7	79.1*	6.2	9	69.1*	8.2
Home small appliances	11	77.7	7.1	15	74.1	10.0
Vehicle	52	76.7	6.7	50	74.7	5.8
School special classes	8	76.4	9.6	7	70.2	4.2
School miscellaneous	8	76.3	5.3	10	75.1	7.5
Outdoors	35	75.8	8.8	30	73.0	7.7
Sports, playground	23	75.8	8.7	17	76.2	5.5
School normal class	25	74.5**	5.7	29	68.9**	6.6
Shopping	22	74.3	5.7	24	71.5	7.9
Home radio, T.V.	54	74.1*	7.4	52	70.8*	7.7
Home miscellaneous	33	73.8	9.5	41	72.2	9.0
Home conversation	51	73.4	6.9	55	71.5	7.0
Office	28	66.9	6.8	31	65.7	4.4
Sleep	56	58.3*	6.4	55	55.1*	8.3

* Sex mean difference significant at $p \leq .05$
** Sex mean difference significant at $p \leq .01$

TABLE 63

DESCRIPTIVE STATISTICS OF DURATION (hours) FOR TWENTY SOUND SOURCE CATEGORIES IN 56 BOYS AND 55 GIRLS

CATEGORY	BOYS			GIRLS		
	N	Mean	S.D.	N	Mean	S.D.
Lawnmowers, boats	6	2.1	2.4	1	0.1	--
Live music	16	1.7	1.6	26	1.1	1.0
School bus	11	0.7	0.5	13	0.5	0.3
School assembly, recess	25	1.0	0.3	26	1.0	0.6
Small power tools	9	2.3	2.5	2	0.5	0.1
School gym	8	0.7	0.3	2	0.7	0.1
To and from school	7	0.3	0.2	9	0.5	0.5
Home small appliances	11	0.2	0.2	15	0.4	0.3
Vehicle	52	0.9	0.7	50	1.1	1.0
School special classes	8	1.3	1.1	7	0.8	0.4
School miscellaneous	8	0.3	0.2	10	0.3	0.1
Outdoors	35	1.2	1.0	30	0.9	0.8
Sports, playground	23	1.5	1.2	17	1.2	1.1
School normal class	25	4.2	1.1	29	3.8	1.2
Shopping	22	1.2	1.2	24	1.3	1.2
Home radio, T.V.	54	3.5	2.6	52	4.0	2.6
Home miscellaneous	33	1.1	1.3	41	1.0	1.3
Home conversation	51	2.0	1.7	55	2.6	2.1
Office	28	0.6	1.1	31	0.4	0.7
Sleep	56	9.8	1.9	55	9.6	1.5

NOISE EXPOSURE QUESTIONNAIRES

Noise exposure data were obtained from participant children at each audiometric examination. These data were recorded on detailed noise exposure questionnaires for the intervals of time (usually 6 months) between examinations. The noise exposure questionnaires allow gross estimates of noise exposure from many sources, including home location, television, radios, stereo equipment, musical instruments, live entertainment, toys, motor vehicles, fireworks, guns, power tools, and farm machinery. Answers concerning each noise source were weighted differentially on the basis of the duration of the exposure to the noise or the number of noise-related events, plus the estimated amount of noise per unit time or per event (Roche et al., 1977; 1978). The total noise exposures for the preceding 6 months, called "total interval noise scores", were derived from questionnaires. Despite their many limitations, these scores provide a summary of the questionnaire responses.

Noise "event" scores were also derived from the interval noise exposure questionnaires in order to provide an alternative analytical strategy for the noise exposure assessment instrument. These scores were obtained by assigning values of 1 or 0 to each child depending on whether or not the child had been exposed to an event considered particularly important in regard to noise exposure (Appendix D of Roche et al., 1977). The purpose of the noise event score was to quantify noise exposure by identifying the number of events of a particular type that may be important sources of noise exposure for a child. This approach obviates the uncertainties involved in assigning the values for various intensities and durations of noise that comprise the total noise score. In addition, the total number of events considered to be important sources of noise was calculated for each child (event score). There were nine such events, and consequently, each child's score for each interval was on a scale from 0 to 9. The potential sources of noise that were scored are:

Home - Participant lives within 100 feet of a busy road or under an airport flight pattern.

Loud T. V. - Participant considers the T. V. is usually loud when he or she watches it.

Loud Music - Participant considers the volume of a radio or stereo system is loud when he or she listens to it.

Amplified Musical Instrument - Participant plays an amplified musical instrument.

Loud Vehicles - Participant is often near or involved with motorcycling, motorboating, drag or auto racing, go-carting, minibiking, etc.

Fireworks - Participant had been within 50 feet of exploding firecrackers or small gas engines.

Firearms - Participant has used firearms or been near others using firearms.

Power Tools - Participant used or was near others using power tools such as drills, saws, gasoline lawn mowers, etc.

Farm Machinery - Participant used or was near farm machinery.

Ranges of scores for each noise-related question, and the derived scores from interval noise questionnaires, are given in Tables 64 and 65 for children aged 6-11 and 12-17 years, respectively. With few exceptions, the distributions of the scores are significantly skewed, being truncated at zero. This, of course, is why the means and medians are not coincident, and why many of the medians are zero. For data of this nature, non-parametric statistical approaches are appropriate. There are no apparent sex differences in median score in either age range.

Percentiles for total noise scores in boys and girls from the interval noise histories are broken down into 2-year age groups in Table 66. The extreme points for the interval noise exposure scores represent children with unusually high scores. These extreme scores result primarily from exploding a large number of firecrackers (question 16), or noise exposure from operating or being near power tools (question 23), particularly gasoline lawn mowers.

As mentioned earlier, event scores were devised in an attempt to define noise exposure by identifying the number of different types of events that may be important sources of noise exposure for a child. As shown in Tables 64 and 65, there is little difference between boys and girls in the number of important noise events experienced. These data show higher total noise scores for boys after 14 years (Table 66). This effect is not seen in the median event scores (Figure 53) which presents median event scores at each age for boys and girls.

The total noise scores and the total event scores are imprecise and susceptible to large errors in estimating the sound levels resulting from various activities. One person's exposure to a "loud stereo" or "loud vehicle" may be 10, 20 or more dB higher than that of another person giving the same response to the question. For this reason, an alternative method of analysis was devised. Information contained in the questionnaire was used to group participants into those reporting exposure to a particular category of noise, and those who were not exposed to that noise. The means and medians of each group were compared. The nine categories selected are the components of the total event score. While these categories are arbitrary, they are considered to be the most likely sources of noise exposure; as mentioned earlier, these are: flight pattern, amplified instrument, firearms, loud music, loud T.V., farm machinery, fireworks, loud vehicles, and power tools.

TABLE 64

INTERVAL NOISE SCORES FOR CHILDREN 6-11 YEARS OF AGE

Question	Mean	S.D.	Median	Minimum	Maximum
	BOYS				
(9) home	0.0	0.1	0.0	0.0	1.0
(10) T.V.	0.1	0.3	0.0	0.0	1.0
(11) stereo	0.2	0.4	0.0	0.0	1.0
(12) instrument	0.0	0.2	0.0	0.0	1.0
(15) motor bikes	0.3	0.5	0.0	0.0	1.0
(16) eng/fire wks.	0.3	0.5	0.0	0.0	1.0
(18) guns	0.2	0.4	0.0	0.0	1.0
(23) tools	0.5	0.5	0.0	0.0	1.0
(24) machinery	0.3	0.4	0.0	0.0	1.0
Bus	2.3	2.9	1.7	0.0	15.0
Chain saw	0.6	2.9	0.0	0.0	17.8
Gun	0.0	0.5	0.0	0.0	9.5
Event	1.9	1.5	2.0	0.0	7.0
Total	16.3	18.7	9.8	0.0	142.2
	GIRLS				
(9) home	0.0	0.1	0.0	0.0	1.0
(10) T.V.	0.2	0.4	0.0	0.0	1.0
(11) stereo	0.2	0.4	0.0	0.0	1.0
(12) instrument	0.0	0.2	0.0	0.0	1.0
(15) motor bikes	0.3	0.5	0.0	0.0	1.0
(16) eng/fire wks.	0.2	0.4	0.0	0.0	1.0
(18) guns	0.1	0.3	0.0	0.0	1.0
(23) tools	0.4	0.5	0.0	0.0	1.0
(24) machinery	0.2	0.4	0.0	0.0	1.0
Bus	2.1	2.6	1.1	0.0	10.0
Chain saw	0.3	1.9	0.0	0.0	17.8
Gun	0.6	6.5	0.0	0.0	100.0
Event	1.7	1.4	2.0	0.0	5.0
Total	14.8	21.0	8.5	0.0	236.7

Based on data from approximately 317 examinations in boys and 270 examinations in girls.

TABLE 65

INTERVAL NOISE SCORES FOR CHILDREN 12-17 YEARS OF AGE

Question	Mean	S.D.	Median	Minimum	Maximum
	BOYS				
(9) home	0.0	0.0	0.0	0.0	1.0
(10) T.V.	0.1	0.3	0.0	0.0	1.0
(11) stereo	0.3	0.5	0.0	0.0	1.0
(12) instrument	0.0	0.2	0.0	0.0	1.0
(15) motor bikes	0.4	0.5	0.0	0.0	1.0
(16) eng/fire wks.	0.3	0.5	0.0	0.0	1.0
(18) guns	0.2	0.4	0.0	0.0	1.0
(23) tools	0.7	0.5	1.0	0.0	1.0
(24) machinery	0.2	0.4	0.0	0.0	1.0
Bus	1.9	2.7	0.8	0.0	15.0
Chain saw	1.1	3.9	0.0	0.0	20.0
Gun	2.2	14.7	0.0	0.0	130.0
Event	2.3	1.5	2.0	0.0	7.0
Total	26.5	28.1	17.5	0.0	232.6
	GIRLS				
(9) home	0.0	0.1	0.0	0.0	1.0
(10) T.V.	0.1	0.3	0.0	0.0	1.0
(11) stereo	0.2	0.4	0.0	0.0	1.0
(12) instrument	0.0	0.2	0.0	0.0	1.0
(15) motor bikes	0.4	0.5	0.0	0.0	1.0
(16) eng/fire wks.	0.2	0.4	0.0	0.0	1.0
(18) guns	0.1	0.3	0.0	0.0	1.0
(23) tools	0.5	0.5	0.0	0.0	1.0
(24) machinery	0.2	0.4	0.0	0.0	1.0
Bus	2.0	2.8	0.8	0.0	15.0
Chain saw	0.8	3.4	0.0	0.0	19.5
Gun	1.4	12.2	0.0	0.0	123.2
Event	1.9	1.5	2.0	0.0	7.0
Total	20.3	24.5	12.2	0.0	273.3

Based on data from approximately 436 examinations in boys and 455 examinations in girls.

TABLE 66

PERCENTILE VALUES FOR TOTAL NOISE SCORES FROM INTERVAL NOISE EXPOSURE HISTORIES OF BOYS AND GIRLS 6-21 YEARS OF AGE

		Percentiles				
	N	10	25	50	75	90
Boys						
6-7 years	74	2.6	3.8	7.8	18.8	32.5
8-9 years	119	2.5	4.3	7.8	16.0	33.3
10-11 years	124	2.8	5.9	12.8	27.2	46.2
12-13 years	106	3.6	6.4	13.6	32.4	44.8
14-15 years	159	4.3	8.8	18.2	34.7	56.4
16-17 years	166	3.9	9.3	19.4	42.3	69.6
18-19 years	66	2.4	5.8	18.8	42.6	76.7
20-21 years	14	6.3	13.9	28.0	40.2	66.0
Girls						
6-7 years	65	1.7	3.7	7.2	18.3	30.9
8-9 years	99	2.7	5.2	8.3	16.2	31.9
10-11 years	103	3.3	5.3	10.8	22.0	33.3
12-13 years	102	3.6	6.6	11.7	24.8	47.0
14-15 years	171	3.9	6.5	13.2	26.4	46.5
16-17 years	181	3.0	6.2	11.2	27.1	48.0
18-19 years	65	3.1	4.8	7.5	7.3	23.8
20-21 years	13	1.6	5.3	18.8	38.1	11.6

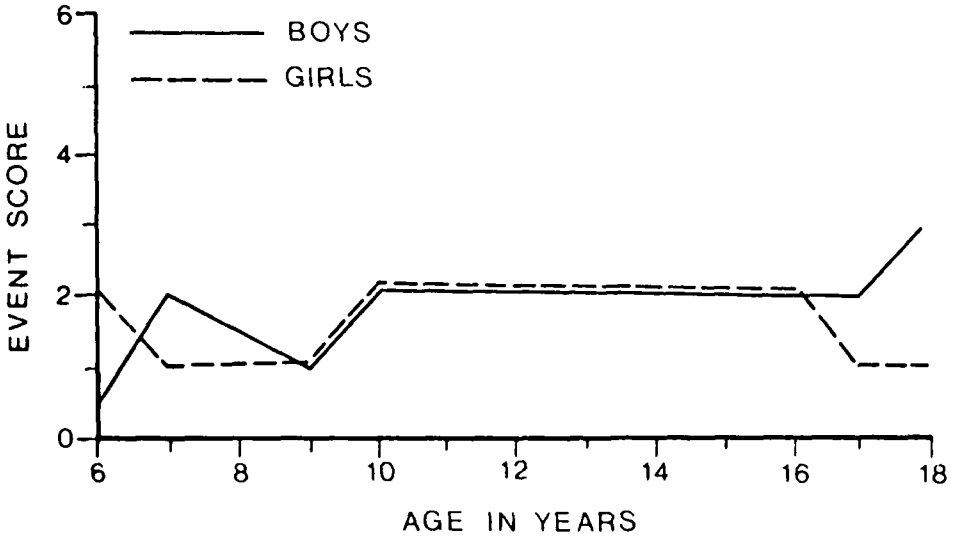


Figure 53 MEDIAN EVENT SCORES FROM INTERVAL NOISE EXPOSURE HISTORIES FOR BOYS AND GIRLS

The percentage of boys and girls 6 to 11 or 12 to 17-years-old who reported exposure to the various noise source categories are summarized in Table 67. For many noise categories, a slightly higher percentage of children in the 12-17 year age group reported exposure than in the younger age group. However, there is relatively little difference between the two age groups in the proportion exposed to any noise category with the possible exception of loud music, for which older children report increased exposure. Sex differences are relatively small for most categories. In the 12 to 17-year-old age group a larger proportion of boys report exposure to firearms, loud stereo and fireworks than do girls.

The median total noise scores obtained from the interval noise exposure histories (Figure 54) indicate consistent sex differences and age trends. For boys and girls, the median total noise scores from the interval histories tend to increase with age. At most ages, boys have greater median total noise scores than girls, the differences becoming most pronounced after the age of 10 years, when the medians for boys increase rapidly. The age trend in noise exposure is also apparent from the Spearman rank correlation coefficients between age and interval total noise exposure scores (Table 68). The correlations are significant in both boys and girls; however, in girls the correlation is quite small. There is also a significant correlation between event scores and age in boys but not in girls (Table 68).

TABLE 67

PROPORTION OF EXAMINATIONS FROM BOYS AND GIRLS AGED 6 TO 11 YEARS AND 12-17 YEARS, RESPECTIVELY, REPORTING EXPOSURE TO SPECIFIC NOISE EVENTS, AND EVENT SCORES > 0 FOR CERTAIN EVENTS

Event	Age 6-11		Age 12-17	
	Boys	Girls	Boys	Girls
Flight pattern	0.6	0.7	0.2	0.7
Amplified instrument	2.5	2.6	4.6	4.8
Firearms	16.1	13.0	22.7	13.6
Loud music	18.3	17.4	29.8	23.3
Loud T.V.	14.2	17.0	10.8	13.0
Farm machinery	27.8	23.3	23.4	23.5
Fireworks	28.4	21.5	33.5	19.3
Loud vehicles	34.7	29.6	39.0	36.7
Power tools	46.4	44.8	69.3	52.7
Chain saw score >0	5.0	1.9	8.5	5.7
Gun score >0	0.3	1.9	3.4	2.2
Total Event score >0	81.4	76.3	89.7	80.9
Bus score >0	61.0	57.1	55.0	57.9

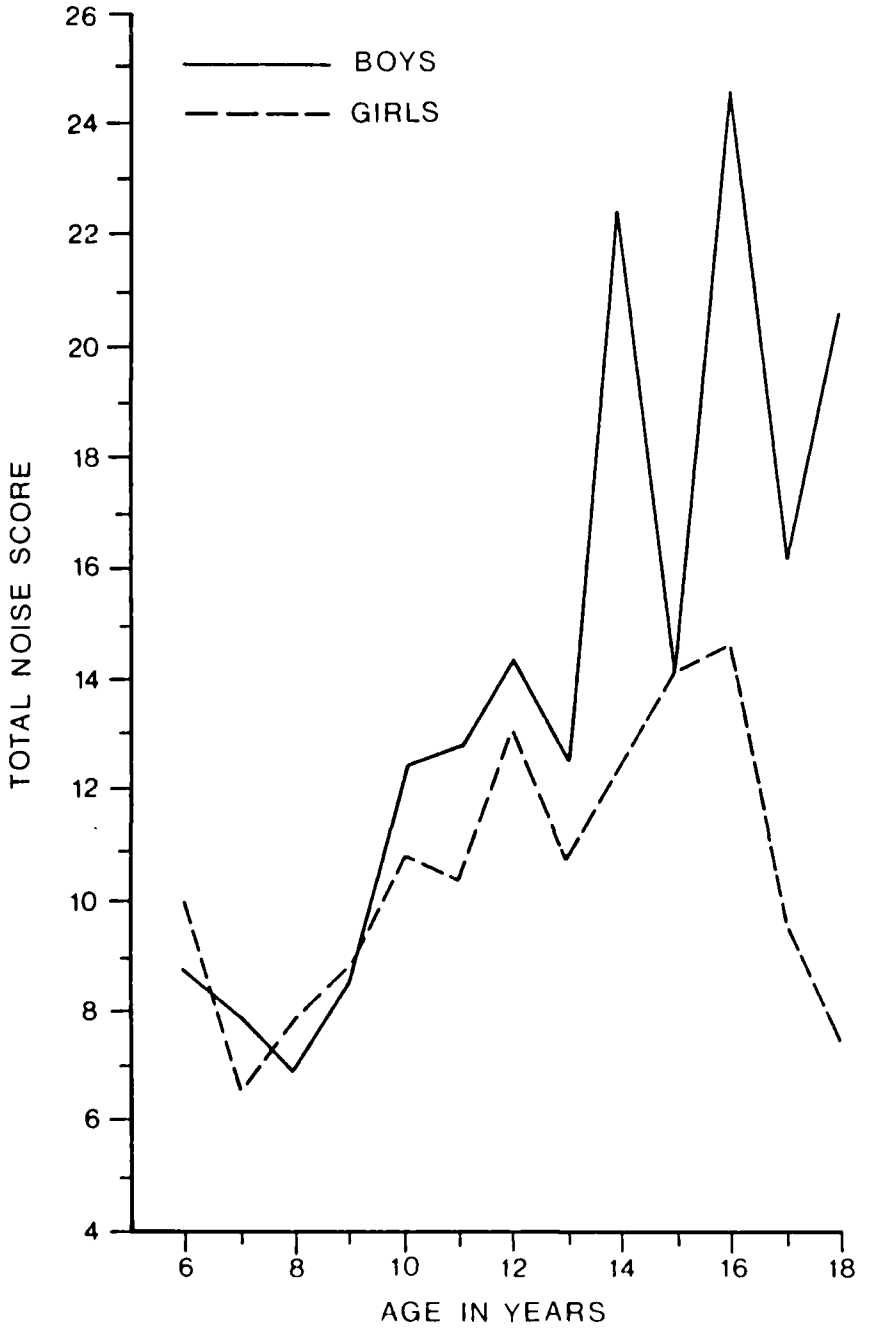


Figure 54 MEDIAN TOTAL NOISE SCORES FROM INTERVAL NOISE EXPOSURE HISTORIES FOR BOYS AND GIRLS

TABLE 68

SPEARMAN RANK CORRELATION COEFFICIENTS BETWEEN AGE AND NOISE SCORES

Period	Boys n	Boys r	Girls n	Girls r
Total interval noise score	807	.24**	778	.08*
Total interval event score	812	.18**	783	.01

* $p \leq .05$

** $p \leq .01$

ASSOCIATIONS BETWEEN QUESTIONNAIRE AND DOSIMETER SOUND EXPOSURE ASSESSMENT

The potential relationships among $L_{eq(24)}$ measured with Metrosonics dosimeters, total noise scores and total event scores from the interval questionnaire covering the period during which the dosimeter was worn were investigated by computing the correlation matrix for these variables. As shown in Table 69, there are no significant correlations between $L_{eq(24)}$ and either questionnaire score in boys or girls. There is, however, a significant correlation in each sex between total noise score and total event score from the questionnaires. In addition, there were no significant correlations between $L_{eq(t)}$ measured for any dosimetry sound source category and the corresponding event scores from the questionnaire. This reflects fundamental differences between these two types of information.

TABLE 69

CORRELATIONS AMONG METROSONICS $L_{eq(24)}$ AND QUESTIONNAIRE NOISE SCORES

	Boys (N=44) Total Noise	Boys (N=44) Total Event	Girls (N=39) Total Noise	Girls (N=39) Total Event
$L_{eq(24)}$	-.16	-.23	-.13	.21
Total Noise	--	.74**	--	.40*

* $p < .05$

** $p < .001$

ASSOCIATIONS BETWEEN AUDITORY THRESHOLDS AND NOISE EXPOSURE

Correlations between pure-tone AC thresholds adjusted for examination effects and total noise scores were computed at each annual age from 7 to 18 years for boys (Table 70) and girls (Table 71). There is no association between total noise scores and AC thresholds across age. In each sex only about 5 percent of the correlations are at the 0.05 level of significance. However, in girls, there tend to be concentrated at 14-16 years of age. As mentioned earlier, these are no significant correlations between $L_{eq(24)}$ measured with Metrosonics dosimeters and AC thresholds. There are, however, significant correlations at each frequency between thresholds and $L_{eq(24)}$ measured with General Radio Dosimeters in girls (Table 56).

ASSOCIATIONS BETWEEN AUDITORY THRESHOLDS, BLOOD PRESSURE AND TOTAL NOISE SCORES

To determine if associations were present between systolic or diastolic blood pressure and auditory threshold, ear- and frequency-specific multiple regression equations were computed for boys and girls at ages 7, 11, 15 and 17 years. This produced 160 regression equations (2 blood pressures x 4 ages x 2 sexes x 2 ears x 5 frequencies). At each age, the blood pressures were adjusted for the body size of the children and AC thresholds were adjusted for examination effects. The relationship between BP and AC thresholds is significant ($p<0.05$) in only 9 of the 160 regression equations; this is about the number expected by chance. The significant correlations were not concentrated at 4 or 6 kHz.

Multiple regression analyses among systolic or diastolic blood pressure and weight/stature^2 (W/S^2) and total noise scores were also computed for each sex at ages 7, 11, 15 and 17 years. The results are significant only for systolic blood pressure in boys and girls at age 15 years and in boys at age 7 years. At 15 years of age, the slope of the equation indicates a decrease of 0.2 noise units per mm Hg in boys and girls. In 7-year-old boys the relationship is an increase of 0.3 noise units per mm Hg.

ASSOCIATIONS AMONG SIZE, MATURITY AND NOISE EXPOSURE

A sex specific multiple regression analysis of weight/stature^2 (W/S^2) and relative skeletal age (skeletal age less chronological age, see p. 35) on total interval noise score was computed for the children at whole ages between 6 and 18 years. A similar analysis including age at menarche was computed for the girls also. These analyses were conducted to determine if possible relationships exist among a child's body size, the level of biological maturity, and the amount of noise exposure as determined from the questionnaires. In boys, the only significant association appears at 10 years of age where the boys with high values of W/S^2 tend to have high noise scores. This relationship is no longer significant after the effect of relative skeletal age is removed. Similarly, the regression analysis of W/S^2, relative skeletal age and noise scores in the girls has only one significant association at age 7 years. The more mature girls have higher noise scores irrespective of their values for W/S^2.

At older ages among the girls, age at menarche becomes an additional measure of maturity and a more informative structure emerged from the analysis despite the small sample sizes. At 13 years of age, the more mature girls are heavier for their stature and appear to be exposed to significantly greater amounts of noise than the less mature girls. This relationship between maturity and noise exposure continues to exist at 14 and 15 years of age. After 15 years of age, almost all the girls in the study have attained menarche or adult skeletal maturity.

TABLE 70

PEARSON PRODUCT MOMENT CORRELATIONS AT ANNUAL AGES BETWEEN PURE TONE AC AUDITORY THRESHOLD LEVELS (CORRECTED FOR EXAMINATION EFFECTS) MEASURED IN THE RIGHT (R) AND LEFT (L) EARS AT VARIOUS REQUENCIES AND TOTAL INTERVAL NOISE EXPOSURE SCORES IN GIRLS

Age years	N	Frequency (kHz) 0.5 R	0.5 L	1.0 R	1.0 L	2.0 R	2.0 L	4.0 R	4.0 L	6.0 R	6.0 L
7	41	-.06	-.03	-.06	-.02	.01	-.05	-.02	-.001	.06	.05
8	39	-.14	-.06	-.20	-.14	-.09	.04	-.005	-.12	-.03	-.10
9	58	-.04	-.11	-.08	-.03	-.04	-.17	-.02	-.04	-.09	-.11
10	47	.19	.15	.12	.09	.16	.15	.22	.24	.18	.13
11	55	.03	-.02	.007	-.03	-.03	-.03	.13	.16	.05	.16
12	47	.06	-.12	.08	.04	.02	-.02	.007	-.02	.06	.09
13	61	.04	-.04	.14	-.03	-.11	.04	-.10	-.05	-.22	-.12
14	83	.06	.03	-.08	-.003	.11	.07	.05	.02	.42*	.14
15	97	.37*	.29*	.28*	.04	.19	.14	.17	.11	.38*	.26*
16	89	.17	.15	.25*	.04	.27*	.16	.24*	-.11	.19	.04
17	97	-.05	-.02	-.03	.12	.07	.07	.17	.08	.18	.06
18	31	-.09	.21	-.16	.10	-.03	.15	.09	-.24	-.17	.04

* $p < 0.05$

TABLE 71

PEARSON PRODUCT MOMENT CORRELATIONS AT ANNUAL AGES BETWEEN PURE TONE AC AUDITORY THRESHOLD LEVELS (CORRECTED FOR EXAMINATION EFFECTS) MEASURED IN THE RIGHT (R) AND LEFT (L) EARS AT VARIOUS FREQUENCIES AND TOTAL INTERVAL NOISE EXPOSURE SCORES IN BOYS

Age		Frequency (kHz)									
		0.5		1.0		2.0		4.0		6.0	
years	N	R	L	R	L	R	L	R	L	R	L
7	52	-.21	-.35*	-.27*	-.36*	-.21	-.16	-.12	-.28*	-.17	-.23
8	66	-.07	-.21	-.19	-.16	-.06	-.16	-.12	-.06	-.04	-.08
9	57	-.04	-.04	.07	.01	-.04	.12	-.12	-.09	-.07	-.04
10	65	.19	.16	.21	.22	.09	.10	.06	.14	.17	.09
11	61	.11	.003	.12	.09	.0005	-.04	.12	.05	-.02	.14
12	61	-.02	.04	-.05	-.03	-.06	.11	-.12	.06	.01	-.15
13	46	-.38*	-.34*	-.40*	-.22	-.28	-.23	-.29	-.15	-.28	-.26
14	70	.02	-.04	.06	.10	.11	.23	.05	.09	.04	.02
15	86	.09	-.05	-.07	.06	.03	.26*	.05	.25*	-.05	.06
16	82	.12	-.001	.05	-.11	-.10	.16	.10	.03	-.0006	.09
17	85	-.04	-.05	-.12	-.05	-.07	-.05	.03	.05	.002	-.04
18	41	-.13	-.15	-.02	-.09	-.12	-.09	-.20	-.09	-.13	-.10

* $p < 0.05$

SUMMARY AND DISCUSSION

EXAMINATION EFFECTS

The results of the present study were derived from analyses of 1964 serial audiometric examinations of 270 children. A portion of these results, the recorded air conduction (AC) thresholds for children with more than a single visit, are subject to possible "examination effects." The term "examination effects" is used to describe the combined influence of a complex of mechanisms that cause the findings at an examination to vary systematically from those at one or more preceding examinations. The possible mechanisms include increases in familiarity with the test procedure, the test environment and the technicians, changes in motivation to perform as well as possible and changes in exposure to noise because of an added interest in hearing conservation due to participation in the study. Examination effects are a potential problem in longitudinal studies; however, changes within individuals can be analyzed only if the data are serial.

The total examination effect was analyzed and the recorded data were adjusted accordingly, before any analyses of the present data were conducted. Consequently, all subsequent analyses are based upon estimates of data that would have been recorded had every examination been a first examination. Three points need to be made in regard to these adjustments. First, the adjustments to the raw data are frequency-and ear-specific, and are based upon estimates of the total examination effect. Attempts have not been made to separate this effect into those effects associated with habituation, motivation, and noise exposure. Secondly, the adjustments are applied so that all the recorded AC thresholds match estimates of what would have been observed at each child's first examination. This was the obvious choice because, a priori, there is no examination effect at the first examination. Although every participant had a first examination, the AC threshold data for some of the participants could not be used because of equipment failure in the initial phase of this study. The data from such examinations were not analyzed, but the examinations were counted to establish the number and sequence of examinations for individuals. Thirdly, examination effects have been analyzed only in regard to AC thresholds. The only other serial records in the present study that could show examination effects are those for speech discrimination. The serial sets of data for children with a particular tape are too short to allow the analysis of examination effects.

Two statistical methods were used to estimate the total examination effect upon serial AC thresholds. In each of these analyses, data recorded from participants with temporary or permanent pathologies were excluded because effects due to pathology would have obscured the examination effect. The first was a multivariate analysis of variance for repeated measures. This method requires a complete set of data for individuals, and consequently, estimates of the total examination effect could be made for the first 8 examinations only. Estimates of the total examination effect could not be computed using participants with more than eight consecutive examinations because of an inadequate sample size. The repeated measures analysis of variance shows a significant linear effect of age at first examination in the direction that older participants tend to have lower thresholds. Therefore, age effects were removed before further analyses were conducted. The total examination effect upon AC thresholds of these children, independent of age, is about 4 dB. This total effect extends over eight examinations at 6-month intervals and varies

slightly by ear and frequency. The frequency specific change in AC thresholds due to the examination effect is in the direction of better hearing (negative slopes) and tends to be linear for each frequency except at 4 kHz where deviations from linearity occur at the second and third examinations. Also, total examination effect irrespective of frequency tends to be larger in the right ear than the left ear. Systematically, the right ear is tested first; therefore, it can be speculated that the findings for the right ear reflect more habituation and motivation than those for the left ear.

This method of estimating the total examination effect is not fully appropriate for application to the present data because it was necessary to adjust each recorded threshold in order to analyze the relationship of AC thresholds to other data for the same individuals. Such adjustments were obtained, however, by using a linear regression of AC thresholds against examination order for all the children from 6 to 18 years of age. The changes in AC thresholds due to the total examination effect demonstrated by this regression analysis are about the same as those from the multivariate analysis for repeated measures. The total examination effect on AC thresholds does not differ by sex or ear but is significantly larger for the higher frequencies (4 and 6 kHz) than for the other three frequencies tested.

The mean changes in AC thresholds due to the total examination effect are significantly different among the children when they are grouped by age. The mean changes for children 6 to 10 or 14 to 18 years of age are larger than that of children 10 to 14 years of age. Also, the mean examination effects are greater for boys than girls in the youngest group. The reasons for these differences are unknown. It could be postulated that the examination effect is larger at young ages because young children are more anxious than others at early examinations, and there is a rapid decrease in this anxiety. However, the examination effect also tends to be large in the children aged more than 14 years. Perhaps, they are quicker to develop hearing strategies that could assist test performance. Data recorded for the children after 18 years of age were analyzed separately because the examinations were conducted annually at these ages, and it was considered the associated examination effects could differ from those at 6-month examinations.

These changes in AC thresholds due to examination effects determined by either method of analysis are in general agreement with the findings of Robinson et al. (1979) and Royster et al. (1980) for adults. They differ from some earlier data where skewed attenuation in examination effects were reported after the third examination (Ward, 1957; Zwislocki, 1958). This difference may be due to the fact that the present examinations were at more widely spaced intervals. The estimation of the magnitude of the total examination effect in those children is important because in interpreting repeated tests of individuals, examination effects may be mistaken for improvements in AC thresholds due to intervention. Examination effects are less important in clinical circumstances because they are small relative to clinically significant AC threshold levels.

AGE EFFECTS

Linear regressions of AC thresholds on age were computed after the examination effect was removed. Data for those children with temporary or permanent pathologies were again excluded from this analysis. The findings are in general agreement with those for data at first examinations when there are no examination effects.

Neither intercepts nor slopes from the regressions of AC thresholds on age differ significantly between ears in boys and girls except for the intercept at 0.5 kHz, but there are significant differences in the slopes of AC thresholds on age among frequencies. The lower frequencies have a more rapid improvement in hearing ability with age than the higher frequencies. i.e., more negative slopes. Despite a good linear fit to the data of children 6 to 18 years, analyses for shorter age ranges 6 to 10, 10 to 14, and 14 to 18 years indicate that the decreases in AC thresholds with age, or the improvement in hearing, is less in the older age groups. Also, there are some sex differences within these shorter age ranges. The slopes are more negative for girls than boys between 6 and 10 years of age, but the reverse is found from 10 to 14 years with little sex difference in the oldest age group. Also, the improvement in hearing ability with age in the younger age group is more marked in the right ear than in the left ear.

CROSS-SECTIONAL STATISTICS

Regression equations of AC thresholds on age summarize many important aspects of the data contained in the distribution statistics for AC thresholds by year of age (Tables 14 to 39). In these distribution statistics, data from many of the same participants, free of examination effects or the effects of temporary or permanent pathologies, are included at more than one age. This introduces a bias because thresholds are almost certainly correlated across age, and the new information obtained from the repeated examination of an individual is less than what would be obtained by examination of a different individual at each age. However, the central purpose of the present study is to examine changes in hearing ability in relation to environmental noise and this necessitates a longitudinal design. The present data base is almost purely longitudinal, and great efforts have been made to retain the cooperation of the children and their families necessary to achieve this.

The mean and median thresholds for the left and right ears are generally about +2 dB until 12 years of age, after which they are near zero in each sex. The variances of the AC thresholds are high, reflecting true variability in the population and the relatively large measurement errors. The median thresholds at 4 kHz are generally about 3 dB higher than those at 1 kHz (D4 in tables) which may be due to the effects of noise. These results are similar to those from some earlier reports that hearing sensitivity tends to increase with age in children (Black, 1939; Reymert and Rotman, 1946; Kennedy, 1957). However, there are also several reports that hearing sensitivity decreases in adolescence (Lipscomb, 1972, 1975; Roberts and Ahuja, 1975). Some of the differences between the present findings and those from earlier studies may reflect the fact that few earlier investigations were restricted to data from otologically normal children. Also, the present study was conducted with a high level of precision and the participants were highly motivated and somewhat higher socio-economically than many other groups that have been studied.

There are more significant lateral differences in AC thresholds than would be expected due to chance. The directions of these differences indicate that hearing sensitivity tends to be poorer in the right ear than in the left ear. Most earlier studies report there are no significant lateral differences in hearing sensitivity (Kodman and Sperrazzo, 1959; Glorig and Roberts, 1965; Roberts and Auja, 1975). Findings in agreement with the present data have been reported by Glorig et al. (1957).

Some relevant data have been collected in the present study, but they are insufficient to allow definite analyses of the relationships between the changes in AC thresholds during adolescence and during young adulthood within individuals.

COMPARISONS WITH NCHS DATA

Tables 14 to 39 are necessary to document the AC threshold status of the study sample; however, it is not suggested that they replace the excellent reference data obtained from the NCHS surveys although there are some limitations to the latter data. The NCHS data are from a random sample of the non-institutionalized U.S. population, within specified age ranges,and children with temporary and permanent pathologies affecting hearing ability were included in the NCHS surveys. Also, there are unexplained major changes in mean threshold levels from 11 to 12 years of age particularly at 4 and 6 kHz. The 11- and 12-year-old children were examined in different surveys, and procedural differences could be responsible for the changes. Finally, there is some bias in the NCHS data because they are not purely cross-sectional as is generally believed. About one-third of the children examined in Cycle III (12 to 17 years) had been examined previously in Cycle II (7 to 11 years; Zack et al., 1979).

In the present study, there are marked increases in AC thresholds after 14 years at 0.5 and 2 kHz for girls but little change for boys at the same frequencies. At 1, 4, and 6 kHz, the sex differences in AC thresholds are slight at all ages. In the NCHS survey data, there are no sex differences in AC thresholds at any frequency for the children until after 11 years of age when the AC thresholds tend to be higher in girls than boys but by very small amounts at the lower frequencies (Roberts and Huber, 1970; Roberts and Ahuja, 1975). The changes in AC thresholds with age in the present study are in agreement with those of Robinson et al. (1977). However, other researchers have reported that AC thresholds tend to be higher in boys than girls at all ages and that the sex difference increases somewhat with age (Ciocco and Palmer, 1941; Kodman et al., 1957; Crum, 1968; Lipscomb, 1972; Sheridan, 1972; Cozad et al., 1974).

In other comparisons between the present data and the NCHS data, the differences between median AC thresholds at a frequency, for children 6 to 11 years of age range from 0 to 4 dB except at 6 kHz, where the difference is almost consistently 6 dB. The Fels children have the lower thresholds at almost all ages. At the older ages, the difference in median AC thresholds increases to 8 to 12 dB, and the Fels children have consistently lower thresholds. At 0.5 and 4 kHz, there is a sudden increase in the differences between the NCHS data sets at 12 years due to a marked difference between the NCHS values from Cycle II (6 to 11 years) and from Cycle III (12 to 17 years). The reason for this difference is not likely to be biological.

There are additional differences between the Fels and NCHS data sets. For example, the AC thresholds for the Fels girls at 1 and 2 kHz improve by about 15 dB after 12 years, but there is no corresponding change in the NCHS data. The reasons for these differences in patterns of change are unexplained. The possibility that they are associated with the inclusion of children with aural pathologies in the NCHS sample will be discussed later.

Sex-associated differences in AC thresholds at 4 kHz were examined using cumulative frequency distributions. The sex difference between pairs of distributions are small at 7, 10, 12, 13, and 14 years. However, at 8 and 9 years, the distributions for the boys are about 2 dB lower than those for the girls. There is an opposite difference of similar magnitude at 15 years. At 16 and 17 years, the cumulative frequency distributions for the girls are steeper than those for the boys indicating a smaller variance in the girls. Also, the upper ends of the distributions for the girls are relatively truncated compared with those for the boys which indicates less tendency to high thresholds. This latter finding confirms previous reports that elevated thresholds are more common in boys than girls particularly in the latter teenage period (Ciocco, 1936; Cozad et al., 1974; Berger et al., 1977; Robinson et al., 1977).

Comparisons between cumulative frequency distributions for AC thresholds at 4 kHz in the better ear in the Fels and similar NCHS data indicate that hearing sensitivity tends to be better in the Fels group by about 2 dB to 11 years and afterwards by about 6 dB. In these comparisons the NCHS distributions extend to the left of the Fels distributions at the lower threshold ranges because the audiometers used differ in their lower limits. Also, the NCHS cumulative frequency distributions extend further to the right at the upper threshold levels. It could be speculated that this shift is due to the inclusion of some children and youths with aural pathologies in the NCHS study group.

When data from children with permanent or temporary aural pathologies are included in the Fels data set, there are reductions in the differences between thresholds for the Fels and NCHS data at corresponding frequency distributions. This is to be expected because aural pathologies are often associated with elevated AC thresholds (Katz, 1978; Brooks, 1979; Lildholdt et al., 1980). This fact is also confirmed in the NCHS data (Roberts and Huber, 1970; Roberts and Ahuja, 1975) and in the Fels data (Roche et al., 1979). However, despite the inclusion of children with permanent and temporary pathologies in the Fels data, the cumulative frequency distributions for thresholds at 4 kHz are still to the left of those for the NCHS survey groups at most younger ages. After 12 years of age, the difference between corresponding distributions is about 4 dB. The tendency for the NCHS distributions to extend further to the right at the upper ends of the distributions remains unchanged. It must be concluded that factors other than the inclusion of children and youth with aural pathologies are responsible for the differences between the Fels and NCHS data sets.

SIGNIFICANT THRESHOLD SHIFTS

Analyses of long-term and short-term significant threshold shifts included examination data for those children with temporary pathology, i.e., abnormal otoscopy and/or tympanography. The inclusion of these data in the regressions of AC thresholds on age result in a decrease in the negative value of the slopes of the equations from what they had been when the data were excluded. This result may not agree with that of Saltzman (1949)but is similar to the results of several other researchers (Carter et al., 1978; Robinson and Sutton, 1978; Robinson et al., 1979). They reported that samples of children with otological problems had slightly higher thresholds than samples of children without problems.

The largest positive residual from the regressions of AC thresholds on age for individuals was used as an estimate of short-term threshold shift. The results are tentative because of the limits of fitting regression lines to a small number of data points. However, the fact that the majority of the largest residuals are positive indicates that their occurrence is not due to chance. Also, the tendency for the largest positive residual for a child to occur in all frequencies at the same examination indicates that whatever produced the shift had an effect upon a broad spectrum of the child's auditory ability. This fact would appear to indicate that an abrupt loud noise is an unlikely cause of a short-term threshold shift in most cases. Loud noise has a tendency to produce effects more often at specific frequencies. Also, most of the children with either the largest long-term shift or a short-term shift over +20 dB, for whom some association could be made with their medical or noise exposure data, reported a head cold or allergy. Associations with noise could be made for only two children. One of these associations, however, was between an increase in the child's AC thresholds over those at the previous visit and her attendance at a rock concert a few days before the examination.

The significant shifts in AC thresholds of these children are inconclusive, but the trends in the data are similar to the findings of others. The single known association in these data between a significant threshold shift and rock music agrees with the work of Hanson (1975). Associations between thresholds and other kinds of noise exposure are discussed elsewhere. Also, significant threshold shifts occur more frequently in boys than girls. In this study, associations between thresholds and exposure to firearms and machinery, as reported by Weber and co-workers (1967) and Litke (1971 could not be made.

RELATIONSHIPS OF AIR CONDUCTION THRESHOLDS TO AGE AFTER 18 YEARS

An interpretation of the changes in AC thresholds in individuals between 18 and 25 years of age is limited by the few participants over age 20 years, but values of the thresholds for these participants are very similar to NCHS data for young adults at the same ages (Glorig and Roberts, 1965). The improvement in hearing ability during adolescence appears to continue for a short period after 18 years of age. However, only a few of the participants had serial data during adolescence that extended past 20 years of age. The data from these few participants indicate a possible tendency for hearing ability to start to decrease with age. A decrease in hearing ability with age has been demonstrated in the cross-sectional NCHS data (Glorig and Roberts, 1965). It is not known whether the change in the hearing of these participants is one that occurs naturally with age, or is the result of the cumulative effects of noise exposure, both inside and outside, plus the occupational environment. The decrease might also be due to noise exposure in their occupational environment. As the Fels participants grow older, more data will be collected regarding changes in the hearing abilities of individuals in this young adult period. A more conclusive determination of the changes will then be possible.

SPEECH DISCRIMINATION

Speech discrimination tests were conducted in the present study in order to detect possible relationships with AC thresholds and noise exposure. However, the present results are inconclusive due to a change of tapes in the middle of data collection, and as a result, a limited amount of data were collected for each tape.

The first Tape (Tape 1, Tests A and B) used a male speaker and a signal/noise ratio of 0 dB. Tape 2 (Test B) was introduced because it employed a female speaker and a +6 dB signal/noise ratio. Part of the rationale for Tape 2 is that children generally encounter more female than male primary and secondary education teachers, thus the new tape should be more representative of a classroom scenario. The children had significantly higher speech discrimination scores (SDS) on Tape 1, Test A, than on Tape 2, Test B. This difference should not be due to the differences in test materials (Katz, 1978). Also, the difference in the signal/noise ratio between the tests should have produced the opposite effect, if any, upon the SDS of normal children (Surr and Schwartz, 1980). Thus, it would appear that a possible remaining cause of the differences in SDS between tapes and tests is the sex of the speaker's voice. This would seem unlikely; however, Gruber and Gaebelein (1979) have reported that under controlled conditions male speakers get the attention of an audience more easily than female speakers.

The breakdown of SDS by groups of words within a test indicates some intra-test examination effect. Regardless of the tape or test, children make more mistakes in the first 10 words of the test than in the remaining groupings. As more SDS are collected, inter- and intra-test examination effects will possibly become more evident as will individual serial changes in SDS. Additional SDS may provide more conclusive results in relation to the AC thresholds of children.

EYE COLOR AND THRESHOLDS

Despite reports by several researchers (Tota and Bocci, 1967; Carter, 1980; Carlin and McCroskey, 1980; Ward, 1980) that eye color or pigmentation of the iris appears to be associated with a hearing loss, a similar association was not detected in the present study. While it is possible that eye color may be related in some way to an individual's response to an auditory stimulus, a more general relationship to AC thresholds in a normal sample of children appears remote. However, data from this or other investigations are presently inadequate to provide a suitable answer. In addition, there are significant methodological differences among investigations.

COMPARISON OF DOSIMETERS

In comparing dosimeters, significant difference in mean $L_{eq(24)}$ between the GR dosimeters and the Metrologgers can probably be explained by the differences in the design of the two instrument types. Variations in the experimental protocol should not have contributed to these group differences. All dosimeters were calibrated at the beginning and end of each recording period, and in most cases, the same calibrator was used for both dosimeters. Even though there are no significant differences in mean $L_{eq(24)}$ between two groups using GR dosimeters with different dynamic ranges, the 21 test conducted with the GR dosimeter with the 60 to 110 dB dynamic range provided slightly lower mean $L_{eq(24)}$ (82.49 versus 83.81 dB) than the 145 tests conducted with the 80 to 130 dB dynamic range GR and Metrosonics dosimeters. This is expected due to the problem described earlier regarding inflated values caused by crossing the threshold. The fact that the mean $L_{eq(24)}$ values for GR dosimeters with different dynamic ranges were not significantly different indicates that, although the GR dosimeter with an 80 to 130 dB dynamic range has the potential for substantially overestimating sound exposure, this problem is apparently not serious with the sources of sound to which children are exposed.

While in theory, sampling could have produced group differences by chance, age is the only obvious variable by which the two groups differ. The fact that age effects are absent in each set of dosimeter data, and that the mean $L_{eq(24)}$ values are significantly different between dosimeters, even for a sub-group aged 16 years and older, strengthens the argument that age differences between the two groups do not contribute to group differences. In those children tested at successive examinations with both dosimeter types, the GR dosimeter recorded $L_{eq(24)}$ values five to eight dB higher than the Metrosonics dosimeter which is consistent with the overall mean differences between groups. Furthermore, when a child simultaneously wore both dosimeters, the GR dosimeter recorded an $L_{eq(24)}$ about 7 dB higher than the Metrosonics dosimeter. These findings make it difficult to accept that chance sampling differences, or other procedural factors differing between the groups, produced the discrepancy.

The source of difference in mean $L_{eq(24)}$ values between groups tested with the GR dosimeters and those tested with Metrologgers is explained by the difference in the recording properties of the two instruments with different types of noise patterns as shown in Figure 52. In addition to the systematic difference shown in Figure 52, the Metrologgers fail to record some of the energy of highly fluctuating sounds that might come from loud shouts, claps, hammering, etc., because of their lower crest factor. The number of dB by which the Metrologger might underestimate daily exposure to such sounds is difficult to determine accurately. To illustrate the amount of error that might occur, 100 one-second shouts at 115 dB will produce a $L_{eq(24)}$ of 96 dB. The Metrologger would record a 91.5 dB $L_{eq(24)}$ from these sounds, resulting in a 4.5 dB underestimation. The small differences between

the two dynamic ranges of the GR dosimeter seem to indicate that, in practice, the GR instrument probably overestimates $L_{eq(24)}$ by only 1 or 2 dB due to the noise fluctuating about the threshold of the instrument. If this be true, the deviation from the true $L_{eq(24)}$ caused by the low crest factor of the Metrosonics instrument is probably 5 or 6 dB.

Clearly, a more accurate measurement of sound exposure in children than that obtained with the Metrosonics dosimeter could be achieved with an instrument having a crest factor greater than 10 dB. However, because the Metrologgers record and store sound exposure for each 3-minute period, they provide a unique opportunity to obtain information about noise exposure from specific sources and to better investigate the sound sources in the acoustic environments of children. Therefore, in the latter part of the present study, Metrologgers were used exclusively. Regardless of which dosimeter might be considered more accurate, it is clear that the typical sound exposure of children is considerable. The true average daily sound exposure in the children studied is probably between that recorded with the Metrologgers and that recorded with the GR dosimeters.

DAILY SOUND EXPOSURE

The results indicate a significant and consistent sex difference in noise exposure, whether measured by dosimetry or questionnaire. However, further studies confirming this finding of more noise exposure in boys than in girls should be conducted. There are major differences between the dosimetry and questionnaire noise assessment approaches. The questionnaire estimates all noise exposure during a six-month period, while the dosimeter records exposure during a 24-hour period. The noise exposure data from questionnaires also suggest a positive age effect (increasing noise with increasing age), especially in boys (Roche et al., 1978), but there is no indication of a similar trend in the dosimetry data.

Schori and McGatha (1978) reported an average $L_{eq(24)}$ of 73.3 dB in the results of a dosimetric study of 50 individuals 5 to 54 years of age. In that study, sex differences were not observed and age trends were not examined; however, participants were monitored 24-hours per day for seven consecutive days while they went about their normal activities. The dosimeters used were Loomis Laboratories and Bruel and Kjaer brands similar to those used in the early part of the present study. Ten subjects aged 5 to 16 years ($\bar{X}$ = 12.4 years) were included among those studied by Schori and McGatha (1978). These children had a mean $L_{eq(24)}$ of 76.2 dB, which was the highest mean $L_{eq(24)}$ of any category although it was not significantly different from the others. Other categories (all adults) were "factory/commercial," "office," "homemaker," and "college," and each consisted of ten subjects. Little variation occurred in daily $L_{eq(24)}$ values within participants, indicating that a single daily sample was almost as representative of the individual's typical daily noise exposure as seven days of measurement.

While one should use caution in extrapolating from the findings of Schori and McGatha (1978), a one-day 24-hour sampling of noise was considered fairly representative of the typical noise exposure of a given individual in the present study. This is supported by the standard deviation of the

differences between repeated measurements using the same dosimeter which, in the current study, is between 6 and 8 dB (Table 53). Furthermore, the mean of the absolute value of these increments is only 5.8 dB with a range of 0.1 to 19.5 dB.

The Environmental Protection Agency (EPA) has estimated that the typical average daily noise exposure ($L_{eq(24)}$) for "school children" is about 77 dB in both urban and suburban locations (EPA, 1974; von Gierke, 1975). These estimates were based on various assumptions including established EPA average day and night urban and suburban noise levels, as well as levels for various activities based on previous EPA reports on appliance, transportation, and aircraft noise. The EPA estimate is virtually identical to that actually measured by Schori and McGatha (1978) and to that obtained in the current study using the Metrologgers (77.8 dB in boys and 75.2 dB in girls). The mean $L_{eq(24)}$ level measured with the GR dosimeters is about seven dB higher.

The positive relationship between $L_{eq(24)}$ and AC auditory thresholds in girls in the present study should be interpreted with caution. The fact that in boys there is no indication of associations between AC auditory thresholds and $L_{eq(24)}$, measured by either correlations or comparisons between extreme groups, suggests that the relationship noted in girls may be spurious. Although the relationship is present at all frequencies in girls for data obtained with the GR dosimeters, data obtained with the Metrologgers are not in agreement. However, since an association between noise and hearing is well-established, the relationship in the present study cannot be ignored and further investigation is warranted.

The EPA has calculated that, as a consequence of a long-term (i.e., 40 years) daily exposure to a $L_{eq(24)}$ of greater than 70 dB, there may be a measurable (greater than 5 dB) noise-induced permanent threshold shift at 4 kHz (EPA, 1974). The fact that most youth apparently experience levels considerably in excess of this level implies they are at risk of suffering permanent noise-induced threshold shifts. However, the 70 dB level was established by extrapolation from occupational data so as to protect virtually all the population. In addition, an "adequate margin of safety" was used to ensure that the assumptions were conservative which tended to reduce the recommended level. Other approaches have led to recommendations of 75 dB (Johnson, 1978) or 80 dB (von Gierke, 1975); however, using the Metrologgers, which tend to record a value lower than the actual, the 80 dB level was exceeded by many youths. Clearly a risk of noise-induced hearing loss in children appears to be a real concern but the recommendations are not specific for children.

In summary, the different design philosophies used in constructing current noise measurement devices can cause differences in recorded noise exposure. This demonstrates a need for better standardization of noise dosimeters. However, even with the limitations of the current devices, reasonable estimates of noise exposure can be obtained for children. Noise may have serious health-related effects for children, but little is known about the levels and sources of noise to which they are exposed (Mills, 1975). The present study of children and youths aged 7 to 20 years from generally suburban or rural environments, indicates there are no significant age effects in noise exposure, but that small sex effects are present, with boys having slightly higher noise exposure than girls. Children in the present study are experiencing noise exposure (mean $L_{eq(24)}$ between 77 and 84 dB) far in excess of the level (70 dB) considered "safe" by the EPA.

Clearly, more data than simple $L_{eq(24)}$ measurements are needed to assess accurately the typical daily noise exposure of children. In particular, the sources of noise and the levels from these sources need to be identified. This is possible using the Metrologgers which can provide conservative estimates (i.e., err in the direction of underestimating noise exposure) of three-minute L_{eq} values. When coupled with activity diaries, these estimates can provide some of the necessary information.

With the current sample, the many sound sources were grouped into 20 categories for the statistical analysis to be meaningful. In virtually every category, boys have a larger mean $L_{eq(t)}$ than the corresponding figure for girls; however, the means are only significantly different in a few cases (Table 57). This finding is in line with the sex difference observed in $L_{eq(24)}$; boys tend to have an $L_{eq(24)}$ about 2 dB higher than girls.

Race and seasonal (school year vs summer) differences do not appear to be important for most sound source categories. Small age effects are present for many sound sources (Tables 58 and 59); in most cases the slopes are negative, indicating decreasing noise exposure with increasing age. This finding is in some disagreement with the findings from the questionnaire. The total noise score from the questionnaire indicates a sharp increase in noise exposure with age, especially in boys. The dosimetry findings do not support this, considering either $L_{eq(24)}$ measurements or measurements from individual sound sources. The exception is sound from live music. The level of sound from this source, as well as the duration of exposure, increase with age in girls. In addition, older girls spend more time exposed to vehicular sound than younger ones.

The rank ordering of the sound sources as shown in Tables 60 and 61 is similar to what might have been predicted a priori. Clearly, lawnmowers, live music, school bus and school recesses and assemblies are important noise sources to which children may be exposed. With the exception of lawnmowers, these are also important because of the number of children exposed to these sound sources and the average duration of exposure. In these categories, which all have an $L_{eq(t)} > 80$ dB in boys and girls, the average duration is from 0.5 to 2.1 hours per day for each activity (Table 63).

The correlation between noise data obtained from dosimeters and that from questionnaires is rather poor. There is no relationship between $L_{eq(24)}$ and total noise scores or total event scores from questionnaires (Table 69). In addition, there is little evidence for an association between noise scores measured by either method and hearing ability. While there is no indication of an association between blood pressure adjusted for body size and AC thresholds adjusted for examination effects, there is a hint of an association between total noise scores and blood pressure.

The lack of a relationship between questionnaire results and data from dosimeters is expected, in part, because one method estimates noise exposure over a six-month period and the other measures it directly during a 24-hour period. Clearly the dosimeter is more accurate, but questions remain. For example, how representative is the single day of measurement? Also, can a one-day activity diary (without a dosimeter) be used to accurately predict noise exposure? The first question may be addressed by the use of serial data from individuals. In this way, the amount of variation in day to day noise exposure may be assessed. Further study is required to answer the second question as well. The obvious approach to answering the latter question is to obtain daily diaries blindly (i.e., without examining the dosimeter results) from children wearing dosimeters. The dosimeter data may be used to determine average sound levels for different activities, and these data, together with diary data, can then be used to predict $L_{eq(24)}$. The predicted values can then be compared to the actual measurements to determine the accuracy of the prediction. Obviously, much work remains in this area of investigation.

ASSOCIATIONS AMONG SIZE, MATURITY AND NOISE EXPOSURE

In the previous report (Roche, et al., 1979), more mature girls at 12 to 13 years of age tended to have a reduced hearing ability when compared to less mature girls. In the present results, more mature girls at the same age range and up to 15 years of age are exposed to significantly more noise than less mature girls. These two associations with maturity lend support to the hypothesis that noise exposure affects hearing ability. An association between maturity and noise exposure appears in girls and not boys due, in part, to the lack of a suitable marker such as menarche. Also, activity patterns are possibly more diverse among girls at various levels of maturity than among boys at the same age.

CONCLUSION

Environmental noise may have adverse effects upon auditory thresholds at any age, but there are convincing reasons why hearing ability in children relative to their noise exposure should be examined with particular care. To properly accomplish such a task requires a longitudinal study design. Longitudinal or serial studies offer several advantages over cross-sectional studies. The major reasons why serial studies of auditory thresholds and noise exposure in children are needed are as follows:

1. Children may be more susceptible to auditory damage from noise exposure than adults.

2. Children may be exposed to different sources of noise than adults and some of these may not be recognized currently as influencing hearing.

3. Hearing loss in a child may have more severe effects on learning and communication than a similar loss in an adult.

4. Hearing thresholds during childhood may be correlated with hearing ability in adult life.

5. Some effects found in cross-sectional studies may not be general trends in all individuals, but are either artifacts of sampling or reflect marked changes in subgroups.

6. A longitudinal study is the only way to determine if there are critical or sensitive periods when a child's hearing ability is more susceptable to damage.

7. There may be critical periods when hearing sensitivity is prone to change, and a serial study is necessary to document and evaluate these changes.

8. A longitudinal study, especially in children, allows one to examine the effect of developmental and growth changes on hearing levels and to separate these from environmental effects.

9. To determine if there are changes in peripheral blood pressure that may be related to noise exposure and elevated auditory thresholds.

This longitudinal study of human hearing was undertaken partly because of the factors enumerated above and because very little is known about environmental and developmental effects upon the hearing ability in children. The results presented in this report represent only the first five years of data collection. The findings should still be considered preliminary because the study is only beginning to meet its full serial potential. In the past reports, relatively few of the participants in the study had suitable multiple measurements of auditory thresholds and the analyses were cross-sectional rather than longitudinal. In the present report, more than half of the study sample has 8 or more visits. An "examination effect" is present but it cannot be fully described and explained without additional data.

Also, the results of the present analyses of serial relationships among AC thresholds, speech discrimination scores, tympanometry, otoscopy, noise exposure, blood pressure and maturity in children and young adults can only be considered preliminary, without continued examinations.

Children and young adults in the Fels study have relatively good hearing. Mean and median AC thresholds at almost all frequencies are 2 to 6 dB lower than those from United States national surveys for children of corresponding ages (Roberts and Federico, 1970; Roberts and Ahuja, 1975). Probably these differences reflect dissimilarities between the Fels and national samples in many aspects (e.g., geographical, socioeconomic, and racial factors).

There are indications that some abnormal otological findings may be associated with hearing losses. Also of interest are analyses of auditory thresholds in relation to body size and sexual and skeletal maturity. There is a suggestion of possible developmental correlates because the auditory thresholds decrease during adolescence, and rapidly maturing children tend to have lower thresholds than others although the picture is not entirely clear.

The older group of children (11 to 18-year-olds) had lower thresholds than the younger group (6 to 10-year-olds), and a much larger proportion of the older children were hearing at the lowest possible limit of the audiometer. However, there is a significant negative correlation between AC thresholds and the number of examinations (i.e. an examination effect) and between AC thresholds and age. With subsequent examinations, a significant improvement in the children's AC thresholds appear to be due to some multifactorial aspect that probably includes age, increased familiarity with the test equipment and operators, motivation and awareness of the importance of the study, etc. In addition, hearing ability appears to continue to improve up to young adulthood.

Auditory thresholds tend to be higher at 4 and 6 kHz than at the other frequencies tested in each group examined. Similarly at these frequencies, slopes from the regressions of AC thresholds on age are less negative for children 6 to 18 years of age than slopes for the same children at the lower frequencies. These results are consistant with the view that noise might be important with regard to auditory thresholds of children. The higher frequencies (especially 4 kHz) are the more sensitive to damage by noise, whether permanent or tempory threshold shifts are considered. Therefore, the higher initial thresholds and less negative slopes of the regression equations at higher frequencies may result from noise exposure.

In general, girls have slightly lower mean thresholds than boys and less variation in threshold measurements at a given age. This is possibly a reflection of differences in behavior that involve less noise exposure, and therefore, a reduced potential to a hearing loss due to noise exposure. This explanation is supported by the fact that threshold differences between boys and girls are larger in the 14- to 18-year-olds than in the 6- to 10-year-olds. Moreover, the median total noise exposure scores show a marked

sex difference only in the older group, with boys having the higher total noise exposure. Furthermore, the dosimetry data indicate that boys have an average $L_{eq(24)}$ about 2 dB higher than girls. Therefore, if noise is having an adverse effect, boys should have higher thresholds. This hypothesis is consistent with the present data. Finally, the slopes of the regressions of AC thresholds on age are less negative, in the direction of hearing loss, in the older group and more pronounced in boys. Certainly, the trend of increasing sex differences in mean thresholds with age is in accordance with the trend of increasing sex differences in noise exposure measured by questionnaire although the correlations between noise exposure scores and auditory thresholds were not significant.

It is clear that participants in the Fels Longitudinal Study have a wide range of noise exposure and a wide range of sources of this noise. The noise exposure questionnaires of many participants suggest high levels of noise exposure. The current quantification procedure applied to the noise exposure questionnaire is imprecise. However, the concept should be retained because it allows comparisons that are very difficult to make qualitatively. The quantitative noise exposure scores from the interval noise exposure questionnaire are potentially important measures of noise exposure; however, relationships with the data from the dosimeter studies will be necessary to demonstrate their accuracy and reliability. Metrosonics dosimeters allow the identification of specific sound sources that may be significant biologically. Various data concerning noise exposure indicate fireworks and being near firearms were not problems in this sample with respect to noise-induced hearing loss, although the potential for considerable loss from the use of firearms has been demonstrated in other studies. Lawnmowers, live music, school assemblies and recess, and riding a school bus are the sources of the greatest average sound exposure in boys and girls. Noise exposure may be associated with some elevation of auditory thresholds in the present sample. Such findings in these noise categories indicate the need for further investigation.

The major long-term aims of this study are to determine the pattern of auditory threshold levels in children and to relate changes in these thresholds to developmental and environmental events (particularly noise exposure). As the study continues, additional adolescent participants and audiometric tests such as bone conduction thresholds, brief tone audiometry and tone on tone masking thresholds should be added. These tests and added participants would provide valuable maturational data, be useful for the development of reference data, and supply information needed to predict the effects of noise upon hearing abilities at sensitive or critical ages in children. These additional tests would also more clearly describe possible changes in the hearing abilities of young adults in relation to the new types of noise exposure they encounter in their occupations.

While it is too early in the study to establish patterns or unequivocally relate changes to specific events, it is clear from these results that the design, sample, and methodology of the study are ideally suited for the attainment of these long-term aims. These preliminary findings of sex, age,

and examination effects, as well as relationships among auditory thresholds, slopes of the regressions of thresholds on age, noise exposure, speech discrimination, tympanometry and otoscopy and other related measurements, only hint at the potential of this study to answer important questions that relate to human hearing.

APPENDIX A

AUDITORY THRESHOLD LEVEL

RECORDING FORM

Name_____ ☐☐☐ ☐☐☐☐ (1-7)

Clan Subject Number

Subject's Birthdate

☐☐ ☐☐ ☐☐ ☐ ☐ ☐☐ ☐☐ ☐☐ (15-21)

Month Day Year (8-14) Month Day Year

Date of Test

Tester
1 = Eileen
2 = Lee
3 = Marty
4 = Kathleen

Sex
1 = male
2 = female

OTOSCOPIC EXAMINATION

Tragus. Right ear ☐ Left ear ☐ (22-23)

0 = normal
1 = very large
8 = other--see comments
9 = no examination

Comments:_____

Meatus. Right ear ☐ Left ear ☐ (24-25)

0 = normal
1 = completely closed
2 = badly obstructed with wax, dirt, hair, almost closed
3 = very small or slit-like opening but unobstructed
4 = small opening badly obstructed with wax
5 = much wax, etc. in canal but not obstructed
6 = canal open but rather inflamed (very red) looking
8 = other--see comments
9 = no examination

Comments:_____

Ear Drum. Right ear ☐ Left ear ☐ (26-27)

0 = normal
1 = perforated
2 = not seen because meatus small or obstructed
3 = scarred
8 = other--see comments
9 = no examination

Comments:_____

Ear Drum, Cone of Light. Right ear ☐ Left ear ☐ (28-29)

0 = cone of light seen
1 = cone of light not seen because meatus too small or obstructed
8 = other--see comments
9 = no examination
2 = cone of light not seen for other reasons

Comments:_____

APPENDIX A

AUDITORY THRESHOLD LEVEL RECORDING FORM [Page 2]

Name _____

Ear Drum, Color. Right ear ☐ Left ear ☐ (30-31)

0 = normal
1 = very red and inflamed looking
2 = dull
3 = yellowish
4 = redder than normal, but not inflamed looking
8 = other--see comments
9 = no examination

Comments _____

GENERAL HEALTH AT TIME OF TEST ☐ (32)

0 = normal, not ill
1 = has "cold," but no ear problems
2 = is congested due to "sinus allergy"
3 = both ears "stopped up"
4 = right ear "stopped up"
5 = left ear "stopped up"
6 = has ear infection, but no earache
7 = has ear infection, with earache
8 = other--see comments
9 = not recorded

Comments _____

COMMENTS ABOUT HEARING TEST

Continuity and completeness of testing ☐ (33)

0 = testing completed, no breaks
1 = testing completed, one short (< 5 min) break between ears
2 = testing completed, one short (< 5 min) break during testing of right ear
3 = testing completed, one short (< 5 min) break during testing of left ear
4 = testing completed, took more than one break (specify in comments)
5 = testing completed, certain frequencies retested (specify in comments)
6 = testing discontinued, participant insisted (tired, restless, etc.)
7 = testing discontinued, responses too erratic (lack of cooperation, etc)
8 = other--see comments

Comments _____

APPENDIX A

AUDITORY THRESHOLD LEVEL RECORDING FORM [Page 3]

Name_____

Responses of participant ☐ (34)

0 = normal good responses or better
1 = often signaled when no tone played
2 = participant disinterested, not trying hard
3 = participant's responses seemed somewhat erratic
4 = participant very restless and "fidgety"
5 = participant talked frequently throughout test
6 = participant claimed to hear extraneous noises during test (explain in comments)
7 = participant's parent in booth during testing
8 = other--see comments
9 = participant did well at the beginning but lost concentration toward end of test

Comments_____

_____

Comments written for individual frequencies

right ear ☐ (35) left ear ☐ (36)

0 = no comments written
1 = 1000 HZ
2 = 2000 HZ
4 = 4000 HZ
5 = 500 HZ
6 = 6000 HZ
8 = comments at more than one frequency

RIGHT EAR AUDITORY THRESHOLD LEVEL

Comments:_____

_____	1000	☐☐☐ (45-47)
_____	2000	☐☐☐ (48-50)
_____	4000	☐☐☐ (51-53)
_____	6000	☐☐☐ (54-56)
_____	1000	☐☐☐ (57-59)
_____	500	☐☐☐ (60-62)

LEFT EAR AUDITORY THRESHOLD LEVEL

Comments: _____

_____	1000	☐☐☐ (63-65)
_____	2000	☐☐☐ (66-68)
_____	4000	☐☐☐ (69-71)
_____	6000	☐☐☐ (72-74)
_____	1000	☐☐☐ (75-77)
_____	500	☐☐☐ (78-80)

APPENDIX B

BIOGRAPHICAL, NOISE EXPOSURE, AND OTOLOGICAL HISTORY QUESTIONNAIRE
(Do not ask Fels participants circled questions.)

A. General Information

1. Clan number ☐☐☐ A1-3
2. Subject Number ☐☐☐ A4-7
3. Name _____ ☐ A8

4. Today's date ☐☐ ☐☐ ☐☐ A9-14
mo. day yr.

5. Questioner
Eileen ☐ A15
Lee ☐ A16
Marty ☐ A17
Roger ☐ A18
Other ☐ A19
_____ Specify

6. Sex of participant
male ☐ A20
female ☐ A21

7. Participant's birthdate ☐☐ ☐☐ ☐☐ A22-27
mo. day yr.

8. What is your address and phone number?
address: _____
street

A28 A29
_____
city state
(b l a n k)

_____
zip telephone

B. Noise Exposure History

9. Have you ever lived very near a busy road (such as a state highway or freeway), airport, noisy factory, downtown in a city, etc.?

☐ no ☐ yes
A30 A31

a) busy road or airport
within 100 ft. of road or flight pattern ☐ A32
100 ft. to 100 yds. from road or flight pattern (length of football field) ☐ A33
greater than 100 yds. from road ☐ A34

b) How long have you lived there? ☐☐ years A35-36

c) Other ☐ A37
specify _____

_____

10. How would your parents rate the sound volume of the TV when you watch it the most?

quiet	☐ A38
average	☐ A39
loud	☐ A40

a) How many hours a day (average) do you watch TV? ☐☐ A41-42

11. Have you ever listened to radio, stereo, hi-fi tapes, or records?

☐ no A43 ☐ yes A44

a) What percentage of the time do you listen with headphones?

never	☐ A45
less than 1/4 of the time	☐ A46
between 1/4 and 1/2 of the time	☐ A47
between 1/2 and 3/4 of the time	☐ A48
greater than 3/4 of the time	☐ A49

b) About how many hours each day do you listen?

less than one	☐ A50
1-2	☐ A51
3-4	☐ A52
more than four	☐ A53

c) How loud do you like the volume?

quiet	☐ A54
medium	☐ A55
loud	☐ A56

d) What type of music do you usually listen to?

hard rock--soul	☐ A57
pop--country--western	☐ A58
classical	☐ A59

12. Have you ever played a musical instrument or sung with a band?

☐ no A60 ☐ yes A61

a) Instrument _____ ☐☐ A62-63

amplified	☐ A64
not amplified	☐ A65

b) About how many hours per week have you played it? ☐☐ A66-67

c) Do you mostly play with a

rock band?	☐ A68
marching or concert band?	☐ A69
orchestra?	☐ A70
by yourself?	☐ A71

13. Do you listen to more than about one hour of live rock music each week?

☐ no A72 ☐ yes A73

Approx no. of hours/week ☐☐ A74-75 ☐ A80

APPENDIX B

CARD B- col. 1-7 same as A | [2] B8 | 3

14. Have you ever played with any very loud toys?

[ ] no B9 [ ] yes B10

a) Cap guns, pop guns, air guns
   1. Rarely (less than 1 hr/wk.) [ ] B11
   2. Occasionally (1-2 hrs/wk.) [ ] B12
   3. Frequently (4-6 hrs/wk.) [ ] B13
   4. Very often (more than 7 hr/wk.) [ ] B14

b) Other toys [ ] B15
   Specify _____

15. Have you done or been around much motorcycling, motor boating, drag or auto racing, go-carting, minibiking, etc.?

[ ] no B16 [ ] yes B17

(estimate times while engine is running)

a) Motorcycles, outboard motor boats (> 35 H.P. engines)
   1. Rarely (less than 1 hr/wk.) [ ] B18
   2. Occasionally (2-7 hrs/wk.) [ ] B19
   3. Frequently (7-15 hrs/wk.) [ ] B20
   4. Very often (more than 15 hrs/wk.) [ ] B21

b) Minibikes, auto or drag racing, snowmobile, go-carts, small outboard or inboard motor boats
   1. Rarely (less than 1 hr/wk.) [ ] B22
   2. Occasionally (2-7 hrs/wk.) [ ] B23
   3. Frequently (7-15 hrs/wk.) [ ] B24
   4. Very Often (more than 15 hrs/wk.) [ ] B25

c) Other [ ] B26
   Specify _____

16. Have you ever played with loud or explosive devices (except guns; e.g., small gas driven engines like on model airplanes; fireworks, etc.)

[ ] no B27 [ ] yes B28

a) Firecrackers (within 50 ft. of explosives)
   1. Seldom (once or twice in 6 mos.) [ ] B29
   2. Occasionally (3-5 times in 6 mos.) [ ] B30
   3. Often (more than 6 times in 6 mos.) [ ] B31

   Estimate total no. exploded since last visit [ ][ ] B32-33

b) Small gas driven engines (e.g., model airplanes) (while engine is running)
   1. Seldom (less than 1 hr/mo.) [ ] B34
   2. Occasionally (1-4 hrs/mo.) [ ] B35
   3. Often (more than 1 hr/wk.) [ ] B36

c) Other
   Specify _____ [ ] B37

17. What are your parents' hobbies and recreational activities?

activities _____

B38 B39

(b l a n k)

To be judged by questionnaire giver:
Are any of these a noise-relevant activity? [ ] no B40 [ ] yes B41

18. Have you ever fired or been around anyone else firing a gun?

☐ no B42 ☐ yes B43

a) Who fired?

you ☐ B44
someone else ☐ B45

B46 - B48
B49 - B50
(b l a n k)

b) What type of gun?
rifle or shot gun ☐ B51
pistol ☐ B52

c) What caliber?
.22 or smaller ☐ B53
larger than .22 ☐ B54

d) How do you shoot?
right handed ☐ B55
left handed ☐ B56

B57-59 Blank

e) Did you wear hearing protectors ☐ no ☐ yes B60-61

f) How many hours per month do you shoot or are around someone else shooting? (average) ☐☐ B62-63

g) For how many years? ☐☐ B64-65

19. Have you ever been employed?

☐ no B66 ☐ yes B67

job description _____

_____

To be judged by questionnaire giver:
Is this a noise-relevant job? ☐ no ☐ yes B68-69

20. What is your father's occupation?

☐ no B70 ☐ yes B71 (blank)

occupation: _____

employed by: _____

To be judged by questionnaire giver:
Is this a noise-relevant job? ☐ no ☐ yes B72-73

21. What is your mother's occupation?

☐ no B74 ☐ yes B75 (blank)

occupation: _____

employed by: _____

To be judged by questionnaire giver:
Is this a noise-relevant job? ☐ no ☐ yes B76-77

[A] B80

CARD C col. 1-7 same as B | [3] C8 | 5

22. What are your hobbies or recreational activities?

activities _____

no C9 yes C10 (blank)

To be judged by questionnaire giver:
Is this a noise-relevant activity? ☐ no ☐ yes C11-12

23. Have you ever used or been around power tools? (e.g., drills, saws, sanders, grinders, etc.)

☐ no C13 ☐ yes C14 (1 = yes 0 = no)

	yes or no	Occas-sionally	Often	
electric tools (drills, saws, sanders, grass edgers, etc.)	☐	☐	☐	C15-17
grinders	☐	☐	☐	C18-20
gas lawnmowers, edgers, etc.	☐	☐	☐	C21-23
chain saws	☐	☐	☐	C24-26
other	☐	☐	☐	C27-29

specify _____

24. Have you ever used farm machinery or been close by when it was operating? (e.g., tractors, combines, etc.)

☐ no C30 ☐ yes C31

a) Tractors or combines
1. Rarely (less than 1 hr/mo.) ☐ C32
2. Occasionally (1-8 hrs/mo.; up to 2 hrs/wk.) ☐ C33
3. Frequently (2-10 hrs/wk.) ☐ C34
4. Very often (more than 10 hrs/wk.) ☐ C35

b) Other motor-driven farm equipment ☐ C36
specify _____

25. What sports have you participated in more than a few hours?

a) none	☐	C37	hiking	pool	
b) swimming	☐	C38	jogging or running	ping-pong	
c) baseball	☐	C39	track	wiffle ball	
d) football	☐	C40	roller skating	weight lifting	
e) soccer	☐	C41	ice skating	cheerleading	
f) basketball	☐	C42	skate-boarding	disco dancing	
g) bowling	☐	C43	volleyball	Frisbee	
h) bicycling	☐	C44	racquet ball	Other	
i) tennis	☐	C45	kick ball		
j) horseback riding	☐	C46	dodge ball		
k) gymnastics	☐	C47	golf		
l) other	☐	C48	skiing		

specify _____

26. Have your ever worn hearing protectors for any reason other than shooting?

☐ no C49 ☐ yes C50

a) Worn protectors
1) When driving tractor or mowing ☐ C51
2) When near power tools or other machinery ☐ C52
3) Other ☐ C53
specify _____

C. Otological History

27. Have you noticed a temporary or permanent change for any reason in your ability to hear or understand spoken words?

☐ no C54 ☐ yes C55

a) Where did this trouble occur most often?
at home ☐ C56
at school ☐ C57
at work ☐ C58
other ☐ C59
specify _____

b) When did you first notice the change?

☐☐ year C60-61 C62 Blank

28. Have you had any roaring or ringing in your ears?

☐ no C63 ☐ yes C64

a) roaring ☐ C65
ringing ☐ C66

b) right ear ☐ C67
left ear ☐ C68

c) frequency
once ☐ C69
2-5 times ☐ C70
more than 5 times ☐ C71

d) duration
less than 45 minutes ☐ C72
1-12 hours ☐ C73
about 1 day ☐ C74
more than a day ☐ C75

e) Did you go to a doctor and/or receive treatment
☐ no C76 ☐ yes C77

f) How old were you when it started? ☐☐ years C78-79

[A] C80

CARD D col. 1-7 same as C [4] D8 7

29. Have you ever had any earaches, ear infections, running ears?

☐ no D9 ☐ yes D10

a) Which?
- ear infection ☐ D11
- ear ache ☐ D12
- running ears ☐ D13

b) Which ear(s)?
- right ☐ D14
- left ☐ D15

c) Frequency
- once ☐ D16
- 2-5 times ☐ D17
- more than 5 ☐ D18

d) Duration ☐☐ days D19-20

e) How old were you when it started? ☐☐ years D21-22

f) Did you go to a doctor and/or receive treatment?

☐ no D23 ☐ yes D24

REMINDER NON-FELS ONLY

D. General Health

30. Which of the following problems have you ever been bothered by?

a) high blood pressure ☐ D25
b) diabetes ☐ D26
c) allergy ☐ D27
d) sore throat ☐ D28
e) mumps ☐ D29
f) encephalitis ☐ D30
g) meningitis ☐ D31
h) high fever (greater than 103°) ☐ D32
i) excessive mouth breathing ☐ D33
j) sinusitis ☐ D34
- mild ☐ D35
- moderate ☐ D36
- severe ☐ D37

k) dizzy spells
- occasional (1/6 mo.) ☐ D38
- frequent (1/mo.) ☐ D39
- very frequent (more than 1/mo.) ☐ D40

l) none of the above ☐ D41
m) any other health problem not mentioned above ☐ no ☐ yes D42 D43-44

explain _____

31. Have you ever been hospitalized?

☐ no D45 ☐ yes D46

a) For what and how long?_____

_____

_____

32. Have you ever had any of the following medications?

a) Streptomycin	☐ D47
b) Neomycin	☐ D48
c) Kanomycin	☐ D49
d) Quinine	☐ D50
e) Large amounts of aspirin (more than 8 in a day or 20 in a week)	☐ D51
f) none of the above	☐ D52

33. Are there any other medications that you have taken regularly?

☐ no D53 ☐ yes D54

a) What and how much? _____

_____

34. Have you ever been unconscious (either knocked out, fainted, blacked out, seisure, etc.)?

☐ no D55 ☐ yes D56

a) How many times	☐ D57
b) What was the cause each time?	
accident	☐ D58
fainting	☐ D59
seisure	☐ D60
c) How long were you unconscious each time?	
a few seconds	☐ D61
less than a minute	☐ D62
5 minutes to an hour	☐ D63
more than an hour	☐ D64

35. Have you ever had any vision or hearing problems resulting from an illness or an accident?

☐ no ☐ yes

a) What? _____

_____

D65-66

36. (Girls only) When did you have your first period?

month	☐☐ D67-68
year	☐☐ D69-70
not yet	☐ D71

37. If you answered "yes" to Question 30, Part II (Have you ever had a high fever?), complete the following:

a) How old were you? ☐☐ years D72-73

b) How long did it last? ☐☐ days D74-75

38. Were your tonsils removed?

☐ no D76 ☐ yes D77

39. Have you ever had frequent colds?

☐ no D78 ☐ yes D79

☐A D80

CARD E., Col. 1-7, same as D ☐5 E8

E. Information for Initial Audiometry History

40. Do you think your hearing is:

☐ Good E9 ☐ Fair E10 ☐ Poor E11

a) If fair or poor, is loss in:

right ear ☐ E12

left ear ☐ E13

b) What do you think caused the loss?

illness ☐ E14

accident ☐ E15

other ☐ E16

explain _____

_____

c) Have you seen a doctor about your hearing loss?

☐ no E17 ☐ yes E18

d) Have you received any treatment?

☐ no E19 ☐ yes E20

medical ☐ E21
surgical ☐ E22
hearing aid ☐ E23
other ☐ E24
explain _____

41. Have you had your hearing tested before?

☐ no E25 ☐ yes E26

a) When? ☐☐ year E27-28

b) Where?
doctor's office ☐ E29
school ☐ E30
other ☐ E31
explain _____

c) How?
audiometer ☐ E32
spoken voice ☐ E33
tuning fork ☐ E34
other ☐ E35
explain _____

d) What were you told about the results?
nothing ☐ E36
good or normal hearing ☐ E37
loss in right ear ☐ E38
loss in left ear ☐ E39

42. Does anyone in your family have a hearing loss?

☐ no E40 ☐ yes E41

a) Who?
mother ☐ E42
father ☐ E43
sister ☐ E44
brother ☐ E45
other ☐ E46
explain _____

b) How old was relative when loss started or was first complained of? ☐☐ years E47-48

If exact age isn't known, was relative

Under 40 ☐ E49

Over 40 ☐ E50

c) Did loss occur ☐ suddenly ☐ gradually E51-52

(Participants only after September 1976)

43. Do you ride a bus to school?

☐ no E53 ☐ yes E54

a) One way? ☐ E55
b) Both ways? ☐ E56
c) Number of days each week? ☐ E57
d) About how long does the bus ride last one way? (mins.) ☐☐ E58-59

44. Were auditory thresholds tested on the same day that underwater weighing was done?

0 = no 1 = yes ☐ E60

45. What is the date of your most recent menstrual period?

mo.	day	year
☐☐	☐☐	☐☐
E61 62	63 64	65 66

F. General Information (not to be put on computer cards)

A. Father's name:

B. Mother's name:

C. Names and ages of brothers and sisters:

a.
b.
c.
d.
e.
f.
g.
h.

[A] E80

12

CARD F, col. 1-7, same as E [6] F80

43. List the schools you have attended since Jan. 1, 1976.

		month year	to month year	
a.	_____	□□□ □□ □□	□□ □□	F9-19
b.	_____	□□□ □□ □□	□□ □□	F20-30
c.	_____	□□□ □□ □□	□□ □□	F31-41
d.	_____	□□□ □□ □□	□□ □□	F42-52
e.	_____	□□□ □□ □□	□□ □□	F53-63
f.	_____	□□□ □□ □□	□□ □□	F64-74

[A] F80

CARD G, col. 1-7, same as F [7] G8

44. (For any Participant NOT having DGG measurements.)

Blood Pressure: Heart rate/min.

1. _____/_____/_____ _____

2. □□□ □□□ □□□ □□□
G09 10 11 / G12 13 14 / G15 16 17 G18 19 20

3. □□□ □□□ □□□ □□□
G21 22 23 / G24 25 26 / G27 28 29 G30 31 32

[A] G80

APPENDIX C

INTERVAL AUDIOMETRY QUESTIONNAIRE
(Do not ask DGG participants circled questions.)

A. General Information

1. Clan number ☐☐☐ A1-3
2. Subject Number ☐☐☐☐ A4-7
3. Name _____ [1] A8
4. Today's date ☐☐ ☐☐ ☐☐ A9-14 (mo. day yr.)
5. Questioner
   - Eileen ☐ A15
   - Lee ☐ A16
   - Kathleen ☐ A17
   - Roger ☐ A18
   - Other ☐ A19 _____ Specify
6. Sex of participant
   - male ☐ A20
   - female ☐ A21
7. Participant's birthdate ☐☐ ☐☐ ☐☐ A22-27 (mo. day yr.)
8. Has your address changed since your last visit?
   ☐ no A28 ☐ yes A29
   new address: _____ street
   _____ city _____ state
   _____ zip _____ telephone

B. Noise Exposure History

9. Is your present home very near a busy road (such as a state highway or freeway), airport, noisy factory, downtown in a city, etc.?
   ☐ no A30 ☐ yes A31
   a) busy road
      - within 100 ft. of road ☐ A32
      - 100 ft. to 100 yds. from road (length of football field) ☐ A33
      - greater than 100 yards from road ☐ A34

   b) airport
      - lives under the flight pattern ☐ A35
      - lives near flight pattern ☐ A36

   c) other ☐ A37
      specify _____
      _____

10. How would your parents rate the sound volume of the TV when you watch it the most?

quiet	☐	A38
average	☐	A39
loud	☐	A40

a) How many hours a day (average) do you watch TV? ☐☐ A41-42

11. Since your last visit have you listened to radio, stereo, hi-fi tapes, or records?

☐ no A43 ☐ yes A44

a) What percentage of the time do you listen with headphones?

never	☐	A45
less than 1/4 of the time	☐	A46
between 1/4 and 1/2 of the time	☐	A47
between 1/2 and 3/4 of the time	☐	A48
greater than 3/4 of the time	☐	A49

b) About how many hours each day do you listen?

less than one	☐	A50
1-2	☐	A51
3-4	☐	A52
>4	☐	A53

c) How loud do you like the volume?

quiet	☐	A54
medium	☐	A55
loud	☐	A56

d) What type of music do you usually listen to?

hard rock--soul	☐	A57
pop--country--western	☐	A58
classical	☐	A59

12. Since your last visit have you played a musical instrument or sung with a band?

☐ no A60 ☐ yes A61

a) Instrument _____ ☐☐ A62-63

amplified	☐	A64
not amplified	☐	A65

b) About how many hours per week have you played it? ☐☐ A66-67

c) Do you mostly play with a

rock band?	☐	A68
marching or concert band?	☐	A69
orchestra?	☐	A70
by yourself?	☐	A71

13. Do you listen to more than about one hour of live rock music each week?

☐ no A72 ☐ yes A73

Approx no. of hours/week ☐☐ A74-75 ☐ A80

APPENDIX C

CARD B- col. 1-7 same as A | 2 | B8 | 3

14. Have you played with any very loud toys since your last visit?

☐ no B9 ☐ yes B10

a) Cap guns, pop guns, air guns
   1. Less than 1 hr/wk. ☐ B11
   2. 1-2 hrs/wk. ☐ B12
   3. 4-6 hrs/wk. ☐ B13
   4. More than 7 hrs/wk. ☐ B14

b) Other toys ☐ B15
   Specify _____

15. Since your last visit, have you done or been around much motorcycling, motor boating, drag or auto racing, go-carting, minibiking, etc.?

☐ no B16 ☐ yes B17

(estimate times while engine is running)

a) Motorcycles, outboard motor boats (> 35 H.P. engines)
   1. Less than 1 hr/wk. ☐ B18
   2. 2-7 hrs/wk. ☐ B19
   3. 7-15 hrs/wk. ☐ B20
   4. More than 15 hrs/wk. ☐ B21

b) Minibikes, auto or drag racing, snowmobile, go-carts, small outboard or inboard motor boats
   1. Less than 1 hr/wk. ☐ B22
   2. 2-7 hrs/wk. ☐ B23
   3. 7-15 hrs/wk. ☐ B24
   4. More than 15 hrs/wk. ☐ B25

c) Other ☐ B26
   Specify _____

16. Since your last visit, have you played with any loud or explosive devices (except guns; e.g., small gas driven engines like on model airplanes; fireworks, etc.)

☐ no B26 ☐ yes B27

a) Firecrackers (within 50 ft. of explosives)
   once or twice in 6 mos. ☐ B29
   3-5 times in 6 mos. ☐ B30
   more than 6 times in 6 mos. ☐ B31
   Estimate total no. exploded since last visit ☐☐ B32-33

b) Small gas driven engines (e.g., model airplanes) (while engine is running)
   1. Less than 1 hr/mo. ☐ B34
   2. 1-4 hrs/mo. ☐ B35
   3. More than 1 hr/wk. ☐ B36

c) Other ☐ B37
   Specify _____

17. Have your parents or any of your brothers or sisters changed their hobbies or recreational activities since your last visit? (especially related to noise increase or decrease)

☐ no B38 ☐ yes B39

new activities _____

To be judged by questionnaire giver:
Is this a noise relevant activity? ☐ no B40 ☐ yes B41

18. Have you fired or been around anyone else firing a gun since your last visit?

☐ no B42 ☐ yes B43

a) Who fired?

☐ you B44 ☐ someone else B45

i) how many rounds (bullets)? B46-48 ☐☐☐

ii) did you wear hearing protectors? ☐ no B49 ☐ yes B50

iii) what type of gun?
- rifle or shot gun ☐ B51
- pistol ☐ B52

iv) what caliber:
- .22 or smaller ☐ B53
- larger than .22 ☐ B54

b) How do you shoot?
- right handed ☐ B55
- left handed ☐ B56

c) How many rounds (bullets)? ☐☐☐ B57-59

d) Did you wear hearing protectors? ☐ no ☐ yes B60-61

e) What kind of gun?
- rifle or shot gun ☐ B62
- pistol ☐ B63

f) What caliber:
- .22 or smaller ☐ B64
- larger than .22 ☐ B65

19. Have you worked at any new jobs (especially noise-related ones) or changed jobs since your last visit?

☐ no B66 ☐ yes B67

job description _____

To be judged by questionnaire giver:
Is this a noise relevant job? ☐ no ☐ yes B68-69

20. Has your father's ocupation changed since your last visit?

☐ no B70 ☐ yes B71

new occupation _____

employed by _____

To be judged by questionnaire giver:
Is this a noise relevant job? ☐ no ☐ yes B72-73

21. Has your mother's ocupation changed since your last visit?

☐ no B74 ☐ yes B75

new occupation _____

employed by _____

To be judged by questionnaire giver:
Is this a noise relevant job? ☐ no ☐ yes B76-77

☐ B80

CARD C col. 1-7 same as B | [3] C8 | 5

22. Have you taken up any new hobbies or recreational activities since your last visit?

☐ no C9 ☐ yes C10

new activities _____

To be judged by questionnaire giver:
Is this a noise relevant activity? ☐ no ☐ yes C11-12

23. Since your last visit, have you used or been around power tools for more than a total of about one hour in six months? (e.g., drills, saws, sanders, grinders, etc.)

☐ no C13 ☐ yes C14

(1 = yes 0 = no) (2 = yes, hrs. ÷ 10)

	yes or no	hours near since last visit	
electric tools (drills, saws, sanders, grass edgers, etc.)	☐	☐☐	C15-17
grinders	☐	☐☐	C18-20
gas lawnmowers, edgers, etc.	☐	☐☐	C21-23
chain saws	☐	☐☐	C24-26
other	☐	☐☐	C27-29

specify _____

24. Since your last visit, have you used farm machinery or been close by when it was operating? (e.g., tractors, combines, etc.)

☐ no C30 ☐ yes C31

a) Tractors or combines
- Less than 1 hr/mo. ☐ C32
- 1-8 hrs/ mo (up to 2 hrs/wk. ☐ C33
- 2-10 hrs/wk. ☐ C34
- More than 10 hrs/wk. ☐ C35

b) Other motor driven farm equipment ☐ C36

specify _____

25. Has your participation in sports altered since your last visit? Since your last visit, what sports have you participated in for more than a few hours?

a)	none	☐	C37	hiking	pool
b)	swimming	☐	C38	jogging or running	ping-pong
c)	baseball	☐	C39	track	wiffle ball
d)	football	☐	C40	roller skating	weight lifting
e)	soccer	☐	C41	ice skating	cheerleading
f)	basketball	☐	C42	skate-boarding	disco dancing
g)	bowling	☐	C43	volleyball	Frisbee
h)	bicycling	☐	C44	racquet ball	wrestling
i)	tennis	☐	C45	kick ball	Other
j)	horseback riding	☐	C46	dodge ball	
k)	gymnastics	☐	C47	golf	
l)	other	☐	C48	skiing	

specify _____

26. Since your last visit, have you worn hearing protectors for any reason other than shooting?

☐ no C49 ☐ yes C50

worn protectors
a) When driving tractor or mowing ☐ C51
b) When near power tools or other machinery ☐ C52
c) Other ☐ C53
specify _____

C. Otological History

27. Since your last visit, have you noticed a temporary or permanent change for any reason in your ability to hear or understand spoken words?

☐ no C54 ☐ yes C55

a) Where did this trouble occur most often?
at home ☐ C56
at school ☐ C57
at work ☐ C58
other ☐ C59
specify _____

b) Cause of change:
illness (earaches, stopped up ears, etc.) ☐ C60
accident ☐ C61
other ☐ C62
specify _____

28. Since your last visit, have you had any roaring or ringing in your ears?

☐ no C63 ☐ yes C64

a) roaring ☐ C65
ringing ☐ C66

b) right ear ☐ C67
left ear ☐ C68

c) frequency
once ☐ C69
2-5 times ☐ C70
more than 5 times ☐ C71

d) duration
less than 45 minutes ☐ C72
1-12 hours ☐ C73
about 1 day ☐ C74
more than a day ☐ C75

e) did you go to a doctor and/or receive treatment
☐ no C76 ☐ yes C77

☐ C80

CARD D col. 1-7 same as C | [4] D8 | 7

29. Since your last visit, have you had any earaches, ear infections, running ears?

☐ no D9 ☐ yes D10

a) Which?
- ear infection ☐ D11
- ear ache ☐ D12
- running ears ☐ D13

b) Which ear(s)?
- right ☐ D14
- left ☐ D15

c) Frequency
- once ☐ D16
- 2-5 times ☐ D17
- more than 5 ☐ D18

d) Duration
- less than a day D19
- 2-4 days ☐ D20
- 4-7 days ☐ D21
- more than 1 week ☐ D22

e) Did you go to a doctor and/or receive treatment?

☐ no D23 ☐ yes D24

REMINDER NON-DGG ONLY

D. General Health

30. Since your last visit, which of the following problems have you been bothered by?

- a) high blood pressure ☐ D25
- b) diabetes ☐ D26
- c) allergy ☐ D27
- d) sore throat ☐ D28
- e) mumps ☐ D29
- f) encephalitis ☐ D30
- g) meningitis ☐ D31
- h) high fever (> 103°) ☐ D32
- i) excessive mouth breathing ☐ D33
- j) sinusitis ☐ D34
  - mild ☐ D35
  - moderate ☐ D36
  - severe ☐ D37
- k) dizzy spells
  - occasional (1/6 mo.) ☐ D38
  - frequent (1/mo.) ☐ D39
  - very frequent (more than 1/mo.) ☐ D40
- l) none of the above ☐ D41
- m) any other health problem not mentioned above ☐ no ☐ yes D42-44

explain _____

31. Since your last visit, have you been hospitalized?

☐ no D45 ☐ yes D46

a) For what and how long? _____

_____

_____

32. Since your last visit, have you had any of the following medications?

a) Streptomycin	☐ D47
b) Neomycin	☐ D48
c) Kanomycin	☐ D49
d) Quinine	☐ D50
e) Large amounts of aspirin (more than 8 in a day or 20 in a week)	☐ D51
f) none of the above	☐ D52

33. Are there any other medications that you have taken regularly since your last visit?

☐ no D53 ☐ yes D54

a) What and how much? _____

_____

34. Since your last visit, have you been unconscious (either knocked out, fainted, blacked out, seisure, etc.)?

☐ no D55 ☐ yes D56

a) How many times	☐ D57
b) What was the cause each time?	
accident	☐ D58
fainting	☐ D59
seisure	☐ D60
c) How long were you unconscious each time?	
a few seconds	☐ D61
less than a minute	☐ D62
5 minutes to an hour	☐ D63
more than an hour	☐ D64

35 Since your last visit have you had any vision or hearing problems resulting from an illness or an accident?

☐ no ☐ yes

a) What? _____

_____

D65-66

36. (Girls only) When did you have your first period?

month	☐☐ D67-68
year	☐☐ D69-70
not yet	☐ D71

37. Do you ride a bus to school?

☐ no D72	☐ yes D73	a) One way?	☐ D74
		b) Both ways?	☐ D75
		c) Number of days each week?	☐ D76
		d) About how many minutes does the ride last one way?	☐☐ D77-78

38. Were auditory thresholds tested on the same day that underwater weighing was done?

0 = no 1 = yes

☐ D79 ☐ D80

CARD E- col. 1-7 same as D ☐5 E8

39. Have your habits with regard to riding a bus to school changed since January, 1976? (Please provide details.)

☐ no E9 ☐ yes E10

40. (For any Participant not having DGG measurements.)

Blood Pressure: _____/_____/_____ Heart rate/min. _____

2. ☐☐☐ / ☐☐☐ / ☐☐☐ ☐☐☐
E11 12 13 / E14 15 16 / E17 18 19 E20 21 22

3. ☐☐☐ / ☐☐☐ / ☐☐☐ ☐☐☐
E23 24 25 / E26 27 28 / E29 30 31 E32 33 34

41. What is the date of your most recent menstrual period?

☐☐ mo. ☐☐ day ☐☐ year E35-40

42. Eye Color: (Clan 999 One time only) R ☐☐ E41 42 L ☐☐ 43 44

(For any participant not having DGG measurements.)

43. Stature (cm) ☐☐☐☐☐ E45 46 47 48 49

44. Weight (kg) ☐☐☐☐☐ E50 51 52 53 54 ☐ E80

10

CARD F, col. 1-7 same as E | 6 | F8

43. List the schools you have attended since Jan. 1, 1976.

		month year	to	month year	
a.	_____	□□□	□□	□□	F9-19
b.	_____	□□□	□□	□□	F20-30
c.	_____	□□□	□□	□□	F31-41
d.	_____	□□□	□□	□□	F42-52
e.	_____	□□□	□□	□□	F53-63
f.	_____	□□□	□□	□□	F64-74

□ F80

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