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# Hearing and noise annoyance in schoolteachers

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Objective: Danish school teachers report exposure to high noise levels, and experience hearing problems, noise sensitivity, and tinnitus. The average age of school teachers have increased and it has been suggested that the problems regarding hearing and noise disturbance may be associated with age related hearing deficiencies in poor acoustic environments. Methods: 283 schoolteachers in 10 public schools in Copenhagen participated in a questionnaire survey, and 100 (75 women) were invited to have their hearing tested by pure tone audiometry and oto-acoustic emissions (DPOAE). Results: Left ear hearing (2-4 kHz) was reduced wit age (-0.4 dB/year), in males (-6 dB), and smokers (-3 dB). Adjusted for age and gender, both self-reported noise exposure and disturbance to noise in the classroom was associated to better hearing in measurements of oto-acoustic emissions at frequencies (f2) above 2 kHz. Adjusted only for gender, mental fatigue after work was associated to better hearing at frequencies above 4 kHz. Tinnitus was associated with both self-reported noise sensitivity, and with better hearing at all frequencies. Conclusion: Noise disturbance and tinnitus in schoolteachers were associated with better high frequency hearing, and may be alleviated by improvements of the high frequency acoustic environment of the classrooms.

## 1 Introduction

Noise disturbance has increased over the last decades among Danish schoolteachers. Although the noise levels seldom reaches noise levels with risk of noise induced hearing loss [1], there has also been an increase in the reports of haring problems, tinnitus, and sensitivity to sound. These trends have coincided with an increase in the age of schoolteachers, and it has therefore been hypothesized that complaints of noise disturbance and problems of hearing were linked to the difficulties of hearing among the older schoolteachers in classrooms with low acoustic quality. One of the mechanisms in breeding the general noise levels in classrooms is that people tend to increase their voice levels when talking in background noise or in reverberating rooms, an effect known as the Lombard effect [2]. This has been demonstrated by measurements of background noise levels in classrooms, which shows that noise levels are higher in highly reverberant classrooms compared to non-reverberant classrooms when comparing similar classroom activities [1]. In order to evaluate whether complaints of noise disturbance in the classroom and fatigue after work were associated to age-related hearing loss in schoolteachers, reports from a questionnaire survey to schoolteachers regarding noise disturbance, mental fatigue after work, tinnitus and noise sensitivity were compared to measurements of pure tone hearing thresholds and oto-acoustic emissions in 100 schoolteachers from the City of Copenhagen.

# 2 METHODS

## 2.1 Participants

Teachers in ten schools in the City of Copenhagen were invited to participate in the study. Out of 419 potential respondents from 10 schools 283 (67.5%) filled in a questionnaire on health, disturbance by noise, and other work-related items [3]. Of the respondents 89 were men (31%) and 194 women (69%), mean age (range) was 45 (21-65) years (men) and 45 (25-66) years (women), respectively. The response rate ranged from 43-89% from different schools. None of the participants used hearing aid.

## 2.2 Questionnaire items

The following items and response categories used to evaluate noise disturbance, mental fatigue and hearing related symptoms:

Smoking:

- ñDo you smoke?ò (*Dichotomised to:1 = Yes; 0 = no or never)*

Noise disturbance:

- ñAre you exposed to noise that disturbs you when you are teaching?ò (1 = *Never, 2 = rarely or very little, 3 = approximately ¼ of the time, 4 = approximately ½ of the time, 5 = approximately ¾ of the time, 6 = Almost all of the time*)

- ñHow disturbing is the noise from the children in the class (for example, speech, rattling with furniture, agitationò (*Discrete scale 1-7, where 1 = Not disturbing, and 7 = Almost unbearable*)

Mental Fatigue: A Danish translation of the Swedish Occupational Fatigue Inventory-20 (SOFI-20) was used to measure work-related fatigue in four dimensions: lack of energy, physical discomfort and exertion, physical discomfort, lack of motivation, and sleepiness. The dimension used in the analysis is lack of energy:

- ñTo what extent do you feel the following expressions describe your the experience of fatigue after workò: ñDrainedò; ñSpentò; ñWorn outò; ñOverworkedò (*Discrete scale 1-6, where 1=**ñ**Not at all**ò** and 6=**ñ**To a very high degree. Collected in a single measure of mental fatigue: Lack of energy = (Drained + Spent + Worn out + Overworked)/4)*

Noise Sensitivity: ñ

- ñWhen you in daily life hear sounds, like chairs being moved, rattling with cutlery, or childrenôs high pitched voices, how often do you feel distress or pain?ò *(1 = Never or almost never, 2 = rarely, 3 = Some times, 4 = Often, 5 = Always)*

Tinnitus:

- ñDo you within the last 3 month have ringing or buzzing in your ears?ò (*Dichotomised to 1 = No, 2 = either: monthly, weekly, or daily)*

## 2.3 Measurements of hearing

From the 283 respondents, 106 were invited to have their hearing tested. Otoscopic examination was performed before the tests of hearing, and individuals with excessive ear wax were asked to contact their doctor for removal of the ear wax before the hearing test. Over100 teachers were tested. Distortion product oto-acoustic emissions (DPOAE) were performed bi-aurally with two identical DSP-systems from Tucker-Davis Technologies (TDT, Alchua, FL) and two Ethymotic Research (ER, Elk Grove Village, IL) microphone probe systems (ER10B+ connected by tubes to ER2 sound transducers). The DPOAE assessments on each ear consisted of six DP-grams with measurements of the cubic

distortion product (CDP= 2f1-f2) from 32 sets of primary input tones (f2/f2=1.23; f2 ranging from 707 Hz to 10,374 Hz). The same setup and probe systems was used for assessments of pure-tone hearing thresholds (125.2 Hz, 250.3 Hz, 500.7 Hz, 1001 Hz, 1541 Hz, 2000 Hz, 3085 Hz, 3999 Hz, 6169 Hz, and 7999 Hz) in 5 dB steps. All tests of hearing were performed in a transportable sound booth (IAC 250 Sound Shelter, complying with ISO 6189). Before measurements of either hearing thresholds or oto-acoustic emissions, proper fitting of the earplugs was tested by measurement of the output from each transducer in situ at 500 Hz.

## 2.4 Analysis

Statistical computations were made with IBM SPSS version 19. The effect estimates of hearing on the different items from the questionnaire were assessed by linear regression, with adjustments for age and gender where noted. The associations between the different items were calculated as Spearman ranked order correlations. All effect estimates were adjusted for multiple comparisons where appropriate.

# 3 Results and discussion

None of the teacherôs used hearing aids, and only three participants had a hearing handicap ranging between 0.6 - 8.6 % when calculated by the American Academy of Otolaryngology 1979 equation [4]. The participants of the study had better hearing than expected from recurrent national work-environment surveys, which may indicate either a possible healthy worker effect or a reluctance of teachers with hearing deficiencies in participating. Table 1 shows the effect estimates of age, gender and smoking on the hearing thresholds and the DPOAE of the left ear, in which the hearing in general was slightly worse than the right ear. Note that better hearing is corresponding to a lower hearing threshold and a higher output level of cubic oto-acoustic distortion product (DPOAE) at the f2 primary input tone. As expected, hearing is reduced with age especially at the higher frequencies, and the males had approximately 6 dB worse hearing than the females in the 2-4 kHz frequency range. Further, there is also a statistical significant effect of smoking on the hearing thresholds, but not on the oto-acoustic emissions. This discrepancy between the measurements is caused by the inability of the DPOAE to measure larger hearing deficiencies than allowed by the background noise level, which can be reduced by averaging, but only on the expense of more time for performing the measurements.

Table 1: Slope estimates, 95% confidence intervals and significance levels in a mixed model multiple linear regression of age, gender and smoking on hearing thresholds and DPOAE from *the Left ear* (averaged across three in frequency intervals: <2kHz, 2-4 kHz and > 4 kHz).

| | | Age | Gender (reference: female) | Smoking (reference: never) |
|---|---|---|---|---|
| *Left ear* | | dB/year | dB | dB |
| HT < 2Khz | Estimate | **0.184 (0.093 - 0.274)** | 1.998 (-0.127 - 4.123) | 0.273 (-1.590 - 2.136) |
| | P | **> 0.001** | 0.065 | 0.772 |
| HT 2-4 kHz | Estimate | **0.401 (0.265 - 0.537)** | **6.379 (3.187 - 9.571)** | **3.463 (0.664 - 6.261)** |
| | P | **> 0.001** | **> 0.001** | **0.016** |
| HT > 4kHz | Estimate | **0.617 (0.401 - 0.833)** | 4.800 (-0.281 - 9.881) | **5.064 (0.609 - 9.519)** |
| | P | **> 0.001** | 0.064 | **0.026** |
| DPOAE f2 < 2kHz | Estimate | -0.084 (-0.212 - 0.044) | -2.136 (-5.155 - 0.883) | 0.916 (-1.732 - 3.563) |
| | P | 0.197 | 0.163 | 0.494 |
| DPOAE f2 =2-4 kHz | Estimate | **-0.128 (-0.252 - -0.004)** | **-3.032 (-5.945 - -0.119)** | -0.256 (-2.298 - 2.810) |
| | P | **0.043** | **0.042** | 0.843 |
| DPOAE f2 > 4 kHz | Estimate | **-0.278 (-0.407 - -0.148)** | **-4.397 (-7.436 - -1.358)** | -2.015 (-4.680 - 0.649) |
| | P | **> 0.001** | **0.005** | 0.137 |

Table 2 shows the effect estimates of hearing on self-rated noise exposure and degree of disturbance from noise in the class room, and contrary to the hypothesis, better hearing is associated with statistically significant higher self-rated

noise exposure and noise related noise disturbance at the high frequencies. This is only statistically significant in the measurements of DPOAE, but not in the assessments of hearing thresholds. This is in contrast to the effects of age, gender and smoking on hearing, and seems to emphasize that DPOAE is well suited to detect smaller hearing deficiencies (<20 dB), but less suited to determine manifest hearing losses.

Table 2. Slope estimates, 95% confidence intervals, statistical significance and partial eta squared in a linear regression of hearing thresholds and DPOAE (averaged across three in frequency intervals : <2kHz, 2-4 kHz and > 4 kHz) of the best ear on self-rated exposure to disturbing noise during teaching and the degree of disturbance from noise attributed to children in the class. The estimates are adjusted for age and gender.

| Measurement of hearing | Self-rated exposure to disturbing noise during teaching | | | | Degree of disturbance from noise attributed to children in the class | | | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | | P | Partial Eta Sq. | Estimate | | P | Partial Eta Sq. |
| HT < 2Khz | -0.043 | (-0.099 - 0.014) | 0.137 | 0.023 | -0.052 | (-0.117 - 0.013) | 0.115 | 0.026 |
| HT 2-4 kHz | -0.007 | (-0.041 - 0.026) | 0.663 | 0.002 | -0.029 | (-0.067 - 0.010) | 0.139 | 0.023 |
| HT > 4kHz | -0.016 | (-0.040 - 0.008) | 0.179 | 0.019 | -0.023 | (-0.050 - 0.004) | 0.099 | 0.006 |
| DPOAE f2 < 2kHz | -0.012 | (-0.049 - 0.026) | 0.545 | 0.004 | 0.017 | (-0.027 - 0.060) | 0.450 | 0.006 |
| DPOAE f2 = 2 - 4 kHz | 0.011 | (-0.026 - 0.049) | 0.555 | 0.004 | **0.046** | **( 0.003 - 0.089)** | **0.035** | **0.046** |
| DPOAE f2 > 4 kHz | **0.046** | **( 0.012 - 0.079)** | **0.008** | **0.071** | **0.058** | **( 0.019 - 0.096)** | **0.004** | **0.085** |

The statistical model is adjusted for age and gender, but in general it is the younger teachers, which are most affected by the noise. These data suggest, the problems with noise in the classroom for the teachers is not just a matter of slight discomfort, but as the problems increases with better hearing, the noise may be experienced as a more or less unavoidable stress factor. This is further supported by the association between mental fatigue and assessment of DPOAE at high frequencies, which is shown in Table 3. The association between hearing and mental fatigue in this analysis is not statistically significant when the model is adjusted for age. Better hearing at the high frequencies and increased mental fatigue coincide primarily in the younger participants, and adjustment of for age will therefore reduce the association. In contrast, adjustment of the model for both age and gender does not change the associations between tinnitus and the measurements DPOAE.

Table 3. Slope estimates, 95% confidence intervals, statistical significance and partial eta squared in a linear regression of DPOAE (averaged across three in frequency intervals:<2kHz, 2-4 kHz and > 4 kHz), on symptoms of mental fatigue (lack of energy), self-rated sensitivity to loud noise, and occurrence of tinnitus within the last 3 month. The estimates are adjusted for gender only.

| | | Mental Fatigue | | Noise sensitivity (reference: never) | | Tinnitus (reference: never) | |
|---|---|---|---|---|---|---|---|
| DPOAE f2 < 2kHz | Estimate | 0.013 | (-0.040-0.067) | 0.011 | (-0.021-0.044) | **0.020** | **(0.004-0.037)** |
| | P | | 0.629 | | 0.493 | | **0.015** |
| | Part. Eta Sq. | | 0.002 | | 0.055 | | **0.060** |
| DPOAE f2 = 2 - 4 kHz | Estimate | 0.048 | (-0.003-0.099) | 0.021 | (-0.010-0.052) | **0.017** | **(0.001-0.033)** |
| | P | | 0.065 | | 0.187 | | **0.036** |
| | Part. Eta Sq. | | 0.035 | | 0.018 | | **0.045** |
| DPOAE f2 > 4 kHz | Estimate | **0.057** | **( 0.014-0.101)** | 0.014 | (-0.007-0.048) | **0.017** | **(0.004-0.031)** |
| | P | | **0.011** | | 0.140 | | **0.014** |
| | Part. Eta Sq. | | **0.065** | | 0.022 | | **0.060** |

In contrast to self reported noise exposure, disturbance to noise, and mental fatigue, noise sensitivity seems not to be associated to hearing in any of the analyzed frequency bands. Tinnitus seems also associated to better hearing in the

assessment of DPOAE, and the association seems more or less equal in all frequency bands. In general, the hearing of the participants is better than expected, and only 4 reported to have tinnitus daily. The presented association between hearing assessments and tinnitus may therefore not relate to permanent tinnitus, but could reflect sporadic tinnitus caused by returning noise exposure. As smoking is associated to hearing loss, this could indicate that the noise exposure of the participants may potentiate the effects of the coincident noise exposure [5]. The reports of noise sensitivity and mental fatigue is statistically significantly correlated (R=0.27), and the same is noise sensitivity and tinnitus (R=0.22), but mental fatigue and tinnitus is not. Mental fatigue and tinnitus may there for be independent effects of the noise exposure, which is both associated to noise sensitivity, possibly by to decreased inhibition to signals from the auditory periphery [6,7].

# 4 Summary

The hearing of the participants in the study had better hearing than expected from recurrent national work-environment surveys. However, reduced hearing at the mid- to high frequencies were associated to age, male sex and smoking. In contrast to expectations, better high-frequency hearing of the participants was associated to reports of higher self-reported noise exposure, increased disturbance from noise in the class-room, and without adjustment for age, also to mental fatigue. Sporadic tinnitus was associated to better hearing, while noise sensitivity was not associated to the measurements of hearing at all. The reported associations may not reflect the outcome in a population of teachers with more manifest hearing deficiencies.

# 5 Funding

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