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Popmusic through headphones and hearing loss

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INTRODUCTION

The Minister of Health, Welfare and Sport remarked in a letter to the Lower House at the end of 1995 that she considered the use of walkman's and possible noise-induced hearing loss by using this audio equipment of sufficient interest to survey the research possibilities to get a better insight into the exposure-effect relationships. After consultation, TNO-PG has been requested to carry out a project on the exposure to popmusic of young people in the Netherlands. The project consisted of two parts.

The first part of the project concerned a *questionnaire* among a representative sample of young people, aged between 12 and 30 years, about their popmusic activities. The results have been presented in Dutch and English (Passchier-Vermeer and Vos, 1997a, 1997b). Based on the data of the first part the group of young people for the second part of the project has been selected. The main criterion of this selection was a high exposure to popmusic through headphones. Both the number of listening years (the listening period) and the extent of listening (with respect to present listening level and number of listening hours per day at the tome of the investigation) played a role in the selection. The selected group has therefore not been chosen on the basis of a high exposure to popmusic at other activities (popconcerts, discotheques, house-parties, playing in a popgroup, acting as disc jockey). On the basis of the questionnaire these exposures are expected to be relatively low in the selected group.

The second part of the investigation aimed at determining the relationships between exposure to popmusic through headphones and noise-induced hearing loss. To that aim test subjects have been submitted to an extensive *questionnaire*, with questions about their exposure to popmusic during several activities and a number of other relevant items. A part of the questionnaire contained questions identical to those in the questionnaire of the first part of the investigation. A *listening test* has been carried out in which the listening level under headphones of a discman has been determined. Also an *audiometric investigation*[1] has been carried out to determine the hearing threshold levels of the test subjects. The hearing threshold level (at a given ear) at a given frequency is the level (in dB) at which a test subject is just able to hear the test tone in that ear. Tests have been carried out in an audiomobile which has been especially constructed for those purposes and which has been made available by 'Umwelt Bundesambt' in Berlin.

Based on a combination of the data of the first and second part of the investigation an estimate has been

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1 Test tones have been presened and hearing threshold levels have been determined according to the specifications given in ISO 6189 (1983). Hearing threshold levels have been determined seperately at both ears at the following frquencies: 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz.

made of the prevalence of hearing loss induced by exposure to popmusic through headphones in the young Netherlands population.

This report and its executive summary

The main text of the report contains the statistical analysis of the data of the second part of the investigation and is a translation of the Netherlands text given in Passchier-Vermeer, Vos and Steenbekkers (TNO-PG report 98.016). This executive summary is a translation of the Netherlands text given in Passchier-Vermeer, Steenbekkers and Vos (TNO-PG report 98.035), which gives a summary, conclusions and recommendations. Detailed results of statistical tests presented in the main text of the report, including the types of tests and levels of significance have been omitted in this executive summary. Annex A presents the definitions of sound exposure and other measures also used in this executive summary.

Audiometric terminology

Hearing threshold level and hearing loss are both used in the report. A small hearing loss corresponds with a low hearing threshold level. Where hearing losses are compared worse hearing stands for higher hearing threshold levels and more hearing loss. Changes in hearing threshold levels induced by exposure to popmusic through headphones is called popmusic-induced hearing loss, excluding the words 'through headphones'.

Test subjects investigated in the second part

Test subjects in the second part of the investigation are students/pupils of the third classes of schools for lower professional education in Rotterdam and students from the job-related educational school in Leiden. Apart from some students who could occasionally not participate in the test only a few invited students did not participate for unknown reasons. Therefore it is quite improbable that selection occurred which has an impact on the relationships between popmusic exposure and noise-induced hearing loss.

In total 405 pupils/students participated in the tests: 269 male and 136 female students/pupils. Male students/pupils were aged between 14 and 21 years and female students/pupils between 14 and 18 years. Although a part of the students/pupils could better be indicated by pupils for all of them the terms male and female students have been used.

1. QUESTIONNAIRE

Popmusic activities in calender year 1997

The investigation at the schools took part in December 1997 and January 1998. Questions have been asked to the students related to each of the following popmusic activities:

- Listening to popmusic through headphones (walk- and discman's or other audio equipment);
- Visiting popconcerts;
- Visiting discotheques and other locations with loud popmusic, with the exception of house-parties;
- Visiting house-parties;
- Playing popmusic in a band or acting as disc-jockey.

These questions were identical to those of the first part of the investigation. Table 1 shows the percentage of students who performed a given activity in 1997 and for how many times a year or how many hours a day/week.

Table 1 Percentage students carrying out a popmusic activity in 1997 and number of times or duration of the activity among these students.

Popmusic activity	Percentage students	Extent
Use of headphones	85	1.3 hours a day
Visiting popconcerts	33	2.8 times a year
Visiting discotheques	85	3.0 times a month
Visiting house-parties	26	0.7 times a month
Popgroup/disc-jockey	8	1.4 times a month

Questions were also asked about the position of the volume regulator of the own audio equipment while listening through headphones. On average those students that used headphones turned on their regulator at 65% of its maximum. Respondents from the first part of the investigation did so at an average of 53%.

A measure has been defined for the combined exposure of a student to all four popmusic activities, listening through headphones not taken into account. This combined exposure measure takes into account the duration of the exposures and the (estimated) noise levels during exposure.

There is only a weak correlation between the listening duration in 1997 per day for popmusic through headphones and the durations of the other four popmusic activities in 1997. The same applies to the correlation with the combined exposure measure of the four other popmusic activities in 1997.

Popmusic activities over the years

With regard to the five popmusic activities mentioned, it was also questioned for how many years each of these activities have been or are being carried out. The result is given in table 2.

Table 2 Percentage students that ever carried out a popmusic activity and duration of the activity among these students.

Popmusic activity	Percentage students	Number of years
Use of headphones	85	5.7
Visiting popconcerts	33	1.9
Visiting discotheques	85	2.8
Visiting house-parties	26	2.2
Popgroup/disc-jockey	8	1.4

Correlation between activity duration (in years) and extent of an activity in 1997

For each of the five popmusic activities there is a high correlation between number of years of expose and extent of exposure in 1997. The five correlation coefficients are between 0.56 and 0.87. For different activities the correlation is weak. The correlation coefficients are all less than 0.17. This implies among other things that the extent of listening to popmusic through headphones is not related to the other popmusic activities.

Tinnitus

Over 68% of the students observed tinnitus, a clogged or deafened feeling in the ears during and after popmusic activities in 1997. This feeling in the ears is observed most frequent after popconcerts. During or after a concert 16% of the students observe tinnitus etc.. For houseparties this percentage is 7 and for discotheques and playing in a popgroup the percentages are about 1 to 2. About once in a thousand times tinnitus is observed by a student after listening to popmusic through headphones. There is no difference in the results for male and female students.

Relationship between tinnitus and hearing threshold levels

Tinnitus, a clogged or deafened feeling in the ears after exposure to noise is probably a sigh that something happened to the inner ear haircells. Experts and the layman consider frequent occurrence sof tinnitus sometimes as an increased risk of acquiring permanent hearing loss. It has been examined whether the number of times tinnitus was observed in 1997 by a student had any relationship with her/his hearing threshold levels. It turned out that no statistically significant relationships exist between hearing threshold levels at any frequency and the number of times tinnitus was observed in 1997.

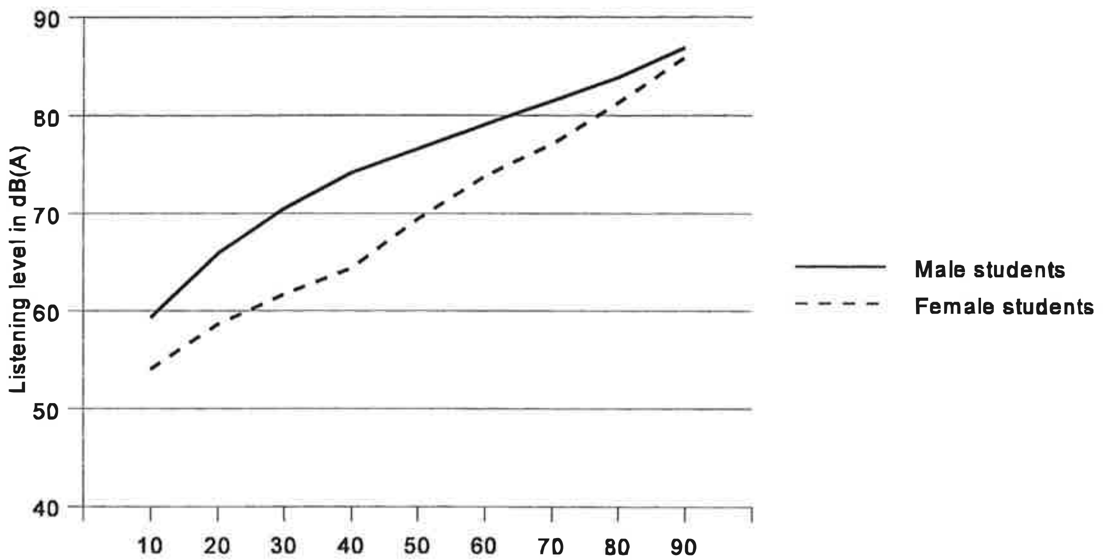
2. LISTENING TEST

A student carrying out a listening test sets the volume regulator of the discman of the test equipment at a level for which the popmusic through the headphones is as loud as it usually is while listening with the own audio equipment. Then the student listens for one minute. If the student used to listen at another level in the past, the student resets the regulator and listens again for one minute. An 'average'[2] sound level over the minute is determined by connecting the output of the discman to the headphoned to an integrating sound level meter and reading this meter after the test is over[3].

Present listening level

The median[4] value of the present listening level is 75 dB(A) of all students which used headphones in 1997. On average male students listen at a higher level than female students. This is shown in figure 1, in which the cumulative distribution of the present listening levels has been plotted for male and female students separately. The median values differ by 7 dB(A). However, the 10% value of the listening levels of the male students is only 1 dB(A) higher than the corresponding value for the female students.

Figure 1 Cumulative distribution of the listening levels (in dB(A)) of the male and female students listening in 1997 to popmusic through headphones. The lines indicate the maximal listening level for a percentage of male or female students. E.g. 90% of the female students have a listening level of at most 87 dB(A).



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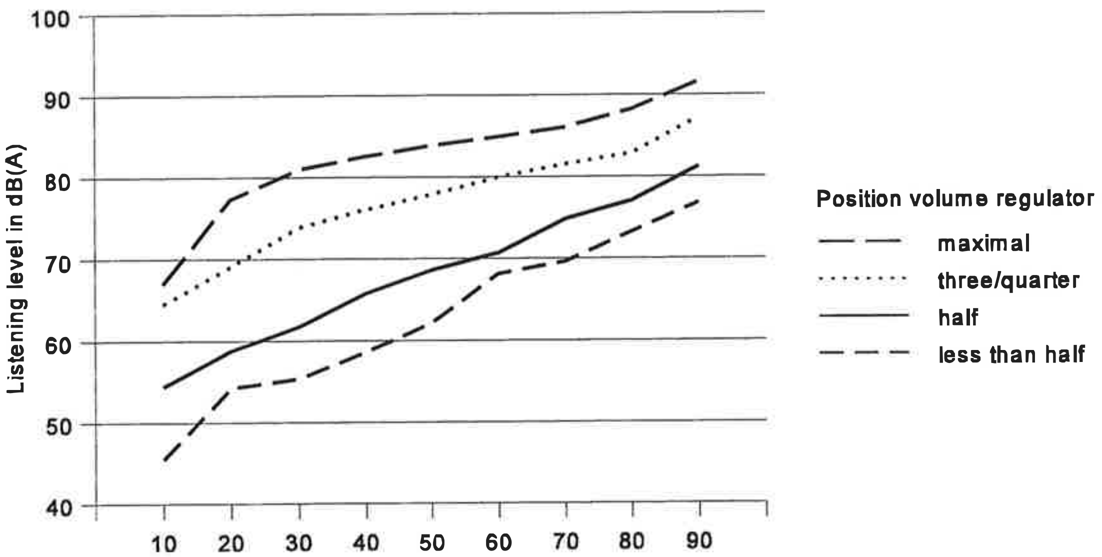
2 In acoustics this 'average' sound level is termed equivalent sound level (ISO 1999, 1990). It is an exponential averaging of the instantaneous sound levels occurring during the minute.

3 The equipment has been calibrated such that the listening level obtained by the test corresponds to the level of popmusic in a room which would cause the same noise exposure in the ear canal.

4 The middle observation of the observations arranged by level.

There is a clear relationship between the listening level of a student during the test and his/her position of the volume regulator of the own equipment (as indicated by the students during the questionnaire). This is shown in figure 2. The students have been divided in four classes according to the position of their volume regulator: less than half the possible maximal position, about half the maximal position, about 3/4 of the maximal position and at the maximum output of the own audio equipment. The median values of the present listening levels in the four classes are: 62, 69, 78 and 84 dB(A).

Figure 2 Cumulative distribution of the listening levels (in dB(A)) of the students listening in 1997 to popmusic through headphones classified according to the position of the volume regulator of the own audio equipment while listening to popmusic through headphones. The lines indicate the maximal listening level for a percentage of students in a certain class.



In the past measurements have been carried out to determine the maximal output of walkman's (Richter, 1990). Using these measurements the median listening levels have been estimated for the four positions of the volume regulator mentioned: 75, 80, 88 and 100 dB(A) (Passchier-Vermeer and Vos, 1997). The differences between the listening levels in the listening tests and these estimated values are 10 to 16 dB(A). *This implies that the listening levels determined in the investigation are 10 to 16 dB(A) lower than estimated earlier.*

The highest present listening level observed in the tests is 94 dB(A). This is an 'average' value determined over one minute. The French regulations in the field of maximal permissible sound levels under headphones do not use an average value but a maximal value (100 dB(A)). This maximum is for popmusic about 6 to 9 dB(A) above the average value. This implies that the present highest listening level observed in the tests is just above the maximal permissible sound level in the French regulations.

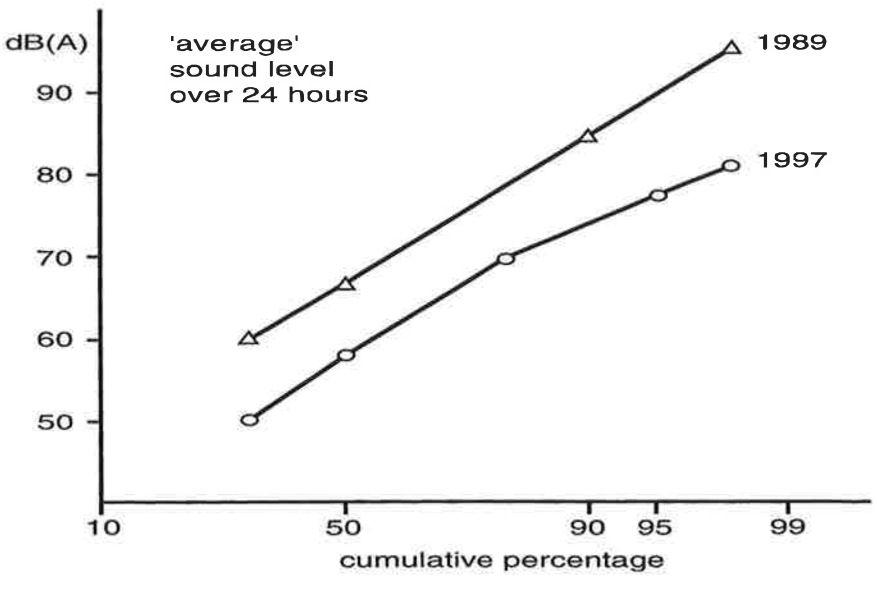
'Average' present popmusic exposure through headphones over 24 hours

The present listening level and the number of hours listened during 24 hours determine together the present exposure over 24 hours. The 'average'[5] popmusic exposure over 24 hours has been calculated for each of the students. In figure 3 the cumulative distribution of the 'average' popmusic exposure over 24 hours of those students listening through headphones in 1997 has been given. The result has been indicated by 1997. The figure also gives the result of earlier estimations (Passchier-Vermeer, 1989). The difference in median values is 9 dB(A) and increases to 14 dB(A) at the highest levels.

Comparison of 'average' 24 hours popmusic levels with relationships in ISO 1999 (1990)

In the International Standard ISO 1999 (1990) relationships are given of noise-induced hearing loss and 'average' sound level over 24 hours for *daily exposure to occupational noise.* Such noise exposures cause noise-induced hearing loss at the most sensitive frequency (4000 Hz) from 'average' sound levels over 24 hours of 70 dB(A). For other frequencies at higher 'average' sound levels noise-induced hearing loss starts to occur: e.g. for 3000 and 6000 Hz at 73 dB(A). Noise-induced hearing loss increases with increasing number of exposure years. If the relationships in ISO 1999 would also be applicable for exposure to popmusic through headphones popmusic-induced hearing loss would be absent at 'average' levels of at most 70 dB(A), which implies according to figure 3 in at least 80% of the students. Popmusic-induced hearing loss in the other 20% of the students then depends on the 'average' popmusic level over 24 hours and years of exposure. This will be considered in chapter 4.

Figure 3 Cumulative distribution of 24 hours 'average' sound levels (in dB(A)) of students listening in 1997 to popmusic through headphones. The result of the present investigation has been indicated by 1997. Results of earlier estimations (Passchier-Vermeer, 1989) have also been included.



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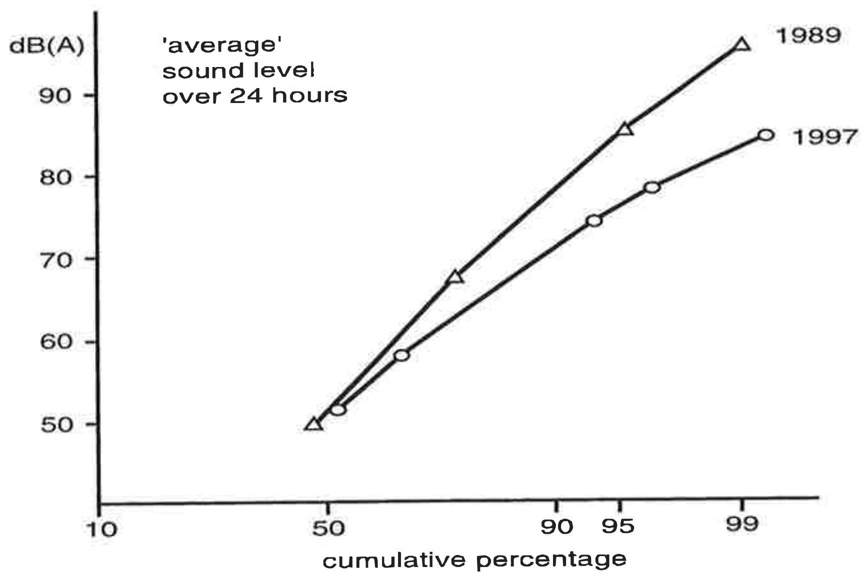
5 In this case it concerns an averaging of the instanteneous sound levels over 24 hours (see note 2).

Estimation of 24 hours headphone popmusic exposure levels of Netherlands young persons

It has been estimated in 1994 (Gezondheidsraad, 1994) that in the beginning of the nineteens about 50% of Netherlands young persons listened to popmusic through headphones. The first part of this investigation showed that in a representative sample of young persons (aged 12 to 20 years) the percentage listeners is about 70%. (The percentage in the second part of the investigation is higher than in the first part, since for part 2 a highly exposed population with regard to the use of headphones has been selected. With regard to prevalence of listening characteristics part 2 does not represent a representative sample of the Netherlands young persons.) By taking the percentage of 50 from the early nineteens and 70% for 1997 the cumulative distributions of the 'average' popmusic levels over 24 hours for Netherlands young subjects have been estimated. The results are given in figure 4. For about 50% of the cases there is no difference in 'average' popmusic level over 24 hours. However, above the median value there is apparently a clear decrease in 'average' popmusic level over 24 hours in Netherlands young subjects.

Figure 4 Cumulative distribution of 24 hours 'average' sound levels (in dB(A)) of the Netherlands population of young subjects (aged 12 to 20) due to listening to popmusic through headphones. The result of the present investigation has been indicated by 1997. Results of earlier estimations (Passchier-Vermeer, 1989; Gezondheidsraad, 1994) have also been included.



3. AUDIOMETRY

Students with substantial hearing loss

The number of students with a hearing threshold level of at least 30 dB at at least one frequency and at least at one ear is 32 (27 male and 5 female students). The question at stake is whether popmusic through headphones may have been the only cause of hearing loss in these students. It seems reasonable to start form the assumption that popmusic-induced hearing loss is like occupational noise-induced hearing loss a high-frequency hearing loss that develops in the course of the years about equally at both ears. This excludes that hearing loss only at the low frequencies and hearing loss only in one ear is caused by popmusic through headphones.[6] None of the students blame their hearing complaints to popmusic, also not to standing close to loudspeakers. Twenty-one of the 32 students have hearing loss which may have be due to causes other than popmusic, such as high occupational noise exposure, specific illnesses, hereditary taint, ototoxic drugs and head injuries. The remaining 11 students (all male students) have hearing loss in the higher frequency region (4000 Hz and over). However, seven of them have a high frequency hearing loss at one ear, while the other ear has normal hearing threshold levels (10 dB or less) . Since it is not reasonable that this hearing loss at one ear has been caused by binaural exposure, only 4 students remain with possibly high frequency binaural hearing loss that is caused by popmusic through headphones. Two of these four students have a very low exposure to popmusic through headphones. The other two students have relatively high exposures to popmusic through headphones. It is reasonable to assume that these two students have high-frequency binaural hearing threshold levels of 30 dB or more **partly** due to popmusic through headphones.

The group of selected students

The analyses of the relationships between hearing threshold levels and exposure to popmusic through headphones has been carried out on the basis of data of a selected group of students. Criteria for selection have been: absence of relevant occupational noise exposures, absence of other possible causes of hearing loss (such as specific illnesses, ototoxic drugs, heriditairy taints, head injury). The group of selected students consists of 238 male students and 122 female students.

Difference in hearing threshold levels of both ears of students in the selected group

A comparison of the hearing threshold levels of the right and left ear showed that hearing threshold levels at the left ear are on average higher than those of the right ear. This is in agreement with earlier

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6 Possibly high-frequency hearing loss at one ear may have been caused by an incidental exposure to very high noise levels presented to one ear, such as possibly during a popconcert when one ear is facing a loudspeaker at very close distance. In that respect the data in the investigation do not permit any conclusion.

findings (Passchier-Vermeer, 1981; Passchier-Vermeer and Rövekamp, 1987). The differences are independent of gender and depend on frequency: on average 1 dB at 1000 Hz and nearly 5 dB at 6000 Hz. Further analyses have been carried out on the average values of the hearing threshold levels at both ears.

Differences in hearing threshold levels of male and female students in the selected group

It was shown that there exist a difference in the average hearing threshold levels of male and female students. At the lower frequencies (500 to 2000 Hz) female students have higher hearing threshold levels than male students. These differences are not statistically significant. At frequencies from 3000 Hz male students have statistically significant higher hearing threshold levels than female students. The differences are 2 to 4 dB.

The reference group and relative hearing threshold levels

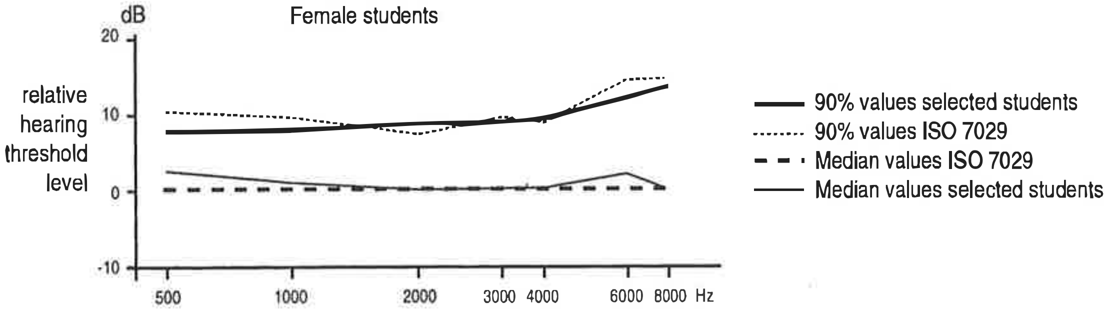
It was intended to select from the selected group of students students without any exposure to popmusic. It turned out not to be possible to use this selection criterion since the selected group contained only one male and one female student without any popmusic exposure. Therefore those students have been selected with only minor exposure to popmusic in the past and at present.

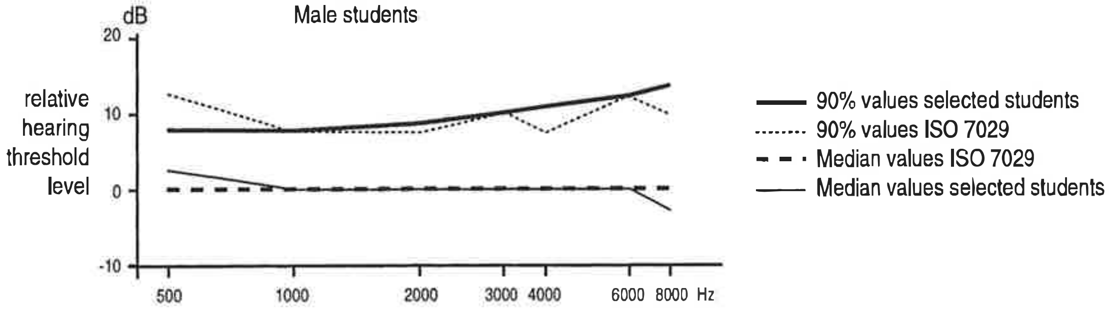
The relationships between exposure to popmusic through headphones and hearing threshold levels have been based on relative hearing threshold levels of the students in the selected group, i.e. on hearing threshold levels of these students relative to the median hearing threshold levels of the male and female reference groups.

Cumulative distribution of relative hearing threshold levels of selected male and female groups

ISO 7029 (ISO, 1997) specifies the cumulative distributions of hearing threshold levels of *reference groups of male and female subjects* as a function of age. Reference groups have been selected according to strict selection criteria. These distributions for reference groups aged 20 years have been compared with those of the selected groups in the present investigation (see figure 5). It turns out that the cumulative distributions of the selected groups in this investigation are almost identical to those of the ISO reference groups of comparable age. Despite the possibility of popmusic-induced hearing loss in the selected groups in the present investigation hearing threshold levels in this population are not higher than those of the ISO reference groups which are assumed not to have had 'any undue exposure to noise'. This does not exclude, however, the possibility of popmusic- induced hearing loss in a small fraction of the selected group .

Figure 5 Median relative hearing threshold levels and relative hearing threshold levels just not exceeded in 90% of the students in the selected groups (upper part of the figure female students, lower part of the figure male students) and these relative hearing threshold levels according to ISO 7029 (1977).





4. RELATIONSHIPS EXPOSURE TO POPMUSIC THROUGH HEADPHONES AND HEARING THRESHOLD LEVELS

Effect other popmusic exposures on relative hearing threshold levels

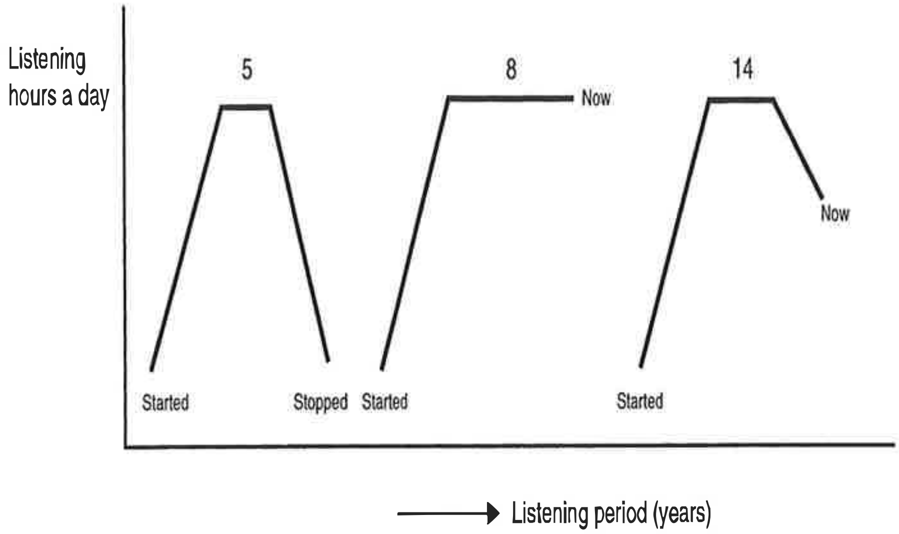
An analysis has been carried out to determine whether other popmusic activities (visiting popconcerts, discotheques, house-parties, playing in a popgroup/acting as disc-jockey) have an effect on the hearing threshold levels of the selected group of students. First the relationships between relative hearing threshold levels (for male and female students separately and considered as one group) and popmusic exposure in 1997 for the four activities separately have been considered. Female students showed a statistically significant increase in hearing threshold level at 8000 Hz in relation to visiting house-parties. Hearing threshold levels have no relationship with any of the other popmusic activities. The relationship between relative hearing threshold levels and the combined measure of the exposure to popmusic during the four activities mentioned showed no statistically significant effect of exposure on hearing threshold level. This implies that exposure to popmusic during the four activities mentioned do not have any effect on the hearing threshold levels of the students in the second part of the investigation. This conclusion does, however, not imply that groups more heavily exposed to popmusic during these four activities also do not acquire noise-induced hearing loss.

Patterns of exposure to popmusic through headphones

The exposure patterns of the students have been classified in 15 classes. In an exposure pattern the extent of exposure to popmusic through headphones is specified during the listening period, i.e. during the years a student listened to popmusic through headphones. Of the 15 exposure patterns defined in the investigation three have been plotted in figure 6. The listening period has been divided in three parts. For each of these three parts three characteristics of the exposure have been determined:

- number of years the part includes;
- average number of hours listened to popmusic through headphones;
- listening level.

Figure 6 Three exposure patterns (no 5, 8 and 14). Exposure pattern 8 is the most frequent pattern in the investigation (24% of the students). In all three exposure patterns number of hours per day listened increases during the first part and remains more or less the same in the second part. In exposure pattern 5 listening to popmusic through headphones stopped after the second period, in exposure pattern 8 number of listening hours a day was about the same in the second and third period and in exposure pattern 14 number of hours listened to popmusic through headphoned decreased up to the present number of hours a day.



BEL for popmusic through headphones

For many of the characteristics that specify popmusic exposure through headphones (listening period, present and past listening level, number of hours per day listened at present and in the past) relationships with relative hearing threshold levels have been considered. None of these characteristics turned out to have a statistically significant relationship with relative hearing threshold levels, although some of the characteristics showed a trend at the higher frequencies.

Further analyses have been carried out with a combined measure (BEL) for the exposure to popmusic through headphones. From the detailed information about the exposure pattern of a student a popmusic-exposure-measure has been determined which takes into account this detailed information in a specific way. The specification of BEL has been based on the model presented in ISO 1999 (1990). By using the relationships between noise-induced hearing loss at 4000 Hz (the frequency at which noise-induced hearing losses are larger than at other frequencies) and 'average' equivalent sound level over 24 hours BEL has been calculated for each student. The specifications of BEL are such that apart from a popmusic-exposure-measure BEL is also equal to popmusic-induced hearing loss to be expected at 4000 Hz, if the model presented in ISO 1999 (1990) would also be applicable to exposure to popmusic through headphones. It turned out to be necessary to specify such a complex exposure metric, since the separate exposure measures did not show any relationship with hearing threshold levels.

The calculations showed that 278 (77%) of the 360 students in the selected groups have a value of BEL equal to 0, 82 students a BEL larger than 0, including 35 (10%) of the students with a BEL > 1. This implies that if the model in ISO 1999 would be correct for exposure to popmusic through headphones 77% of the students would not have any popmusic-induced hearing loss, 13% popmusic-induced hearing loss at 4000 Hz of less than 1 dB and 10% popmusic-induced hearing loss at 4000 Hz over 1 dB.

Hearing loss caused by exposure to popmusic through headphones

An extensive analysis has been carried out to determine whether exposure to popmusic through headphones, specified by BEL, has statistically significant relationships with relative hearing threshold levels. It turned out that relative hearing threshold levels at 4000 and 6000 Hz of the group of 35 students with BEL > 1 are statistically significant larger than relative hearing threshold levels of the remaining students in the selected groups. These 35 students have an average popmusic-induced hearing loss at 4000 and 6000 Hz of 2.7 dB. Of the 47 students with BEL between 0 and 1 relative hearing threshold levels at higher frequencies appeared to be a few dB higher than those of the students with BEL equal to 0, but differences turned out not to be statistically significant.

The number of students in the selected group of students consisted of 337 students that ever listened to popmusic through headphones and 23 students who never listened to popmusic through headphones. This implies that 35 of the 337 (10.4%) listeners acquired popmusic-induced hearing loss at 4000 and 6000 Hz of 2.7 dB.

Application of the model presented in ISO 1999 (1990)

The question is whether the model presented in ISO 1999 which gives relationships for occupational noise-induced hearing loss can also be applied to exposure to popmusic through headphones. The data of the group of selected students have shown the following indications (for listening levels of at most 95 dB(A) and listening periods not exceeding 10 years):

- According to ISO 1999 exposures such as those of the students cause no hearing loss at frequencies 500, 1000 and 2000 Hz. This corresponds to the findings with respect to the relative hearing threshold levels of the selected group of students;
- At frequencies from 3000 Hz frequency-dependency of popmusic-induced hearing loss is somewhat different from the relationships of occupational noise-induced hearing loss given in ISO 1999 (1990). Observed popmusic-induced hearing loss at frequencies from 3000 Hz is more accurately described by relationships in ISO 1999 for frequencies a half octave lower (2000 Hz is half an octave lower than 3000 Hz, 3000 Hz half an octave lower than 4000 Hz, 4000 Hz half an octave lower than 6000 Hz and 6000 Hz half an octave lower than 8000 Hz).

This implies that distinct from occupational noise-induced hearing loss popmusic-induced hearing loss has its maximum at 6000 Hz with somewhat less popmusic-induced hearing loss at 4000 Hz.

5. PREVALENCE OF POPMUSIC-INDUCED HEARING LOSS IN YOUNG PERSONS IN THE NETHERLANDS

Number of young persons with popmusic-induced hearing loss

About 4.05 million young persons aged between 12 and 30 years live in the Netherlands. In part 1 of the investigation several characteristics of exposure to popmusic through headphones (number of years, number of hours per day in 1996, position of the volume regulator of the audio equipment) have been determined in a representative sample of these young persons. In part 2 of the investigation relationships between popmusic exposure and popmusic-induced hearing loss have been specified. The data from part 1 and 2 have been combined to estimate prevalence of popmusic-induced hearing loss in the Netherlands young persons. It has been assumed that listening levels in the past have been equal to the present ones if the position of the volume regulator was the same.

It is estimated that 260 000 young persons (6.5%) aged between 12 and 30 years have popmusic-induced hearing loss at 4000 and 6000 Hz of 3 dB by listening to popmusic through headphones. The 95% confidence interval of this number of young persons is 190 000 to 370 000.

Elucidation: hearing threshold levels in populations increase with increasing age. According to ISO 7029 this increase starts already at an age of 20 years. On average hearing threshold levels at 4000 and 6000 Hz increase by 3 dB if age increases from 20 to 30 years. Relative hearing threshold levels at 4000 and 6000 Hz of the group of Netherlands young persons with popmusic-induced hearing loss corresponds to those levels of a group of young persons without popmusic-induced hearing loss which is on average 10 years older.

It is also estimated that 15 000 young persons (0.4%) in the Netherlands have binaural high-frequency hearing threshold levels of 30 dB or higher which are partly due to exposure to popmusic through headphones. The 95% confidence interval of this number is 1 600 to 51 000.

Elucidation: Persons with binaural high-frequency hearing threshold levels of 30 dB usually have difficulties with speech intelligibility in some everyday situations. Difficulties may arise due to the misunderstanding of for instance *f*- and *s-sounds.*

6. CONCLUSION AND RECOMMENDATIONS

Conclusion

Part 2 of the investigation showed results which are consistent:

- Listening levels under headphones are 10 to 15 dB(A) lower than estimated before. Combined with number of hours listening per day to popmusic through headphones most students have 'average' popmusic exposure levels over 24 hours which do not cause noise-induced hearing loss;
- Taking into account the observed distributions of relative hearing threshold levels it is reasonable to assume that most of the students did not acquire popmusic-induced hearing loss. Nearly 10% of the students have a small popmusic-induced hearing loss of 3 dB.

Recommendations

Exposure to popmusic through headphones and resulting popmusic-induced hearing loss is less than earlier estimated (Gezondheidsraad, 1994; Passchier-Vermeer and Vos, 1997). However, the observed popmusic-induced hearing losses, although small, support the assumption that at higher popmusic exposures popmusic-induced hearing loss will be larger. To prevent increase in prevalence of popmusic-induced hearing loss it is important to prevent increase in popmusic exposure through headphones. It is even recommended to try to reduce the highest exposure levels by about 5 dB(A). This may be accomplished by:

- direct information to young persons to limit the volume of their audio equipment while listening through headphones;
- manufacturing of walk- and discman's with a lower maximal output than the present ones.

In this respect attention should be paid to the possibility of high noise exposure in the future (such as occupational noise exposure and exposure to popmusic during other popmusic activities) of young persons with a presently high exposure to popmusic through headphones. Combination of hearing damaging exposures, even if they do not occur during the same period of life, will most probably have a cumulative effect on hearing threshold levels, which will cause a larger percentage of persons to acquire higher hearing threshold levels.

Further investigations

Part 2 of the investigation has been aimed at specifying hearing loss due to exposure to popmusic through headphones. The group of students in part 2 have been selected accordingly. Research into the effects on hearing of popmusic activities other than listening to popmusic through headphones requires according to the results of part 1 of the investigation another population to be studied. Especially young persons aged 20 to 25 years with a higher education are highly exposed to popmusic at other popmusic activities. The results of part 2 of the present investigation indicate that a frequency-adapted model in ISO 1999 is appropriate for the estimation of hearing loss induced by popmusic through headphones. Suppose that this result is applicable to other popmusic exposures as well. Then the data from part 1 of the investigation show that popmusic-induced hearing loss will be considerable in the population mentioned, if the estimations (Passchier-Vermeer and Vos, 1997) of sound levels during these activities are correct. Therefore further investigation in two parts is recommended: first research of noise exposures at popconcerts, discotheques and house-parties and then audiometric testing of a highly exposed group of young persons.

1. INTRODUCTION

1.1 Framework of the investigation

The Minister of Health, Welfare and Sport remarked in a letter to the Lower House at the end of 1995 that she considered the use of walkman's and possible noise-induced hearing loss by using this audio equipment of sufficient interest to survey the research possibilities to get a better insight into the exposure-effect relationships. After consultation, TNO-PG has been requested to carry out a project on the exposure to popmusic of young persons in the Netherlands. The project consisted of two parts.

The first part of the project concerned a *questionnaire* among a representative sample of young persons, aged between 12 and 30 years, about their popmusic activities. The results have been presented in Dutch and English (Passchier-Vermeer and Vos, 1997a, 1997b). Based on the data of the first part the group of young persons for the second part of the project has been selected. The main criterion of this selection was a high exposure to popmusic through headphones. Both the number of listening years (the listening period) and the extent of listening (with respect to present listening level and number of listening hours per day at the tome of the investigation) played a role in the selection. The selected group has therefore not been chosen on the basis of a high exposure to popmusic at other activities (popconcerts, discotheques, house-parties, playing in a popgroup, acting as disc jockey). On the basis of the questionnaire these exposures are expected to be relatively low in the selected group.

The second part of the investigation aimed at determining the relationships between exposure to popmusic through headphones and noise-induced hearing loss. To that aim test subjects have been submitted to an extensive *questionnaire*, with questions about their exposure to popmusic during several activities and a number of other relevant items. A part of the questionnaire contained questions identical to those in the questionnaire of the first part of the investigation. A *listening test* has been carried out in which the listening level under headphones of a discman has been determined. Also an *audiometric investigation*[1] has been carried out to determine the hearing threshold levels of the test subjects. The hearing threshold level (at a given ear) at a given frequency is the level (in dB) at which a test subject is just able to hear the test tone in that ear. Tests have been carried out in an audiomobile which has been especially constructed for those purposes and which has been made available by 'Umwelt Bundesambt' in Berlin.

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[1] Test tones have been presened and hearing threshold levels have been determined according to the specifications given in ISO 6189 (1983). Hearing threshold levels have been determined seperately at both ears at the following frquencies: 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz.

Based on a combination of the data of the first and second part of the investigation an estimate has been made of the prevalence of hearing loss induced by exposure to popmusic through headphones in the young Netherlands population.

This report contains the statistical analysis of the data of the second part of the investigation and is a translation of the Netherlands text given in Passchier-Vermeer, Vos and Steenbekkers (TNO-PG report 98.016). The executive summary of this report is a translation of the Netherlands text given in Passchier-Vermeer, Steenbekkers and Vos (TNO-PG report 98.035), which gives a summary, conclusions and recommendations. Parts of this report have been included in the executive summary.

1.2 Contents of the report

In paragraph 1.3 results of part 1 of the investigation have been summarized, in as far as they are relevant for part 2 of the investigation. Chapter2 considers the organization of the measurements carried out in part 2. Chapter 3 gives an overview of the data collected in part 2 and a comparison with the results in part 1. In chapter 4 the relationships between exposure to popmusic through headphones and popmusic-induced hearing loss has been analysed. In chapter 5 prevalence of popmusic-induced hearing loss in Netherlands young persons has been estimated.
The report contains four annexes. Annex A contains definitions and descriptions of terminology used in the report. Annex B presents the questionnaire. In Annex C technical specifications are given of audiometric and listening test equipment. Annex D contains the tables of the report.

1.3 Part 1: inventory of popmusic exposure among Netherlands young persons

The inventory in the first part of the investigation has been carried out in December 1996 (Passchier-Vermeer and Vos, 1997) by means of a questionnaire among a representative sample of young persons, aged between 12 and 30 years, about their popmusic activities. These activities are:

- Listening to popmusic through headphones (walk- and discman's or other audio equipment);
- Visiting popconcerts;
- Visiting discotheques and other locations with loud popmusic, with the exception of house-parties;
- Visiting house-parties;
- Playing popmusic in a band or acting as disc-jockey.

The questionnaire consisted of 13 questions. The first five questions considered the total number of years a respondent ever carried out one of the five popmusic activities mentioned. The next six questions concerned the frequency of each of the five activities in 1996 and with regard to listening through headphones also the position of the volume regulator of the audio equipment. The last two questions have been devoted to the occurrence of tinnitus during and after popmusic activities.

Based on the results of the first part of the investigation the group of young persons for the second part have been selected. The main criterion of this selection was a high exposure to popmusic through headphones. Both the number of years of listening (the listening period) and the extend of listening (with respect to listening level and number of listening hours per day) played a role in the selection. According to the results of the first part of the investigation young persons aged 12 - 17 years with a lower school education had the highest exposure to popmusic through headphones in 1996. Also the duration of exposure did not differ much with that of the older populations. Groups of students have been selected at the upper part of the age range (14 years and over). The selected group has not been chosen on the basis of a high exposure to popmusic at other activities (popconcerts, discotheques, house parties, playing in a popgroup, acting as disc jockey). On the basis of the questionnaire these exposures are expected to be relatively low in the selected group.

2. ORGANIZATION AND EXECUTION OF PART 2 OF THE INVESTIGATION

2.1 Aspects of the organization

Based on power calculations the size of the population to be tested has been set at 400 students. Power calculations have been based on assumed listening levels (Richter, 1990) and the applicability of ISO 1999 (1990) to exposure to popmusic through headphones.

In cooperation with the Public Health Service Centre of Rotterdam a number of schools have been selected. Five schools have been invited to participate, of which all agreed to take part. Three of the schools participated, the other three served as reserves. In total about 200 students of the three schools participated. A preliminary analysis of the data showed that short-term and long-term *durations* of the exposures to popmusic through headphones corresponded well with expectations. However, *listening levels* of the students appeared to be much lower than expected during the power calculations. This implies that *total exposure*, which is a combination of level and duration, turned out to be much less than used in the power calculations. Based on these observations it was decided to carry out the second part of the investigation with an older group of students, which were expected to have a relatively still higher exposure to popmusic through headphones than the students from the schools at Rotterdam. The School for Job Related Education in Leiden has been contacted and appeared to be willing to cooperate. Students of this school are somewhat older than students in Rotterdam and they are also for the larger part male students. Since part 1 of the investigation showed exposure of male respondents to popmusic through headphones to be higher than exposure of females it seemed likely that the students of the school in Leiden would have relatively high exposures. Somewhat over 200 students of the school at Leiden participated in the tests.

Each of the students of the classes at the schools in Rotterdam and of the groups selected from the school in Leiden received a letter in which they were invited to participate and in which the procedures during the test was explained. Apart from some students who could occasionally not participate in the test only a few invited students did not participate for unknown reasons. Therefore it is quite improbable that selection occurred which has an impact on the relationship between popmusic exposure and popmusic-induced hearing loss.

If a student turned out to have hearing threshold levels in excess of 30 dB at any frequency at any of the two ears and was not/never under medical treatment or control for hearing deficits students and their parents have been noticed that the audiometric test results were deviating from normal and the advice given to contact the Public Health Service Centre of Rotterdam or Leiden, which one was appropriate. The audiometric test results of these students have been submitted to the Centres.

2.2 Execution of the test at the schools

The audiomobile

Tests have been carried out in a so called audiomobile. This audiomobile has been made available by the Umwelt Bundesambt in Berlin. The audiomobile has been located near the schools, usually on the terrain at the quieter side of the school. In the audiomobile sound insulation measures had been taken. Since these measures might not be sufficient to assure sufficient low ambient sound levels at any time during hearing threshold level measurements from -10 dB (a level of 10 dB lower than audiometric zero) it was decided during the preparation of the measurements to carry out the tests with an audiometer with headphones built in large hearing protectors (see annex C). Measurements before and during the tests at the schools confirmed that the equipment allowed measurements down to -10 dB at any frequency, including 500 Hz as the most critical frequency in this respect.

Testing of a student

The total test time took about 20 minutes.

The testing went as follows:

- After acquaintance has been made with the test leader the questions of the questionnaire were put forward. The student responded to the questions and answers have been stored by the test leader at the same time in the computer. The questionnaire is given in annex B. A part (part 3) of the questions is identical to the questionnaire in the first part of the investigation. Another part of the questions concerned a detailed construction of the exposure to popmusic through headphones. On the basis of the questions put forward by the test leader the student selected his/her pattern of exposure to popmusic through headphones. At this stage it was also questioned whether the student listened formerly to popmusic through headphones at a different level than at the time of the investigation;
- Then the audiometric test was performed. For a description of the test and technical specification of the audiometric equipment, see annex C;
- After the audiometric test the student performed the listening test. The student listened to his/her choice of popmusic through headphones of a discman. Various compact discs were available in the audiomobile. Usually the students choose their preferred number beforehand. The student was requested to put the position of the volume regulator such that the popmusic sounded as loud as he/she was used to at present with his/her own equipment. If the student did no longer listen to popmusic through headphones he/she was questioned to adjust the volume regulator according to

the former listening level. After the position of the volume regulator was selected, the student was allowed to listen for one minute to his/her choice of popmusic. If the student listened in the past at another listening level than at the time of the investigation the student was requested to adjust the volume regulator again to match the former listening level. A specification of the determination of the listening levels is given in annex C;

- At the end of the test the test leader explained in qualitative terms the result of the audiometric test. In case of test results deviating from normal the student was recommended to contact the Public Health Service Centre and a letter for the parents was given along with the student.

3. DATA PART 2 AND COMPARISON WITH DATA PART 1

3.1 Introduction

In this chapter an overview is given of the data compiled in this investigation. Paragraph 3.2 presents the results with respect to the questionnaire, the listening test and audiometric test. Next in paragraph 3.3 the information of part 2 has been compared with the information compiled in part 1 of the investigation. Some of the students have relatively high hearing threshold levels. It has been analysed in paragraph 3.4 whether exposure to popmusic through headphones contributed to these hearing threshold levels. Paragraph 3.5 handles the question whether there is a relationship between characteristics of listening to popmusic through headphones and satisfaction with learning achievements. This paragraph also deals with the question whether tinnitus experienced during or after a popmusic activity is related to hearing threshold levels. Terms and definitions used in this chapter are given in annex A of this report.

3.2 Characteristics of the group of students in part 2

Results of the questionnaire

Annex B contains the questionnaire. The results of the questionnaire in this paragraph are presented in about the same sequence as the questions in the questionnaire. Most of the times results are presented for all 405 students and for the students classified according to location of the schools (Rotterdam and Leiden).

The first tables of annex D present the distributions of various personal characteristics (group 1 of the questionnaire). Table 1 shows the distribution according to gender and age: 269 male students and 136 female students took part in the investigation. Data about the type of education is given in table 2. Table 3 specifies the satisfaction with school achievements. The tables 4 to 9 specify several items with respect to hearing and ear problems. Table 4 shows that 172 of the 405 students ever visited a (family) doctor about ear or hearing problems. Most of the 172 students visited their (family) doctor at most three times, but 9 of them went at least 10 times. 29 of the students visited an ear specialist, an audiological centre or a hospital because of hearing complaints. The number of students wearing hearing-aids is five (1%). Table 8 shows that less than half of the students that went to an ear specialist etc. know the origin of their hearing complaints. None of the students blames popmusic as the origin of their complaints. According to table 9 speech intelligibility of the students is good. Less than 1/4 of the students is in the two lower classes.

The tables 10 to 14 present the number of years the students ever performed each of the five popmusic activities. In the tables 15 - 22 information is given about popmusic activities in 1997. It concerns the number of times, and in the case of listening to popmusic through headphones the number of hours per day, the activity has been performed in 1997. With regard to listening to popmusic through headphones there was also a question about the position of the volume regulator of the audio equipment.

It turned out that among the students there is only one male and one female student which did not perform any popmusic activity in their whole life.

The tables 21 and 22 present data about the observation of tinnitus, a clogged or deafened feeling in the ears during and after popmusic activities in 1997. Table 21 shows that somewhat over 68% of the students did not observe any of these phenomenons in 1997. The question has not been completed by 24 (6%) respondents, since they did not perform any popmusic activity in 1997. Table 22 shows which of the popmusic activities caused tinnitus etc. The respondent have been allowed to give more than one answer to this question. In total 277 respondents with tinnitus etc. indicated 365 popmusic activities. In that respect visiting discotheques are mentioned more than the other popmusic activities: 53.7% of 365 responses concern discotheques. House-parties are mentioned 62 times. This difference may have been caused by the fact that discotheques have been much more visited than house-parties. To analyse this, the number of students who performed a popmusic activity has been taken into account. The third column of table 22 shows these percentages. The next column shows for each of the popmusic activities the percentage of students with tinnitus etc. after the popmusic activity. Obviously, now house-parties have the highest score, directly followed by discotheques. Popmusic through headphones and acting as disc-jockey have the lowest score. The last column does not only take into account the number of students who performed a popmusic activity in 1997, but also how many times these activities have been performed in total in that year[2]. The last column of the table shows that the percentage of times respondents observe tinnitus etc. after an activity is highest for popconcerts, followed by house-parties. Discotheques and playing in a popgroup or acting as disc-jockey give about the same result, whereas the percentage of times tinnitus is observed after listening to popmusic through headphones is lower than after each of the other activities. In part 1 of the investigation the same sequence has been observed: 12.4% in case of popconcerts, 5.0% for house-parties, 1.5% for discotheques, 1.4% for acting as discjockey/playing in a popgroup and 0.1% for popmusic through headphones. In both parts of the investigation in one out of 1000 times after listening to popmusic

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[2] This has been determined as follows. For each of the exposure time classes the number of respondents within a class has been multiplied with the mean value of that class. For the lowest class half the value of the upper value has been taken and for the highest class 1.25 times the lowest value. Then each of the outcomes of the multiplications have been added. With respect to the use of headphones, it is estimated that the average listening time is three hours.

through headphones tinnitus etc. has been observed.

Group 4 of the questionnaire considered exposure to popmusic through headphones. Questions have been asked in a systematic way to determine the exposure pattern of a student and after the pattern has been chosen the characteristics of the exposure pattern. The exposure patterns have been classified in 15 classes. In an exposure pattern the extent of exposure to popmusic through headphones is specified during the listening period, i.e. during the years a student listened to popmusic through headphones. The 15 exposure patterns defined in the investigation have been plotted at the end of annex B. The listening period has been divided in three parts. For each part three characteristics of the exposure have been determined:

- number of years the part includes;
- average number of hours listened to popmusic through headphones;
- listening level.

Table 23 gives the distribution of the exposure patterns of the students. Each of the patterns have been chosen, although the majority of the patterns correspond to pattern 7 and 8. With the exception of pattern 9 there is apparently no difference between male and female students.

At the time and just before part 2 of the investigation a television and radio campaign (SIRE campaign) has been held about the possible adverse effects of too loud walkman's on the hearing of listeners. Just over 3/4 of the students were not aware of the campaign. Unfortunately the question has not been put forward to 52 students from the school at Leiden. At the start of the tests at that school the question was erroneously removed from the questionnaire during the inclusion of questions with regard to occupational noise exposure. Since also the test leader was another person than in Rotterdam, only after some days the absence of the question in the questionnaire has been detected.

The students from the school at Leiden visit this school one day a week and during the other weekdays they have a profession. In principle those groups of students have been selected with minor occupational noise exposure. However, due to circumstances this failed to a certain extent. Therefore, in the questionnaire questions about occupational noise exposure have been included. 71 of the 205 students have been exposed to occupational noise to such an extent that it was (for some time during the workday) difficult to understand other persons. It concerns 69 male and 2 female students. Data with respect to the duration of the loud occupational noise exposure, the use of personal hearing protection is given in table 25.

Listening levels under headphones

The next group of results concerns the listening levels of the students under headphones. A student carrying out a listening test sets the volume regulator of the discman of the test equipment at a level for which the popmusic through the headphones is as loud as it usually is while listening with the own audio equipment. Then the student listens for one minute. If the student used to listen at another level in the past, the student resets the regulator and listens again for one minute. An equivalent sound level over the minute is determined by connecting the output of the discman to the headphoned also to an integrating sound level meter and reading this meter after the test is over. The equipment has been calibrated such that the listening level obtained by the test corresponds to the level of popmusic in a room which would cause the same noise exposure in the ear canal. For details, see annex C.

Table 26 gives the cumulative distribution of the listening levels for students classified according to gender and location and for all students together. During the tests 6 students turned out to listen to a higher listening level at home than could be produced by the equipment in the audiomobile. For these students their listening level is taken as the level at the maximum output of the equipment at the selected number of the CD plus 5 dB(A). Later in this report the value of 5 dB(A) will be justified.

The median value of the present listening level is 75 dB(A) of all students which used headphones in 1997. On average male students listen at a higher level than female students. This is shown in figure 1, in which the cumulative distribution of the present listening levels has been plotted for males and females separately. The median values differ by 7 dB(A). However, the 10% value of the listening levels of the male students is only 1 dB(A) higher than the corresponding value for the female students.

There is a clear relationship between the listening level of a student during the test and his/her position of the volume regulator of the own equipment (as indicated by the questionnaire). This is shown in figure 2. The students have been divided in four classes according to the position of their volume regulator: less than half the possible maximal position, about half the maximal position, about 3/4 of the maximal position and at the maximum output of the own audio equipment. The median values of the present listening levels in the four classes are: 62, 69, 78 and 84 dB(A).

Figure 1 Cumulative distribution of the listening levels (in dB(A)) of the male and female students listening in 1997 to popmusic through headphones. The lines indicate the maximal listening level for a percentage of male or female students. E.g. 90% of the female students have a listening level of at most 87 dB(A).

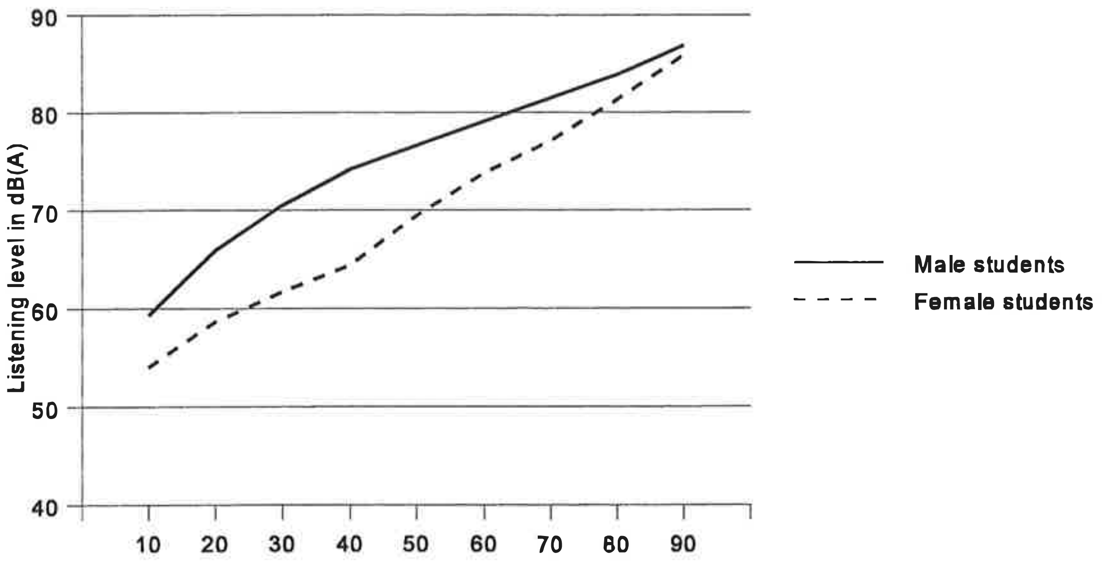
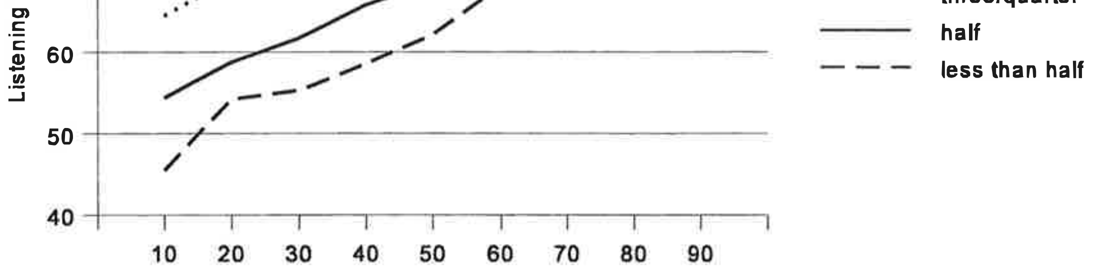


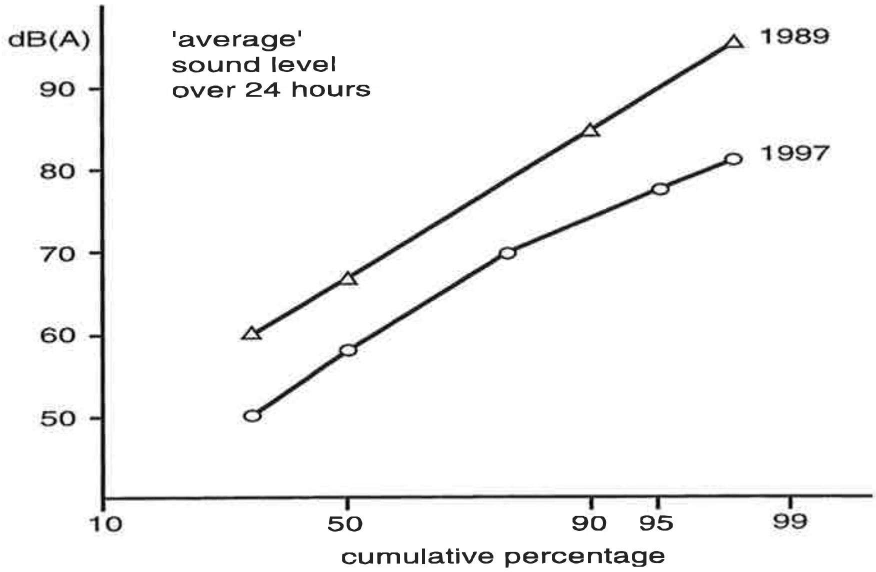
Figure 2 Cumulative distribution of the listening levels (in dB(A)) of the students listening in 1997 to popmusic through headphones classified according to the position of the volume regulator of the own audio equipment while listening to popmusic through headphones. The lines indicate the maximal listening level for a percentage of students in a certain class.



In the past measurements have been carried out to determine the maximal output of walkman's (Richter, 1990). Using these measurements the median listening levels have been estimated for the four positions of the volume regulator mentioned: 75, 80, 88 and 100 dB(A) (Passchier-Vermeer and Vos, 1997). The differences between the listening levels in the listening tests and these estimated values are 10 to 16 dB(A). *This implies that the listening levels determined in the investigation are 10 to 16 dB(A) lower than estimated earlier.*

In figure 3 the cumulative distributions of the listening levels classified according to gender of the students and position of the volume regulator are given.

Figure 3 Cumulative distribution of the listening levels (in dB(A)) of the students listening in 1997 to popmusic through headphones classified according to gender and position of the volume regulator of the own audio equipment while listening to popmusic through headphones. The lines indicate the maximal listening level for a percentage of students in a certain class.



Students who stopped listening to popmusic through headphones have indicated their former listening level. It concerns 30 students: 18 male and 12 female students. The cumulative distributions of the former listening levels of those students that ceased listening are given in table 29. During the tests three students turned out to listen to a higher listening level at home than could be produced by the equipment in the audiomobile. For these students their former listening level is taken as the level at the maximum output of the equipment at the selected number of the CD plus 5 dB(A). There is only a slight difference between the former listening levels of those students who ceased listening and the present listening levels. The median value of the former levels is 2 dB(A) less than that of the present levels. Comparisons have also been made between former and present listening levels of male students and female students separately. No clear differences could be detected.

Results of former listening levels of students that changed their listening level in the course of time are given in table 30 together with the present listening levels. During the tests 6 students turned out to listen to a higher listening level at present at home than could be produced by the equipment in the audiomobile. Three of these 6 students indicated to have had their equipment at home in former times at an even higher level. For those three students their former listening level has been taken as the level at the maximum output of the equipment at the selected number of the CD plus 10 dB(A).

The median value of the former listening levels is 1 dB(A) lower than the median value of the present listening levels. For male students this difference is also 1 dB(A) and for female students the median value used to be 1 dB(A) higher. These differences are very small and statistically not significant. The results therefore show that present and former listening levels are the same. It should be borne in mind that this conclusion has shown to be valid only for the exposure time considered, i.e. on average 5 years.

Table 31 gives the cumulative distributions of the difference between former and present listening levels for students which used to listen at another level in the past. Classified according to a positive and negative value of the differences between former and present listening level the median values differ by +6 and -6 dB(A) respectively. Another listening level therefore appears to have a difference of 5 dB(A). In the former calculations for this difference a value of 5 dB(A) has been chosen.

Audiometric test results

This paragraph specifies the audiometric test results. Three types of groups are distinguished: *all* 405 students, 360 students in the *selected groups* of 238 male students and 122 female students and the *reference groups* of 60 male and 40 female students. The data of the selected groups will be used for the relationships between exposure to popmusic through headphones and hearing loss. In these groups students have been excluded with possible causes of hearing loss, with the exception of exposure to popmusic, such as hereditary effects, ototoxic drugs, specific llnesses and occupational noise exposure. For selection criteria: see annex A.

Usually in epidemiological research a population of subjects not exposed is compared with the exposed population. In this investigation such a reference group of students not at all exposed to popmusic consisted of only two students: one male and one female student. Apparently it is not possible to select a reference group that is large enough to be able to act as such. Therefore a reference group has been selected with a minimal exposure to popmusic. For details, see annex A.

It has been shown earlier (Passchier-Vermeer, 1981, 1986) that in populations a difference exists in hearing threshold levels at the right and left ear. Also for the group of selected students such a difference exists. Table 32 shows these differences together with results for two other groups of Netherlands young persons (Passchier-Vermeer, 1981, 1986). Table 32 shows that the present group of students also show higher hearing threshold levels at the left ear.
The difference between hearing threshold levels at the left and right ear have been considered as a function of gender and average hearing threshold level at both ears. Table 33 shows the result for classification according to gender. The two-sided Students-t-test showed that at 6 out of 7 frequencies there is no statistically significant difference between male and female students ($P > 0.05$). At 500 Hz the difference in hearing threshold levels of male students is 4.2 dB and this difference for female students is 1.3, which gives a difference of 2.9 dB ($t = 3.2$, $P = 0.01$).

By using a linear regression model differences between hearing threshold at the right and left ear have been considered as a function of average hearing threshold levels. The slope of the best fitting straight lines are given in table 33. These slopes are not statistically significant different from 0 at the frequencies 500, 1000, 2000, 3000 and 4000 Hz for all students and for students classified according to gender. At 6000 and 8000 there is a slope different from 0, if the group is not classified according to gender. Since the slopes are positive the difference between hearing threshold levels increase with average value. With a range of 20 dB in the average value, the increase in the difference is 3.0 dB at 6000 Hz and 3.6 dB at 8000 Hz.

In the following the mean value of the hearing threshold levels of both ears is indicated by gx, with x the frequency. In the text the wording mean is omitted.

Table 34 shows the average values of the hearing threshold levels (right and left ear averaged) for all students and for the groups of selected students. The differences in average values are about 1 dB.

Table 35 shows values of some measures of central tendency of the hearing threshold levels of the selected groups of students. There is a difference between values for male and female groups. In table 36 information is given about the significance of these differences, using Students-t-test. At the lower frequencies (500 to 2000 Hz) female students have higher hearing threshold levels than male students, although the differences are not statistically significant. At frequencies from 3000 Hz male students have statistically significant higher hearing threshold levels than female students. The differences are 2 to 4 dB.

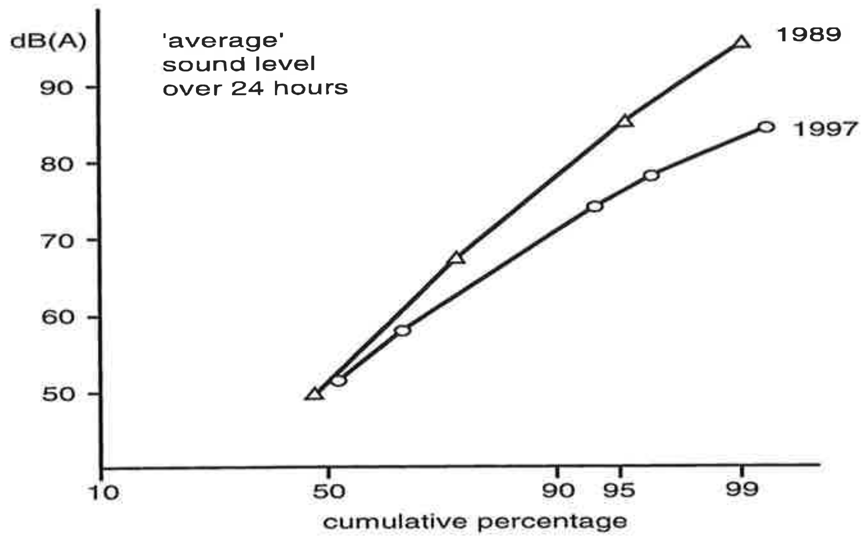
In table 37 median hearing threshold levels of the reference group are given as a function of frequency.

The median value of the female students is within 2.5 dB from audiometric zero of the audiometer used. This is also applicable for male students for hearing threshold levels with frequencies up to 4000 Hz, but the median value at 6000 Hz is 7.5 and that at 8000 Hz 5 dB above audiometric zero. The audiometric zero of the audiometer used with headphones built in hearing protectors have as yet not been standardized within ISO and discussions within the relevant ISO working group are going on about the exact values of the audiometric zero for this equipment. Also a change is expected in the audiometric zero of presently standardized equipment of a few dB at 500 Hz and 5 to 10 dB at 6000 Hz. For further discussions see annex C.

In the following chapters differences between hearing threshold levels and audiometric zero are taken into account by subtracting from the hearing threshold level at each frequency of a student the median value of the median hearing threshold level at that frequency of the reference group having the same gender as the student. The difference is called relative hearing threshold level and is indicated by gcx, with x equal to frequency.

ISO 7029 (ISO, 1997) specifies the cumulative distributions of relative hearing threshold levels of *reference groups of male and female subjects* as a function of age. Reference groups have been selected according to strict selection criteria. These distributions for reference groups aged 20 years have been compared with those of the *reference* groups in the present investigation (see figure 4).

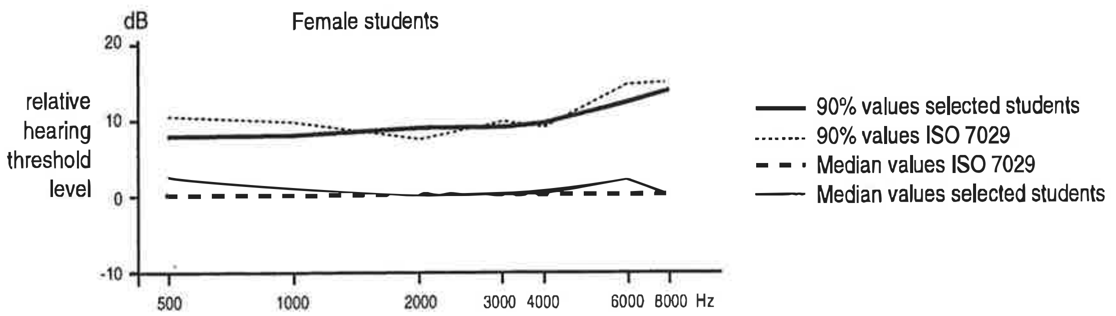
Figure 4 Median relative hearing threshold levels and relative hearing threshold levels just not exceeded in 90% of the students in the reference groups (upper part of the figure female students, lower part of the figure male students) and these relative hearing threshold levels according to ISO 7029 (1997).

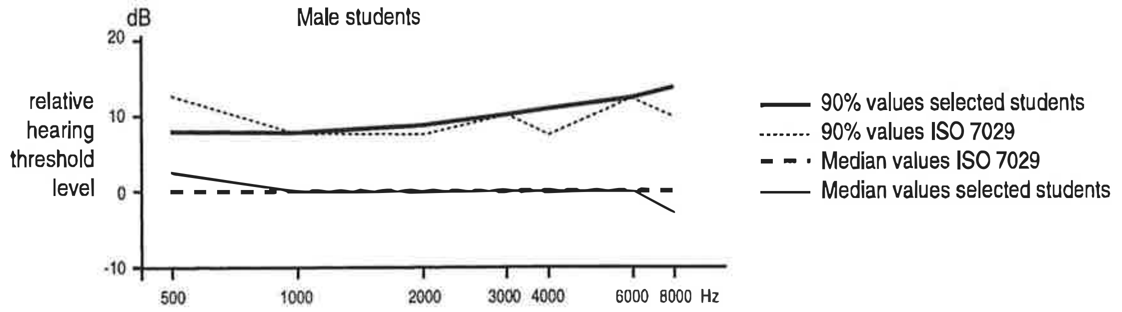


The median values of the reference groups have been defined such that they are all 0 dB at any frequency. There is a good agreement between the 90% values for the male students in this investigation and those of the ISO reference group. The 90% values of the female reference group in the present investigation exceed those of the ISO reference group. A Student-t-test, however, showed these differences not to be statistically significant.

Relative hearing threshold levels of the selected groups in the present investigation have been compared with those of the ISO reference groups(see figure 5). It turns out that the cumulative distributions of the selected groups in this investigation are almost identical to those of the ISO reference groups of comparable age. Despite the possibility of popmusic-induced hearing loss in the selected groups in the present investigation relative hearing threshold levels in this population are not higher than those of the ISO reference groups which are assumed not to have had 'any undue exposure to noise'. This does not exclude, however, the possibility of popmusic-induced hearing loss in a small fraction of the selected groups.

Figure 5 Median relative hearing threshold levels and relative hearing threshold levels just not exceeded in 90% of the students in the selected groups (upper part of the figure female students, lower part of the figure male students) and these relative hearing threshold levels according to ISO 7029 (1997).





3.3 Comparison of popmusic activities in part 1 and part 2

Introduction

The questions of section 3 of the questionnaires in part 1 and 2 are identical. The only difference is the year about which questions have been asked, for part 1 (carried out in December 1996) 1996 and for part 2 (carried out end of 1997 and early 1998) 1997.

For a correct comparison of the results of part 1 and 2 those respondents in part 1 have been selected to obtain subgroups that corresponds with regard to age with the group of students in part 2: a subgroup of 70 female respondents aged 14 to 18, a subgroup of 51 male respondents aged 15 through 17 and a subgroup of 49 male respondents aged 18 through 21. The group of male students of part 2 have been classified according to age in the same classes: a group of 114 male students aged 15 through 17 and a group of 155 male students aged 18 through 21.

Comparison of numbers in subgroups

First it has been tested by means of a P^2-test whether statistically significant differences exist between the distributions of the answers to the questions of section 3 of the questionnaire. Those questions with statistically different distributions are given in table 38, along with the direction of change between both parts. Apart from some differences for other than listening tp popmusic through headphones in some of the subgroups there is no statistically significant difference between listening to popmusic through headphones with the exception of the number of years listened by the female groups. That number was on average smaller in part 2 (5 years) than in part 1 (7 years).

Table 39 gives detailed information about the position of the volume regulator of the own audio equipment while listening to popmusic through headphones. Table 39 includes between brackets the percentage of answers with 'different' excluded. For both subgroups of males the percentage of males with the position of the volume regulator at 3/4 or the maximum output is larger in part 2 than in part 1. For the female subgroups the percentage with the volume regulator at at least ½ in part 2 is larger than in part 1. On average those students that used headphones in 1997 turned on their regulator at 65% of its maximum. Respondents from the first part of the investigation did so at an average of 53%.

Comparison of other popmusic exposures in part 1 and 2

In TNO-PG 97.001 for the results of part 1 exposure in a calender year to popmusic at activities other than listening to popmusic through headphones has been specified as L24_wal, all five exposures together as L24tot and exposure to popmusic through headphones as L24head. For a specification of these characteristics see annex A. The determination of these exposure characteristics for each of the subgroups in part 1 and 2 have been based on answers to questions identical in part 1 and 2. Table 40, 41 and 43 give the cumulative distributions of the exposure characteristics for each of the three subgroups in part 1 and 2. These distributions are also presented in figure 6, 7 and 8. In each case the distribution of the characteristic for the subgroups of part 2 are above those of part 1, although the difference is only slight for some characteristics. Exposure to popmusic through headphones in the older subgroup of males of part 2 is clearly above that of that subgroup of part 1, whereas this difference is to a certain extent also observable for the younger age groups of males. Apparently there is no difference between the distributions of this exposure characteristic for the two subgroups of females. The other popmusic exposure characteristics in part 2 are, but not appreciable, above those of part 1. This relates to all subgroups.

Figure 6 Cumulative distributions of L24tot, L24head and L24_wal of the male subgroups aged 15 - 17 years.

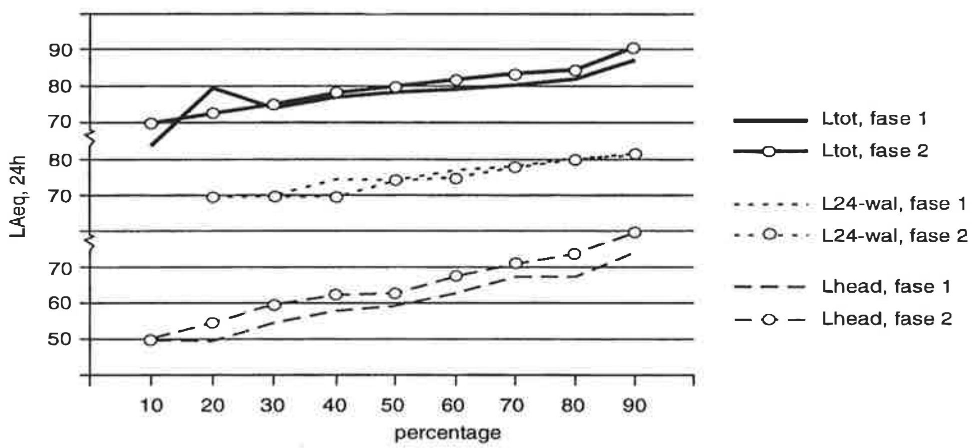


Figure 7 Cumulative distributions of L24tot, L24head and L24_wal of the male subgroups aged 18 years and over.

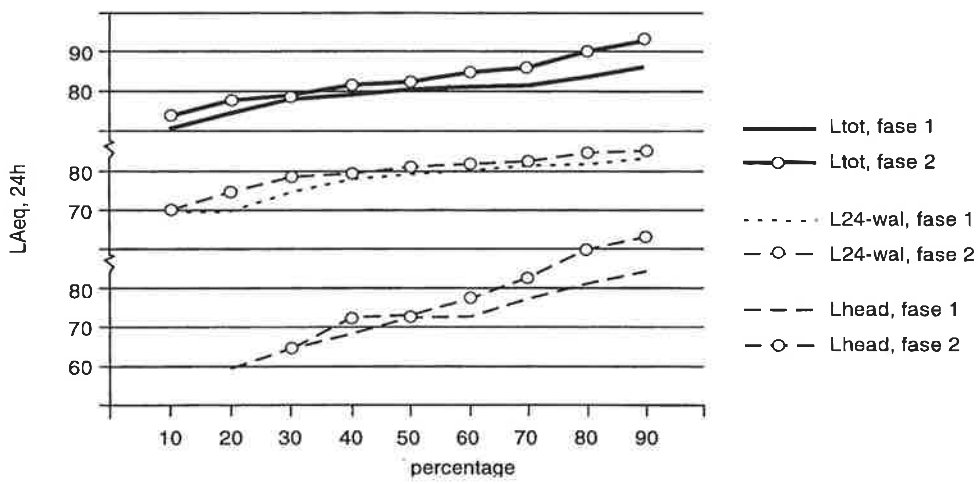
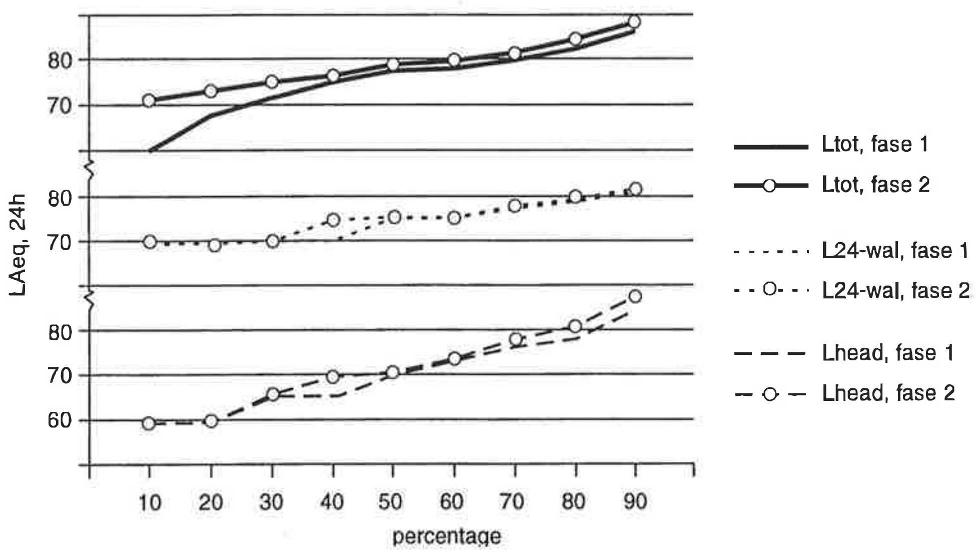


Figure 8 Cumulative distributions of L24tot, L24head and L24_wal of the female subgroups aged 14 - 18 years.



The definition chosen in this report for 'substantial' hearing threshold levels is a hearing threshold level of 30 dB and over at at least one test frequency at at least one ear. The question at hand is whether popmusic exposure through headphones may have been the cause of popmusic-induced hearing loss to the extent that it raised hearing threshold levels to 30 dB and over. It seems reasonable to start form the assumption that popmusic-induced hearing loss is like occupational noise-induced hearing loss a high-frequency hearing loss that develops in the course of the years about equally at both ears. This excludes that hearing loss only at the low frequencies and hearing loss only in one ear is caused by popmusic through headphones.[3] None of the students blame their hearing complaints to popmusic, also not to standing close to loudspeakers.

The number of students with substantial hearing threshold levels is 32, 27 male and 5 female students. Twenty-one (66%) of these 32 students have hearing loss which may have been due to causes other than popmusic, such as high occupational noise exposure, hereditary taint, ototoxic drugs and head injuries. Nine of the 32 students went to see a specialist for hearing complaints and 6 of them still do. Strikingly is the high prevalence of large differences between maximal hearing threshold levels at both ears, in 9 out of the 32 students even 45 dB or more. At such high differences between the two ears 'cross'-hearing might have occurred during audiometric testing of the worse ear. This implies that hearing loss at the worse ear may be even larger than measured. Among the 32 students 8 students have

3 Possibly high-frequency hearing loss at one ear may have been caused by an incidental exposure to very high noise levels presented to one ear, such as possibly during a popconcert when one ear is facing a loudspeaker at very close distance. In that respect the data in the investigation do not permit any conclusion.

low frequency hearing loss only, among which three female students. Not less than 14 of the 32 students have hearing threshold levels at the best ear which are within normal limits (at most 10 dB over the frequency range considered).

The 11 students (all male students) without other possible causes of hearing loss than exposure to popmusic have hearing loss in the higher frequency region (4000 Hz and over). Hearing threshold levels of these 11 students are given in table 43. Seven of them have a high frequency hearing loss at one ear only, while the other ear has normal hearing threshold levels. Since it is not reasonable that this hearing loss at one ear has been caused by binaural noise exposure, only 4 students remain with possibly high frequency binaural hearing loss that may be to a certain extent have been caused by popmusic through headphones. Two of these four students have a very low exposure to popmusic through headphones. The other two students (nr 3 and 7 in table 43) have relatively high exposures to popmusic through headphones. It is reasonable to assume that these two students have high-frequency binaural relative hearing threshold levels of 30 dB or more **partly** due to popmusic through headphones.

3.5 Other items

This section discusses two questions which are also related to the relationships between exposure to popmusic through headphones and hearing loss. These two questions are:
- Is the use of headphones related to satisfaction with learning achievements;
- Is tinnitus during or after popmusic activities related to hearing threshold levels.

<u>Use of headphones related to satisfaction with learning achievement</u>
Following German research (Ising, 1996, personal communication) students have been questioned about their satisfaction with their learning achievements. The assessment of their learning achievements have been related to the following popmusic exposure characteristics:
- Position of the volume regulator of the own audio equipment;
- Present listening level (Lnuveld);
- Highest equivalent sound level over 24 hours during the listening period (Lrep);
- number of hours a day listening to popmusic through headphones at present;
- Listening period in years.

First the correlation coefficients have been determined for each of the exposure characteristics and satisfaction with learning achievements (expressed in a number from 1 to 10 with 1 very unsatisfied and 10 extremely satisfied) for the students classified according to gender. Results are given in table

44. All correlation coefficients are negative, although not statistically significant different from 0.

Next, in a multiple regression analysis the variance explained by satisfaction with learning achievements has been calculated with as many independent variables as possible and age and type of school as co-variant. First the analysis has been carried out with the male and female groups separately. All variables together have in both cases an explained variance of only 0.03. The total group of students give also an explained variance of 0.03 if gender is also taken as independent variable and it is 0.02 if gender is not used as independent variable. F-ratio's are in all analyses not statistically significant. It is therefore concluded that satisfaction with learning achievements does not have an effect on characteristics of listening to popmusic through headphones.

Relationship between tinnitus and threshold hearing level

Tinnitus, a clogged or deafened feeling in the ears is a sigh that probably something happened to the inner ear haircells. Experts and the layman consider frequent occurrence of tinnitus sometimes as an increased risk of acquiring permanent hearing loss. It has been examined whether the number of times tinnitus was observed in 1997 by a student had any relationship with her/his hearing threshold levels. For this subject the group of selected students has been taken. The number of times tinnitus, a clogged or deafened feeling in the ears has been observed in 1997 has been classified in 6 classes, with 'different' as one of them. This last class with one student is not taken into account in the following analysis. First it has been considered whether there is a difference between male and female students. A One-Way ANOVA showed that differences are not statistically significant ($F = 0.17$, $P = 0.69$).

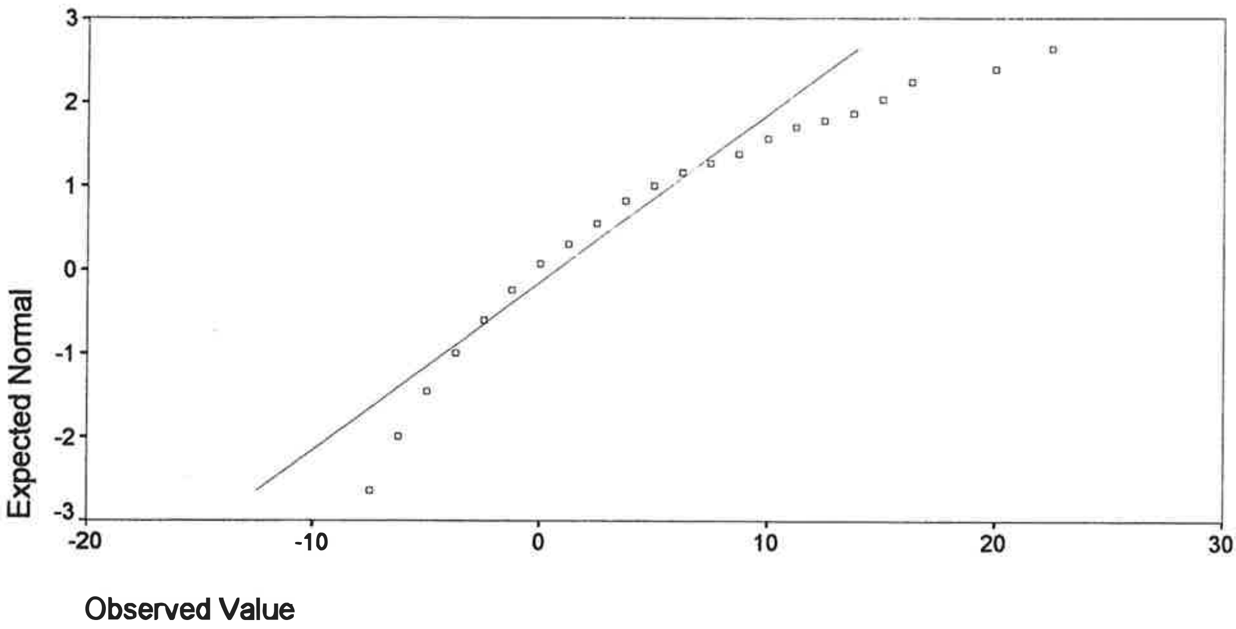
To determine whether tinnitus is related to hearing threshold levels a Two-Way-ANOVA has been carried out. Dependent variables are the relative hearing threshold levels at the various frequencies. First tinnitus and gender have been considered as the two independent variables, as well as the interaction between these two variables and in one case with Ltot24 as co-variant and in the other case not. The results are given in table 45. The F-ratio's and P-values of these ratio's are given for the various cases. None of the F-ratio's has a P-value less than 0.05. Since gender and the interaction between gender and tinnitus do not statistically significant contribute to the explanation of relative hearing threshold levels, an analysis has also been carried out with tinnitus as the only independent variable. Table 45 does show that there are no statistically significant relationships with hearing threshold levels.

4. RELATIONSHIPS BETWEEN EXPOSURE TO POPMUSIC THROUGH HEADPHONES AND HEARING LOSS

4.1 Introduction

In this chapter relationships between popmusic exposure through headphones and relative hearing threshold levels (gcx) have been considered. Analyses have been carried out by using the data of the students in the *selected* groups. Relative hearing thresholds of the male and female groups of students are not statistically normally distributed (test of Kolmogorov-Smirnov). An example of the cumulative distribution is given in figure 9 (gcx at 1000 Hz for male students). The straight line in the figure represents a normal distribution.

Figure 9 An example of a cumulative distribution of relative hearing threshold levels (gcx). The values of gcx are not distributed according a normal distribution.



To obtain a normal distribution a logarithmic transformation has been used, by introducing a new parameter: lpdx. Lpdx and gcx are related as follows:

$$lpdx = lg\ (gcx + d)$$

For each frequency d has been determined. By using the following constants a normal distribution of lpdx has been obtained:

500 Hz: d = 10

1000 Hz: d = 10

2000 Hz: d = 20

3000 Hz: d = 12

4000 Hz: d = 15

6000 Hz: d = 30

8000 Hz: d = 25

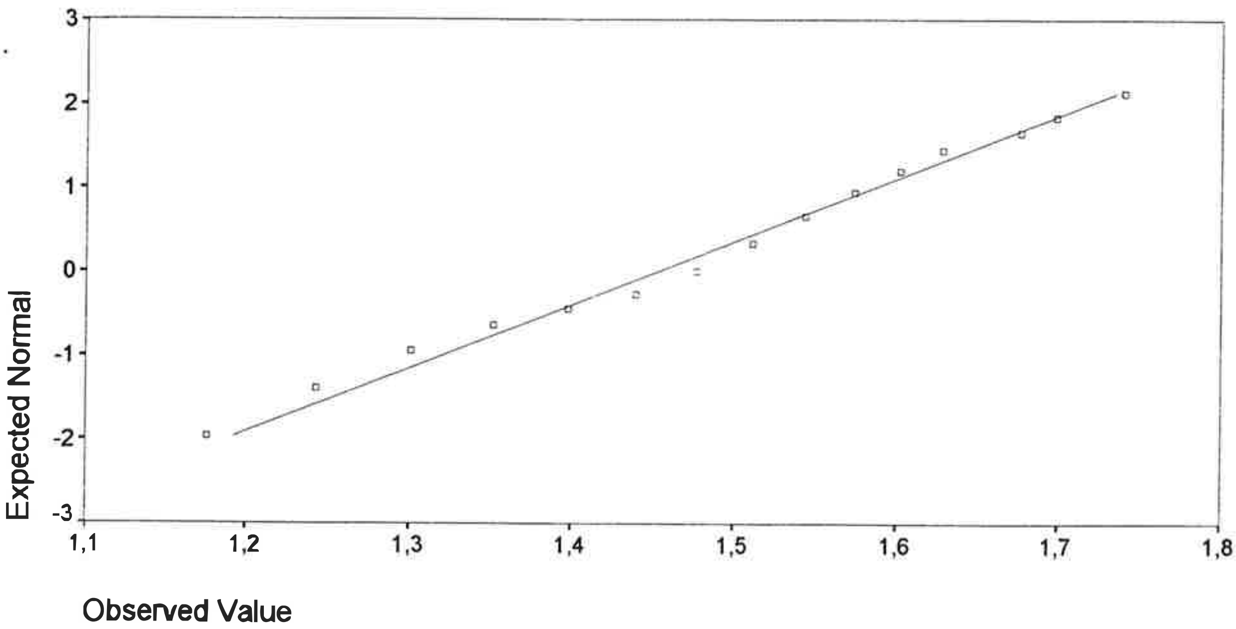
average at 3000, 4000 and 6000 Hz: d = 19

average 4000 and 6000 Hz: d = 22.5.

By using these values of d for each of the frequencies a new variable lpx has been defined. Tests have been performed by using these variables and usually the results have been presented in terms of relative hearing thresholds without presenting the logarithmic transformed results.

In figure 10 an example is given of the logarithmic transformed relative hearing threshold levels.

Figure 10 An example of a cumulative distribution of logarithmic transformed relative hearing threshold levels (lpx). The values of lpx are distributed according to a normal distribution.



4.2 Intervening variables

To determine relationships between lpx and popmusic exposure through headphones regression analyses have been carried out. An important aspect of these analyses is the presence of possible intervening variables. Such possible variables are the exposures to popmusic during popmusic activities other than listening to popmusic through headphones. Therefore this subject has been considered by taking L24disco, L24popgr, L24popco, L24house as variables for each of the exposures and L24_wal as representative for these four exposures combined.

Analyses with more than one independent variable should preferably be performed with independent variables which are not too much correlated (correlation coefficients below 0.80). Therefore the various correlation coefficients of possible intervening variables have been considered. The results have been given in the tables 46 and 47. The tables show that the correlation between the various popmusic activities in 1997 have such low correlation coefficients that they can be used as separate independent variables in the analyses. Table 47 shows that duration of a popmusic activity over the years and extent of the activity in 1997 are highly correlated. Therefore duration over the years and extent in 1997 have not been entered in the regression analyses simultaneously.

A multiple regression analysis on the data of all selected students has been carried out with gender, L24disco, L24popgr, L24popco, L24house as independent variable. The dependent variable is lpx for each of the frequencies and combination of frequencies. Multiple R has been given in the left columns of table 48. Corresponding values of adjusted R^2 (variance explained) are at most 0.03 (at 2000 and 8000 Hz) and in both cases only gender contributes statistically significant to the explained variance. Therefore the separate popmusic exposures during activities other than listening through headphones do have no relationship with relative hearing threshold levels.

The results for the groups of male and female students are also given in table 48. The result is that none of the independent variables contribute significantly to the variance in lpx, with the exception of visiting house-parties by female students and relative hearing threshold levels at 8000 Hz. The increase of the relative threshold level at that frequency is 1.6 dB over the range of values of L24house considered.

Also the combined effect of the four popmusic exposures on lpx has been considered by using L24_wal as representative for these four combined exposures. Correlation coefficients have been given in the right columns of table 48. None of the correlation coefficients are statistically significant.

The conclusion of these analyses is therefore that there is no relationship between characteristics of exposure to popmusic at any of the four activities specified nor for the combined exposure to popmusic other than listening to popmusic through headphones.

Analyses in which the durations of exposure during the various popmusic activities have been taken as independent variables also did not show any statistically significant relationships with lpx.

4.3 Relationships between popmusic exposure through headphones and hearing threshold levels

Introduction

The questionnaire and listening test allowed to determine for each of the students several popmusic through headphone exposure characteristics: Lnuveld (present listening level), Lrep (highest equivalent sound level over 24 hours during one of the three exposure periods in which the listening period has been divided), trrep (the number of exposure years representative for exposure to Lrep), and BEL (a measure of popmusic exposure, in which all popmusic exposure variables have been combined in a specific way).

In preparation of the analyses the following interaction variables have been defined:

- lnuvxgen = lnuveld if gender = male and = 0 if gender = female;
- BELxgen = BEL if gender = male and = 0 if gender = female;
- trepxgen = trrep if gender = male and = 0 if gender = female;
- lrepxgen = lrep if gender = male and = 0 if gender = female.

Relationships with separate popmusic exposure characteristics

First the first order regression lines have been determined for the selected male and female group with each of the independent exposure variable and lpx as dependent variables. Statistficantly positive slopes of the regression lines could be shown only for the male group with BEL as independent variable and lp46 and lp6 as dependent variable.

Combination of independent exposure variables

Next a multiple linear regression analysis has been carried out. The correlation coefficient of Lrep and Lnuveld is 0.84 and of BEL and trrep 0.64. Therefore it has been decided not to use these combinations of independent variables. Then four combinations of independent variables remain:

- Lrep and BEL;
- Lnuveld and BEL;
- Lrep and trrep;
- Lnuveld and trrep.

For each of the combinations of exposure measures, gender and the 2 corresponding interaction variables with gender a multiple regression analysis has been carried out. One time with L24_wal as co-variable and the other time without L24_wal as co-variable. It turned out that the interaction variables did have a negligible effect on the variances explained. Therefore these variables have been omitted from the further analyses. Table 49 gives adjusted R^2 if L24_wal and gender have also been

taken as independent variables. Adjusted R^2
is about equal to that value if only BEL is used as independent variable. Therefore an analysis has been carried out with BEL as only exposure variable.

BEL as exposure variable

If the model specified in ISO 1999 for occupational noise exposure would be applicable to popmusic through headphones only a part of the students would acquire popmusic-induced hearing loss, even at the frequency most vulnerable Hz. It would be the 82 students of the selected group with BEL > 0. For a further analysis, the selected group of students have been classified in three BEL-classes: BEL = 0, 0< BEL # 1, and BEL > 1. The average relative hearing threshold levels of the students divided in these three BEL classes are given in table 50 together with the values of the subgroups classified according to gender. On the basis of lpx statistically significant differences have been specified. There are statistically significant differences only if the relative hearing threshold levels of the group with BEL > 1 are compared with those of the group with BEL = 0. These statistical effects have been indicated in table 50 in bold (Student-t-test, tested one-sided, level of significance 0.05). For values underlined there is a tendency of an effect (0.05 < P< 0.10). Since there is no statistically significant difference between the two lower BEL groups, these groups have been combined . The relative hearing threshold levels of this combined group have been given in table 51. Statistically significant differences and trends have been indicated as in table 50. There are no statistically significant differences for the group of female students. However, the group of female students with BEL > 1 only consists of 12 persons and due to this small number the average difference has to be substantial to be statistically significant. Since there is no statistically significant differences in the relative hearing threshold levels of the male and female subgroups with BEL > 1, the results for the combined group of male and female students are taken as representative for the ultimate result of the analysis.

The final result can be summarized as follows: 35 of the 360 students in the selected group have acquired a popmusic-induced increase in relative hearing threshold level at 4000 and 6000 Hz of 2.7 dB and no effect has been observed in the other students of the selected group. Of the 360 students considered 23 never listened to popmusic through headphones. This implies that 35 of 337 listeners (10.4%) have popmusic-induced hearing loss of on average 2.7 dB at 4000 and 6000 Hz.

4.4 Testing of the model in ISO 1999

The data suitable to test the model in ISO 1999 at presumably hearing damaging levels are much less than expected at the start of the investigation. The main reason is that listening levels appeared to be 10 to 15 dB(A) lower than expected beforehand. The hypothesis that the model in ISO 1999 is also suitable for exposure to popmusic through headphones can be tested by using nx (see annex A). Table 52 shows the number of students with nx values larger than 0 at the various frequencies. This concerns one student for 500 Hz, 5 for 1000 Hz and 20 for 2000 Hz. Average popmusic-induced hearing losses of these few students are also given in table 52. Tests to show that the observed relative hearing threshold levels correspond to these average hearing losses would undoubtedly show that the hypothesis mentioned need not be rejected. Such a conclusion, however, is so weak that this testing has been abandoned. Nevertheless, it can be stated that the low values of nx at the three frequencies at these three frequencies mentioned correspond to the findings that relative hearing threshold levels of the students do not show any popmusic-induced hearing loss.

The following analysis is aiming at the higher frequencies. In table 53 a comparison has been made between observed average differences in hearing threshold levels at various frequencies and differences in expected popmusic-induced hearing loss according to ISO 1999 for groups of students classified in two groups according to expected popmusic-induced hearing loss. Testing of the hypothesis that expected and observed values are not statistically significant different shows that the hypothesis does not have to be rejected. The conclusion that ISO 1999 can be used for the estimation of popmusic-induced hearing loss, however, does not justice the trends that can be observed in the data, which show that:

- differences in observed relative hearing threshold levels are larger at 6000 Hz than at 4000 Hz, although this is the opposite according to ISO 1999;
- At 6000 Hz expected hearing losses are in agreement with hearing losses expected from ISO 1999, although observed values are somewhat larger than observed values;
- At 4000 Hz the observed hearing losses are about half the expected values;
- At 3000 Hz the observed hearing loss is also about half the expected value if groups are classified according to BEL $1 and BEL <1, and the difference is negative if the students are classified according to BEL > 0 and BEL = 0.

Therefore it has been considered whether the observed hearing losses agree to a larger extent with a frequency-adapted model of ISO 1999, in which the relationships in ISO 1999 have been shifted to half an octave lower frequencies. The results are given in table 54. Expected and observed hearing losses are in reasonable agreement. The results can therefore be summarized as follows. The data of the group of selected students have shown the following indications (for listening levels of at most 95 dB(A) and listening periods not exceeding 10 years):

- According to ISO 1999 exposures such as those of the students would not induce hearing loss at frequencies 500, 1000 and 2000 Hz. This corresponds to the findings with respect to the relative hearing threshold levels of the students;
- At frequencies from 3000 Hz frequency-dependency of popmusic-induced hearing loss is

somewhat different from the relationships given in ISO 1999 (1990). Observed popmusic-induced hearing loss at frequencies from 3000 Hz is more accurately described by relationships in ISO 1999 for frequencies a half octave lower (2000 Hz is half an octave lower than 3000 Hz, 3000 Hz half an octave lower than 4000 Hz, 4000 Hz half an octave lower than 6000 Hz and 6000 Hz half an octave lower than 8000 Hz). This implies that different from occupational noise-induced hearing loss popmusic-induced hearing loss has its maximum at 6000 Hz with somewhat less popmusic-induced hearing loss at 4000 Hz.

5. PREVALENCE OF HEARING LOSS DUE TO POPMUSIC THROUGH HEADPHONES IN YOUNG PERSONS IN THE NETHERLANDS

5.1 Introduction

In this chapter the number of Netherlands young persons with popmusic-induced hearing loss has been estimated. Young persons are considered those persons with ages between 12 and 30 years, as defined in the first part of the investigation (Passchier-Vermeer and Vos, 1997). The estimation has been carried out in 2 steps:

1. Popmusic-induced hearing loss of the respondents in part 1 has been estimated;
2. From the popmusic-induced hearing losses of the respondents in part 1 the prevalence of popmusic-induced hearing loss among the Netherlands young population will be estimated. In that respect it is supposed that the respondents in part 1 are a representative sample of the Netherlands persons in the same age range.

5.2 Estimation of popmusic-induced hearing loss of the respondents in part 1

The variables determined in part 1 with respect to listening to popmusic through headphones concern the listening period (in years), the position of the volume regulator in 1996 and the number of listening hours a day in 1996. The last two variables have been combined to L24head. An estimate of popmusic-induced hearing loss in the respondents of part 1 has been based on Lhead and listening period, assuming that at equal values of L24head and listening period popmusic-induced hearing loss is equal in both parts of the investigation.

The results with regard to part 2 have been summarized as follows. In 35 of the 337 (10.4%) students that ever listened to popmusic through headphones popmusic-induced hearing loss at 4000 and 6000 Hz is 2.7 dB. The 95%-confidence interval of this percentage with 337 observations is 7.7% to 14.7%.

Paragraph 3.4 showed that 2 (0.6%) of the 337 listeners have binaural high-frequency hearing threshold levels of at least 30 dB, partly caused by listening to popmusic through headphones. The 95%-confidence interval of this percentage with 337 observations is 0.075% to 2.22%.

Effect of differences in listening period in part 1 and 2

Table 66 of TNO-PG 97.001 specifies the listening period of the respondents in part 1. The 'average'[4] listening period of all respondents is 5.3 years. The 'average' listening period of the students in part 2 is 4.5 years. According to the frequency-amended model in ISO 1999 the popmusic-induced hearing loss would have been 3.0 dB if the exposure time would have been 5.3 instead of 4.5 years. This 3.0 is taken as representative for the respondents in part 1.

Effects from differences in L24head in part 1 and 2

Cumulative distributions of L24head of part 1 and 2 are given in figures 6, 7 and 8. For all three subgroups in part 2 the cumulative distributions of L24head are above those of part 1. These differences can be explained by differences in level of education. From the information in PG97.001 it has been estimated that 0.73 of 10.4% (7.6%) would have been in the higher exposure class if the educational levels in part 2 would have been according to the educational levels of the respondents in part 1.

It can then be estimated that 7.6% of the listeners in part 1 would have acquired popmusic-induced hearing loss of 3.0 dB at 4000 and 6000 Hz.

5.3 Estimation of prevalence of popmusic-induced hearing loss in Netherlands young persons

For this estimation it is accepted that the respondents in part 1 have been a representative sample of the Netherlands young persons, aged 12 to 30 years.

The number of young persons in the Netherlands within the age range considered is 4.05 million (estimate 1996, CBS, 1998): 1.10 million 12-17 years old, 1.40 million 18-24 years old, 1.55 million 25-30 years old. Taking into account the percentages of respondents who never used headphones in the three age groups the number of persons with popmusic-induced hearing loss at 4000 and 6000 Hz in the Netherlands in the youngest age group is 77000, in the middle age group 89000 and in the eldest age group 96000. In total it concerns 262000 young persons, which corresponds to 6.5% of the Netherlands young persons. Taking into account the 95%-confidence interval mentioned earlier the 95%-confidence interval of the Netherlands young persons with popmusic-induced hearing loss is

4 In TNO-PG97.001 it is discussed that in the estimation of popmusic-induced hearing loss the exponential average of exposure time is more appropriate than the arithmetic average, since popmusic-induced hearing loss inceases exponentially with exposure time.

190000 to 370000.

It has been estimated also that 5.7% of the young persons with popmusic-induced hearing loss have binaural high-frequency hearing threshold levels of 30 dB or more. This percentage is taken also for an estimation of the prevalence in the Netherlands young persons. This results in an estimation of that prevalence of 15000. Taking into account the 95%-confidence levels given earlier in this chapter the 95%-confidence interval is 1600 to 51000. The result of the estimations is therefore that the estimated prevalence of young persons in the Netherlands with binaural hearing threshold levels of 30 dB or more **partly** due to listening to popmusic through headphones is 15000 with 95%-confidence limits of 1600 to 51000.

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ANNEX A TERMS AND DEFINITIONS

Equivalent sound level over 24 hours

This report takes the equivalent sound level over a representative 24 hours period ($L_{Aeq,24h}$)[5] as a basis. In the construction of exposure-effect relations with $L_{Aeq,24h}$ as the noise metric, a difference of 5 dB(A)[6] is assumed to take into account the difference in representative exposure time. A similar approach is taken for the present analysis. First, an equivalent sound level over a representative period of 8 hours a day has been determined from the exposure in 1996 and then from this equivalent sound level over 8 hours 5 dB(A) has been subtracted. The following assumptions have served as a basis for the calculations:

- The equivalent sound level during a popconcert is 105 dB(A) and each concert lasts 3 hours;
- The equivalent sound level during house-parties is 105 dB(A) and the duration of a visit is 3 hours;
- In discotheques the equivalent sound level is 95 dB(A) and a visit takes 3 hours a time;
- The equivalent sound level at the position of the players in a popgroup is 105 dB(A) and a performance lasts 3 hours. The same is applicable to disc-jockeys;
- With respect to listening to popmusic through headphones, the respondents were requested to give the number of hours during a representative day. These numbers have been multiplied with 365 to obtain the total number of hours a year;
- The position of the volume regulater of the audio equipment used for listening to popmusic through headphones has been estimated to be related with equivalent sound levels, which are comparable to levels as measured in open space, as follows:
    - At the maximum output this equivalent sound level under the headphones is 100 dB(A);
    - With the position at about 3/4 of the maximum output this equivalent sound level is 88 dB(A);
    - At about ½ the maximum output this equivalent sound level is 80 dB(A);
    - With the position lower than ½ of its maximum this equivalent sound level is 75 dB(A).

For each of the respondents three equivalent sound levels have been determined from their exposure to

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5 This terminology can be understood as follows. Suppose a person is exposed during all the 24 hours during each day of a year to noise with a constant level of x dB(A). His equivalent sound level over a representative period of 24 hours is then equal to x dB(A). This exposure during a year represents a certain total sound energy over that year. The exposure to popmusic is not constant, but fluctuates strongly in time. But, if to the popmusic exposure an equivalent sound level over a representative 24 hours period equal to x dB(A) has been attributed, then the total sound energy of this popmusic exposure is equal to that energy of the constant noise exposure mentioned before.

6 In fact this value should be 6 dB(A). However, it is common practice to take this value equal to 5 dB(A).

popmusic during the various popmusic activities:

- $L_{Aeq,24h,total}$, het equivalent sound level over 24 hours due to all five popmusic activities;
- $L_{Aeq,24h,headphones}$, the equivalent sound level over 24 housr as a result of listening to popmusic through headphones;
- $L_{Aeq,24h,other}$, the equivalent sound level over 24 hours due to all popmusic activities, with the exception of listening through headphones.

The following equation has been used:

$$L_{Aeq,24h,total} = 10*\lg\left(10^{L_{Aeq,24h,1}/10} + 10^{L_{Aeq,24h,2}/10} + 10^{L_{Aeq,24h,3}/10} + 10^{L_{Aeq,24h,4}/10} + 10^{L_{Aeq,24h,5}/10}\right),$$

in which the equivalent sound level over 24 hours of the i-th popmusic activity is $L_{Aeq,24h,i}$.

The value of $L_{Aeq,24h,total}$ is taken equal to zero if all $L_{Aeq,24h,i}$ values are equal to zero.

To calculate $L_{Aeq,24h,other}$ the summation takes place over four popmusic activities.

It is explicitly mentioned here that the calculated equivalent sound levels are estimations. They may not be fully representative for the Dutch situation. The calculations are meant to get some insight in the relations between several popmusic exposures. In the calculations several assumptions have been made and therefore the actual noise exposure levels may be higher or lower than calculated.

Present listening level (Lnuveld)

A student carrying out a listening test sets the volume regulator of the discman of the test equipment at a level for which the popmusic through the headphones is as loud as it usually is while listening with the own audio equipment. Then the student listens for one minute. An 'average'[7] sound level (Lnuveld) over the minute is determined by connecting the output of the discman to the headphoned to an integrating sound level meter and reading this meter after the test is over[8].

Past listening level (Lvr1)

If the student does no longer listen to popmusic through headphones, but used to do so in the past, the student is requested to set the volume regulator at a level for which the popmusic through the headphones is as loud as it used to be while listening with the own audio equipment. Then the student listens for one minute. The result is Lvr1.

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7 In acoustics this 'average' sound level is termed equivalent sound level (ISO 1999, 1990). It is an exponential averaging over the instantaneous sound levels occurring during the minute.

8 The equipment has been calibrated such that the listening level obtained by the test corresponds to the level of popmusic in a room which would cause the same noise exposure in the ear canal.

Past listening level (Lvr2)

If the student used to listen at another level in the past, the student resets the regulator after the first test and listens again for one minute. The resulting listening level is Lvr2.

Listening period

The number of years a student listened to popmusic through headphones.

Exposure pattern

The exposure patterns of the students have been classified in 15 classes. In an exposure pattern the extent of exposure to popmusic through headphones is specified during the listening period. The listening period has been divided in three parts (i = 1, 2, 3). For each part three characteristics of the exposure have been determined:

- number of years the part includes;
- average number of hours listened to popmusic through headphones;
- listening level.

For each part an equivalent sound level over 24 hours (L_i) has been determined. Together with each of the three numbers of years a period lasted, one popmusic exposure measure (BEL) has been calculated.

Equivalent sound level over 24 hours representative for maximal exposure (Lrep)

The highest value of the three equivalent sound levels (L_1, L_2, L_3) over 24 hours specified before.

Hearing threshold level at one ear at a specified frequency x

The hearing threshold level specified relative to the audiometric zero at a specified frequency and at a specified ear. Hearing threshold levels have been determined in accordance with ISO6189 and hearing threshold levels have been determined from the subject's responses to the test signals according to ISO 6189. Tests have been performed at the frequencies 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz.

Average hearing threshold level at a specified frequency x (gx)

The average value of the hearing threshold levels at the two ears at frequency x. The following average values have been considered in the report: g500, g1000, g2000, g3000, g4000, g6000, and g8000.

Selected groups of students

The analyses of the relationships between hearing threshold levels and exposure to popmusic through headphones has been carried out on the basis of data of a selected group of students. Criteria for selection have been:

- wearing of a hearing-aid;

- visiting an ear specialist or an audiological centre for three times or more because of hearing problems;
- a hearing threshold level of 30 dB or more at one or two ears in the low frequency region, combined with frequent visiting a family doctor or ear specialist/audiological centre in the past;
- occupational noise exposure for more than one hour a day without the consequent use of personal hearing protection. Occupational noise exposure is assumed if it is difficult to understand other persons in the occupational situation.

Reference groups

Those students from the selected group without any substantial exposure to popmusic. Selection criteria have been:

- L24_wal < 70 dB(A) in 1997;
- Lrep < 70 dB(A);
- Number of years of exposure to any popmusic activity at most three years.

Reference hearing threshold level at a given frequency

The median hearing threshold level of a reference group classified according to gender.

Relative hearing threshold level

The value of gx at a given frequency minus the reference hearing threshold level at that frequency and gender of the student. The following relative hearing threshold levels have been used in the report: gc500, gc1000, gc2000, gc3000, gc4000, gc6000, gc8000, gc 46000 (average value of gc4000 and gc6000) and gc346000 (1/3(gc3000 + gc4000 + gc6000)).

Expected popmusic-induced hearing loss (nx) at a specified frequency x

Expected popmusic-induced hearing loss due to popmusic exposure at frequency x if the model specified in ISO1999 is also applicable to exposure to popmusic through headphones.

BEL of popmusic through headphones

Measure of exposure to popmusic through headphones. The calculation of BEL of a student has been based on the model specified in ISO1999. **It is stressed that BEL is determined by the values of the popmusic exposure characteristics of a student and that the calculation is independent of the relative hearing threshold levels of the student. The calculation of BEL has been arranged such that the value of BEL happens also to be the popmusic-induced hearing loss at 4000 Hz due to exposure to popmusic through headphones if the model specified in ISO1999 for 4000 Hz is applicable to this exposure.**

Determination of nx, BEL and trrep

ISO 1999 specifies median noise-induced hearing loss (N) in dB as a function of equivalent sound level L over 24 hours and the exposure time T (in years) for $L > L_0$:

$N_{T<10} = (u + v*\lg T)\ (\lg (T + 1)/\lg 11)*\ (L - L_0)^2$ [1]

$N_{T>10} = (u + v*\lg T)*\ (L - L_0)^2$, [2]

in which u, v and L_0 are dependent on frequency. Values are given in table 1 of annex A.

If $L < L_0$ then N = 0.

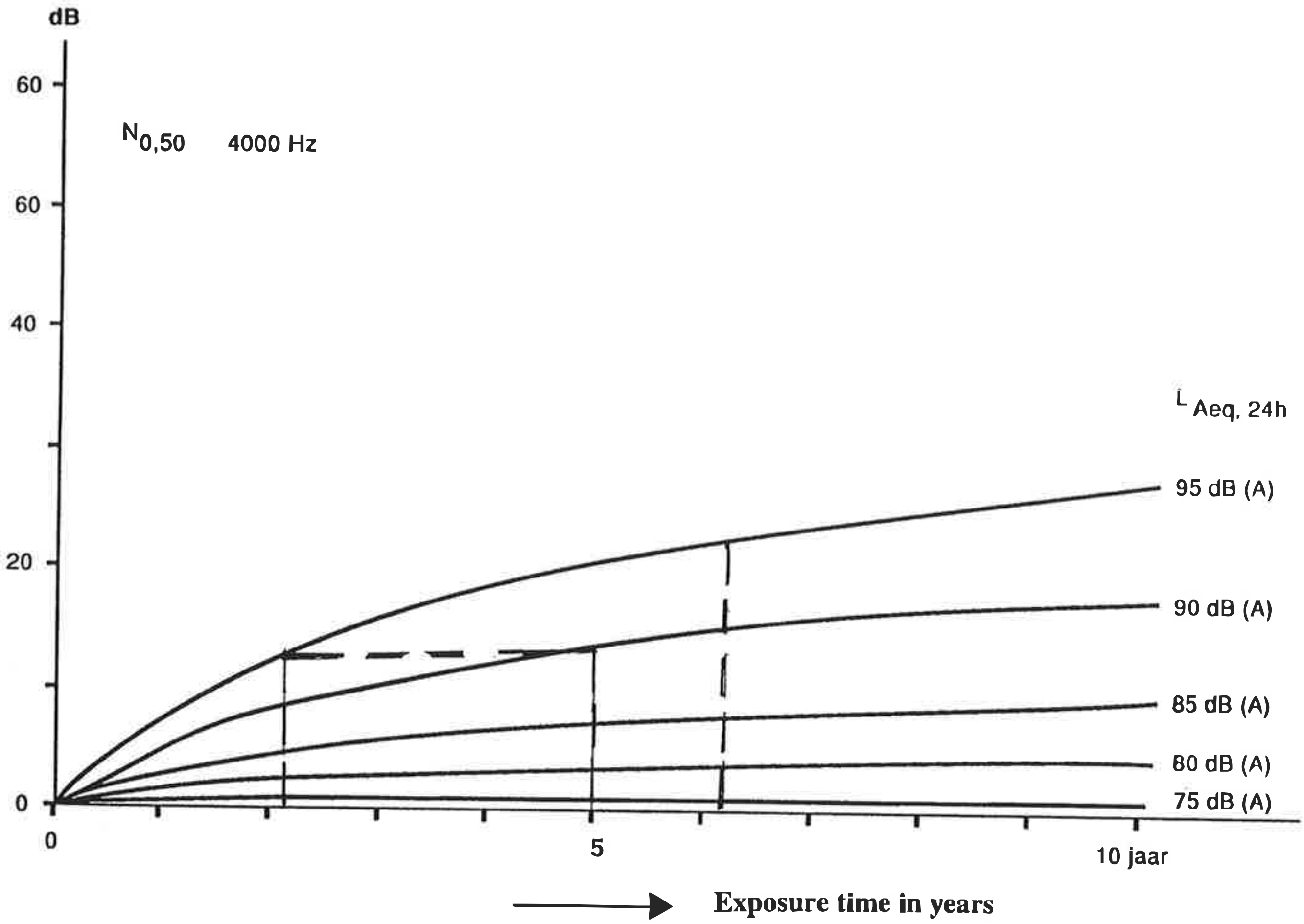
Table 1 of annex A Values of u, v and L_0 (ISO 1999)

Frequency in Hz	$u * 10^3$	$v * 10^3$	L_0 (for 24 hours) in dB(A)
500	- 33	110	88
1000	- 20	70	84
2000	- 45	66	75
3000	+ 12	37	72
4000	+ 25	25	70
6000	+ 19	24	72

To estimate noise-induced hearing loss due to exposure to varying equivalent sound levels over the years, a model[9] is used which has been reproduced in figure 1 of this annex. In this example a person has been exposed for 5 years to an equivalent sound level over 24 hours of 90 dB(A) and thereafter 4 years to an equivalent sound level of 95 dB(A) over 24 hours. What is the resulting noise-induced hearing loss after 9 years exposure? The example relates to noise-induced hearing loss at 4000 Hz. After 5 years exposure to 90 dB(A) noise-induced hearing loss is 13 dB. This 13 dB noise-induced hearing loss would have been caused by a 2 year exposure to 95 dB(A). Therefore the 5 years of exposure to 90 dB(A) is translated to 2 years exposure to 95 dB(A). Taken together with 4 years exposure to 95 dB(A) this results in exposure to 95 dB(A) of 2 + 4 = 6 years, and noise-induced hearing loss of 21 dB. The representative exposure time in this example is for 4000 Hz equal to 6 years and the representative exposure level equal to an equivalent sound level over 24 hours of 95 dB(A).

9 It should be emphasized that this model should not be used to estimate noise-induced hearing loss in individuals.

Figure 1 of annex A



In this report the following calculation scheme has been followed.

Suppose noise exposures for T_1 years to L_1 dB(A), for T_2 years to L_2 dB(A), and for T_3 years to L_3.

Determine j = i for which L_i has the highest value.

If $L_j < L_0$ then $T_j = T_{representatief}$ and $L_j = L_{eq,max}$.

If $L_j > L_0$ and L_1 and L_2 are both smaller than L_0, then $T_j = T_{representatief}$ and $L_j = L_{eq,max}$.

Else: determine $c_{i...j}$ from:

$$3_{i...j}[c_i (T) * (L_i - L_0)^2] = c_{i...j} * (L_j - L_0)^2$$

Take in the summation only those factors for which $L_i > L_0$ and take the other factors equal to zero.

If $c_{i...j} > u + v$ calculate x from:

$$c_{i...j} = u + v * \lg x$$

If $c_{i...j} < u + v$ calculate x from:

$$\lg x = - u/2v + 1/2[(u/v)^2 + 4 * c_{i...j}]^{1/2}$$

Next determine:

$$x + T_j = T_{representatief}$$

At the same time the following equation applies:

$$L_j = L_{eq,max}$$

Using these values nx at the various frequencies is calculated according to[1] and [2]. In this report n4000 is equal to BEL.

Determination of Lrep and nx from the data of the students

All exposure patterns (1 to 15) are characterized by three periods (although a period may be 0 years) . The listening levels for each of the three periods are determined form the variables 70, 71 and 72 (see annex B). These listening levels are denoted by: L1(ongec), L2(ongec) and L3(ongec). To determine the equivalent sound level over 24 hours from these levels the average number of listening hours per day should be taken into account. The next table specifies for each of the exposure patterns which variables contain relevant information. Dependent upon the values of the variables values ÎL1, ÎL2 and ÎL3 have to be subtracted from L1(ongec), L2(ongec) and L3(ongec). Results are indicated by L_1, L_2 and L_3 respectively. The values of ÎL depend upon the average number of listening hours a day:

. 25.3 dB(A) for less than one hour a week;
. 16.2 dB(A) for les than one hour a day but more than 1 hour a day;
. 12.0 dB(A) for 1 - 2 hours a day;
. 8.4 dB(A) for 3 - 4 hours a day;
. 5.7 dB(A) for 5 - 8 hours a day;
. 3.8 dB(A) for 9 hours or longer a day.

By means of L_1, L_2, L_3 and T_1, T_2, T_3 at each frequency the representative equivalent sound level over 24 hour ($L_{eq,max}(x)$) and the representative exposure time ($T_{representatief}(x)$) have been determined, in the way indicated before. Some simplifications have been used in the calculations. These are given in the footnote after table 2 .

$L_{eq,max}(4000)$ is equal to Lrep and $T_{representatief}(4000)$ to trrep.

Table 2 of annex A Variables per exposure pattern to determine $L_{eq\,max}$ and $T_{representatief}$ (see also aanex B).

pattern	variable	T(total) in years	T1 in years	T2 in years	T3 in years	ΔL1	ΔL2	ΔL3
0	*42*	0	0	0	0	-	-	-
1	*44*	*43*	0	*43*	0	-	4	-
2	*44*	*43*	*43-46*	*46*	0	from *47*	*47*	-
3	*44*	*43*	0	*43*	0	-	from *48*	-
4	*49*	*43*	0	50	*43 - 50*	-	*51*	from *51*
5	*49*	*43*	½ *(43 - 52)*	*52*	½ *(43 - 52)*	from *53*	*53*	from *53*
6	*49*	*43*	0	½ *(43)*	½ *(43)*	-	from *54*	from *54*
7	*57*	*55*	0	*55*	0	-	*56*	-
8	*57*	*55*	*55-58*	*58*	0	from *56*	*56*	-
9	*57*	*55*	0	*55*	0	-	from *56*	-
10	*60*	*55*	0	*61*	*55-61*	-	*59*	*56*
11	*60*	*55*	*62*	*63*	*55-62-22*	from *59*	*59*	*56*
12	*60*	*55*	*64*	0	*55-64*	from *59*	-	*56*
13	*65*	*55*	0	*66*	*55-66*	-	*59*	½ (59 - 56)
14	*65*	*55*	½ *(55-67)*	*67*	½ *(55-67)*	from *59*	*59*	½ *(59 - 56)*
15	*65*	*55*	0	*68*	*55-68*	-	from *59*	½ *(59 - 56)*

With respect to the calculation of T ´½ (variable - variable)´ means half the difference between the values of both variables.

With respect to the calculation of ÎL ´from variable´ means the value of the varaiable diminished with 3 dB(A) and ´½ (variable - variable)´ means the average of both values[10].

[10] If there is during a period of time a gradual change in number of hours listened to popmusic through headphones the equivalent sound level changes also gradually.By using the model it is possible to calculate representative values of the exposure. In principle this should be calculated by dividing the period in smaller parts. Since this is a cumbersome method, calculations have been made to compare the results of a precise division with those in which the average equivalent sound level is used. It has been examined what effects occur for changes of 5, 6, 10 and 12 dB(A) over a period of 3 and 5 years and for levels at the beginning ranging from 70 to 95 dB(A). The method of average equivalent sound level differs never more than 1 year and usually the difference is smaller. Therefore the method of average equivalent sound level over a period is used.

ANNEX B QUESTIONNAIRE AND LISTENING TEST

This annex contains the questionnaire and the questions put forward at the listening test. The questions have been asked face-to-face and the responses have been typed at location in the computer.

The questionnaire contained four parts.

Students from the school at Leiden combine a job with a one day a week course at school. Although students have been selected with jobs with presumed low occupational noise exposure, after the investigation in Rotterdam the questionnaire has been expanded with some questions about occupational noise exposure. These questions have been included in question 7 of the questionnaire.

QUESTIONNAIRE

GROUP 1: PERSONAL DATA

1. Last name, first name
2. Birthdate
3. Gender
4. Place of residence
5. School
6. Class
7. Satisfaction with learning achievements
   (A number from 1 (very unsatisfied) to 10 (very satisfied))

7' Do you work in a surrounding in which it is difficult to understand other persons?
   If yes, how many hours a day on average?
   - less than one hour;
   - 1 - 4 hours;
   - 4 - 8 hours.

   If yes, do you wear personal hearing protectors?
   If yes, which type?
   - Ear muffs;
   - Something in the ears;
   - Different.

   If yes, do you use protection consistently?
   - Yes;
   - Not always when noisy;

- No.

GROUP 2: DATA ABOUT HEARING

1. Did you ever visit a (family) doctor because of pain in your ears?

   If yes:
   - less than 3 times;
   - 3 - 10 times;
   - more than 10 times.

2. Did you ever go to hospital or a specialist because of pain in your ears?

   If yes:
   - less than 3 times;
   - 3 - 10 times;
   - more than 10 times.

   If yes: what were the reasons of your complaints?

   Choose one or more of the possibilities:
   - persons in my family are hard of hearing/deaf;
   - (road) accident;
   - fireworks;
   - occupational noise;
   - ototoxic drugs;
   - problems after illness;
   - different:
   - other reason:

3. Do you wear a hearing-aid?

   If yes, at which ear(s)?

4. This question concerns your ability to understand speech from friends, relatives, acquintances and strangers. Indicate what is most suitable to you.
   - Perfect speech intelligibility, also in very noise situations, such as a disco;
   - Perfect speech intelligibility, except in noisy situations;
   - Good speech intelligibility in more quiet situations, such as in the class or at home;
   - Only good speech intelligibility when two or more persons are present if it is very quiet in the room, e.g. if no audio equipment is in operation;
   - Only good speech intelligibility if it is a very quiet situation and no more than two other persons are present;
   - In fact, never appropriate speech intelligibility; usually I am gessing;
   - I do not know.

GROUP 3: QUESTIONS ABOUT POPMUSIC

These questions concern your involvement in present and past in popmusic activities. Popmusic is popular music like music from the hitparade, raggae, soul, (hard) rock, ballads, easy listening, etc.

Question 1

For how long do you already visit POPCONCERTS? Or, if you don't do that any more, how long did you visit popconcerts in the past?

If you are not quite sure, please estimate it as accurate as possible.

1. Never visited a popconcert;
2. Less than 1 year;
3. 1 - 3 years;
4. 4 - 9 years;
5. 10 years or longer;
6. Still different (does not really know, inclusive).

Question 2

For how long do you already visit DISCOTHEQUES OR OTHER PLACES WHERE LOUD MUSIC IS PLAYED (with the exception of house-parties)? Or, if you don't do that any more, how long did you perform this activity in the past?

If you are not quite sure, please estimate it as accurate as possible.

1. Never visited a discotheque;
2. Less than 1 year;
3. 1 - 3 years;
4. 4 - 9 years;
5. 10 years or longer;
6. Still different (does not really know, inclusive).

Question 3

For how long do you already visit HOUSE-PARTIES? Or, if you don't do that any more, how long did you visit house-parties in the past?

If you are not quite sure, please estimate it as accurate as possible.

1. Never visited a house-party;
2. Less than 1 year;
3. 1 - 3 years;
4. 4 - 9 years;
5. 10 years or longer;

6. Still different (does not really know, inclusive).

Question 4

For how long do you already use HEADPHONES attached to a walkman or other audio equipment? Or, if you don't do that any more, how long did you do this in the past?

If you are not quite sure, please estimate it as accurate as possible.

1. Never used headphones;
2. Less than 1 year;
3. 1 - 3 years;
4. 4 - 9 years;
5. 10 years or longer;
6. Still different (does not really know, inclusive).

Question 5

For how long do you already PLAY IN A POPGROUP OR ACT AS DISC-JOCKEY? Or, if you don't do that any more, how long did you play in a popgroup or act as disc-jockey in the past?

If you are not quite sure, please estimate it as accurate as possible.

1. Never;
2. Less than 1 year;
3. 1 - 3 years;
4. 4 - 9 years;
5. 10 years or longer;
6. Still different (does not really know, inclusive).

Now take the year 1997 in your mind in answering the following questions

Question 6

How many times did you visit POPCONCERTS in 1997?

If you are not quite sure, please estimate it as accurate as possible.

1. Did not visit a popconcert in 1997;
2. 1 - 2 times;
3. 3 - 4 times;
4. 5 - 9 times;
5. 10 times or more often;
6. Still different (does not really know, inclusive)

Question 7

How many times did you visit DISCOTHEQUES OR OTHER PLACER WHERE LOUD POPMUSIC IS PLAYED, except house-parties, in 1997?

If you are not quite sure, please estimate it as accurate as possible.

1. Did not visit a discotheque or so in 1997;
2. Less than once a month
3. 1 - 2 times a month;
4. 3 - 4 times a month (about once a week);
5. 5 - 7 times a month;
6. 8 times a month or more often (2 times a week or more often);
7. Still different (does not really know, inclusive)

Question 8

How many times did you visit HOUSE-PARTIES in 1997?

If you are not quite sure, please estimate it as accurate as possible.

1. Did not visit a house-party in 1997;
2. 1 - 2 times;
3. 3 - 4 times;
4. 5 - 9 times;
5. 10 times or more often;
6. Still different (does not really know, inclusive)

Question 9

How many hours did you listen <u>on average per day</u> to popmusic through HEADPHONES (walkman or other audio equipment) in 1997?

If you are not quite sure, please estimate it as accurate as possible.

1. Did not use headphones in 1997;
2. Less than one hour a day;
3. 1 - 2 hours a day;
4. 3 - 4 hours a day;
5. 5 - 8 hours a day;
6. 9 hours a day or longer;
7. Still different (does not really know, inclusive)

Question 10

If you used HEADPHONES in 1997, what is usually the position of the volume regulator of your equipment?

1. Less than half of the maximum output;
2. About half of the maximum output;
3. About 3/4 of the maximum output;
4. At the maximum output;
5. Still different (does not really know, inclusive).

Question 11

How many times did you PLAY IN A POPGROUP OR ACT AS DISC-JOCKEY in 1997?

If you are not quite sure, please estimate it as accurate as possible.

1. Did not play in a popgroup or act as disc-jockey in 1997;
2. Less than once a month
3. 1 - 2 times a month;
4. 3 - 4 times a month (about once a week);
5. 5 - 7 times a month;
6. 8 times a month or more often (2 times a week or more often);
7. Still different (does not really know, inclusive)

<u>Introduction to the question 12 and 13</u>

Sometimes you may have noticed after listening to popmusic peeps, tinnitus, a clogged or deafened feeling in your ears.

Question 12

How many times did that occur to you in 1997?

If you are not quite sure, please estimate it as accurate as possible.

1. Not once, did not occur to me;
2. 1 - 2 times;
3. 3 - 4 times;
4. 5 - 9 times;
5. 10 times or more often;
6. Still different (does not really know, inclusive)

Question 13

If it did occur to you in 1997, after which popmusic activity(ies) did you observe it? (more than one answer is possible)

1. Visit of popconcert;
2. Visit of discotheque or other place where loud popmusic is played;
3. Visit of house-party;
4. Listening through headphones (walkman or other audio equipment);
5. Playing in popgroup or acting as disc-jockey;
6. Still different (does not really know, inclusive).

GROUP 4: QUESTIONS ABOUT HEADPHONES

These questions concern again your use of headphones. The first questions concern how many hours you used headphones and the following questions concern how loud you listen to popmusic with headphones.

If responded earlier with never used headphones, this group of questions is not asked.
If headphones were ever used, the following questions are asked. The possible answers are labelled with a variable number, which has been used in annex A. Possible choices of exposure patterns from 1 to 15 are given at the end of this annex.

How many years did you use headphones? Number of years □

Answer nr 2 43

We are now going to explore how the use of headphones looked like in the foregoing years.

Did you stop suddenly in using headphones?

Yes Yes: further possible choices 1, 2 and 3:

Answer nr 3 44

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1. During the period you used headphones you did so approximately the same number of days. How many hours a day/week?

Card 7:

- □ less than one hour a week;
- □ more than one hour a week, but less than one hour a day;
- □ 1 - 2 hours a day;
- □ 3 - 4 hours a day;

- ☐ 5 - 8 hours a day;
- ☐ 9 hours a day or longer;
- ☐ different.

Answer nr 4 45

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2. After you started listening through headphones, the number of hours increased and then remained about the same after which you stopped listening through headphones: how many years did it remain the same?

Card 10: Number of years:

- ☐ less than one year;
- ☐ 1 - 9 years; Number of years:
- ☐ 10 years or longer.

Answer nr 5 46

How many hours a week\day:

Card 7 (see above)

Answer nr 6 47

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3. After you started listening through headphones, the number of hours increased and then you stopped listening through headphones. How many times did you listen just before you stopped suddenly?

Card 7 Answer nr 7 48

No: choices 4, 5 and 6: you stopped gradually.

Answer nr 8 49

---

4. From the beginning you listened a number of hours, which remained some years the same, after which listening decreased gradually?

Card 10

Answer nr 9 50

How many hours did you listen in the beginning?

Card 7

Answer nr 10 51

---

5. After you started listening through headphones, the number of hours increased and then remained about the same after which you stopped gradually listening through headphones: how many years did it remain the same?

Card 10

Answer nr 11 52

How many hours did you listen in the constant period

Card 7

Answer nr 12 53

---

6. After you started listening through headphones, the number of hours increased and then within a year gradually decreased. How many times did you listen at the maximum?

Card 7

Answer nr 13 54

<u>If on question 11 answer 2 and higher was given, then:</u>

Number of years listening with headphones ☐

Answer nr 14 55

At present you listen to popmusic through headphones. How long during a week/day?

Card 7

Answer nr 15 56

Question: did you formerly listen more often to popmusic through headphones than at present?

If no: choices 7, 8 and 9

Answer nr 16 57

---

7 during the years you have listened about the same time a week/day.

8 After you started listening through headphones, the number of hours increased and then remained about the same up till now. How many years did it remain the same?

Card 10

Answer nr 17 58

---

9 After you started listening through headphones, the number of hours increased until the present number of hours.

Yes: when you listened more often to popmusic through headphones, how long was it then?

Card 7

Answer nr 18 59

Did you suddenly or gradually decrease the time listening to popmusic through headphones?

Suddenly: choices 10, 11 and 12.

Answer nr 19 60

---

10 After you started listening through headphones, the number of hours increased and then remained about the same at a maximum after which the number of hours listening through headphones decreased: how many years did it remain at the maximum?

Card 10

Answer nr 20 61

---

11 After you started listening through headphones, the number of hours increased and then remained about the same at a maximum after which the number of hours listening through headphones decreased suddenly. How many years took the increase.

Card 10

Answer nr 21 62

How many years did it remain at the maximum?

Card 10

Answer nr 22 63

---

12 After you started listening through headphones, the number of hours increased and then within a year the number of hours decreased. remained about the same at a maximum after which the number of hours listening through headphones decreased suddenly. How many years took the increase?

malen luisteren met koptelefoons bent gekomen?

Card 10

Answer nr 23 64

Gradually: choices 13, 14 and 15

Answer nr 24 65

---

13 After you started listening through headphones, the number of hours increased and then remained about the same at a maximum after which the number of hours listening through headphones decreased gradually. How many years took the listening at the maximal number of hours?

Card 10

Answer nr 25 66

---

14 After you started listening through headphones, the number of hours increased and then remained about the same at a maximum after which the number of hours listening through headphones decreased gradually. How many years took the listening at the maximal number of hours?

Card 10

Answer nr 26 67

---

15 After you started listening through headphones, the number of hours increased up to a maximum after which within a year the number of hours listening through headphones decreased gradually. How many years took the listening at the maximal number of hours?

Card 10

Answer nr 27 68

---

2 Estimation of present and former listening levels

<u>Before the listening test starts</u> the following is asked about their listening through headphones in the past:

Those who listen to popmusic through headphones at present. Hereafter we are going to determine your present listening level. Did you listen in the past

- ☐ clearly at a lower level;
- ☐ at about the same level;
- ☐ clearly at a higher level.

Answer nr 28 69

If in the past at a higher or lower level:

Indicate at which period you listened at another level than presently:

- □ at the beginning;
- □ during the middle period;
- □ during the last period.

Answer nr 29 70

For those who do no longer listen to popmusic through headphones, but did in the past: We will now determine your past listening level.

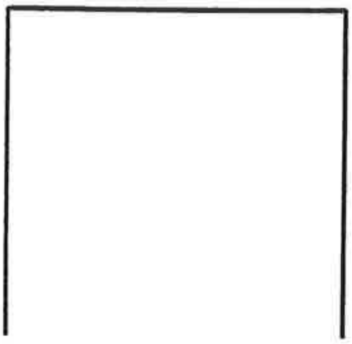
Answer nr 30 xx

Did you see anything of the SIRE campaign on television about using walkman's?

Answer	Yes	□
	No	□

EXPOSURE PATTERNS 1 TO 15

1



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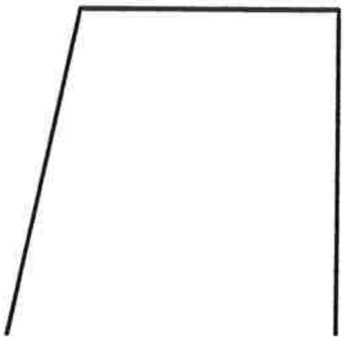

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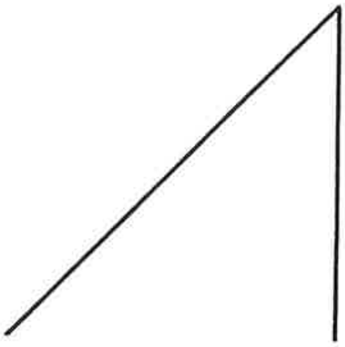

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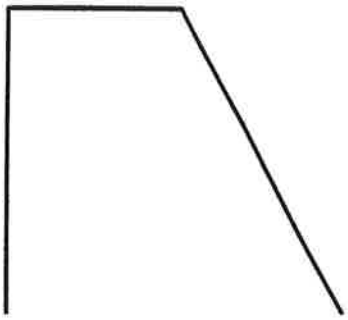

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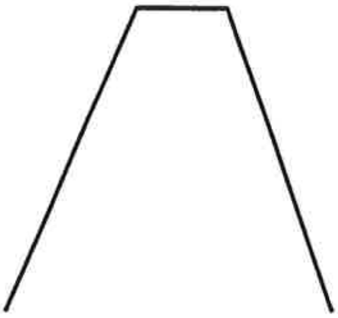

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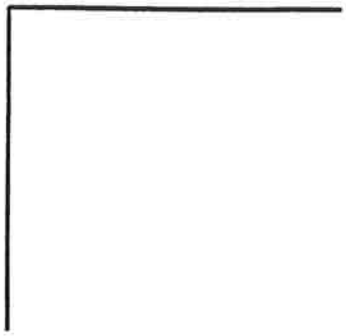

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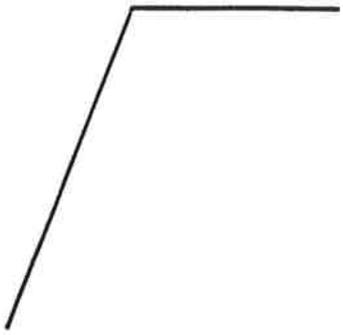

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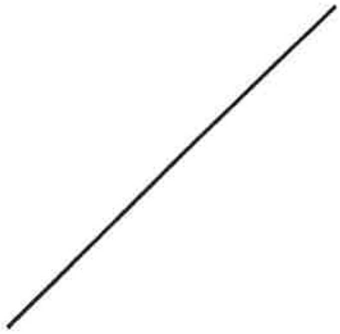

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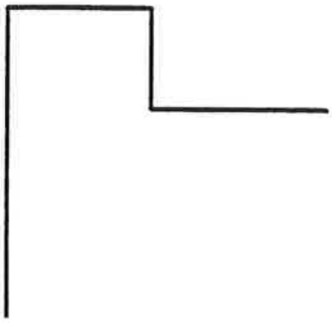

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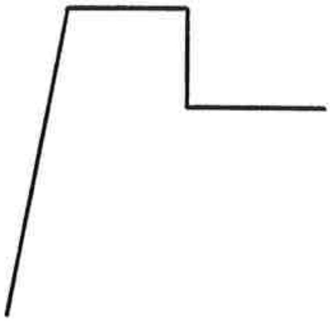

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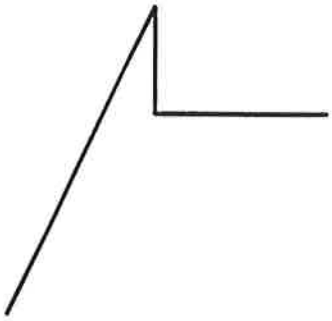

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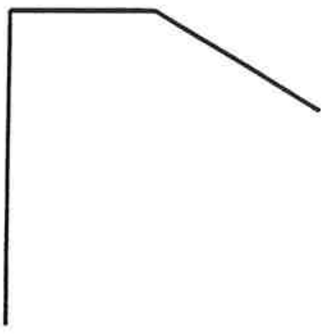

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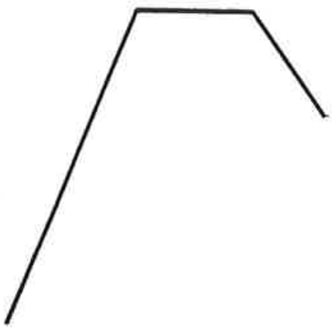

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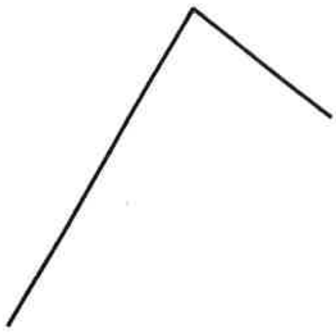


LISTENING TEST

GROUP 5: LISTENING TEST

For those students who are at present listening to popmusic through headphones: L_{nu2}

Answer nr 30 71

For those students who are at present listening to popmusic through headphones, the former listening level: L_{vr1}

Answer nr 31 72

For those students who are at present not listening to popmusic through headphones: L_{vr}

Answer nr 32 73

ANNEX C TECHNICAL DATA AUDIOMETRY AND LISTENING TEST

C1 Information about the audiometer(s) used in the investigation

An EFEU - A120 audiometer has been used (and another one was stand-by). The audiometer presents test tones to a subject according to the specifications in ISO8253-1. The audiometer has been equipped with Sennheiser HDA-200 headphones. These headphones have been built in ear protectors Peltor H7. The audiometer operated with the following characteristics:

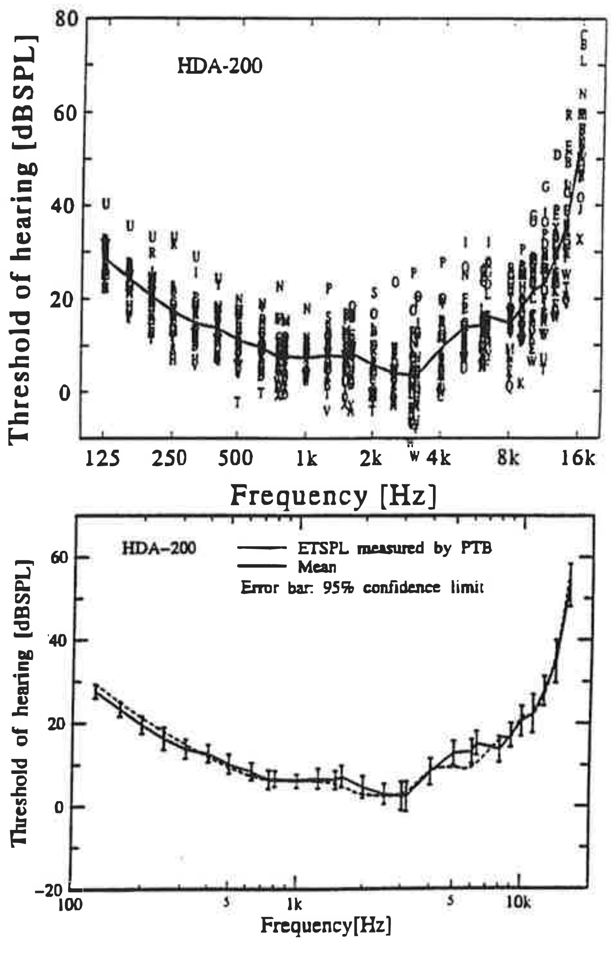
- Sequence of test tones: 500, 1000, 2000, 3000, 4000, 6000, 8000 Hz and a repeat at 1000 Hz. There was no (statistically significant) difference between the first and repeat measurement at 1000 Hz. In the analysis the average value has been taken;
- The lowest test tone level was -10 dB (versus audiometric zero) and the highest level + 60 dB;
- Test tones have not been masked;
- Test tones have been presented in 5 dB steps;
- The level of the first test tone has been + 20 dB;
- The duration of the test tones has been 2 s. The time between presentation of testones was on average 2 s, with a variation of 0.4 s (20%).

At the start of a test day the test supervisors (both with very good hearing) performed an audiometric test with him/herself and listened to clicks and other noises during the presentation of the test tones. The audiometric test result has been compared to the results of the audiometric tests performed at the Institute before the start of the measurements at the schools. There turned out to be no systematic change. Differences usually have been not more than an occasional 5 dB and seldomly 10 dB. Such accidental differences should be expected. This implies that no systematic or sudden change in the calibration of the audiometer occurred and that the test environments in the audiomobile while located near the schools allowed audiometric tests to be carried out without masking of test tones by ambient noise, at least for the hearing levels used by the test supervisors.

Audiometric zero for the combination of Sennheiser headphones and Peltor ear protectors has as yet not been standardized by ISO, as has been done for other headphones (ISO389-1). Audiometric zero of the audiometer used in the investigation has been calibrated according to the test results by PTB (Richter,1993). ISO/TC43/WG1 (Threshold of hearing) discussed audiometric zero of the configuration used. Poulson states (ISO/TC43/WG1 N 199 (1994)) on the basis of measurements of 8 test subjects that his reference levels are lower than specified by Richter. Susuki and colleagues (ISO/TC43/WG1 N 231 (1996)) also carried out measurements to establish reference levels for the configuration under consideration. Their results have been copied in figure C1 of this annex. The measurements have been performed with 24 test subjects. The reference levels determined by Susuki and Richter are the same at 1000, 3000, and 4000 Hz and different at 500 Hz 0.5 dB, at 2000 Hz 1.8 dB, at 6000 Hz 3.5 dB and at 8000 Hz - 2.7 dB. Therefore at the higher frequencies uncertainties are present with regard to the correct position of audiometric zero of the equipment under consideration.

To this the following contemplations. For some time there are deliberations within WG1 whether audiometric zero for the standardized headphones corresponds to the median hearing threshold level of reference groups. Due to lack of consensus about this subject ISO 7029 (1997) did specify the term hearing threshold deviation by stating: 'The hearing threshold deviation as defined herein and the hearing threshold level as defined in other standards (ISO 8253-1, ISO 8253-2, IEC 60645-1) express the hearing threshold of an individual relative to, respectively, a) the median hearing threshold of a population of 18-year old persons, or b) a reference zero level specified in various parts of ISO 389. To the extent that the reference zero level represents the median of the 18-year old population, the values of the two terms will be the same.' During the revision of the old ISO 7029 an estimate has been made of the difference between the median hearing threshold level of reference groups and audiometric zero, as specified in ISO 389 (Passchier-Vermeer, (ISO/TC43/WG1 N 218 (1996)). The weighted average difference turned out to be between + and - 2.5 dB for frequencies up to 6000 Hz and turned out to be + 3.5 dB at 6000 Hz (and no calculated values at 8000 Hz)

Figure C1 Data about the determination of audiometric zero of an audiometer equipped with Dennheiser HDA-200 headphones in Peltor ear protectors.



2 The equipment for the listening test

The CD-player used has been a PARASONIC (type SL-S125), equipped with SONY headphones (type MDR-009). This are headphones with small foam cushions. The exit of the CD player has been connected to a type 1 integrating sound level meter (B & K 2230). By means of the sound level meter an equivalent sound level has been determined in the minute after the students set the preferred listening level. From the equivalent sound level thus obtained a field-equivalent equivalent sound level has been determined by using a transfer value of 10 dB(A) specified by Damongeot for the same combination of discman and headphone with cushions (Damongeot, 1996). Damongeot tested a number of combinations of walk- and discman's and headphones under various circumstances. For the combination used in the investigation Damongeot determined the average difference between diffuse field equivalent sound level and equivalent sound level under the headphones for 'average' popmusic as a value of 9.9 dB(A), with a standard deviation of 1 dB(A). This standard deviation is mainly due to different placements of the headphones by the test persons. For the present investigation a value of 10 dB(A) has been taken. To determine Lnuveld 10 dB(A) has been subtracted from the measured one minute equivalent sound level during the test.

ANNEX D TABLES

Table 1 Distribution of students according to gender and location

	number of students					
gender	Rotterdam		Leiden		R + L	
male	90		179		269 (66%)	
female	115		21		136 (34%)	
total	205		200		405 (100%)	
age in years	male students	female students	male students	female students	male students	female students
≤ 14	30	48	-	-	30	48
15	50	54	-	-	50	54
16	8	12	26	9	34	21
17	1	1	53	8	54	9
18	1	-	55	4	56	4
19	-	-	29	-	29	-
≥ 20	-	-	16	-	16	-

Table 2 Distribution of students according to level of education and location of school

	number of students		
level of education	Rotterdam	Leiden	R + L
MAVO	159	-	159
VBO	46	29	75
Combination of job and school	-	171	171

Table 3 Distribution of students according to satisfaction with learning achievements and location

	number of students		
satisfaction	Rotterdam	Leiden	R+L
<5	9	6	15
5	26	12	38
6	50	42	92
7	89	102	191
>8	31	38	69
total	205	200	405

Table 4 Distribution of students according to visiting the (family) doctor for pain in the ears and location

	number of students		
(family) doctor	Rotterdam	Leiden	R+L
yes	91	81	172
no	112	119	231
different	2	-	2
total	205	200	405

Table 5 Distribution of students according to number ogf times the (family) doctor was visited for pain in the ears

	number of students		
number of visist	Rotterdam	Leiden	R+L
< 3 times	50	43	93
3-10 times	32	33	65
> 10 times	4	5	9
different	5	-	5
total	91	81	172

Table 6 Distribution of students according to visiting a specialist for hearing complaints

	number of students		
specialist	Rotterdam	Leiden	R+L
yes	23	6	29*
no	182	193	375
different	-	1	1
total	205	200	405

* Of the 29 students 8 are still visiting a specialist (6 living in Rotterdam and 2 in Leiden). Five students are wearing hearing-aids, of which 2 binaurally and 3 at the right ear only

Table 7 Distribution of students according to the number of times a specialist was visited for hearing complaints

	number of students		
number of visits	Rotterdam	Leiden	R+L
< 3 times	5	3	8
3-10 times	11	4	15
> 10 times	5	1	6
total	21	8	29

Table 8 Distribution of assumed reasons for hearing complaints

	number of students		
	Rotterdam	Leiden	R+L
family	8	1	9
accident	-	-	-
fireworks	1	-	1
occupational noise exposure	-	-	-
ototoxic drugs	-	2	2
diseases	4	-	4
other + do not know	10	3	16
total	23	6	29

Table 9 Distribution of students according to speech intelligibility

	number of students		
intelligibility	Rotterdam	Leiden	R+L
perfect	63	61	124
usually very good	99	90	189
often good	36	39	75
sometimes good/no good	7	10	17
total	205	200	405

Table 10 Number of years students visited popconcerts

	Rotterdam	Leiden	R + L	(%)
never	98	130	228	(56)
< 1 years	52	18	70	(17)
1 - 3 years	45	4	86	(21)
4 - 9 years	10	10	20	(5)
10 years or longer	-	-	-	-
different	-	1	1	(0)
total	205	200	405	(100)

Table 11 Number of year students visited discotheques

	Rotterdam	Leiden	R + L	(%)
never	17	15	32	(8)
< 1 years	49	22	71	(18)
1 - 3 years	121	97	218	(54)
4 - 9 years	15	64	79	(19)
10 years or longer	2	2	4	(1)
different	1	-	1	(0)

Table 12 Number of years students visited house-parties

	Rotterdam	Leiden	R + L	(%)
never	162	119	281	(69)
< 1 years	21	14	35	(9)
1 - 3 years	19	54	73	(18)
4 - 9 years	3	12	15	(4)
10 years or longer	-	1	1	(0)
different	-	-	-	-

Table 13 Number of years students used headphones

	Rotterdam	Leiden	R + L	(%)
never	3	21	24	(6)
< 1 years	27	12	39	(10)
1 - 3 years	64	32	96	(24)
4 - 9 years	90	93	183	(45)
10 years or longer	21	42	63	(16)
different	-	-	-	-

Table 14 Number of years students played in popgroups or acted as disc-jockey

	Rotterdam	Leiden	R + L	(%)
never	188	117	365	(90)
< 1 years	13	8	21	(5)
1 - 3 years	4	13	17	(4)
4 - 9 years	-	2	2	(0)
10 years or longer	-	-	-	-
different	-	-	-	-

Table 15 Number of times students visited popconcerts in 1997 . The lowest row gives the number of participants that never carried out the activity.

	Rotterdam	Leiden	R + L	(%)
not	29	14	43	(11)
1 - 2 keer	58	30	88	(22)
3 - 4 times	17	15	32	(8)
5 - 9 times	1	6	7	(2)
10 times or more	2	5	7	(2)
different	-	-	-	
never	98	130	228	(56)

Table 16 Number of times students visited discotheques in 1997. The lowest row gives the number of participants that never carried out the activity.

	Rotterdam	Leiden	R + L	(%)
not	24	3	27	(7)
< 1 times a month	108	18	126	(31)
1 - 2 times a month	31	34	65	(16)
3 - 4 times a month	15	71	86	(21)
5 - 7 times a month	7	20	27	(7)
8 times or more a month	1	38	39	(10)
different	2	1	3	(1)
never	17	15	32	(8)

Table 17 Number of times students visited house-parties in 1997. The lowest row gives the number of participants that never carried out the activity.

	Rotterdam	Leiden	R + L	(%)
not	16	3	19	(5)
1 -2 times a year	18	30	48	(12)
1 - 2 times per 2 - 6 months	6	21	27	(7)
1 - 2 times a month	2	23	25	(6)
3 times or more a month	-	4	4	(1)
different	1	-	1	(0)
never	162	119	281	(69)

Table 18 Number of times students used headphones in 1997. The lowest row gives the number of participants that never carried out the activity.

	Rotterdam	Leiden	R + L	(%)
not	12	24	36	(9)
less than 1 hour a week	53	52	105	(26)
less than 1 hour a day	49	41	90	(22)
1 - 2 hours a day	50	43	93	(23)
3 - 4 hours a day	32	13	45	(11)
5 - 8 hours a day	4	6	10	(3)
9 hours or longer a day	2	-	2	(1)
different			-	-
never	3	21	24	(6)

Table 19 Information about the position of the volume regulator of the audio equipment of the students who listened to popmusic through headphones in 1997. The lowest row gives the number of participants that never carried out the activity.

	Rotterdam	Leiden	R + L	(%)
less than ½ the maximum output	34	15	49	(12)
about ½ the maximum output	71	48	119	(29)
about 3/4 of the maximum output	63	55	118	(29)
at the maximum output	24	45	69	(17)
different	10	16	26	(6)
never	3	21	24	(6)

Table 20 Number of times students played in a popgroup or acted as disc-jockey in 1997. The lowest row gives the number of participants that never carried out the activity.

	Rotterdam	Leiden	R + L	(%)
not	2	6	8	2
1-2 times a year	8	9	17	4
1 - 2 times in 2-6 months				
1 - 2 times a month	6	1	7	2
3 times or more a month	7	1	8	2
different	-	-	-	-
never	177	188	365	90

Table 21 Number of times students observed tinnitus etc. in 1997.

	Rotterdam	Leiden	R + L	(%)
not	79	49	128	(32)
1 -2 times	71	56	127	(31)
3 - 4 times	42	34	76	(19)
5 - 9 times	8	17	25	(6)
10 times or more	5	42	47	(12)
different	-	2	2	(0)

Table 22 Number of students per popmusic activity that observed tinnitus etc. in 1997 after a popmusic activity.

Description	number of times tinnitus was reported	number of respondents who carried out the activity	percentage of respondents with tinnitus after an activity	percentage of respondents with tinnitus after an activity
popconcert	60 (35 + 25)	134	44.8	100 *60/370=16.2
discotheque	196 (92 + 104)	346	56.7	100*196/11568=1.7
house-party	62 (9 + 53)	105	59.0	100*62/843=7.4
Hadphones	38 (26 + 12)	345	11.0	100*38/53899=0.1
popgroup/ disc-jockey	9 (3 + 6)	105	8.6	100*9/836=1.1

Table 23 Distribution of students according to exposure pattern

	number of students					
	Rotterdam		Leiden		R + L	
exposure pattern	male students	female students	male students	female students	male students	female students
1	1	1	4	-	5	1
2	1	3	1	1	2	4
3	-	1	3	-	3	1
4	-	-	4	2	4	2
5	-	1	2	-	2	1
6	-	1	3	2	3	3
7	22	19	24	7	46	21
8	31	28	37	3	68	31
9	9	16	7	1	16	17
10	2	3	8	-	10	3
11	5	6	20	1	25	7
12	3	8	10	1	13	9
13	2	9	19	1	21	10
14	9	13	12	2	21	15
15	3	5	9	-	12	5
never used headpones	2	1	6	5	18	6
total number	90	115	179	21	269	136

Table 24 Number of students knowing the SIRE campaign about walkman's.

	number of students						
	Rotterdam		Leiden		R + L		
SIRE-campaign	male students	female students	male students	female students	male students	female students	total
yes	20	17	44	1	64	18	82 (23%)
no	70	98	90	13	160	111	271 (77%)
missing	-	-	45	7	45	7	52
total number	90	115	179	21	269	136	405

Table 25 Data about occupational noise exposure and use of personal hearing protection of 71 students exposed to noise during working hours.

Exposure duration on a workday	noise exposure during working hours	use of hearing protection	consistent use of hearing protection
	number of students	number of students	number of students
less than 1 hour	41	22	14
1 - 4 hours	22	14	9
4 - 8 hours	8	8	6
total	71	44	29

Table 26 Cumulative distribution of the present listening level (in dB(A)) under headhphones of students according to age and location.

	number of students						
	Rotterdam		Leiden		R + L		
percentile	male students	female students	male students	female students	male students	female students	total
10	53.1	53.9	66.9	50.4	59.3	54.0	56.2
20	58.5	58.6	71.8	55.2	65.9	58.6	62.8
30	63.4	61.9	74.7	58.3	70.5	61.7	67.6
40	67.1	64.1	76.8	68.5	74.2	64.4	71.4
50	69.8	69.2	78.7	73.9	76.6	69.4	75.0
60	73.3	73.1	81.0	75.0	79.1	73.8	77.5
70	77.0	77.2	83.1	78.9	81.5	77.1	80.6
80	80.8	81.1	85.0	84.2	83.9	81.3	83.3
90	86.4	85.9	87.9	85.1	86.9	85.9	86.7
Nver usec headphones and no headphones in 1997	3	9	33	10	36	19	55
total number	90	115	179	21	269	136	405

Table 27 Cumulative distribution of present listening level (in dB(A)) for male and female students and for 4 positions of the volume regulator of the audio equipment.

percentile	male students	female students	position volume regulator			
			1	2	3	4
10	59.3	54.0	45.5	54.4	63.5	70.0
20	65.9	58.6	54.2	58.8	69.1	77.3
30	70.5	61.7	55.3	61.7	73.8	80.9
40	74.2	644	58.6	65.8	76.0	82.5
50	76.6	69.4	62.1	68.6	77.8	83.8
60	79.1	73.8	68.1	70.7	79.9	84.9
70	81.5	77.1	69.6	74.8	81.5	86.0
80	83.9	81.3	73.2	77.0	82.8	88.2
90	86.9	85.9	76.8	81.2	87.2	91.6
aantal	233	117	44	101	114	68

position 1: lessthan ½ the maximum output
position 2: about ½ the maximum output
position 3: about 3/4 of the maximum output
position 4: at the maximum output

Table 28 Cumulative distribution of present listening level (in dB(A)) for male students and for 4 positions of the volume regulator of the audio equipment and those data for and female students.

percentile	male students				female students			
position*	1	2	3	4	1	2	3	4
10	52.1	55.7	64.6	75.9	40.2	54.0	60.3	62.5
20	57.2	59.8	69.9	77.4	47.0	58.0	67.8	65.3
30	61.1	64.9	74.3	80.9	48.7	60.5	71.4	76.5
40	65.3	67.4	76.2	82.7	54.4	63.1	75.2	81.5
50	68.9	70.4	78.8	83.7	55.6	65.9	76.9	84.7
60	70.4	73.6	80.1	84.8	57.4	69.2	77.8	85.5
70	73.5	75.4	81.5	86.1	58.6	73.0	82.4	86.3
80	76.1	77.8	83.4	88.2	63.1	76.2	85.5	88.7
90	78.5	81.8	86.7	92.3	70.1	80.7	89.2	91.2
N	27	54	82	53	17	47	32	15

* see table 27

Table 29 Cumulative distribution of former listening level (in dB(A)) for students which did not use headphones in 1997 and cumulative distribution of present listening level (in dB(A)) for present users of headphones.

percentile	former users of headphones	present users of headphones
10	58.3	56.2
20	61.4	62.8
30	64.6	67.6
40	68.6	71.4
50	72.6	75.0
60	75.6	77.5
70	78.8	80.6
80	80.4	83.3
90	84.4	86.7
total number	30	350

Table 30 Cumulative distribution of former listening level (in dB(A)) for students which used to listen at another listening level and cumulative distribution of present listening level (in dB(A)) for present users of headphones.

percentile	former users of headphones	present users of headphones
10	56.5	56.2
20	63.7	62.8
30	67.3	67.6
40	71.2	71.4
50	73.7	75.0
60	77.7	77.5
70	82.0	80.6
80	83.9	83.3
90	88.8	86.7
total number	176	350

Table 31 Cumulative distribution of difference between former and present listening level (in dB(A)) for students which used to listen at another listening level specified according to gender and location.

difference in dB(A)	Rotterdam		Leiden		R + L		
percentile	male students	female students	male students	female students	male students	female students	total
10	-9.9	-13.1	-9.3		-9.3	-12.9	-11.7
20	-7.2	-10.3	-8.1		-7.9	-9.6	-8.3
30	-6.7	-8.3	-6.6		-6.7	-8.1	-6.9
40	-5.8	-5.9	-5.0		-5.1	-5.1	-5.1
50	-4.4	-3.1	-0.5		-1.7	-3.2	-2.4
60	1.6	1.8	3.6		2.9	1.7	2.1
70	6.4	4.4	6.2		6.1	4.4	5.1
80	11.1	7.0	9.7		10.7	6.6	9.5
90	14.3	11.7	12.6		12.9	11.6	12.6
total aantal	42	64	67	3	109	67	176

Table 32 Mean difference (in dB) between hearing threshold levels of the left and right ear, determined in three Netherlands investigations

Frequency of hearing threshold level (in hertz)	Present investigation	Passchier-Vermeer, 1981	Passchier-Vermeer and Rövekamp, 1986
500	3.2	3.9	1.3
1000	2.6	1.7	1.0
2000	1.0	1.5	2.2
3000	1.7	2.0	4.3
4000	3.0	1.7	2.4
6000	4.7	3.2	1.3
8000	2.1	1.2	-

Table 33 Average values of the differences between the hearing threshold levels of the left and right ear for male, female and all students. Also the slope of the linear regression line of the mean differences as a function of average hearing threshold level of both ears.

Frequency in hertz	mean difference in dB			slope of best fitting straight line		
	male students	female students	all	male students	female students	all
500	4.2	1.3	3.2	0.16	0.03	0.08
1000	3.0	2.0	2.6	0.05	0.05	0.05
2000	1.5	0.1	1.0	0.00	0.03	0.00
3000	2.4	0.5	1.7	-0.03	0.02	0.00
4000	3.6	2.1	2.1	0.00	-0.06	-0.01
6000	5.0	4.2	4.7	0.15	0.15	0.15
8000	2.3	1.8	2.1	0.22	0.10	0.18

Table 34 Average hearing threshold levels (in dB) of the selected and unselected groups of male and female students seperately and for all students.

frequency in hertz	male students		female students		all	
	not selected	selected	not selected	selected	not selected	selected
500	4.1	3.4	3.6	2.8	5.1	4.4
1000	-0.1	-1.4	-0.5	-1.8	0.7	-0.9
2000	1.7	1.2	1.3	0.9	2.4	1.8
3000	0.9	0.1	1.3	0.8	0.2	-1.1
4000	1.7	0.7	2.8	2.0	-0.6	-1.7
6000	8.2	7.3	9.4	8.9	5.9	4.5
8000	4.1	3.4	4.6	4.3	3.0	1.8
Number	403*	360	269	238	134	122

* Two students did not have a correct audiometric test result.

Table 35 Average, median and modal values of hearing threshold levels (average value for both ears) of the selected groups of male, female and all students.

frequency in hertz	all			male students			female students		
	average	median	modal	average	median	modal	average	median	modal
	value in dB			value in dB			value in dB		
500	3.4	2.5	0.0	2.8	2.5	0.0	4.4	5.0	5.0
1000	-1.4	-2.5	-3.8	-1.8	-2.5	-3.8	-0.9	-1.3	-2.5
2000	1.2	0.0	0.0	0.9	0.0	0.0	1.8	2.5	2.5
3000	0.1	0.0	-2.5	0.8	0.0	-2.5	-1.1	-2.5	-2.5
4000	0.7	0.0	-2.5	2.0	0.0	-2.5	-1.7	-2.5	-2.5
6000	7.9	7.5	10.0	8.9	7.5	10.0	4.5	5.0	2.5
8000	3.4	2.5	2.5	4.3	2.5	1.5	1.8	0.0	0.0

Table 36 Difference (in dB) in average hearing threshold levels of the selected group of male and female students and statistical data about this difference (t-value of the Student t-test and P-value of t).

frequency in hertz	average difference	t-value	P-value
500	-1.6	-2.10	0.04
1000	-0.9	-1.47	0.14
2000	-0.8	-1.18	0.24
3000	1.9	2.27	0.02*
4000	3.7	4.38	0.00*
6000	4.4	4.49	0.00*
8000	2.5	2.39	0.02*

* Statistically significant difference ($P < 0.025$)

Table 37 Median hearing threshold levels of the reference groups

frequency in hertz	median values (in dB)	
	male students	female students
500	0.0	2.5
1000	-2.5	-2.5
2000	0.0	2.5
3000	0.0	-2.5
4000	2.5	-2.5
6000	7.5	2.5
8000	5.0	0.0
av. 4000. 6000	5.0	0.0
av. 3000. 4000. 6000	4.2	-0.8
Number of students	60	40

Table 38 Significance of differences in variable in part 2 and part 1 for three groups. A + means a statistically significant higher occurrence in part 2 and a - a significantly higher occurrence in part 1.

Description of variable	group		
	male students ≤ 17 years	male students >17years	female students
discotheque number of years			+
house-parties number of years		+	+
headphones number of years			-
discotheque in 1996/1997	-	+	-
headphones in 1996/1997			
tinnitus after popmusic activity in 1996/1997		+	-
tinnitus after popmusicthrough headphones in 1996/1997		+	

Table 39 Position of the volume regulator of participants of part 1 and the sudents of part 2, if they use headphones. Results for three groups.

position of volume regulator with respect to maximal volume	male group < 17 years		male group > 17 years		female group 15-18 years	
	part 1	part 2	part 1	part 2	part1	part2
less than 1/2	12 (26)	18 (17)	6 (14)	11 (9)	18 (28)	20 (16)
abour 1/2	17 (37)	29 (28)	12 (28)	34 (26)	17 (27)	56 (46)
about 3/4	10 (22)	40 (39)	20 (47)	46 (37)	18 (28)	32 (26)
maximal	7 (15)	16 (16)	5 (12)	38 (28)	11 (17)	15 (12)
different	2	7	2	12	3	7
total	48	110	45	141	67	130

Table 40 Distribution of equivalent sound levels (in dB(A)) over 24 hours for male persons at most 17 years. The lowest row gives the number of persons for which the distribution has been determined.

percentile	L24tot		L24head		L24_wal	
	part 1	part 2	part 1	part 2	part1	part2
10	63.5	69.5	59.5	59.5	0.0	0.0
20	79.8	72.5	59.5	64.5	0.0	69.5
30	74.3	74.9	64.5	69.5	69.5	69.5
40	76.8	78.1	68.0	72.5	74.5	69.5
50	78.1	80.0	69.5	73.0	74.5	74.5
60	79.3	81.9	73.0	77.5	77.0	75.0
70	80.8	83.9	77.5	81.0	78.0	78.0
80	82.2	84.6	77.5	84.0	79.2	80.1
90	87.3	91.1	84.5	89.5	81.3	81.7
Number	47	108	48	110	50	112

Table 41 Distribution of equivalent sound levels (in dB(A)) over 24 hours for male persons over 17 years. The lowest row gives the number of persons for which the distribution has been determined.

percentile	L24tot		L24head		L24_wal	
	part 1	part 2	part 1	part 2	part1	part2
10	70.5	74.2	0	0.0	69.5	69.5
20	74.6	77.7	59.5	0.0	69.5	74.5
30	78.3	79.1	64.5	64.5	74.5	78.0
40	79.4	81.7	68.3	72.5	78.0	79.3
50	81.3	82.8	72.5	73.0	79.3	81.1
60	81.5	84.9	72.5	77.5	80.0	82.0
70	82.0	86.2	77.5	82.5	81.3	82.6
80	83.9	90.2	81.0	89.5	82.0	85.0
90	86.5	93.5	84.5	93.0	83.6	86.6
Number	47	153	49	154	49	154

Table 42 Distribution of equivalent sound levels (in dB(A)) over 24 hours for female persons aged between 14 and 18 years. The lowest row gives the number of persons for which the distribution has been determined.

percentile	L24tot		L24head		L24_wal	
	part 1	part 2	part 1	part 2	part1	part2
10	59.5	70.7	59.5	0.0	0.0	69.5
20	67.5	72.5	59.5	59.5	0.0	69.5
30	71.4	74.6	64.5	64.5	69.5	69.5
40	75.0	76.0	64.5	69.5	69.5	74.5
50	77.0	78.5	69.5	70.3	74.5	75.0
60	78.1	79.6	72.5	73.0	74.7	75.0
70	79.8	81.8	76.0	77.5	77.3	77.7
80	82.5	84.3	77.5	81.0	78.7	79.2
90	85.9	88.3	84.5	87.5	80.6	81.4
Number	67	134	69	134	68	136

Table 43 Hearing threshold levels (in dB) at the higher frequencies of 11 students (all males) with substantial hearing loss without otological abnormalities and no history of noise exposure.

	Hearing threshold level in dB								
	right ear				left ear				one normal ear
	3000 Hz	4000 Hz	6000 Hz	8000 Hz	3000 Hz	4000 Hz	6000 Hz	8000 Hz	
1	15	20	50	60	10	20	20	40	-
2	5	5	5	5	10	40	30	5	+
3	20	25	25	20	15	25	35	15	-
4	10	0	10	0	10	45	60	55	+
5	5	5	20	10	5	15	30	40	-
6	-5	-5	5	-5	10	5	40	15	+
7	5	0	5	20	10	15	10	45	-
8	0	35	10	10	0	10	0	10	+
9	0	0	0	50	5	0	10	15	+
10	-10	-10	0	0	10	25	35	30	+
11	15	10	40	30	10	15	15	15	+

Table 44 Correlation coefficients of satisfaction with learning achievement and variables related to listening to popmusic through headphones.

variables related to listening to popmusic through headphones	male students	female students
Lnuveld	- 0.09	- 0.10
Lrep	- 0.12	- 0.08
Position volume regulator	- 0.14	- 0.06
Number of hours a day listening	- 0.14	- 0.13
Listening period	- 0.13	- 0.16

Table 45 F-ratio from a (Two-Way) ANOVA, in which L24tot has and has not been included as co-variable and gender has or has not been used as explaining variable. Number of students is equal to 362.

Hearing threshold level (gcx) in dB	F- ratio			
frequentie(x) in hertz	tinnitus and gender; L24tot co-variabele	tinnitus and gebder; L24tot no co-variable	tinnitus; L24tot co-variable	tinnitus; L24tot no co-variable
500	0.53	0.49	0.55	0.50
1000	0.42	0.40	0.45	0.42
2000	1.54 (P = 0.13)	1.63 (P = 0.10)	0.62	0.54
3000	0.61	0.72	0.36	0.46
4000	1.21	1.31	1.26	1.34
6000	0.92	0.93	0.54	0.61
8000	1.41 (P = 0.18)	1.47 (P = 0.15)	1.52 (P = 0.19)	1.48 (P = 0.20)
4000 + 6000	0.87	0.92	0.59	0.67
3000 + 4000 + 6000	0.77	0.84	0.53	0.59

Table 46 Correlation coefficients of popmusic activities in 1997. Number of students at least 352.

	variable						
	l24_wal	l24head	l24tot	l24disco	l24house	l24popco	l24popgr
l24_wal	1.00	0.12	0.61	0.84	0.32	0.30	0.19
l24head	0.12	1.00	0.49	0.08	0.12	0.12	0.09
l24tot	0.61	0.49	1.00	0.52	0.31	0.22	0.18
l24disco	0.84	0.08	0.52	1.00	0.19	0.11	0.13
l24house	0.32	0.12	0.31	0.19	1.00	0.06	0.12
l24popco	0.30	0.12	0.22	0.11	0.06	1.00	0.18
l24popgr	0.19	0.09	0.18	0.13	0.12	0.18	1.00

Table 47 Correlation coefficients between duration of an activity and extent of an activity in 1997.

Variable over 1997	variable (number of years)				
	headphones	discotheque	house-party	popconcert	popgroup
l24head	0.56	0.03	0.09	0.10	0.09
l24disco	0.14	0.57	0.16	0.17	0.14
l24house	0.13	0.26	0.87	0.04	0.09
l24popco	0.10	0.15	0.06	0.73	0.16
l24popgr	0.06	.12	0.13	0.14	0.83

Table 48 Multiple correlation coefficients of the relationship between lpx and four popmusic activities all used as independent variables for all, male and female students and the correlation coefficients of lpx and L24_wal.

Hearing threshold level variable	all	male students	female students	male students	female students
	multiple correlation coefficient			correlation coefficient	
lp46	0.15	0.12	0.25	0.08	0.04
lp346	0.13	0.10	0.21	0.08	0.05
lp4	0.18	0.16	0.22	0.06	0.03
lp6	0.15	0.13	0.25	0.07	0.04
lp8	0.21	0.13	0.24	0.13	0.02
lp3	0.13	0.09	0.13	0.06	0.04
lp2	0.20	0.13	0.20	0.07	0.01
lp1	0.09	0.09	0.12	0.10	0.04
lp05	0.10	0.14	0.16	0.01	0.03

Table 49 Adjusted R^2 according to a multiple regression analysis in which two exposure variables, gender and L24_wal have been used.

Variable	BEL/Lnuveld	Lrep/BEL	Lrep/trrep	trrep/Lnuveld
lp46	0.06	0.06	0.02	0.02
lp346	0.04	0.04	0.01	0.01
lp4	0.03	0.03	0.03	0.03
lp6	0.07	0.06	0.01	0.03
lp8	0.04	0.04	0.04	0.04
lp3	0.01	0.01	0.01	0.01
lp2	0.04	0.04	0.03	0.03
lp1	0.01	0.01	0.01	0.01
lp05	0.02	0.02	0.01	0.02

Table 50 Average relative hearing threshold levels (in dB) for three groups divided according to the value of BEL and gender. A value in bold indicates a statistically significant difference with class BEL = 0 (P≤ 0.05, one-sided test). For values underlined only a trend has been observed (0.05 < P < 0.10).

Relative hearing threshold level	BEL = 0			0 < BEL ≤ 1			BEL > 1		
	all	male students	female students	all	male students	female students	all	male students	female students
gc46	0.6	-0.1	1.5	0.7	0.8	-0.7	3.4	3.7	2.8
gc346	0.7	0.3	1.5	0.8	0.9	-0.4	2.9	2.8	2.9
gc4	0.1	-0.2	1.0	0.8	1.3	-1.0	1.9	2.1	1.5
gc6	1.1	0.4	2.1	0.5	0.5	-0.3	4.9	5.4	4.3
gc8	0.2	-1.0	2.4	-1.2	-1.1	-1.7	1.4	0.7	2.9
gc3	1.0	0.7	1.6	1.0	1.1	0.3	2.1	1.4	3.5
gc2	0.3	0.8	-0.7	0.6	1.4	-2.8	0.4	0.5	0.0
gc1	1.0	0.6	1.8	1.0	1.3	-0.1	1.3	1.4	1.0
gc5	2.4	2.5	2.3	2.7	3.8	-2.2	3.9	5.2	1.5
Number	278	177	101	47	38	9	35	23	12

Table 51 Average relative hearing threshold levels (in dB) for two groups divided according to the value of BEL and gender. A value in bold indicates a statistically significant difference with class BEL = 0 (P≤ 0.05, one-sided test). For values underlined only a trend has been observed (0.05 < P < 0.10).

Relative hearing threshold level	BEL ≤ 1			BEL > 1		
	all	male students	female students	all	male students	female students
gc46	0.7	0.3	1.3	3.4	3.7	2.8
gc346	0.7	0.4	1.4	2.9	2.8	2.9
gc4	0.3	0.0	0.8	1.9	2.1	1.5
gc6	1.0	0.4	1.9	4.9	5.4	4.3
gc8	0.0	-1.0	2.1	1.4	0.7	2.9
gc3	1.0	0.8	1.5	2.1	1.4	3.5
gc2	0.3	0.9	-1.9	0.4	0.5	0.0
gc1	1.0	0.7	1.6	1.3	1.4	1.0
gc5	2.4	2.7	1.9	3.9	5.2	1.5
n	325	215	120	35	23	12

Table 52 Number of students with popmusic-induced hearing loss if the model from ISO 1999 would be applicable to popmusic through headphone exposure and the average values of popmusic-induced hearing loss according to ISO 1999.

Frequency in hertz	number of students with popmusic-induced hearing loss	average popmusic-induced hearing loss (in dB) of these students
500	1	0.04
1000	5	0.21
2000	20	0.47
3000	66	1.22
4000	82	1.75
6000	66	1.16

Table 53 Comparison of observed average differences in hearing threshold levels at various frequencies and differences in expected popmusic-induced hearing loss according to ISO 1999 for several groups of students classified in two groups according to expected popmusic-induced hearing loss according to ISO 1999.

frequency in hertz	group divided according to popmusic-induced hearing loss expected from ISO 1999 of 0 dB and > 0 dB			group divided according to popmusic-induced hearing loss expected from ISO 1999 of ≤1 dB and > 1 dB		
	classification of students. Number of students in the two groups	difference observed in gcx (in dB)	difference (in dB) in popmusic-induced hearing loss expected according to ISO 1999	classification of students. Number of students in the two groups	difference observed in gcx (in dB)	difference (in dB) in popmusic-induced hearing loss expected according to ISO 1999
3000	66/294	- 0.16	1.22	22/338	1.65	3.20
4000	82/278	1.07	1.75	35/325	1.16	2.89
6000	66/294	1.36	1.16	23/337	3.83	3.75

Table 54 Comparison of observed average differences in hearing threshold levels at various frequencies and differences in expected popmusic-induced hearing loss according to an adapted model of ISO 1999 for several groups of students classified in two groups according to expected popmusic-induced hearing loss according to the adapted model of ISO 1999.

frequency in hertz	group divided according to popmusic-induced hearing loss expected from the adapted model of ISO 1999 of 0 dB and > 0 dB			group divided according to popmusic-induced hearing loss expected from the adapted model of ISO 1999 of ≤ 1 dB and > 1 dB		
	classification of students. Number of students in the two groups	difference observed in gcx (in dB)	difference (in dB) in popmusic-induced hearing loss expected according to ISO 1999 adapted	classification of students. Number of students in the two groups	difference observed in gcx (in dB)	difference (in dB) in popmusic-induced hearing loss expected according to ISO 1999 adapted
3000	20/340	0.64	0.47	8/352	not calculated	not calculated
4000	66/294	1.36	1.22	22/338	2.23	3.20
6000	82/278	1.42	1.75	35/325	3.36	2.89
8000	66/294	0.22	1.16	23/337	3.15	3.75

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